



# **2014 SCAR OPEN SCIENCE CONFERENCE**

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# **COMNAP Symposium Success through International Cooperation**

## **ABSTRACTS**

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## OPENING PLENARY

### Acidification of the Southern Ocean

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A major, potential stressor of marine ecosystems is the changing water chemistry following the present and simulated future increase in seawater carbon dioxide (CO<sub>2</sub>), concentration. Increasing CO<sub>2</sub> causes a lowering of pH and a re-organisation of the marine carbonate system, commonly termed ocean acidification. Global average long-term ocean acidification projections are intimately linked with future atmospheric CO<sub>2</sub> levels, however the local expression of this global ocean acidification is much more heterogeneous, as local oceanic processes alter the average expectations of future ocean acidification. Evidence has mounted over the past years showing the importance of these 'bottom-up' local oceanic processes, both natural and anthropogenic, to altering the rate of ocean acidification from the long-term atmospheric top-down perspective. The challenge for Southern Ocean acidification are advancing the observations and constraints at understanding the underlining natural variability and the mechanisms that drive it, which are still poor. Pelagic ecosystems are changing fast, especially in the productive, euphotic zone. Autotrophic production may be changing in the surface Southern Ocean through increased primary productivity and a changing stoichiometry of oceanic primary production. This will have consequences both for energy flow and nutrient transport through Southern ocean ecosystems. Calcifying plankton, such as pteropods, have been shown to be adversely effected by current Southern Ocean acidification. These organisms are prominent players in the Southern Ocean ecosystem both as predator and prey, and control to a significant degree the export of carbon and other elements to the intermediate and deep ocean. There is concern over the future of polar marine organisms that are uniquely adapted towards their extreme and cold surroundings. In an environment where development is ten times slower that that in warmer regions of the world, the ability of these (mostly benthic) organisms to adapt to these changing conditions is questionable. Responses of benthic ecosystems have generally resulted in negative impacts (smaller size, slowed growth and high levels of abnormal development. There is a growing international effort to observe and monitor the marine carbonate system with the emphasis moving away from purely physic-chemical approach to an integrated observing system approach based on ecosystem-carbon-climate coupling. Additionally, coupled biogeochemical-ecosystem modeling efforts are becoming much more unified and assimilated through both a multi-model approach and that regional models are becoming much more to the fore. SCAR has appointed an international ocean acidification Action Group to document the scientific understanding of ocean acidification. This presentation will inform on the latest knowledge of chemical and biological consequences of ocean acidification in the Southern Ocean through an ecosystem and earth system approach. It will also identify important gaps in current research and propose approaches to gain a better understanding of the rates, effects and feedbacks of future ocean acidification. New understanding on Southern Ocean change will also be assessed in light of the recent findings of the AMAP Arctic Ocean Acidification report.

## Global messages from Antarctica

**Bergstrom D**<sup>1</sup>, Allison I<sup>2</sup>, Bell R<sup>3</sup>, Cary C<sup>4</sup>, Gales N<sup>1</sup>, Pattyn F<sup>5</sup>, Rintoul S<sup>6</sup>, Strugnell J<sup>7</sup>, Terauds A<sup>1</sup>, van Ommen T<sup>1</sup>, Chown S<sup>8</sup>

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A century ago, when polar science, exploration and political ambition were scarcely distinguishable, Antarctica was essentially a closed book about to be opened. One hundred years on, Antarctica is no longer the isolated, uninhabited, unchangeable place of the past. This progress has come from a sustained and rich scientific program, much of it multidisciplinary and multinational and in response to increasing evidence that human activities have come to dominate planetary changes. This opening address will provide an integrated perspective on recent big scientific advances in our understanding of Antarctica and its place in the Earth system which is revolutionizing modern thinking and drawing attention to the science and policy required to manage an uncertain future. In doing so, the talk aims to set the scene for an exciting and remarkable SCAR Open Science Conference.

## Deciphering past climate and ice sheet dynamics from sedimentary records

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Polar ice is an important component of the modern climate system, affecting global sea level, ocean circulation, heat transport, marine productivity, and planetary albedo. Antarctica became glaciated ~34 million years (m.y.) ago, whereas full-scale permanent Northern Hemisphere continental ice only began forming ~3 m.y. ago. The study of ice cores retrieved from the Antarctic ice cap has resulted in major breakthroughs in understanding natural climate variability (i.e., correlations between the records of temperature, CO<sub>2</sub>, ice sheet volume and equivalent sea level) over the last 800,000 years, and offers insight into the future response of the Earth to anthropogenic forcing. These records show that at no time during the last 800,000 years have CO<sub>2</sub> concentrations in the atmosphere reached the 400 ppm that we experience at present. In fact, the lowest forecasted increases of atmospheric CO<sub>2</sub> and temperatures for the end of this century (IPCC, 2013) have not been experienced on our Planet for over 3 m.y. (i.e. before permanent Arctic ice sheets formed), and the highest forecasted increases have not occurred since before the ice sheets in Antarctica formed 34 m.y. ago. Antarctica and its margins are therefore key locations from which to retrieve the long-term sediment records needed for a detailed understanding of how ice sheets respond to past climate forcing.

During the last decades, geological and geophysical studies around Antarctica have improved our knowledge about sea ice and continental ice sheet development and evolution. Sediment records have provided insight into the environment of an ice-free Antarctica during the early Eocene, the first cooling during the middle Eocene, the erosional consequences of the onset of the continent-wide glaciation during the Eocene-Oligocene transition 34 m.y. ago, and the glacial effect on rising sea level around the Antarctic coastlines. Sediment records also provide insights into the subsequent waxing and waning of the continental ice sheets, sea ice, and ecosystems during the icehouse world, including environmental constraints during past climate warm conditions. Although these records are still sparse and incomplete, they are complementary and allow for a preliminary assessment of ice-sheet response to past climate forcing in different regions. However, additional records are needed if we are to address key knowledge gaps. For example, what are responses of ice sheets to past elevated CO<sub>2</sub> and temperatures?; how fast, how large, and how frequent are glacial and interglacial changes?; and what are the forcing mechanisms for these changes?. This information will provide constraints to sea-ice and ice sheet models, which are the basis for forecasting the future of the cryosphere in a warming world.

The SCAR PAIS (Past Antarctic Ice Sheet Dynamics) Program has developed a strategy to collect sediment records from continent-to-abyss transects in vulnerable areas of the Antarctic ice sheets. With this strategy, PAIS aims to improve our understanding of the sensitivity of the Antarctic Ice Sheets to a broad range of past climatic and oceanic warm conditions (i.e., “greenhouse” climates, times of more recent warming and ice sheet retreat during glacial terminations) in order to improve predictions of ice sheet and sea level response to future climate change and ocean warming.

## Martha T Muse Lecture: Paleoclimate perspectives on Antarctic ice sheet sensitivity

Tim Naish

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Near- and long-term future projections of global mean sea level rise (SLR) are hampered by a lack of understanding of the potential dynamic contribution of the polar ice sheets, and in particular the Antarctic ice sheets. With the completion of the Intergovernmental Panel on Climate Change's Assessment Report a major challenge continues to be placing an upper bound in sea-level projections for 2100 and beyond. The so-called "deterministic" approach which sums observed- and model-projected trends in the known contributions (e.g. ice sheet and glacier surface mass balance, ocean thermal expansion and ground water storage changes) implies a "likely" upper bound of +100cm by 2080-2100. The "semi-empirical" approach which scales past observed sea-level change to mean surface temperature, and uses this relationship to scale future temperature scenarios, predicts a significantly higher upper bound of up to ~2m by 2100. The discrepancy between the two approaches may in part reflect the poorly understood contribution of ice dynamics – that is the rate of flow of ice sheets into the ocean. An ensemble of Antarctic ice sheet models produces highly divergent results for future sea-level projections, primarily because of uncertainties around the mass changes in the East Antarctic Ice Sheet with some models showing increased precipitation driving a positive mass balance overall, even with loss of the marine-based West Antarctic Ice Sheet (WAIS). Current best estimates suggest a 10-20cm dynamic ice sheet contribution by 2100 to global SLR.

Of concern is that marine based ice sheets are highly sensitive to increases in ocean temperature at their margins and rapid disintegration may ensue if the ice sheets grounding lines retreat into deep sub-glacial basins. Recent studies show the highest rates of ice sheet thinning and retreat are occurring at locations around the WAIS where the surface ocean has warmed, and that some WAIS loss may now be irreversible.

Geological records allow the equilibrium sensitivity of polar ice volume and global sea-level change to be reconstructed and assessed during past warm climates and deglaciations, that may be representative of our future climate trajectory. In this talk I will focus on ice sheet responses to climate forcing during: (1) The mid-Pliocene warm period ~3 million years ago when the world was 2-3°C warmer, and atmospheric carbon dioxide concentrations were 400ppm. (2) The Last Interglacial Period ~ 125,000 years ago when the world was 1-2°C warmer. (3) The warming period from the Last Glacial Maximum ~20,000 years ago to our present interglacial. All three past times provide natural experiments with insights into the future response of the polar ice sheets to global warming.

## ANTARCTIC CONSERVATION FLIPPED SYMPOSIUM

### Antarctic Conservation in the 21st Century

**Chown S**

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The Antarctic is one of the Earth's last great wildernesses. Indeed, it can rightly be considered one of the 'last of the wild'. Recognizing its unique position the Protocol on Environmental Protection to the Antarctic Treaty has designated Antarctica '...a natural reserve, devoted to peace and science'. At face value, therefore, the Antarctic continent and the oceans and islands surrounding it are better protected than almost anywhere else on earth. Recent developments suggest, however, that this is too sanguine a characterization. The Antarctic is facing several conservation challenges which are immediately familiar from a global perspective.

As a consequence, a process has been set in motion to provide a strategy for conservation for the region – the Antarctic Conservation Strategy (ACS). The ACS will provide a guide for conservation that is evidence-based and adopts best practise in both conservation science and its application. The ACS development phase involved a scoping of challenges facing the region in the immediate and more distant futures. Subsequently, much of the evidence required to develop effective modern conservation strategies has been marshalled. What does this evidence indicate?

Surprisingly little is known about the Antarctic biodiversity that is the subject of management. In the context of current and future challenges the extent of area protection (for biodiversity conservation) is poorer than in many areas of the world. Even pressures that are thought to have been addressed by the Environmental Protocol continue to be felt in a range of surprising ways. Conservation responses are much less effective than they might be, with questions of increasing activity and resource use being identified as growing conservation challenges that need to be addressed explicitly by science and by diplomacy.

Nonetheless, successful conservation interventions have been made, especially in the context of biological invasions, and particularly at the local scale. Moreover, strong policy guided by robust science can broaden the scope of conservation successes. The Antarctic Conservation Strategy will provide that robust evidence-base.

## Biodiversity Surprises in Antarctica

### Fraser C

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High latitude (polar and sub-polar) regions have traditionally been considered to have very low species diversity when compared to temperate and tropical regions. However, emerging evidence is now showing that Antarctica's biodiversity is considerably greater than previously thought. Many new, 'cryptic' species are being identified, as well as diverse genetic lineages within species, and much diversity probably still remains to be discovered. Research into broad-scale patterns of biodiversity has, unfortunately, been hindered by the logistical challenges of working in Antarctica, and there remain enormous sampling gaps – entire regions where almost nothing is known of the diversity of life, such across most of Marie Byrd Land. Research efforts should focus on closing these knowledge gaps, but we cannot wait until all diversity is identified to take measures to protect it. With increasing human pressure on the Antarctic environment, we need to move quickly to introduce protective measure to conserve the continent's unique diversity. Of particular importance is identifying areas where diversity is likely to be particularly high. Glacial refugia (pockets of ice-free terrain where species could survive through past ice ages) usually support much higher levels of diversity than areas that have only become ice-free since the Last Glacial Maximum. Glacial refugia could have included nunataks and parts of the Dry Valleys, but new research also indicates that geothermal regions – areas warmed either through volcanic activity or radiogenic decay of rocks – supported terrestrial life throughout past glacial periods and represent regions of high diversity. Likewise, geothermal areas in the ocean might represent diversity hotspots. An immediate focus on protecting regions around geothermal areas could help to preserve much of Antarctica's endemic terrestrial and marine biodiversity.

## Addressing Conservation Challenges in the Ross Sea Region

**Gilbert N, Newman J**

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By international accord Antarctica is designated as a natural reserve devoted to peace and scientific research. High standards of environmental protection are set through the international agreements that make up the Antarctic Treaty System. The Ross Sea region of Antarctica encompasses regionally and globally significant conservation and research values. The Ross Sea includes one of the least disturbed marine ecosystems on Earth. The Ross ice shelf is the largest ice-shelf on the planet and its regional marine and atmospheric interactions are of significant scientific interest. The McMurdo Dry Valleys are the largest ice-free area of Antarctica and are of significant conservation and research interest. The region contains several active volcanoes and important geothermal sites supporting unique microbial communities. The region has significant historic value through the remains of the first human settlements in Antarctica; the huts of Scott, Shackleton and Borchgrevink.

Partly driven by these conservation and research values, human activity in the region is showing a steady increase. Governmental research activities are supported from several year-round and summer-only stations and new facilities are being constructed or planned in the region.

Commercial fishing for Antarctic tooth-fish takes place annually in the Ross Sea and ship-borne tourism lands passengers at several locations throughout the region during the austral summer.

The implications of a changing Antarctic environment for the region's values, remains a significant unknown. In the context of the growing interest in the Ross Sea region and the potential for environmental and climate change, this presentation will examine the sustainability of the region's current values; assess the effectiveness of existing environmental standards and regulations; consider options for taking a regional approach to Antarctic conservation and identify opportunities for better integrating scientific research so as to support meaningful environmental management outcomes.

## The footprint of human impacts in cold climates: Lessons learned at McMurdo Station, Antarctica

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The largest of the three scientific bases operated by the United States Antarctic Program (USAP), McMurdo Station, has experienced localized environmental impacts over its fifty-plus year history. Starting in 1999 and continuing until present, a long-term environmental monitoring program has examined the impact of science and operations on the station's local terrestrial and marine environments. This program was developed from an assessment of system attributes amenable to monitoring, an understanding of the nature of historical and ongoing environmental impacts and a consideration of the spatial scales over which impacts would be expected.

Synthesizing more than ten years of environmental monitoring measurements has revealed the spatial patterns of impact in both terrestrial and marine environments. This time series now enables investigation of changes in contamination concentrations at McMurdo Station over time. With the exception of a small number of marine sites, no statistically significant temporal trends in the contamination levels over the 2003-2011 period are apparent. This is true both for the station as a whole and for individual areas where inadvertent releases of petroleum hydrocarbons, the most common contaminant, are most likely to occur.

Based on the monitoring program decade of observations, we reexamine how well the program's initial assumptions aligned with our observations. We also discuss how past monitoring can inform changes to future monitoring at McMurdo Station to make it more effective and cost efficient and enable it to continue to provide the scientific basis for future assessments of human impacts.

The monitoring program began at McMurdo Station is now being translated geographically to sites including the McMurdo Dry Valleys and Palmer Station. We discuss how the lessons learned at McMurdo Station have informed the design of monitoring activities at these sites; as well as being valuable to programs at other international Antarctic research stations with similar physical settings and mix of human activities to McMurdo Station.

## **Eradicating invasive alien species**

**Lee J**

Government of South Georgia and the South Sandwich Islands

Eradication of invasive species is often costly and complicated, but if successful, can have profound benefits for native biota. South Georgia's history of human exploration and exploitation began in the 18<sup>th</sup> and 19<sup>th</sup> century's with whaling and sealing expeditions and continues today with a thriving tourist industry and research base. As a consequence, numerous alien species have been introduced both intentionally and accidentally. The Government of South Georgia and the South Sandwich Islands, as custodian of the island, is mandated to conserve and restore habitats, and as part of this role has undergone a prioritisation exercise to determine which species should be subject to eradication attempts. At present, projects are underway to eradicate reindeer, rodents and several species of alien plants. Each eradication attempt presents its own challenges whether it is due to the species life history traits, its geographical spread or the public perception of its removal. By using the current eradication projects as exemplars, it is possible to better understand the challenges and consequences of undertaking such wide-scale habitat restoration work and look more broadly to see how these lessons can be applied elsewhere.

## Conservation Challenges at Fildes Peninsula

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Since the inception of the Antarctic Treaty, numerous regulations for environmental protection have been adopted by the Treaty Parties to minimize negative environmental impacts of human activities. Nevertheless, the concentration of a variety of human activities in some Antarctic regions has led to a conflict of interest. Fildes Peninsula, Ardley Island and adjacent small islands are located in the south-western part of King George Island, South Shetland Islands, Antarctic Peninsula. This region represents one of the largest ice-free areas in the maritime Antarctic. As a consequence of their high biodiversity and rich fossil deposits two Antarctic Specially Protected Areas (ASPAs) have been designated: ASPA No. 125 Fildes Peninsula and No. 150 Ardley Island. At present Fildes Peninsula hosts six permanent Antarctic stations, built between 1968 and 1994. The Fildes Peninsula represents a unique example of increasing human pressure due to multiple human uses. Scientific research, station construction and operations, transport logistics, tourism, conservation, and protection of geological and historical values regularly overlap in space and time. A standardised monitoring of bird and seal breeding sites, the occurrence of non-native species and the recording of human activities, with special attention to their associated environmental impacts was conducted between 2003–2006 and 2008–2014 to provide a comprehensive dataset that documents the environmental state of the region. Current breeding pair numbers for the three penguin species that breed on Ardley Island confirm the trend that has been observed in the population development of this colony. This trend is linked to the continuing warming of the climate and the associated reduction in winter sea ice expansion, which is itself connected with the development of krill, the main food source for Adélie penguins. The breeding success of the southern giant petrel (*Macronectes giganteus*) which is known to be very sensitive to human disturbance has decreased significantly during the last decades. Many incidences of damage to vegetation have been documented, caused mainly by vehicles being driven outside the road network or by construction activities and the associated quarrying of building materials. Based on our area of expertise, we are expecting a continuation of the current trends of increasing human activities and further anthropogenic influences affecting Fildes Peninsula on different scales. Further, we believe that there is urgent need for action with regard to improving management and co-operation on-site, e.g. by designating the Fildes Peninsula region as an Antarctic Specially Managed Area (ASMA).

## Remedying Terrestrial Protected Area Planning Deficiencies

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Antarctica is widely regarded as one of the planet's last true wildernesses, insulated from threat by its remote location and declaration as a natural reserve dedicated to peace and science. However, rapidly growing human activity on the continent is accelerating threats to biodiversity. We examined how well the existing Antarctic Protected Area network represents biodiversity and assessed protected area risk from biological invasions. We found that Antarctica is one of the planet's least protected regions. Five of the ecoregions remain completely unprotected and currently every one of the 55 designated areas that protect Antarctica's biodiversity lie closer to sites of high human activity than expected by chance, and seven of these areas lie in high risk areas for biological invasions. By any measure, including recently agreed targets under the Convention on Biological Diversity, Antarctic terrestrial biodiversity is poorly protected by reserves and those reserves are relatively highly threatened.

Clearly, in light of these deficiencies, more representative, and evidence-based protected areas are needed. However, conservation planning for the region is confounded by a lack of biodiversity data in many areas. Habitats can be robust proxies for biodiversity and there is growing recognition that habitat heterogeneity should be considered in the development of area protection and conservation strategies. Here we define different habitats in terrestrial Antarctica, on both a continental and bioregional scale. We use optimisation techniques to show how a hypothetical protected area network could be created that protects an adequate proportion of each of these habitats, while ensuring representative bioregional coverage. Our results suggest that, in conjunction with contemporary biodiversity data, habitat heterogeneity is a useful tool for delineating and identifying Antarctic Specially Protected Areas.

## Conservation Challenges - the Role of National Antarctic Programs

### Shears J

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An integral part of what is required for effective, practical conservation in Antarctica, and for addressing conservation challenges, lies in the hands of the national Antarctic programs that undertake operations and logistics, and are supporting scientific activity, in the region. Therefore, a joint scoping workshop was held between the Council of Managers of National Antarctic Programs (COMNAP) and the Scientific Committee on Antarctic Research (SCAR) in September 2013 to begin to identify the ways in which national Antarctic programs can help address conservation challenges and the requirements of conservation in a practicable manner.

The workshop explored the conservation challenges set out by Chown *et al.* in their *Science* (2012) paper. Workshop discussions confirmed that national Antarctic programs have a vital role to play in dealing with many, but not all, of the conservation challenges, which were identified by Chown *et al.* The workshop agreed that national Antarctic programs were best placed to address local conservation challenges, such as invasive species, habitat alteration and activity impacts, and pollution from local sources (including fuel handling and waste management). National Antarctic programs also provide vital support to Antarctic scientists undertaking monitoring and research into global conservation challenges, such as climate change and ocean acidification. In order for any conservation strategy to be effective, clear information must be available to managers of national Antarctic programs on the range of possible actions that can be implemented in response to the various conservation challenges. Such information can only be developed through clear communication between Antarctic conservation scientists and those responsible for enabling and supporting Antarctic science.

This presentation will present the key findings of the scoping workshop and explore the role of national Antarctic programs in responding to short and long-term conservation challenges. The presentation will also allow for further discussion of practical implementation strategies and their timeframes in order to inform the Antarctic Conservation Strategy.

## MINI SYMPOSIUM – CONNECTIONS BETWEEN THE SOUTHERN CONTINENTS

### Is the evolution of psychrophilic microorganisms related with major geological events in Antarctica?

**Blamey J**<sup>1,2</sup>

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The microbiota, and particularly the bacterial populations that have colonized modern Antarctica, remains largely uncharacterized. Antarctic microbial ecosystems provide useful models for general questions in evolutionary ecology and microbiology, given the relative isolation of the South Polar Region, the severe biological constraints imposed by the polar environment, and the absence of higher plants and animals in the Antarctic habitats.

The discovery of much fossil evidence along the geologic timescale support the idea of warmer conditions with extended ice-free zones existed in Antarctica. The new more detailed data are even more controversial: the existence of warm intervals after the “official” cooling of Antarctica, phenomenon that happened at least 23 million years ago.

Several new microbiological taxa have been recently described. The phylogeny of these microorganisms indicates that they may have arisen when the continent was warmer than it is today.

Not only its present environmental conditions harbor unique combinations of challenges for metabolic performance, but also its very distinct geological and climate history, shaping in a unique manner the evolutionary history of the microorganisms that lived under those extreme conditions. The Antarctic frozen environments such as permafrost, glaciers and permanent frozen lakes, are a source of ancient pool of genes that remains captured and might have been lost through evolution in warmer environments.

## **Ancient connections between Antarctica and South America: an approach from fossil vertebrates**

**Gelfo J**<sup>1</sup>, Acosta Hospitaleche C<sup>1</sup>, Reguero M<sup>1,2</sup>

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The relationship between South America and Antarctica is expressed both from geology and from the biotic history distribution. The marine and land vertebrates of Antarctica came from West Antarctica in the James Ross Basin. The proposed Austral Kingdom which comprises the southern areas in South America, South Africa, Australasia and Antarctica, arises as a good working hypothesis to explain several biotic patterns. The historical origin of the Austral Kingdom could be tested through the fossil record. Antarctica appears to have been a center of origin for many waterbirds that survived to the K-P boundary. Gaviiformes are represented in the Upper Cretaceous of Vega and Seymour islands, and also in Southern Chile. They survived during the Eocene, migrating to the Northern Hemisphere occupying the niche left by Hesperornithiformes. The origin of the Sphenisciformes that are highly diversified along the Eocene is closely related with Gaviiformes and Procellariiformes, whose oldest records belong to Antarctica. Antarctic penguins are besides known from the middle Eocene of Chile. Non-avian dinosaurs and land mammals were restricted to land bridge connections in order to distribute through or from Antarctica. Non-therian mammals as Gondwanatherians show a wide Southern Hemisphere distribution during the Late Cretaceous and Paleogene of South America, Madagascar and India, so their presence in the Eocene of West Antarctica could be interpreted as a relictual distribution. Despite the unknown Xenarthra origin, the rest of the therian mammals arrived to Antarctica from South America. Molecular phylogenies and the fossil record of marsupials agree with the idea that they used a West Antarctic route to reach Australia. In contrast to the high diversity of native ungulates in South America, sparotheriodontids and astrapotherians are by now the only which seems to arrive to Antarctica. Notoungulata started the most important South American ungulate radiation in Patagonia in the early Eocene, but strikingly they seem to be absent from the Antarctic record. These ungulates suggest an interruption of the terrestrial communication between the land masses by middle-late Paleocene, which could be consistent with the final break-up of the Weddellian Isthmus. In sum, vertebrates suggest that land relationship between South America and Antarctica could be dated back to the Jurassic if Australosphenida distribution are considered and seems to be no longer than late Paleocene.

## Paleobiogeography as a tool to reconstruct the evolution of Antarctic biota

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The Austral regions host a unique record of the diverse processes that took place before and during the opening of the Drake Passage, and the following period of isolation of the Antarctic continent. Many fundamental aspects of the driving forces controlling the biological, palaeoecological and geological evolution of the Antarctic Peninsula and Southern South America still remain unknown. The paleobiogeography, during the last decades, has advanced as a discipline due to the increasing utilization of phylogenetic tools coupled with an improved paleontological record, to the study of biogeographic patterns. No so sharp boundaries among disciplines have permitted to contrast palaeontology with molecular systematics through methods to date evolutionary divergence events. Those new analysis makes it possible to study both geo-dispersal and vicariance in a phylogenetic context, suggesting that biogeography as a discipline should focus on the analysis of a variety of congruent phenomena, not just vicariance. One of the paradigmatic relations between continents was the intermittent connections between South America and Antarctica during the Cretaceous. The existence and persistence of different vicariant events for marine and terrestrial ecosystems were inferred from the palaeogeographic reconstructions, but in the last decade, an amount of evidence is permitting to check the validity of those models. The timing of plate tectonic separation of Patagonia and Antarctica is crucial to understanding the origin of the austral biota. During most of the Jurassic-Cretaceous interval both landmasses were disconnected by the "Rocas Verdes Basin" and by the opening of the Weddell Sea, but a temporary reconnection occurred during the Turonian. From this and subsequent periods of the Late Cretaceous, remarkable marine and terrestrial deposits are recorded in the James Ross Basin and in the Fildes Peninsula Group, King George Island, Antarctica, as well as in the Magallanes basin in southern Patagonia, and the Quiriquina basin of northern Patagonia. New evidence from molecular phylogeography reinforces the model of reconnection, as shown by Struthioniformes and marsupials phylogenetic studies. On the other hand, end-Cretaceous dinosaurs of the Antarctic Peninsula (a megalosaurian type theropod, a nodosaur, an iguanodont, and a hypsilophodont) appear to have evolved from an older cosmopolitan fauna of Gondwana, as well as, new findings of Antarctic Maastrichtian flora in Magallanes region are indicating a reconnection pattern at the end of the Cretaceous.

## Reconstruction of high-resolution climate variability from coastal Dronning Maud Land, East Antarctica

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Antarctic climate variability is linked to the low and mid latitude climatic modes such as the Southern Annular mode (SAM) and the El-Niño Southern Oscillation (ENSO). The SAM, also known as the Antarctic Oscillation, is the principal mode of variability in the atmospheric circulation of the mid and high latitudes of the Southern Hemisphere. The ENSO, on the other hand, is characterized by a pattern of warm and cold sea surface temperature anomalies in the central and eastern equatorial Pacific with coupled atmospheric changes, which extend to Antarctica. However, both these climatic modes are known to be associated with each other. Variability of the SAM on an interannual time scale are known to be at least in part related to the ENSO during the austral summer. As an El-Niño causes a higher global mean temperature (GMT), a negative SAM is also associated with a higher GMT on interannual time scales. Thus, the combination of ENSO and SAM may partially offset or enhance their influence on the Antarctic Climate. Since the climatic forcing by SAM and ENSO can lead to an increase in air temperatures, these climatic modes can be traced through the analysis of oxygen isotopes from ice-cores, as oxygen isotopes are used as a proxy for air temperature. The  $\delta^{18}\text{O}$  record of last 100 years from a coastal Dronning Maud Land (DML) ice core, shows a significant relation to the SAM with a dominant  $\sim 4$  years variability, except during specific periods when ENSO teleconnection was established through the in-phase relation between SAM and ENSO. Surface air temperatures derived from  $\delta^{18}\text{O}$ , depict a significant warming of  $1^\circ\text{C}$  for the past century at coastal DML. The El-Niño leads to intensified cyclonic activity in the Weddell Sea which brings in warm air to the DML region. The moisture advection into the coastal region would be supplemented by the negative SAM, which leads to the weakening of westerlies. This would result in warm atmospheric air mass from lower latitudes to advect over Antarctica causing rise in surface air temperatures during austral summer. Climatic reconstructions reveal that throughout the last century, SAM was the dominant mode of climatic variability in the coastal region of DML on a decadal scale.

## The Southern Ocean: Source or Sink?

**Strugnell J**

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Many members of the benthic fauna of the Antarctic continental shelf share close phylogenetic relationships to the deep-sea fauna adjacent to Antarctica and in other ocean basins. It has been suggested that connections between the Southern Ocean and the deep sea have been facilitated by the presence of a deep Antarctic continental shelf coupled with submerging Antarctic bottom water and emerging circumpolar deep water. These conditions may have allowed 'polar submergence', whereby shallow Southern Ocean fauna have colonized the deep sea and 'polar emergence', whereby deep-sea fauna colonized the shallow Southern Ocean. Evidence for these connections between the deep sea and the Southern Ocean fauna will be described based on investigations of evolutionary relationships of Antarctic and deep-sea octopods.

## MINI SYMPOSIUM – INNOVATION IN ANTARCTIC SCIENCE

### Airborne Geophysics for Antarctic Tectonics: innovations in interpretation and modelling

Alan Aitken

School of Earth and Environment, University of Western Australia

Of all the Earth's continents Antarctica possesses the least geological exposure, and what does exist is focused along the spine of the Transantarctic Mountains and around widely-spaced areas of coastal outcrop, with very few regions of inland exposure. As a consequence, large tracts of Antarctica cannot be understood using "normal" tectonics research, which is heavily reliant on access to rocks through outcrop or drilling.

Geophysical methods that can image geology beneath the ice sheets are paramount in understanding the tectonics of Antarctica, and interior East Antarctica in particular. The most practical methods are airborne gravity and magnetic data, in concert with ice penetrating radar. These allow the only reliable means to image large tracts of Antarctica in a reasonable timescale and within logistical capabilities, although they primarily image the shallower crust. The IPY data collection efforts are due to be a cornerstone of Antarctic tectonic research for several years. For tectonics purposes, these data are not normally used in such isolated circumstances, and they require innovative approaches to interpretation and modelling to maintain robustness and maximise knowledge gain. We can appeal to several rapidly developing fields to achieve this.

**Tectonics reconstruction.** A traditional approach to understanding Antarctic geology is to use inferred intercontinental pierce points to constrain the Gondwana supercontinent reconstruction, and to extrapolate boundaries between regions of outcrop. The new higher resolution data, allied with new approaches to reconstruction, provide the opportunity to reverse this and to use these data to discriminate between reconstruction models, test some long-lived hypotheses, and to generate new ideas. A fully coupled understanding of reconstruction kinematics and Antarctica's emerging geological record requires a significant effort.

**Geophysical modelling.** Although not new, process-oriented modelling approaches are becoming routine, with capabilities including lithospheric flexure, and continental margin stretching examples. Numerical modelling provides the opportunity to build physically-valid tectonic scenarios that can be tested against real-data constraints. Recent research in gravity and magnetic inversion methods has focused on developing robust and useful methods for joint inversion of these. For many datasets, the joint approach reduces non-uniqueness in the model results. Robust approaches now exist for 3D joint inversion of gravity and magnetic data that can be applied to the new IPY datasets.

## Use of high-throughput sequencing in understanding Antarctic microbial communities

**Soon Gyu Hong**

Korean Polar Research Institute (KOPRI)

Understanding microbial community is an important first step to understand ecological functioning of microorganisms in Antarctic ecosystems. There have been advances in technology to understand microbial diversity and composition from culture-based methods to fingerprinting methods such as T-RFLP, SSCP, DGGE and ARDRA, and sequencing of clone libraries. They have served as key tools to study ecosystem composition and microbial ecology for a long time. Study of microbial community in natural environments was much advanced by recent introduction of Next Generation Sequencing (NGS) technologies. The NGS technology for high-throughput sequencing can provide fast, cheap and massive sequence information on environmental samples such as terrestrial soil, sediments, sea water, fresh water, and biotic samples. With the development of reliable databases and bioinformatics tools to analyze massive sequence information, microbial community structures, relationships with abiotic and biotic environmental factors can be understood. In this seminar, efforts to establish bioinformatics pipeline to analyze microbial community structures from massive sequence information will be introduced, highlighting sensitive steps that can lead to biased conclusions. As examples to show the power of high-throughput sequencing technology in microbial ecology, studies on soil microbial community in terrestrial soil samples from Victoria Land and King George Island and endolichenic fungal community in Antarctic lichens will be introduced.

## **Landscape-scale analysis of terrestrial and coastal ecosystems using remote sensing and satellite imagery**

**Joseph Levy**

University of Texas Institute for Geophysics

How do geology, hydrology, glaciology, and geomorphology shape the distribution of microbial mats and ecosystem processes at the landscape scale in the cold deserts of Antarctica? Determining how biotic and abiotic systems interact to create habitable oases at the limits of life in the soil, stream, lake, and glacier ecosystems of the McMurdo Dry Valleys (MDV) of southern Victoria Land has been a significant area of interdisciplinary research for over three decades. Here we describe new ways in which satellite, airborne, and ground-based remote-sensing are being used to develop a landscape-scale perspective on physical, chemical, and biological processes in the MDV that provide a quantitative framework for understanding the interactions among geological, biological, hydrological, and cryosphere systems shaping these cold desert landscapes.

Ground-based remote-sensing provides a tactical approach to measuring changing landscape conditions on inter-annual timescales. Repeat terrestrial laser scanner observations from Garwood Valley will be used to highlight rapid ground ice melting and thermokarst subsidence in this coastal valley. Coupled ground-based imaging and in situ meteorological sensor data will be used to illuminate physical drivers of landscape change. Airborne remote-sensing provides a regional view of changing surface conditions. Historical and modern aircraft-based imaging from Taylor Valley will be used to highlight changing extents of seasonally wetted soils in the MDV that have been implicated in soil ecosystem processes including changes to soil respiration, chemical weathering of sediments, and delivery of concentrated brines to MDV lakes. Limitations of existing data and next generation airborne and drone-borne spectroscopic techniques will be briefly highlighted. Finally, space-based sensors offer long-duration repeat imaging of MDV ecosystems on daily to weekly timescales. The strengths and weaknesses of satellite remote sensing platforms for understanding the distribution of geological and biological materials across the MDV will be summarized, and integrated into a broader understanding of how different sensor scales and platforms can provide an integrated view of polar landscape and ecosystem processes.

## **Reliable ice sheet modelling techniques, especially grounding lines**

**Frank Pattyn**

Laboratoire de Glaciologie, ULB, Brussels, Belgium

Significant improvements in ice sheet modelling have been made over the last couple of years, motivated by the need to understand continuing changes and by the challenge to make more realistic projections for the next few centuries. Models have increased in complexity and either the full Stokes equations are solved or equivalent approximations have been developed. Current Antarctic ice sheet modelling efforts focus on assimilating observations on surface velocities in initializations and improving the representation of grounding line migration due to the loss of buttressing and sub-shelf melting. These international efforts have been guided through marine ice sheet model inter-comparison exercises. Recent modelling efforts concentrate on the level of drainage basins, such as Pine Island and Thwaites glaciers.

## Timeline of Antarctic innovation - a brief introduction

**Martin Siegert**

Grantham Institute, Imperial College London

The Golden Age of discovery led to an appreciation of Antarctica as a place for science and innovation, which has characterised research developments in the Century since. This innovation, often learning lessons from failure, can be taken back to the pioneering use of motor-tractors by the Scott Expedition, through to the utility of aircraft in the 1930s, and to the ill-fated US 'snow cruiser' of the late 1930s. Post World War Two, and as a consequence of the 3<sup>rd</sup> IPY in 1957-58, a marked increase in technological change in Antarctic research took place. This transition can be characterised in glaciology from the development of seismic sounding in the early 1950s, providing the first measurements of ice-sheet thickness and volume, to the use of ice-penetrating radar in the late 1960s, allowing the measurements of ice thickness to increase in rate by five orders of magnitude. This innovation step led to our ability to measure the ice sheet at a continental scale, from which our understanding of ice sheet flow, stability and subglacial geology was forged. Much of today's research endeavour in Antarctic glaciology stems from this innovation, yet there is much still to do. Several places of Antarctica are without data, and in most places data are sparse, restricting our knowledge of the ice sheet and its bed. A future innovation step is therefore required, which may take the form of AUVs and swath-type systems, if a full knowledge of the Antarctic ice sheet and continent is to be gained. The lesson from history is that such technological developments revolutionise subsequent research.

## High resolution mapping of ice-free environments: examples from the West Antarctic Peninsula region

Gonçalo Vieira

CEG/IGOT – Universidade de Lisboa, Portugal

The West Antarctic Peninsula is one of the Earth's regions with a fastest warming signal since the 1950's with an increase of over +2.5 °C in mean annual air temperatures. Widespread changes have been reported for glaciers, ice-shelves and sea-ice, and recently, also for the permafrost environment. Changing permafrost will influence the terrestrial ecosystems by modifications in the active layer thickness, ground freezing regime, hydrology, geomorphodynamics and possibly, by changes in biogeochemical fluxes. Mapping and monitoring of the ice-free areas of the Antarctic Peninsula region has been until recently limited by the available aerial photo surveys, but also by the scarce high resolution satellite imagery (e.g. QuickBird, WorldView, etc.) that are seriously constrained by the high cloudiness of the region. The later provide excellent tools for vegetation and geomorphological mapping and therefore have been used for mapping purposes in some areas, but they have never been used for repeat monitoring of changes in land surface conditions. Recent developments in Unmanned Aerial Vehicles (UAV's), which have seen significant technological advances and price reduction in the last few years, allow for a systematical use for mapping and monitoring in remote environments. In this talk, I will present the first results from the application of a Sensefly ebee UAV in mapping the vegetation and geomorphological processes, as well as for digital elevation model generation in a test site in Barton Peninsula, King George Island. The UAV is a lightweight (ci. 700g) aircraft, with a 96 cm wingspan, which is portable and easy to transport. It allows for up to 40 min flight time, with possible application of RGB or NIR cameras. We have tested the ebee successfully with winds up to 10 m/s and obtained aerial photos with a ground resolution of 4 cm/pixel. The digital orthophotomaps, high resolution DEM's together with field observations have allowed for deriving geomorphological maps with unprecedented detail and accuracy, providing new insight into the controls on the spatial distribution of geomorphological processes such as patterned ground. The talk will focus on the first results from the field survey of February and March 2014, which were obtained in the framework of an ongoing collaboration between the University of Lisbon (G. Vieira, P. Pina and L. Bandeira) and the Korean Polar Research Institute (S-G. Hong and H-C. Kim).

## Clean technologies for deep subglacial exploration in Antarctica

**J.L. Wadham**

Bristol Glaciology Centre, University of Bristol

A dramatic development in Antarctic Science in recent decades has been the considerable international effort aimed at improving understanding of the hidden subglacial aquatic environments (SAEs) beneath the ice sheet. These include a diverse range of lakes, rivers and deep sedimentary basins, which have been isolated from the atmosphere for some millions of years. Technology challenges associated with the exploration of these environments are substantial because of their remote nature, extreme conditions and the requirement for sterile/clean access and sampling. While two subglacial lakes have now been penetrated (Subglacial Lakes Vostok and Whillans), significant challenges remain for a) the clean access and sampling of deeper SAEs, such as deep sediments in lakes and sedimentary basins, and also b) for *in situ* monitoring of physical, chemical and biological conditions in SAEs. The scientific arguments for deeper drilling into sediments are compelling. Data providing clues to the glaciation history of Antarctica and past climate are likely to be locked up in these deeper sedimentary strata. They are also likely oases for microbial life, which is actively involved in biogeochemical cycling processes, such as methane hydrate formation within deep sedimentary basins. This talk aims to give an overview of the current challenges and technology solutions for the exploration of SAEs, with a particular focus on sensing technologies.

**Advances in understanding the bed of the ice sheet: 1. ice-penetrating radar data collection and processing (SAR, SWATH); 2. use of satellite remote sensing in understanding subglacial systems**

**Duncan A. Young**, Donald D. Blankenship, Dustin M. Schroeder and Jamin S. Greenbaum

University of Texas Institute for Geophysics

Over the last twenty-five years, a combination of advancing spaceborne platforms and airborne geophysical systems have transformed our view of the major ice sheets in Antarctica and Greenland. Comprehensive satellite coverage, beginning with images of increasing resolution and frequency, followed by altimetry, surface velocity, repeat altimetry and then repeat gravimetry, have allowed us insight into both the form and the dynamics of the ice sheet. Understanding the processes and forcings responsible for ice sheet dynamics, as well as the implications of these dynamics, requires the imaging of the volume of the ice sheets and their substrate. As ice is transparent at radio frequencies, and the remote and vast nature of these ice sheets, airborne radar sounding has been the most comprehensive remote sensing tool for understanding ice sheet structure.

The combination of satellite altimetry and radar sounding highlighted the importance of subglacial hydrology under ice sheets, first as subglacial lakes, then as active hydraulic relays, and now as once hypothesized, and now directly observed, organized hydrologic systems underlying much of the ice sheet. Understanding this organization will be key for answering the following questions: What is the interior water supply to regions of active ice sheet dynamic change? Where is deep ice, bearing ancient records of the atmosphere, protected from melting? What is the distribution subglacial water tell us about heat flow at the basal boundary? How is the possible subglacial biotia distributed, and how can we protect it?

We contend that one way forward in answering these questions is targeted survey at the regional scale of the interior of the major ice sheets, paying particular attention to the full recovery of scattering information from the bed now offered by modern nadir profiling methods, and to comprehensive grids designed to sample the full information content of subglacial hydraulic catchments. Rapidly improving interpolation methods can expand the information content of individual profiles, but must be constrained by measurements of basal conditions and the statistical nature of the bed.

Swath mapping by radar is an exciting new tool for understanding the 3D deterministic topography of the bed in local regions. Its use must, however, be carefully traded against the needs for intelligent large scale spatial coverage and radiometric fidelity. Complementary use of both regional and local approaches have tremendous promise to address the exciting questions above. Critical for the success of any of these resource intensive approaches will be the international and interdisciplinary collaborations fostered by SCAR.

## Collection and analysis of micro-climate data to explain biological heterogeneities

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A microclimate is a small-scale (sub-meter to a hundreds of meters) atmospheric zone where air temperature and humidity differs from the surrounding area due to variability in surface radiation and energy balances. Surface radiation balance is a function of net solar and thermal radiation inputs, and is distributed into the atmosphere via sensible and latent heat fluxes and into the ground through ground heat flux. Microclimates respond rapidly to fluctuations in solar radiation and surface characteristics such as soil moisture. The degree of influence that microclimates have on controlling species distribution is highly dependent on latitude, regional synoptic climatology, and complexity of the surface. The simplicity of land-cover in the McMurdo Dry Valleys (MDV) and rapid response to climate change present an opportunity to understand the linkages between large-scale climate change and microclimates at a fundamental level. Through data obtained from the Long Term Ecological Research (LTER) programme, there is evidence to suggest that the terrestrial ecosystem in the MDV responds rapidly to climate shifts, which creates difficulty for climate and ecosystem model predictions. We aim to understand the role of surface heterogeneity in microclimate variation across the MDV by understanding how the surface partitions radiative energy into sensible, latent, and ground heat fluxes. A range of summertime in situ and near-target remote sensing techniques are used to characterise energy partitioning by the surface, and its influence on the atmosphere close to the ground. These include SONIC Detection and Ranging – Radio Acoustic Sounding System (SODAR-RASS) to profile the atmosphere, turbulent eddy-covariance measurements to quantify radiative energy partitioning, and fixed and mobile thermography to understand the variation of land-surface temperature across the landscape. The presentation will provide a summary of challenges in employing such advanced techniques in the MDV, and some preliminary results from the past three field season.

## S01: ANTARCTICA AND THE SOUTHERN OCEAN IN THE 21ST CENTURY

### Estimating Antarctic ice sheet surface mass balance contribution to future sea level rise using the regional atmospheric climate model MAR

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The Antarctic ice-sheet surface mass balance (SMB) is a significant contribution to sea level changes which may mitigate the rise in sea level in a warmer climate, but this term is still poorly known. The Antarctic SMB cannot be directly deduced from global climate models (GCMs) because of their too low resolution (~100 km) and their unadapted physics over cold and snow-covered areas. That is why the use of regional climate models (RCM) specifically developed for polar regions is particularly relevant. We present here new estimations of the Antarctic SMB changes for the 20th and the 21st century at a spatial resolution of 40 km with the MAR (Modèle Atmosphérique Régional) RCM. Recent studies showed that large scale forcings from GCMs were the main source of uncertainty for RCM-deduced SMB, thus we first present a careful analysis of the CMIP5 GCMs (used in the AR5 IPCC report) compared to the ERA-Interim reanalysis over Antarctica and the Southern ocean region, from which we could select the less biased large scale forcing for MAR. Then we show the Antarctic SMB evolution as modeled with MAR forced by the best models (which includes ACCESS1-3) for RCP 4.5 and 8.5 greenhouse gas scenarios. We evaluate our outputs by comparing MAR forced by ACCESS1-3 and ERA-Interim for the 1980-2000 period to more than 2700 quality-controlled observations and to surface meteorological data from the READER database. To finish we give SMB changes estimations for the 21st century together with an analysis of uncertainties coming from the MAR model, the GCM forcing and the greenhouse gas scenarios.

## Chemical characteristics of water masses in the Commonwealth and Amundson Seas

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The main objective of present work is to consider chemical characteristics of shelf and slope waters in the Commonwealth and Amundson Seas. Data of Russian surveys led during the Antarctic summer of 2006 – 2014 on RV “Academic Fedorov” and “Academic Treshnikov” was analyzed. Distribution of dissolved oxygen, silicate, phosphates and nitrates in the water masses of the Commonwealth and Amundsen seas was shown. Significant differences in the structures of the shelf and slope waters of the Commonwealth Sea and the Amundsen Sea were observed.

A water structure at the oceanological sections of the Commonwealth Sea was constituted by the Antarctic Surface Water (AASW) with enough high concentration of silicate, nitrate nitrogen and phosphates compare with other areas of the World Ocean; the Upper Circumpolar Deep Water (UCDW) characterized by a minimum of the oxygen content, and a maximum of nutrient concentrations; The Lower Circumpolar Deep Water (LCDW) primary characterized by a salinity maximum and a minimum of nutritive salts as well; and the Antarctic Bottom water (AABW). It was shown that the local cold, salt and dense Antarctic Shelf water (ASW) formed in the shelf area of the Commonwealth Sea. The ASW was defined by a higher content of dissolved oxygen and lower contents of biogenic elements compared with the CDW characteristics. The ASW mixed with the CDW and their mixture (The Bottom Water of the Prydz Bay (BWPB)) moved down along the slope, and reached the bottom. The chemical characteristics of the BWPB were analyzed. The BWPB was defined by higher content of dissolved oxygen (more 5.5 ml/l) and lower contents of biogenic elements (silicon - low 120  $\mu\text{M}$ , phosphates – low 2.35  $\mu\text{M}$  and nitrates – low 29  $\mu\text{M}$ ) in the bottom layer at the slope compared with the Circumpolar Deep Water (CDW) characteristics. Interannual variability of characteristics of the water masses was observed on the repeated oceanological section along 70° E in the Commonwealth Sea.

A water structure at the section in the Amundsen Sea was constituted by the two basic water masses – the AASW and the CDW. The AASW was characterized by enough low for summer season content of the dissolved oxygen and high concentration of the dissolved silicon, mineral phosphorus and nitrates (50-55  $\mu\text{M}$ , 1.8-1.9  $\mu\text{M}$  and 26-28  $\mu\text{M}$ , accordingly). The CDW was presented by the UCDW and LCDW. The UCDW was shown by available of the Tmax layer on depths 200 – 400 m with temperature in a range 1.2 – 1.6°C and minimum of the dissolved oxygen 3.6-4.2 ml/l and maximum in distribution of phosphates and nitrates (2.5-2.55  $\mu\text{M}$  and 32-35  $\mu\text{M}$ , accordingly). A free entrance to the shelf area of the CDW was observed therefore formation of the Antarctic Shelf Water here was represented impossible.

## Why do different climate models give different answers? An analysis of 21st century wind changes over the Amundsen Sea, West Antarctica, in CMIP5 climate models

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British Antarctic Survey

The influence of changes in winds over the Amundsen Sea has been shown to be a potentially key mechanism in explaining rapid loss of ice from major glaciers in West Antarctica, which is having a significant impact on global sea level. Here, Coupled Model Intercomparison Project Phase 5 (CMIP5) climate model data are used to assess 21<sup>st</sup> century projections in westerly winds over the Amundsen Sea ( $U_{AS}$ ). For a given scenario of greenhouse gas concentrations, differences between different model projections can be split into contributions from internal climate variability and model uncertainty. Model uncertainty comes from differences in the way different climate models are constructed and internal variability of the climate system is a further contributor. These sources of uncertainty are quantified in projections following Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 scenarios.

For the decade 2090-2099 the CMIP5 models show ensemble mean 21<sup>st</sup> century changes in annual mean  $U_{AS}$  of 0.3 and 0.7 m s<sup>-1</sup> following the RCP4.5 and RCP8.5 scenarios respectively. However, as a consequence of large internal climate variability over the Amundsen Sea, it takes until around 2030 (2065) for the RCP8.5 response to exceed one (two) standard deviation(s) of decadal internal variability.

In all scenarios and seasons the model uncertainty is large. However the present-day climatological zonal wind bias over the whole South Pacific, which is important for tropical teleconnections, is strongly related to inter-model differences in projected change in  $U_{AS}$  (more skilful models show larger  $U_{AS}$  increases). This relationship is significant in winter ( $r = -0.56$ ) and spring ( $r = -0.65$ ), when the influence of the tropics on the Amundsen Sea region is known to be important. Horizontal grid spacing and present day sea ice extent are not significant sources of inter-model spread.

## Polar-equatorial interactions off New Zealand from Last Glacial Maximum to 2014

Carter L

Antarctic Research Centre

The combination of modern observations and past ocean/climate reconstructions provides insights into the driving processes and outcomes of polar/tropical influences on offshore New Zealand (NZ) from the Last Glacial Maximum (LGM) to the present day. During the LGM, the Subantarctic and Polar fronts of the Antarctic Circumpolar Current (ACC), migrated north in the Tasman Sea concomitant with shifts of the Subtropical and Tasman fronts. Presumably this change was a response to shifting westerly zonal winds under evolving pole-equator temperature gradients. Off eastern NZ that migration was modulated by the regional bathymetry. ACC fronts compressed against the western boundary presented by Campbell Plateau thus enhancing the ACC, which formed a branch current to central NZ and the eastern lower North Island via gaps in the boundary. As a result, subantarctic surface waters dominated the upper ocean facilitated by a weakened and possibly diverted subtropical inflow to northernmost NZ. However, as zonal westerlies returned south, polar influences declined and the subtropical inflow via the eastward Tasman Front and to a lesser extent, the Subtropical Front, became prominent by the Holocene Optimum.

That trend of polar contraction and tropical expansion continues today, but probably at an accelerated rate under increased greenhouse gases and the “ozone hole”. Since the 1940s, observations show a marked expansion of the subtropics as westerly storm tracks shift south and the South Pacific Gyre spins up. Off eastern Australia, the extension of the East Australian Current has strengthened over 350km southward resulting in the subtropical colonisation of previously subantarctic habitats off Tasmania. Those Australian developments potentially reduced the Tasman Front inflow but that may be offset by an increase in the Subtropical Front linking Tasmania with southernmost New Zealand, as evinced by reconstructions of the last interglacial period. Despite the ongoing subtropical expansion, Antarctica maintains a strong influence on modern NZ climate to as far north as the central North Island.

## Circulation-driven temperature trends at Scott Base and McMurdo Station

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The average temperature difference between Scott Base and McMurdo Station is approximately 3°C, despite both stations being located at the tip of the Hut Point Peninsula, Ross Island, and separated by only ≈3 km. This difference in temperature is coupled with puzzlingly disparate temperature trends in the period 1979-2011. Both stations show cooling in autumn and warming in spring. However, the trend at McMurdo Station is significantly more positive than at Scott Base in both seasons. This disparity is particularly important given the surroundings of the stations, as the historic lack of data means that the stations represent the entirety of the *in situ* surface climate record in the Ross Ice Shelf region before the introduction of reliable automatic weather station units.

We investigate temperature at both locations via the application of a synoptic climatology derived from ERA Interim surface winds. We find that temperatures at Scott Base are highly sensitive to circulation over the greater Ross Ice Shelf region, and postulate that this occurs due to a semi-permanent temperature inversion present at the base. During times of strong winds, such as during Ross Ice Shelf Air-stream (RAS) events, turbulent vertical mixing disrupts this inversion and causes warming at the surface. We find that temperatures at McMurdo Station are less sensitive to synoptic circulation forcing.

In this talk we will demonstrate that the increasing frequency of RAS events in the spring time, associated with a greater number of deep synoptic cyclones in the north-eastern Ross Sea, has driven the positive temperature trend at Scott Base during this period. This is concurrent with a northward shift in the location of the Amundsen-Bellinghshausen Sea (ABS) low and a deepening of its relative pressure.

## SST changes in Admiralty Bay, King George Island over last 50 years: Archaeal lipids (TEX<sub>86</sub> paleothermometry) as temperature proxy

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The Antarctic Peninsula is one of the fastest warming locations on the planet. Recent temperature increases have led to progressive deglaciation, ice-shelf disintegration, and a decline in sea ice area, what may contribute to environmental changes in one of the world's most precious ecosystems. However, to put the current warming trend into perspective, accurate records of past variations in temperature from this region are needed. Here we applied TEX<sub>86</sub> paleothermometry to two short sediment cores (BTP and STH) taken from the Martel inlet, Admiralty Bay (62°02'S, 58°21'W), King George Island. The high sedimentation rates at this location (0.5 cm/yr) allow for bi-annual sea surface temperature (SST) reconstructions over the last 50 years (1960-2007).

The reconstructed SSTs for this period varied between -0.8 and 4.6 °C (mean = 0.9 ± 1.2, n = 20) and -0.1 and 4.9 °C (mean = 2.6 ± 1.6, n = 18) for BTP and STH, respectively. These results are compatible with modern annual mean SST for this location retrieved from the WOA09 (- 0.53 to 0.06 °C). The TEX<sub>86</sub>-based SST increase at a rate of 0.4 and 1.0 °C/decade (BTP and STH, respectively) during the last 50 years. This is similar to but slightly faster than found previously for the more northern Bellingshausen Sea (70°S, 80°W), where the rate has been around 0.2–0.3 °C/decade. Similarly, mean annual air temperatures at King George Island increased by a mean rate of 0.2 °C/decade, with a 0.4 °C/decade increase for the winter season.

In addition to the long-term trend, there are dramatic (up to 3 °C) short-term variations over the past 50 years. It is possible that this represents a random bias with respect to sampling of different seasons. However, we consider that unlikely because each 1-cm sample represents two years and similar features are observed at both BTP and STH. Instead, we suggest that these variations reflect short-term climate variability imposed on the long-term trend.

Despite of the limitations of age model and sampling time resolution, these preliminary results indicate that the marine realm has experienced absolute temperatures and temperature variation broadly similar to that measured on land. In particular TEX<sub>86</sub> data provide evidence ocean warming in the King George Island environment over the last 50 years, coinciding with the recent rapid warming of the Antarctic Peninsula.

## Using high-frequency glider data to understand effects of sub-mesoscale processes and atmospheric forcing on the mixed layer in the Subantarctic Zone.

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Traditional understanding of mixed-layer (ML) dynamics in the African sector of the Southern Ocean suggests that seasonal summer stratification is determined by the onset of a positive net heat flux. However, the impact of intra-seasonal variability on the ML is still relatively unknown. Recent research in the North Atlantic has highlighted the role of sub-mesoscale dynamics (mixed-layer eddies, or MLE) on ML stratification. It is now understood that horizontal density gradients drive these sub-mesoscale eddies, which result in the 'early' onset of spring phytoplankton blooms. To test the MLE hypothesis in the Subantarctic Zone (SAZ), we use high-resolution (~3km, 4 hourly) glider measurements that exhibit contrasts between a highly variable spring ML and strongly stratified summer ML. We propose that among other parameters such as wind stress and mesoscale features, MLE have a large effect on stratification in the austral spring, whereas solar heating dominates control during the austral summer months. As the MLE are governed by the horizontal buoyancy gradient and ML depth, we examine and compare distributions of the observationally inferred gradients in spring, with those from summer, as well as those from the spring North Atlantic Bloom (NAB) model (where MLE are present). Additionally, the time series of glider parameters are examined to understand event scale behavior of the ML.

## The Plateau Laclavere: A new climate relevant potential ice-coring site at the northern Antarctic Peninsula

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Ice cores are of especial interest in a region with atmospheric and oceanic warming as coastal Antarctica, which has been proved to be an important contributor to sea-level rise. However, in this area meteorological records are restricted to the past 50-60 years, thus to the industrial influenced era only.

Ice cores offer a unique look into the past climate variability. However proper geochemical characterizations of different parameters are needed to understand complex signatures especially from polar coastal regions. High accumulation zones, such as the Antarctic Peninsula (AP) allow to study these parameters at high temporal resolution including: single extreme events, moisture source and air-mass pathways, temperature anomalies, as well as other climate relevant parameters such as sea ice cover.

Since 2008, we have continuously investigated the isotope signature of recent precipitation at single-event scale from the Chilean Station O'Higgins (OH) (63°19'15"S, 57°53'55"W). Isotopic information complemented with meteorological and circulation models, like Hysplit, revealed 4 well defined moisture sources for this area (Bellingshausen Sea, Amundsen Sea, South Atlantic and South Pacific).

A complete altitudinal profile of snow and firn cores from sea level from OH to about 1050 m a.s.l. at the Plateau Laclavere (LCL) (63°22'09"S, 57°39'33"W), shows that mean air temperatures as up to 600-700 m a.s.l. can reach well above 0°C during summer, as observed from ice layers on the cores, blurred isotope curves and physical properties of the firn. Therefore, all areas below this critical altitude are not well-suited for further glaciological research at the moment. Above 700 m a.s.l. snow properties are clearly different, with temperature of the snow of around -5°C at surface and -9°C at 2m depth. Concordantly, isotope curves from firn cores retrieved in 2010 and most recently in 2014 are well preserved. Moreover, visual inspection of the cores shows only very restricted melting events during summer as one unusual rain-event during January 2014, observed from sea level to LCL.

Satellite radar observation coincidently shows a clear difference on snow reflection property during summer, which coincides with the line of the wet/warm snow surface below 600-700 m a.s.l. and dry/cold snow above this line.

As expected, the accumulation rates estimated from the firn cores at this area is much higher than other coastal regions from Antarctica, with annual values of around 2.3 m weq (water equivalent). Recently acquired ground penetrating radar information (2014), shows preliminary depth of the ice cover of around 350m at the highest point of the LCL and fairly regular sub-glacial topography. All the information gathered until now, points out that LCL represents a well-suited place to obtain a longer climate record (~150 years). A deeper drilling campaign will be carried out in the near future (2015/2016).

## Seasonal Antarctic station-based pressure reconstructions during the 20th century

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A key component in understanding climate variations across Antarctica, whether from the Southern Annular Mode (SAM) or from tropical teleconnections, is understanding changes in the atmospheric circulation. Normally depicted as changes in advection patterns, these circulation changes are routinely inferred from variations (anomalies) in the surface and/or mean sea level pressure patterns. In this vein, recent studies demonstrate that (a) changes in the atmospheric circulation due to tropical forcing are an important player in temperature variations in West Antarctica and the Antarctic Peninsula and (b) temperature trends across the Antarctic Peninsula are reversing despite no significant changes in the sign/magnitude of the SAM. Together these conclusions suggest that climate variations across Antarctica are quite complicated and many forcing mechanisms need to be considered, especially to detect and attribute trends and decadal scale variability. Yet, as with much of Antarctic data, researchers are left with neither long-term point (station) measurements of pressure variations across Antarctica, nor gridded pressure data from reanalyses or models that can be deemed reliable, given very little *in situ* data to constrain the solution across the high southern latitudes. This talk presents station-based reconstructions of 17 Antarctic manned stations by seasons. We employ principal component regression using midlatitude pressure observations as predictors individually for each Antarctic station. We are able to reconstruct the austral summer and winter pressure back until 1905 with fairly high skill, and modest skill in austral spring and autumn. The reconstruction skill along the Antarctic Peninsula is considerably higher in all seasons. A few reconstructions are used as examples to place the recent atmospheric circulation changes in a longer historical context, thereby highlighting the uniqueness of these recent changes. Future work includes conducting a spatial Antarctic-wide pressure reconstruction back until 1905.

## Possible ocean-forced East Antarctic Ice Sheet instability and sea level change at the Last Interglacial

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The contribution of the Antarctic ice sheets to global sea levels under projected future warming remains uncertain. The Last Interglacial (135,000-116,000 years ago) provides an analogue for future scenarios, with global temperatures some 2°C above present, but with sea level estimated to be 6.6 to 9.4m higher than now. Previous studies suggest that this high stand resulted from collapse of the marine-based West Antarctic Ice Sheet and Greenland, combined with thermal expansion of the oceans with little, if any sea level rise attributed to the East Antarctic Ice Sheet (EAIS). However, Last Interglacial model simulations, cannot fully account for the magnitude of sea level rise suggested by geologic records without significant input from the EIAS. Here we report a series of model simulations that explore the impact of migrating Southern Hemisphere westerly winds on Last Interglacial ocean circulation and Antarctic ice-sheet dynamics. Our simulations suggest that a poleward shift in the westerlies could have affected the Southern Ocean polar gyres, inducing pervasive warming (0.2-0.8°C in the upper 1,200m) adjacent to three regions of the East Antarctic Ice Sheet: the Weddell Sea, Ross Sea and Prydz Bay. Ice-sheet modeling indicates the adjacent sectors of the EAIS are highly sensitive to ocean forcing due to their bed geometries and connectivity to the Southern Ocean, and may have contributed to the 'missing' component of high Last Interglacial sea level. Furthermore, 21<sup>st</sup> century projections indicate that circum-Antarctic warming may be pervasive, suggesting an EAIS response may be anticipated, with important implications for future sea level projections.

## Recent changes in the thickness and depth of Subantarctic Mode Water

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Argo float data indicate that the Subantarctic Mode Water (SAMW) has thickened and deepened between 2005 and 2013. The increase in thickness and depth of the SAMW is attributed to positive (anticyclonic) wind stress curl anomalies in the formation regions of SAMW north of the Subantarctic Front. The pattern of change in SSH is similar to the change in mean depth of the SAMW, consistent with stronger Ekman pumping driving convergence and downwelling, and hence positive anomalies in sea surface height. Changes in wind forcing appear to be largely responsible for the observed changes in the thickness and mean depth of SAMW.

## Assessment of the ECCO2 reanalysis on the representation of Antarctic Bottom Water properties

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We analyzed the ability of the Estimating the Circulation and Climate of the Ocean – Phase II reanalysis to represent the hydrographic properties and variability of the Antarctic Bottom Water (AABW) in the Southern Ocean. We used a twenty-year observational database to perform comparisons of hydrographic properties and reanalysis data for the same time period (1992–2011). In addition, we evaluated four *case studies* based on current meter data and the AABW volume transport estimates previously reported in the literature. The main Southern Ocean oceanographic features, as well as the characteristic shape of the regional potential temperature–salinity ( $\theta$ – $S$ ) diagrams, are adequately represented by the reanalysis. However, the opening of an oceanic polynya in the Weddell Sea Sector, which has been clearly visible since 2005, contributed to an unrealistic representation of the hydrographic properties of the Southern Ocean primarily after 2004. In this sense, our analyses focused on the period that was identified as more reliable (1992–2004). In general, the reanalysis data showed surface waters that were warmer, saltier, and denser than observations, which may have resulted from the absence of Ice Shelf Water and from the overestimation of sea ice concentrations that limit oceanic heat loss during austral winters. Intermediate waters were generally colder, fresher, and denser than observations, whereas deep waters were warmer and less dense. These differences in deep water properties were partially a result of the inability to reproduce the densest AABW variety by reanalysis for most of the analyzed period and also because of the model’s relatively coarse vertical resolution. Despite differences in absolute values, the upper AABW limit ( $\gamma^n \geq 28.27 \text{ kg m}^{-3}$ ) and AABW occupied area were well represented in the WOCE repeat sections SR2 and SR4 for the studied periods. The *case studies* showed a good representation of the AABW volume export and current velocity variability in the most important region of dense water export (i.e., the Weddell Sea). The exception is the AABW volume transport near the Kerguelen Plateau, in which the rugged local bathymetry and the relatively coarse model resolution hampered a fair representation of the transport variability by the reanalysis. Despite the consistency in terms of variability, absolute volume transport, and velocity, estimates were underrepresented in all cases. Moreover, the reanalysis was capable of reproducing the general variability pattern and trends of the AABW hydrographic properties reported by previous studies. Therefore, the ECCO2 data from the 1992–2004 period was considered adequate for investigating the circulation of the AABW and variability of the hydrographic properties, whereas data from the latter period (2005–2011) must be given careful attention.

## Year-round micrometeorological observation of terrestrial photosynthetic organism habitats for capturing the effect of climate change

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Yukidori valley in Langhovde that is located in Sôya coast of the east Antarctica is registered with ASPA (No.154) for the lush vegetation. The aim of this study is to build a basis for monitoring the effect of climate change to terrestrial photosynthetic organisms growing in this area. For achieving continual observation of habitats for long-term period, the year-round micrometeorological observation system was set up during January 2013. The observed objects are each habitats of *Umbilicaria decussate* (lichen), *Ceratodon purpureus* (bryophyte) and *Prasiola crispa* (green algae), and the observing items are air temperature, humidity, light intensity (PAR) and surface temperatures of samples. Snow covered conditions were logged hourly by the stationary camera. In addition to that, ultraviolet intensity was observed during January 2013. We would like to show the analysis result of the micrometeorological observation data from January to December 2013. The differences of growing environments during three photosynthetic organisms became clear. *U. decussate* which was growing on the upper surface of the rock started to be exposed to irradiance that enough to photosynthesis by the end of September, because their habitat was covered with small amount of snow even during winter. And it was expected that *U. decussate* became dry condition by the mid-November for depletion of continuous water supply from the snow drift. After that time, their activity will rely on snowfall and they will repeat dry-wet cycle during summer season. On the other hand, *C. purpureus* and *P. crispa* were covered by more large snow and they seemed to receive water supply until the end of December. The difference of physiological futures among photosynthetic organisms in Antarctica will induce differences of their habitats or active periods. For example, in physiological experiment, it was clear that *P. crispa* has high sensitivity against irradiation especially in UV to blue light region compared to *U. decussate* and *C. purpureus* and the observational result showed that the integrated value of UV radiation in the habitat of *P. crispa* was lowest among three habitats.

Climate change will induce microclimate change of their habitats, change their active periods or energy balance and finally induce ecosystem change. For the evaluation of these effects against climate change to ecosystem of Antarctica, it is important to keep monitoring year-round microclimate observation and to analyze these data in conjunction with their physiological futures.

## Primary production and phytoplankton growth in the West Antarctic Peninsula: Observations and modeling analysis

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Through the development and application of ocean carbon models, we are quantifying the Southern Ocean uptake of atmospheric CO<sub>2</sub> and exploring potential feedbacks of projected global warming on this uptake. However, model projections remain highly uncertain in the Southern Ocean, due to inadequate representation of both physical and biogeochemical processes. Simple models of coupled nutrient-biological cycles are useful for understanding and evaluating biogeochemical processes in the marine environment. Indeed simple models offer advantages over more complex formulations in that they have fewer uncertain parameters.

During each annual cycle of ice formation and decay, the algae associated with the 20 million km<sup>2</sup> of Antarctic sea-ice must survive extreme changes in environmental conditions. Pelagic microalgae are incorporated into the sea-ice matrix as it forms in early winter and dense microalgal mats develop on the underside of the sea-ice during the winter and spring. As the sea-ice melts these algae must survive in the melt-water before the seed the annual ice-edge algal bloom.

Here a four-component ecosystem is used to reproduce the main ecosystem features of the surface mixed layer in the Western Antarctic Peninsula (WAP) and provide insight into the fundamental biological interactions in the ocean. Model outputs are compared to both satellite surface chlorophyll estimates and in situ measurements from one location in the WAP.

Preliminary results suggest that the model is able to reproduce the seasonal cycle, the timing and size of the summer bloom at the sampling site. It is hypothesised that the magnitude of the summer bloom observed in the region may be driven by either iron supply, or variations in zooplankton grazing. The results also provide an indication of the phytoplankton capacity for acclimation to changing light and water chemistry conditions. We suggest that a model that does not incorporate the role of iron in the ecosystem cannot realistically fit the observations.

These results are a contribution to our understanding of the physical forcing of biological processes such as primary production at the scale of WAP region, and inform about possible responses to natural iron fertilization in different locations of the Southern Ocean. This comes at a time when the scientific and broader community is urgently seeking quantification of the regional impacts of a warming ocean.

## Impact of the initialisation on the predictability of the Southern Ocean sea ice at interannual to multi-decadal timescales

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In this study, we assess systematically the impact of different initialisation procedures on the predictability of the sea ice in the Southern Ocean. These initialisation strategies are based on three data assimilation methods: the nudging, the particle filter with sequential resampling and the nudging proposal particle filter. An Earth-system model of intermediate complexity has been used to perform hindcast simulations in a perfect model approach. The predictability of the Southern Ocean sea ice is estimated through two aspects: the spread of the hindcast ensemble, indicating the uncertainty on the ensemble, and the correlation between the ensemble mean and the pseudo-observations, used to assess the accuracy of the prediction. Our results show that, at decadal timescales, more sophisticated data assimilation methods as well as denser pseudo-observations used to initialise the hindcasts decrease the spread of the ensemble but improve only slightly the accuracy of the prediction of the sea ice in the Southern Ocean. Overall, the predictability at interannual timescales is limited, at most, to three years ahead. At multi-decadal timescales, there is a clear improvement of the correlation of the trend in sea ice extent between the hindcasts and the pseudo-observations if the initialisation takes into account the pseudo-observations. The correlation reaches values larger than 0.5 and is due to the inertia of the ocean, showing the importance of the quality of the initialisation below the sea ice.

## Synoptic classification and decadal change in air circulation patterns at Marion Island, 1960-2009

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The climate on Marion Island has shown significant changes over the last thirty years and the current changes in the climate are driven by changes in the synoptic weather systems. At present, available information on climate change is not presented at the temporal scale that allows direct evaluation of its impact on the island's landscape dynamics. In order to provide a basis for such analysis this paper aims to present a regional analysis of mean annual temperature as well as to undertake an objective synoptic climate classification based on a single station principal component (PCA) and cluster analysis of the daily meteorological observations of the Marion Island weather station (46°52'59"S, 37°52'01"E, 24 m a.s.l.). The data uses the daily weather station record over a 50-year period from 1960 to 2009. The PCA analysis indicated 8 distinct synoptic circulation patterns and linear regression show that the circulation patterns in clusters with increasing frequency of occurrence appears to be a southward placement of a sub-tropical high pressure system with resulting influx of maritime air masses from lower latitudes. This may be associated with a strong mid-latitude pressure gradient, warm fronts passing the island or a southward meridional air flow. In contrast, clusters with decreasing frequency of occurrence represent situations with relatively low mid-latitude pressure gradient with a weak polar front and its travelling low pressure systems with cool, moist maritime polar air masses over Marion Island or northward meridional air flow of cold Antarctic air in the westerly ascending limb of a Rossby wave. Warming trends at Marion Island were placed in comparison to other sub-Antarctic islands in the South Atlantic and South Indian Ocean using the NASA/GISS station data from the GHCNv.3 and SCAR database. Stations used were selected on location in proximity of the sub-Antarctic zone and availability of long-term temperature records. Of all stations, Marion Island shows the strongest warming trend (0.21°C per decade,  $R^2 = 0.55$ ) and mean annual temperatures of most islands are positively correlated with their nearest neighbours and individual station data from these locations thus appear representative for larger regional trends. The strong temperature trend and its potential impact on terrestrial ecosystems and landscape dynamics make Marion Island most suitable for synoptic air circulation classification in the sub-Antarctic region.

## What's happening to Antarctic Bottom Water?

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Recent studies provide growing evidence of rapid change in the properties of Antarctic Bottom Water (AABW). As sinking of AABW supplies the lower limb of the global overturning circulation, changes in the properties or the formation rate of AABW might have widespread consequences for climate, sea level, and the supply of oxygen to the abyssal ocean. Observations show that the AABW layer is warming, freshening and contracting in volume. However, the drivers of these observed changes are not yet clear. While widespread freshening has been observed, the origin of the increased supply of freshwater is not fully understood. Increased basal melt of floating ice shelves has been identified as a likely source of additional freshwater, but there is limited oceanographic evidence for enhanced ocean heat flux to drive stronger basal melt. Warming of the abyssal layer is widespread in basins ventilated by AABW, but the sources of dense water have themselves not warmed significantly. Some of these changes have been linked to trends in atmospheric circulation associated with the Southern Annular Mode (SAM), but a direct link between the SAM and changes in bottom water properties or formation rate has been difficult to establish. New studies based on oxygen, chlorofluorocarbons, oxygen isotopes and changes in volume of individual layers have started to provide some insights into how and why AABW is changing. Freshening of the dense shelf waters that sink and mix with surrounding waters to form AABW can explain many of the observed changes. Changes in formation rate alone, on the other hand, cannot explain the observed changes in water mass properties. In this talk we review and attempt to reconcile recent investigations of AABW formation and change, ice shelf melt, and changes in oceanic and atmospheric circulation; highlight remaining unknowns; and speculate on the causes and consequences of future change in AABW change.

## Glacier sediment plumes in bays of the Danco Coast, Antarctic Peninsula

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The glacimarine sedimentary environments and associated processes may provide clues to understanding climate and oceanographic evolution in the region. One of the elements of sedimentary processes is the generation of sediment plumes coming from the glaciers, where an increase in particle concentration could indicate an increased melting of glaciers. The Danco Coast region represents a subpolar-polar transition, so it is expected that the recent changes are more prominent in that location.

In February 2013 INACH Antarctic Scientific Expedition was carried out on board the Chilean Navy vessel "Aguiles". Four relatively small bays were visited (according to SHOA charts): Guesalaga, Frei, Beaupre and Paradise Bay. On board a Zodiac boat, we approached as close as possible to the main glacier and about 5 oceanographic stations were conducted in a perpendicular way to the glacier head. Exploratory bathymetry was performed with a portable 50 KHz echo sounder and SBE 19 Plus V2 CTD measurements were carried out (temperature, salinity, oxygen, fluorometry, pH and turbidity) up to 100 m deep. The CTD data processing consisted simply in manual removal of erroneous data.

We found that in each bay studied exist one or more sediment plumes from the glacier, although with low particles concentrations. The results were consistent with glacimarine models, so it is expected that the sediment flow should be greater near the seafloor. Furthermore, the results agree with the observations about predominance of subsurface plumes, and clearer waters in the surface. Therefore the contribution of sediment systems in those bays, could play an important role in regional sedimentary processes and, in particular, given the glacier vulnerability to climate change. To establish whether these plumes are ephemeral or not, it is necessary to perform repeated measurements over time of the oceanographic variables.

## **The ocean's role in climate: Projections from CMIP5 of the Southern Ocean and Antarctica at the end of the 21st century**

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University of Arizona

The Antarctic continent and the surrounding Southern Ocean have significant impacts on the global climate and the climate system's response to increasing greenhouse forcing. Vertical exchange in the Southern Ocean provides a pathway between the deep and surface waters of the ocean and between the surface ocean and the atmosphere, giving it a disproportionate influence on the climate system. The Antarctic continent and the dynamics of the polar vortex over it influence the stratosphere/troposphere temperature gradient and therefore the strength and position of the southern hemisphere westerly winds. In climate change experiments, Southern Ocean circulation patterns make it a region where much of the future oceanic heat and carbon uptake takes place, although the magnitude of the uptake is one of the larger sources of uncertainty associated with the transient climate response, especially in the latest Earth System Models that explicitly simulate the carbon cycle. We will assess this uptake along with these future simulations from the suite of CMIP5 Earth System Models.

**Latitudinal variation of delta13C and delta15N in Suspended Particulate Organic Matter (SPOM) in the surface waters of Indian Ocean sector of Southern Ocean and Tropical Indian Ocean during austral summer, 2012**

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National Centre for Antarctic and Ocean Research

This study addresses the influence of physiochemical and biological factors on the spatial distribution of stable isotopic composition of carbon and nitrogen in suspended particulate organic matter (SPOM). Surface water samples were collected from the Indian Ocean sector of Southern Ocean and tropical Indian Ocean at 20 locations between 3°N to 53°S onboard *RV Sagar Nidhi* during austral summer, 2012. The seawater samples were filtered through pre-combusted GF/F filters and analyzed for organic carbon, nitrogen,  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  of SPOM along with other supporting oceanographic parameters. The study area was divided into two geographical regimes based on the hydrography and chemistry- i) Tropical Indian Ocean (TIO) defined by warm SST, high SSS, low nutrient concentrations and ii) the Southern Ocean (SO) including Sub-tropical fronts (STF), Sub-Antarctic Zone (SAZ) and Polar waters defined by sharp decline in SST, SSS and an increase in nutrients.

Overall, the results obtained indicate a wide variation in %C, %N,  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  in surface waters, which were influenced by both physical and biological processes. The  $\delta^{13}\text{C}$  of SPOM ranged from -26.82 to -21.40‰, with an average of  $-26.19 \pm 0.51\text{‰}$  and  $-23.70 \pm 1.63\text{‰}$  in TIO and SO respectively. However,  $\delta^{13}\text{C}$  of SPOM were heavier in the STF with an increase of approximately 3‰ within the SO. Similarly,  $\delta^{15}\text{N}$  values varied over a wide range from -5.09 to +4.09‰ with heavier  $\delta^{15}\text{N}$  in nutrient depleted subtropical zone surface waters and a maximum variation in the Tropical Indian Ocean ranging from -5.09 to 2.45‰. Both  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  of SPOM did not show any statistically significant correlation with chlorophyll-a. Nevertheless,  $\delta^{13}\text{C}$  had a significant linear relation with temperature and an inverse relation with  $\text{tCO}_2$  beyond 40°S. From this study, it appears that community structure played an important role in shaping the SPOM characteristics.

## Investigation of the causes of historical changes in the sub-surface salinity minimum of the South Atlantic

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In this study we investigate the sub-surface salinity changes on decadal timescales across the South Atlantic Ocean using the latest version of the Simple Ocean Data Assimilation reanalysis product, as well as with additional climate model experiments. Results show that there is a recent significant salinity increase at intermediate levels. The main underlying mechanism for this sub-surface salinity increase is the lateral advective (gyre) changes due to the Southern Annular mode variability, which conditions an increased contribution from the Indian Ocean high salinity waters. The global warming signal has a secondary but complementary contribution. Latitudinal differences at intermediate depth in response to large-scale features are in part caused by local variation of westward propagation features, and by compensating contributions of salinity and temperature to density changes.

## S02: ANTARCTIC CLIMATE AND THE GLOBAL CLIMATE SYSTEM AND TROPICAL POLAR CONNECTIVITY

### Evolution of the Southern Annular Mode during the last millennium

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The Southern Annular Mode (SAM) is the primary pattern of climate variability in the Southern Hemisphere, influencing latitudinal rainfall distribution and temperatures from the sub-tropics to Antarctica. The positive summer trend in the SAM over recent decades is widely-attributed to stratospheric ozone depletion, however the brevity of observational records from Antarctica – one of the core zones that defines SAM variability – limits our understanding of long-term SAM behaviour. Here we reconstruct changes in the SAM since 1000AD using proxy records that encompass the full mid-latitude to polar domain across the Drake Passage sector. We find that the SAM has undergone a progressive shift towards its positive phase since the 15<sup>th</sup> Century, causing cooling of the main Antarctic continent at the same time that the Antarctic Peninsula has warmed. SAM trends prior to the 20<sup>th</sup> century are more prominent in the proxy-based reconstruction than current climate simulations, and appear to be associated with a teleconnected response to changes in tropical Pacific climate. The positive trend in SAM since ~1940AD is reproduced by multi-model climate simulations forced with rising greenhouse gas levels and later ozone depletion, and the long-term average SAM Index is now at its highest level for at least the last 1000 years. Our findings imply that predictions of further greenhouse-driven increases in the SAM over the coming century also need to account for the possibility of opposing effects from tropical Pacific climate changes.

## Recent trends in Southern Hemisphere subtropical jet and future projections based on CMIP5 models

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Jet streams are important because the position of jet stream signifies the existence of baroclinicity and hence they play a major role in the formation and development of middle-latitudes cyclones and storm tracks follows the jet axis. Therefore changes in jet stream location, intensity, or altitude can have important consequences for the southern hemispheric climate. Latitudinal change of jet stream location is also used as an indicator of Hadley circulation's poleward limit. The Intergovernmental Panel on Climate Change /Fourth Assessment Report (IPCC/AR4) models suggested there would be a poleward shift of the Southern Hemisphere jets as well as its intensification during the next 100 years. In this presentation, predictions of 19 World Climate Research Programme Coupled Model Inter-comparison Project Phase 5 (CMIP5) of the World Climate Research Programme Coupled Models from the IPCC fifth assessment report (AR5) archive are examined to understand and predict changes in the Southern Hemisphere jet over the twenty first century. The main aim of this study is to quantify the trends in the wind speed, position of the southern hemisphere Subtropical Jet stream, to assess the ability of the CMIP5 models to reproduce the variability of Subtropical Jet stream, and the role of broad scale phenomenon such as El Niño Southern Oscillation (ENSO) and Southern Annular Mode (SAM) on the variability of the jet streams.

The first part of the study was carried out to assess how the historical runs of the CIMP5 models represented the strength, position and variability of the Southern Hemispheric jet streams. In order to assess the changes and future projections of the jet streams in terms of strength, latitude and the shift in the location, we performed a three dimensional analysis on CMIP5 model output instead of normal static 200 hPa to eliminate altitude bias. Here, we compared the location of the jets, climatology of zonal wind, its annual cycle and trends in the wind speed from the ERA-interim with the model run. We investigated further the role of Southern Annular Mode (SAM) and El Niño Southern Oscillations on the variability of the jet streams. In the second part of the study, we examined the future trends in the wind speed, location and variability of jets based on the future predictions from CMIP5 model under 4.5 and 8.5 scenarios.

Based on ERA-interim the subtropical jet has shifted significantly poleward by about one degree of latitude over the last thirty years but there has been no significant change in the wind speed. Most of the historic run of the CMIP5 models broadly agree with the observed poleward shift with no significant trend in strength. Majority of CMIP5 models show a poleward shift and significant strengthening of the jet under 4.5 and 8.5 scenarios.

## Possible southward shift of the Southern Hemisphere upper tropospheric jet and impact on weather in the equatorial South China Sea during the austral winter

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Lee and Feldstein (2013) suggest that there may be poleward shift in the upper tropospheric subtropical westerly jet during the *austral summer* due to increasing greenhouse gases, and most importantly, ozone depletion. *Based on the premise of strong baroclinicity in the austral winter*, this present climatological analysis reveals that there is little latitudinal shift of 200 hPa subtropical jet centered near 30°S and located between 60°E and 120°W. Instead, the warm phase of El-Nino Southern Oscillation phenomenon particularly strengthens the jet maximum between 160°E and 140°W. Also, during this El Nino phase, prominent gradients of decreased total column ozone (cooling) to the north and increased (warming) to the south within the jet maximum area enhance further the baroclinicity that leads to stronger jet core. Austral winter corresponds to the summer or southwest monsoon in the Northern Hemisphere. Hadley circulation analysis along the longitudinal band of the equatorial South China Sea merely shows that the Hadley cell strengthens and broadens slightly within the latitudinal band of 8°N and 20°N or drier weather in the equatorial South China Sea during El Nino under the scenario of little Southern Hemisphere upper tropospheric jet shift.

### Reference

Lee, S., and S.B. Feldstein 2013: Detecting ozone- and greenhouse-gas-driven trends with observational data. *Science*, 339(6119), 563-567. DOI: 10.1126/science.1225154.

## The Southern Annular Mode impact on the monthly mean temperatures of Southern Brazil and the Antarctic Peninsula

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For the last 50 years, the Antarctica Peninsula (AP) surface mean air temperature has risen more than 3°C, central West Antarctica also has recorded a 2.4°C warming. Following worldwide trends, but to a much smaller degree, temperatures in continental South America have also increased in the same period. Southern Brazil (SB) has recorded an increase of 0.56°C in the annual mean temperature anomaly from 1961 to 2009. In this presentation, we demonstrate that an important regional context of atmospheric circulation, in the scale of months and seasons, can have marked effects in the air temperatures of the AP and SB under the influence of the Southern Hemisphere Annular Mode (SAM). Thus, we analysed by employing Empirical Orthogonal Function (EOF), correlations and composite analysis the following variables: pressure at mean sea level (MSLP); geopotential at 500 (Z500) and 850 (Z850) hPa; meridional wind ( $v$ ) at 10 m, and mean monthly temperature (MMT) at 2 m of the ERA-Interim (European Reanalysis Agency) database, from 1979 to 2010; MMT at 2 m of the CRU/BADC (Climatic Research Unit/British Atmospheric Data Centre) database, from 1961 to 2009; and SAM index from Nan and Li, 2003. The seasonal mean temperature shows a positive trend (statistically significant,  $\alpha < 1\%$ ) only in autumn ( $+0.0179^\circ\text{C a}^{-1}$ ) in SB. The SAM shows a positive trend (1979–2009), statistically significant ( $\alpha < 5\%$ ) in summer ( $+0.056 \text{ a}^{-1}$ ) and autumn ( $+0.042 \text{ a}^{-1}$ ). The atmospheric fields variability modes (MMT, MSLP, Z850 and Z500) show that the first EOF exhibits a dipole pattern between the subtropical and polar regions in the Southern Hemisphere. The EOF1 fields associated with PNM, Z850 and Z500 reveal this remarkable SAM feature. It is noticeable that this dipole is observed in the first three EOFs of MMT. The SAM has a major impact on the SB and AP seasonal and mean monthly temperatures, showing an autumn negative correlation ( $r = -0.44$ ;  $\alpha < 1\%$ ), where MMT negative (positive) anomalies in SB and positive (negative) in the AP are associated with SAM positive (negative) phases. Correlations between the EOFs atmospheric fields and the SAM time series reveal that there are statistically significant connections ( $\alpha < 1\%$ ) with the observed dipole spatial pattern. Therefore, we point that the positive and negative extremes in seasonal and mean monthly temperatures variability in SB result, in part, from atmospheric circulation changes thousands of kilometres away, in the AP region.

## **RICE - Roosevelt Island Climate Evolution project - a new, intermediate depth ice core record from coastal Antarctica**

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RICE is a collaboration between New Zealand, USA, Denmark, United Kingdom, Germany, Australia, Italy, China, and Sweden. The overarching aim of the project is to help evaluate the stability of the Ross Ice Shelf and West Antarctica in a warming world.

The team recovered a 763m deep ice core from Roosevelt Island during the 2011/12 and 2012/13 field seasons supported by Antarctica New Zealand and the USAP. The core was drilled using the newly built New Zealand intermediate ice core drilling system, which is based on the design of the Danish Hans Tausen drill.

Roosevelt Island, an ice dome grounded 200m below sea level, is situated at the northern tip of the Ross Ice Shelf, which flows around it. The dome has a maximum elevation of 550m above sea level and exhibits a well developed Raymond Bump. Average annual snow accumulation is 20cm ice per year. The RICE core was drilled in the vicinity of the topographic and Raymond Bump divides (79.364°S, 161.706°W). The core was processed at the New Zealand Ice Core Research Facility during May to July 2013 (0-500m) and June to August 2014 (500-760m).

The record has been dated using annual layer count, volcanic markers (incl. 5 ash layers), and correlated to WAIS via an exceptionally high resolution match between the WAIS and RICE continuous flow methane measurements. Geophysical measurements (radar and strain rate measurements) provide information on the thinning history of the island and further help to constrain the age model. The RICE core provides a high resolution record of the deglaciation history in the Ross Sea region and a lower resolution record extending to >60ka. The bottom section of the RICE core contains diatomaceous material from a time when the rise was exposed to open ocean conditions in the absence of the Ross Ice Shelf.

Here we present the first data spanning the entire record and offer initial conclusions.

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## Nitrate profile of a shallow Antarctic firn core

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A 2004/2005 Chilean-Brazilian traverse recovered several shallow cores from the Geographic South Pole to the Parodi Chilean Station (80°18'S, 81°23'W). This paper presents a nitrate profile of one of these firn/ice cores, located about 1050 km from the Antarctic coast line, IC3 (85°59'S, 81°35'W). The IC-3 core was melted into discrete samples at 2-3 cm resolution using the continuous melting system (Osterberg et al., 2006) developed by the Climate Change Institute, University of Maine (USA). The core sampling produced 1049 samples and the ions Na<sup>+</sup>, K<sup>+</sup>, Mg<sup>2+</sup>, Ca<sup>2+</sup>, MS<sup>-</sup>, Cl<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, and SO<sub>4</sub><sup>2-</sup> (µg L<sup>-1</sup>), were determined using a Dionex DX-500 Ion Chromatograph.

Nitrate presents a complicated record in Antarctica, it involves multiple sources, loss pathways and a gas phase chemistry (Lalraj et al., 2010). Correlations between atmospheric NO<sub>x</sub> and NO<sub>3</sub><sup>-</sup> in the ice core records are strongly influenced by post depositional processes (Hastings et al., 2004). Among these processes is the NO<sub>3</sub><sup>-</sup> photolysis in surface snow layers and evaporative loss of HNO<sub>3</sub> (Wolff et al., 2008). High NO<sub>3</sub><sup>-</sup> concentrations in snow and ice cores could be associated with volcanic emissions. This could be indicated by matching peaks in the nitrate and sulfate profiles.

The nitrate profile in the IC3 core presents a small variation around the mean concentration (81.33 ± 23.31 µg L<sup>-1</sup>), demonstrating an attenuation of the record. However, a high concentration peak (201.17 µg L<sup>-1</sup>) near the surface could have resulted from the interaction with Ca<sup>2+</sup> that prevents the NO<sub>3</sub><sup>-</sup> releasing from the snow pack in the gas-phase. But this peak is so close to the surface that, possibly, the NO<sub>3</sub><sup>-</sup> at this depth has not presented the same post depositional effects that occurred in the rest of the core. This suggests a post depositional effect with HNO<sub>3</sub> loss. No simultaneous high concentration peaks of nitrate and sulfate that may indicate a volcanic event are observed. The profile represents 46±3 years of accumulation (a 32.3 cm year<sup>-1</sup> in water equivalent).

## Interpretation of a 2,000 year, high resolution water stable isotope record from the RICE ice core Roosevelt Island, Antarctica

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A 763m ice core was retrieved from Roosevelt Island (W161° 21', S79°41', 560 m a.s.l.), Antarctica. Here we show the high resolution stable isotope record ( $\delta^{18}\text{O}$ ,  $\delta\text{D}$  and d-excess) covering the past 2,000 years, which is contained in the upper 300m of the core. The isotope-temperature relationship has been estimated using temperature correlation with local weather stations and from borehole measurements. The  $\delta$ -records have been back-diffused to remove the post-depositional effect from diffusion that dampens the isotopic signature.

We correlate the modern part of the record (1979 AD to present) with meteorological reanalysis ECMWF Interim Re-Analysis (ERA-Interim) data to identify air mass trajectories and moisture source regions for precipitation at Roosevelt Island. We investigate the importance of local sources (Ross Sea polynya) versus remote regions (Southern Ocean) and the influence of their air mass trajectory on the fractionation pathway of the water vapor. Moreover, we identify relationship of the transport pathway with the El Nino Southern Oscillation (ENSO) and the Southern Annular Mode (SAM) as main drivers of the air mass trajectories to Roosevelt Island.

We also provide data from: snow precipitation samples collected during snowfall events at Roosevelt Island, high resolution snow pit samples and data from shallow ice cores (~10m).

The data were measured using a LGR-35EP analyzer, manufactured by Los Gatos Research (LGR). We developed the first experimental design applying off-axis integrated cavity output spectroscopy (OA-ICOS) to continuously analyze water isotopes from an ice cores. A Water Vapor Isotopic Standard Source (WVISS) calibration unit, was modified to reduce the influence from memory effect (i.e. decrease the response time), which allows us to efficiently perform multi-standard calibrations and make continuous  $\delta^{18}\text{O}$  and  $\delta\text{D}$  measurements with less attenuation introduced by the experimental design.

## Radiogenic Isotopes of Sr and Nd in aerosols as markers of South America air masses reaching the Southern Ocean and Antarctica

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Specific minerals and rocks have different ratios of  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $^{143}\text{Nd}/^{144}\text{Nd}$  according to their geological derivation. These ratios in the isotopic composition of the total aerosol fraction/mineral dust may prove beyond the provenance, the heterogeneity of sources and may reflect the heterogeneity of the exposed rocks in the scale of their drainage basin. Glaciological studies of dust deposits in deep ice cores of Antarctica based on these isotopic ratios suggested the South America as main dust contributor for both glacial and inter-glacial stages. This was achieved by the comparison of the glaciological data with the South America  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $^{143}\text{Nd}/^{144}\text{Nd}$  terrestrial signature. Here we provide a new database for Sr and Nd in South America enclosing the terrestrial tropics and sub-tropics regions (inventory of approximately 400 site investigated) and the signature in aerosols over the Atlantic Ocean. Aerosol samples were collected during six oceanographic campaigns between Rio de Janeiro and the Antarctic Peninsula, aboard the polar Vessel Almirante Maximiano. Dust samples were merged in polycarbonate membranes Whatman 47 $\mu\text{m}$  through suction pumps for typical flow rate of 127 L/min. Determination of  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $^{143}\text{Nd}/^{144}\text{Nd}$  were conducted by mass spectrometry Multicollector by thermal ionization (TIMS) TRITON - Thermo Finnigan / at LAGIR (Laboratory of Geochronology and Isotope radiogenic) / Rio de Janeiro State University. The technique used is the spectrometric analysis dynamic mode called "peak jumping" as used in specific cases where low or very low concentrations are expected. Results of the aerosol isotopic signatures were compared with air mass back-trajectories obtained by the HYSPLIT trajectory model (HYSPLIT - Hybrid Single- Particle Lagrangian Integrated Trajectory) from NASA in order to compare surface terrestrial data with aerosols signatures.

## Varying roles of ENSO and SAM on the Antarctic Peninsula climate in austral spring

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Recent studies have identified a significant warming trend across West Antarctica and the Antarctic Peninsula, which is likely linked to tropical forcing. These studies also agree that the warming trends are most marked across West Antarctica and the Antarctic Peninsula during austral winter and spring. Here we investigate temporal variations in El Niño – Southern Oscillation (ENSO) –related tropical forcing and Southern Annular Mode (SAM) -related forcing on the Amundsen-Bellingshausen Seas Low (ABSL) and the regional climate during austral spring. We find an east-west dependency on the impacts each of these climate modes have on the Antarctic Peninsula: relationships with ENSO and Antarctic Peninsula climate are persistent and significant across the western Peninsula, while relationships with the SAM are persistent with the across the northeastern Peninsula. The other correlations appear weak since 1957 as they vary temporally, fluctuating with the correlation between the SAM index and ENSO in austral spring. Changes in the ENSO-SAM correlations are due primarily to the 1988 La Niña / SAM negative event, which significantly altered the location of the ENSO teleconnection in the South Pacific Ocean and therefore its influence on the regional climate. Whether or not there is decadal variability in the ENSO-SAM relationship remains unclear; however, it is evident that the influence across the Peninsula varies in both space and time, related to the strength and spatial extent of the response in the Amundsen-Bellingshausen Seas. This suggests that in order to accurately attribute the warming to ENSO-related tropical forcing, it is necessary to consider the role of the regional circulation manifested by the phase of each climate mode together.

## Late Pleistocene and early Holocene change in the Weddell Sea: a new climate record from the Patriot Hills, Ellsworth Mountains, West Antarctica

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The transition from the late Pleistocene to the Holocene (30 000–5000 years ago) was a period of considerable climate variability, which has been associated with changes in deep water formation and the intensity of the Meridional Overturning Circulation. Although numerous records exist across the North Atlantic region, few Antarctic ice core records have been obtained from the south.

Here we exploit the potential of upwelling ancient ice – so-called blue ice areas (BIAs) – from the Patriot Hills in the Ellsworth Mountains to derive the first deuterium isotope record ( $\delta D$ ) from continental Antarctica south of the Weddell Sea. Gas analysis and glaciological considerations provide a first relative chronology. Inferred temperature trends from the Patriot Hills BIA and snow pit suggest changing climate influences during the transition between the last glacial period and Holocene.

Under modern conditions, the interplay between the Antarctic high-pressure system and the Southern Annular Mode appears to play a significant role in controlling katabatic wind flow over the site while the BIA record suggests that greater sea ice extent during the last glacial period was a major control. Our results demonstrate the considerable potential of the Patriot Hills site for reconstructing past climate change in the south Atlantic region.

## Ionic records from Dome Fuji, East Antarctica over the past 700 kyrs and their implications

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Ice core drilling at Dome Fuji, Antarctica reached a depth of 3035.22m in January 2007. Here we report the variations of ionic species in the Dome Fuji core for the depths above 3028m, which corresponds to about 700kyrs BP. Fluxes of ss (sea-salt) sodium (a proxy for sea-salt) and nss (non-sea-salt) calcium (a proxy for dust) at Dome Fuji are linked with Antarctic temperature; they are high during cold glacial periods and low during warm interglacial periods, as has been reported by earlier studies. On the other hand, we find no straightforward link between Antarctic temperature and nss sulfate, which has been considered as a proxy for marine biogenic productivity in the Antarctic Zone. They are high during both cold glacial periods and warm interglacial periods. Flux of ammonium, which has been also considered as a proxy for marine biogenic productivity, are high during cold glacial periods and low during warm interglacial periods. We suggest that sources of nss sulfate and ammonium need to be reconsidered. We also suggest that marine biogenic productivity in the Southern Ocean was not constant over glacial cycles, which contradicts the conclusion of previous ice-core studies, but agrees with the results from marine sediment records.

## Investigation of Greenland and Antarctic ice core recorded abrupt climate change using ultra high-resolution laser sampling

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The utilization of ice core records has been paramount in the realization that abrupt climate change (ACC) events occurred in the past. We intend to refine interpretations of select ACC events recorded in polar ice cores through the use of an ultra-high resolution (20  $\mu\text{m}$  as compared to standard 1 cm sampling using melting techniques) sampling method that achieves an ultra high level of temporal resolution (for example, hundreds of samples per year) using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). We will measure concentrations of select glaciochemical species (calcium, iron, potassium and sodium), allowing an in-depth inquiry into the timing and magnitude of atmospheric circulation, seasonality and precipitation changes in the past. The Greenland (GISP2) ice core archive sampled ranges from 2674 to 2680 meters depth, and features the abrupt climate transition from stadial to interstadial (Dansgaard-Oeschger event 21; ~83-85 kya), as recorded by original IC concentrations. The Antarctic (Siple Dome) ice core archive ranges from 713 to 725 meters depth (~19-22 kya), during the last glacial maximum (LGM). Using our state of the art LA-ICP-MS, we are able to look for potential precursors to state changes associated with ACC that were not previously recognizable using the temporal resolution of previous sampling methods.

## Dating of the Dome Fuji deep ice core using O<sub>2</sub>/N<sub>2</sub> of trapped gases and synchronization with Northern Hemisphere records

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Investigation of the roles of different forcings (e.g. orbital variations and greenhouse gases) on climate and sea level requires a paleoclimate chronology with high accuracy. Such a chronology for the past 360 ky was constructed through orbital tuning of O<sub>2</sub>/N<sub>2</sub> ratio of trapped air in the Dome Fuji and Vostok ice cores with local summer insolation (Kawamura et al., 2007). We extend the O<sub>2</sub>/N<sub>2</sub> chronology back to about 500 kyr by analyzing the second Dome Fuji ice core, and find the duration of 11 ka, 5 ka, 9 ka, and 20 ka for MIS 5e, 7e, 9e and 11c interglacial periods in Antarctica, with similar variations in atmospheric CO<sub>2</sub>. The termination timings are within the rising phase of Northern Hemisphere summer insolation, consistent with the Milankovitch theory of glacial cycles.

Marine sediment cores from northern North Atlantic contain millennial-scale signatures in various proxy records (e.g. SST, IRD), including abrupt climatic shifts and bipolar seesaw. Based on the bipolar correlation of millennial-scale events, it is possible to transfer our accurate chronology to marine cores from the North Atlantic. As such an attempt, we correlate the planktonic  $\delta^{18}\text{O}$  and IRD records from a marine core (ODP 980) with the ice-core  $\delta^{18}\text{O}$  and CH<sub>4</sub> around MIS 11. We find that the durations of interglacial plateaus of planktonic  $\delta^{18}\text{O}$  (proxy for sea surface environments) and benthic  $\delta^{18}\text{O}$  (proxy for ice volume and deep-sea temperature) for MIS 11c are 20 and 15 ka, respectively, which are significantly shorter than those originally suggested. These durations are similar to those of Antarctic climate and atmospheric CO<sub>2</sub>. However, the onsets of interglacial levels in ODP980 for MIS 11 are significantly later than Antarctic  $\delta^{18}\text{O}$  and atmospheric CO<sub>2</sub> (by as much as ~10 ka), suggesting very long duration (more than one precession cycle) for the complete deglaciation and northern high-latitude warming for Termination V. Atmospheric CO<sub>2</sub> may have been the critical forcing for this termination. The long duration of Termination V is consistent with our new ice sheet simulations (extended from the work of Abe-Ouchi et al., 2013) in which an ice-sheet/climate model is forced by insolation and CO<sub>2</sub> variations.

## The Southern Annular Mode (SAM) in PMIP2 simulations for the Last Glacial Maximum

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The increasing trend of the Southern Annular Mode (SAM) in recent decades has influenced the climate change in the southern hemisphere. How the SAM will respond to the increase of greenhouse gases in the future still remains uncertain. Understanding the variability of the SAM in the past under colder climate such as the Last Glacial Maximum (LGM) might provide some understanding of the response of the SAM for the future warm climate. We analyzed the changes in the SAM for the LGM in comparison to the pre-industrial (PI) simulations using 5 coupled ocean-atmosphere models (CCSM, FGOALS, IPSL, MIROC, HadCM) from the second phase of Paleoclimate Modelling Intercomparison Project (PMIP2). In CCSM, MIROC, IPSL, and FGOALS, the variability of the simulated SAM appears to be reduced in the LGM than the PI with a decrease in the standard deviation of the SAM index. Overall, four out of five models suggest the weaker SAM amplitude in the LGM, consistent with the weaker southern hemisphere polar vortex and westerly winds found in some proxy records and model analyses. The weakening of the SAM in the LGM is associated with the increase in the vertical propagation of Rossby waves in southern high latitudes.

## Evidence of hemispheric- and local-scale atmospheric pollution in a South Pole ice core

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Human activities now have a major impact on the global atmospheric cycles of many trace elements. Here we present a ~2100-year record of atmospheric Ba and As concentrations as recorded in a South Pole ice core. The ice core was collected during the US International Trans-Antarctic Expedition traverse in 2002 (site US ITASE-02-6) at 89.93°S, 144.39°W at an elevation of 2808 m a.s.l. Samples collected from the top 200 meters of the core were analyzed for major and trace element content using the inductively-coupled plasma sector field mass spectrometry. Our results show significant enrichment of Ba and As during recent decades. We observed large increase in Ba concentrations (by a factor of ~25) since 1980 A.D. Concentrations of As increase by a factor of ~4 since 1970 A.D. Our records show increases in crustal enrichment factor values for Ba (by a factor of ~12) and As (~3) during recent decades, suggesting input from anthropogenic sources. A comparison of the As data with other Antarctic glaciochemical records indicates that the increase in atmospheric concentrations of As is widespread. Increase in As concentrations and As enrichment factors values are most likely related to nonferrous metal production, and stationary fossil fuel and gasoline combustion in the Southern Hemisphere countries. Comparison with previously reported Antarctic Ba records suggests that significant increases in Ba concentrations at South Pole during recent decades are most likely caused by local source pollution, such as diesel fuel combustion and intense aircraft activity at Amundsen-Scott South Pole Station.

## Detailed glaciochemical records from Northern Antarctic Peninsula site - Detroit Plateau

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The Detroit Plateau (DP) is located in the northern sector of the Antarctic Peninsula where glaciological and meteorological observations have revealed a remarkable warming trend over the last five decades ( $+0.56^{\circ}\text{C decade}^{-1}$ , *Turner et al., 2005*). The goal of our Detroit Plateau ice coring activities is to reconstruct past precipitation, atmospheric circulation, and air mass chemistry over the Antarctic Peninsula. For this, we recovered a 133 m DP ice core ( $64^{\circ}05'S$ ,  $59^{\circ}39'W$ , 1937 m a.s.l) in 2007. Preliminary results from chemical and isotopic analysis demonstrate that the DP site has a high annual net accumulation ( $\sim 5$  m of snow). The upper 98 meters of this core covers approximately 27 years (from late 1980 to late 2007). Our analysis revealed that As exhibits large seasonal variability, with a distinct single annual maximum and minimum concentration. In addition, our study shows pronounced increase in trace metal concentrations (Cu, Zn, and Cd), attributed to heavy metals emissions to the atmosphere by human activities in the Southern Hemisphere, especially non-ferrous metal mining and smelting.

## Halogen records from the West Antarctic Ice sheet; Present day to the Last Glacial Maximum

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Annually resolved records of chlorine, bromine and iodine have been measured on the WAIS Divide Ice core. The source of these halogens are primarily oceanic; seawater, sea ice and algae. However each halogen shows a unique seasonal cycle in concentration that emphasises that differences exist not only in the magnitude of each source but in the atmospheric processing that happens during transport and deposition and the preservation of the halogen in the snow. The records discussed here cover the period of the present day - **28,000** yr BP. There is a marked increase in variability of each halogen with decreasing temperatures corresponding to the Antarctic Cold Reversal and the Last Glacial Maximum. Correlations maps confirm that the moisture source for the snow reaching the WAIS Divide site is the Amundsen-Bellingshausen sea, but the correlations between halogens and sea ice conditions reveal that the Wedell sea may also be a likely source of these sea salt aerosols.

## Exploring extra-Antarctic air transport pathways using Rare Earth Element concentrations in dust from the RICE ice core, Roosevelt Island, Ross Sea Sector

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Records of dust contained within ice cores are fundamental to understanding of global-scale shifts in environmental conditions and atmospheric circulation, but also can elucidate detailed atmospheric transport processes on shorter timescales. High-resolution trace element analysis has been performed on samples spanning the satellite era (1979-present) from the recently-recovered Roosevelt Island Climate Evolution (RICE) ice core (79.364°S, 161.706°W, ~550 m a.s.l.). A grounded ice dome within the eastern Ross Ice Shelf, Roosevelt Island is subject to synoptic and mesoscale climate systems originating in the Ross and Amundsen seas, with attending influences from the Pacific Ocean to the north. For the first time, we explore annual to seasonal variations in modern concentrations of the fourteen Rare Earth Elements (REE, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu), constituents of terrestrial mineral particles deposited in the Antarctic. Using ERA-Interim climate reanalysis data, modern relationships between REE and large-scale atmospheric circulation are explored with intent to establish relative importance of mineral dust source strength versus transport efficiency. Additionally, quantitative transfer functions are sought to extend modern relationships to 2000 years BP, using a three-year average REE record from the RICE ice core.

## Amundsen Sea coastal domes: high-resolution Holocene ice core sites

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Recent observations demonstrate that the West Antarctic Ice Sheet (WAIS) is changing rapidly. Much of this dynamic behavior has been focused along the Amundsen Sea coast: Pine Island and Thwaites glaciers are thinning extensively; upwelling warm Circumpolar Deep Water (CDW) is causing extensive melting beneath the Pine Island, Thwaites, and Getz ice shelves; and moist marine air travelling onto the ice sheet, unobstructed by relatively shallow surface gradients, likely contributes to observed WAIS warming. Of any region of Antarctica, the Amundsen Sea coast shows the strongest links to the tropical Pacific Ocean. ENSO influences on regional circulation and surface winds have been shown to impact CDW upwelling and melt rates beneath ice shelves.

Providing context for these recent observations is key to assessing their significance with respect to natural variability. It is well established that ice cores contain proxy records providing insight into air temperature and moisture transport (water stable-isotopes), sea-ice and polynya conditions (methanesulfonic acid, sulfate, Cl<sup>-</sup>), atmospheric circulation (non-sea-salt Ca<sup>2+</sup>), and more. Examining Radar Depth Sounder and Snow Radar data recovered during NASA Operation IceBridge flights, we propose several potential ice coring sites on ice domes within the Getz Ice Shelf (115°W to 135°W) and explore regional variability in snow accumulation rates. Ice thicknesses near the summit of several ice domes range from 500-1000 meters, with snow accumulation rates varying from 1.0 m to greater than 2.0 m. Ice flow modeling suggests ages at 90% depth ranging from 2000 to 8000 years before present.

An ice core record from the Amundsen Sea coast would likely provide an annually resolved, very high-resolution 2000 year record of natural variability in ice, ocean, and atmospheric dynamics relevant to rapid changes observed in this sector of Antarctica. Additional benefits include physical constraints on recent temperature trends from borehole thermometry and thinning history of as yet unstudied ice domes in this region.

## High resolution chemical characterization of West Antarctica's main event

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Previous ice core records and radar sounding data identified a highly acidic layer of ice covering at least 250,000 km<sup>2</sup> in West Antarctica, and spanning approximately 170 years. This layer, referred to as the “main event” and “Old Faithful”, is dated 17,500 ± 500 years BP, corresponding to the beginning of the transitional period between a glacial climate and the warmer Holocene climate. The main event is composed of multiple episodes of high acidity, along with increased concentrations of fluoride and chloride. Despite the high acidity levels, the main event lacks the increased concentrations in sulfate and dust that are typically associated with volcanic eruptions. Regardless, the nature of the main event is still hypothesized to be a series of (possibly subglacial) volcanic eruptions. Due to its correlation with the transition between a glacial climate and the Holocene climate, it has been postulated that the main event may have served as a precursor to this transition. The detailed chemical composition of this layer of ice could give insight into the nature of the main event. We have determined the concentrations of the major chemical species (including fluoride, chloride, and sulfate) at high resolution from the West Antarctic Ice Sheet (WAIS) Divide replicate ice core in order to characterize each individual event (episode) of the 170-year main event. This high resolution record of the main event allows us to study each individual event and determine a more accurate age and duration due to the improved depth-age scale of the WAIS Divide core, as well as compare our data to electrical conductivity measurements (ECM). Additionally, the high resolution characterization of each individual event of the main event will allow for future in-depth studies of the sulfur and oxygen isotopic composition of the ice. This information will help us determine the type of eruptions that compose the main event, as well as whether these eruptions were climate impacting.

## Relationship between the Southern Annular Mode and precipitation anomalies identified at the Lagoa do Peixe National Park, Southern Brazilian coastal region

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Centro Polar e Climático - CPC

The Peixe Lagoon is set within the Lagoa do Peixe National Park (LPNP), stretching 344 km<sup>2</sup> on the coastal plain of Rio Grande do Sul. It is ecologically significant due to its role as resting and feeding grounds for many migrating avian species and endemic flora. This lagoon is a shallow (~30 cm depth) water system presenting a narrow and intermittent channel to the sea. This study investigates the climatic connections between the LPNP precipitation and the Southern Annular Mode (SAM). By employing both Empirical Orthogonal Functions (EOF) and correlation analysis with the ERA-Interim database variables: average sea level pressure (SLP), geopotential at 500 (Z500) and 850 (Z850) hPa (1979-2010); TRMM (*Tropical Rainfall Measuring Mission*) average monthly precipitation (MP), 1961-2008 and SAM Index from Nan and Li (2003). The SAM is widely accepted as the principle Southern Hemisphere (SH) atmospheric circulation variability mode, influencing many different aspects of all the related SH land masses. The SAM shows a positive monthly trend (Jan/1979-Dec/2009) and, seasonally, a positive trend (1979-2009), statistically significant ( $\alpha < 5\%$ ) for summer and autumn. The atmospheric fields (SLP, Z850 and Z500) variability modes show that the main EOF presents a dipole pattern between the SH subtropical and Polar Regions. The correlations between the atmospheric field EOFs and the SAM are statistically significant ( $\alpha < 1\%$ ), presenting a dipole spatial pattern. The SAM and the seasonal precipitation anomalies (SPA) are both positive, 31% of the cases occurring in summer and winter, 27% in autumn and 25% in spring. When the SAM and SPA are negative, 29% of the cases occur in summer and 23% are evenly distributed. For the SAM(-)/SPA(+) 25% of the cases occur in spring. For SAM(+)/SPA(-), 33% of the cases were concentrated in autumn; 31% in winter and 27% in spring. Also, 60% of the SPA, between 1961 and 2008, ensued in summer [the cases for SAM(+)/SPA(+) and SAM(-)/SPA(-)], 63% of the cases with SAM(+)/SPA(+) and SAM(+)/SPA(-) occurred in winter; 60% of the cases with SAM(+)/SPA(+) and SAM(+)/SPA(-) occurred in autumn. Noteworthy are the extreme negative and positive monthly and seasonal precipitation variabilities for the LPNP can result from the variation in the atmospheric circulation between the Antarctic Peninsula and Southern Brazil. This variability puts the LPNP in a fragile position when faced with SAM driven environmental change.

## Snow accumulation rate variability on the Detroit Plateau, Antarctic Peninsula

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This paper examines the variability of the annual net snow accumulation rate at a site located on the Detroit Plateau (64°05'07"S, 59°38'42"W; 1937 m a.s.l.), northern part of the Antarctic Peninsula. We determined the annual snow accumulation rate from hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) variations in an ice core (DP-07-1), collected in the austral summer of 2007/2008, by a joint Brazilian-Chilean-USA research team. The Detroit Plateau ice core represents 27 ± 1 years of accumulation corresponding to the period 1981–2007. The average annual net accumulation rate is 2.43 m in water equivalent (w. eq.) and shows a positive trend during the period (+0.035 m a<sup>-1</sup>).

The observed increase in the accumulation rate is attributed, in the literature, to a greater flow of warm air from north to south originating in the southeast of the South Pacific due to intensified westerlies that encircle Antarctica and are related to a positive phase of SAM (Southern Annular Mode), which began in mid 1960 (Marshall *et al.*, 2005). We, therefore, examined the relationship between changes in the snow accumulation rate with variations in the SAM index and with data from the Faraday/Vernadsky weather station (65°15'S, 64°16'W; 11 m a.s.l.) [Annual averages of air temperature, mean sea level pressure (MSLP) and mean wind speed] in the west of the Antarctic Peninsula. The variability in the snow accumulation rate is correlated with changes in the SAM index,  $r = 0,445$  ( $p < 0,001$ ) [annual value] and therefore to the variability of the climate controls that it represents indirectly. This accumulation rate is related to the mean air temperature and wind speed variations in the western part of the Antarctic Peninsula.

## **Southern Hemispheric climate variability over the last century reconstructed using Antarctic ice core proxy records of atmospheric circulation, moisture source and sea ice variability**

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The significance of Southern Hemispheric climate variability within the global system and its spatial and temporal heterogeneity are still poorly understood due to the limited and very short periods of observational data available. To reconstruct the shifting climatic regime in Antarctic region and its regional/global linkages, we have conducted a high-resolution study of dust fluxes, stable isotope and glaciochemical composition in an ice core from the coastal Antarctica. Reconstructed fluxes of dust and trace metals at the IND-25/B5 core revealed a doubling of dust deposition since 1985. It has been shown that large-scale atmospheric circulation and climate variability in seasonal to decadal scale in the mid to high latitude Southern Hemisphere is primarily responsible for Southern Annular Mode (SAM) variations.

A strong positive correlation between dust flux and SAM suggests a role of SAM in the dust deposition over East Antarctica, through the strengthening of the westerly winds. Modelled back wind trajectories also supported the increase in dust deposition is associated with the air parcels originating from the southern South America. Proxy records of moisture source variability [deuterium excess (d-excess)] as well as sea ice extent [methane sulphonic acid (MSA) and sea-salt sodium ( $ss-Na^+$ )] in the ice core revealed synchronous changes during the last century in coastal DML, supporting their linkages to the climate change in Southern Hemisphere. Major excursion in d-excess and  $ss-Na^+$  profiles during 1940-1960 coincide with the period of negative SAM and when SAM-ENSO in-phase. The shifting of SAM from positive to negative phase coupled with strong SAM-ENSO teleconnection could have diminished the moisture supply from remote source in the mid latitude to higher latitude.

## Tracing anthropogenic pollution in Antarctica from the RICE core

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A high-resolution ice core from Roosevelt Island, West Antarctica (RICE – Roosevelt Island Climate Evolution project), has been analysed for heavy metal concentrations. The location of the ice core at the northern edge of the Ross Ice Shelf presents the opportunity to investigate the production and transport of heavy metals to the Ross Sea sector of Antarctica. More than 2000 samples have been analysed using ICPMS for concentrations of 12 transition metal elements and more than 30 other elements at Curtin University, Perth, Australia. To understand the links between heavy metals, atmospheric circulation and pollutant sources, we have explored correlations between RICE trace metal concentrations and reanalysis data-sets from 1979 to the present. Several reanalysis data-sets have been considered, in order to reduce the uncertainties associated with individual records. Significant technological developments over the past decade now allow detailed records of heavy metal concentrations from ice cores to be produced due to the advanced technology required to analyse the ultra low (ppt to ppb) concentrations.

Heavy metals are elements of interest in climate studies as tracers for the environmental impact of human industrial activities. Monitoring programs tend to operate on local to regional scales, and are usually heavily influenced by local sources of pollution. Antarctica's geographical isolation, and its low population and relative lack of industrial activity, makes Antarctic ice cores an excellent record to investigate:

- The natural background levels and sources of heavy metals prior to industrialisation
- The transport mechanisms of heavy metals to Antarctica
- Identification and quantification of anthropogenic sources

Here we present data from snow collected during storm events at Roosevelt Island, which allow for a precise reconstruction of airmass trajectories and thus pollutant sources. In addition we present a longer 200 year record that shows the transition from natural backgrounds to anthropogenic influenced levels.

## **Aeolian dust in the Ross Sea: Local versus distal sources**

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Investigating dust provenance in the Ross Sea region is important as it provides constraints to atmospheric circulation models. In addition, dust is also an important source of soluble iron which is a limiting nutrient required for phytoplankton growth in the Ross Sea.

Roosevelt Island, located on a rise on the eastern Ross Ice Shelf, is the site of the recently drilled intermediate depth ice core Roosevelt Island Climate Evolution (RICE). It is expected that this core will provide a high-resolution record of dust flux, particle size and provenance spanning the late Holocene in coastal West Antarctica, that according to the last IPCC2013 report this is one of the most sensitive regions of the globe with respect to climate change. We report snow pit data from Roosevelt Island revealing a) strong seasonality in dust advection and deposition; b) seasonal variability in dust particle size distribution; and c) a Nd and Sr isotopic composition of dust suggesting a possible Australian source for present day as suggested by modelling studies of transport and deposition of dust in the Southern Ocean and Antarctica; however, further studies are needed on a possible input from local West Antarctica dust sources.

McMurdo Sound represents one of the most “dusty” locations in Antarctica, and the upper bound of locally-derived dust flux there is more than 2 orders of magnitude greater than long-range transport dust measured in ice cores from the polar plateau. Local dust is deposited at least 120 km north of McMurdo Sound. Transport beyond this is currently unquantified.

### **S03: GLACIERS AND ICE SHEET MASS BALANCE**

#### **One RWV model for precise ice volume estimation on polythermal glaciers**

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The glaciers in Svalbard are mostly polythermal type. On these polythermal glaciers, the radio wave velocity (RWV) of ground penetrating radar (GPR) is variable, and the RWV is an important parameter for the ice volume estimation. But the ice volume estimation usually uses a single RWV for one whole glacier in order to simplify the calculation. How about the difference between the actual volume and the estimated result?

We used a RWV model, derived from common mid-point (CMP) profiles of GPR measurement, to simulate the RWV for each GPR trace on Pedersenbreen in Svalbard. Then a relative accurate volume of glacier Pedersenbreen was acquired. From which we found the difference among those volumes calculated from a single RWV, three RWVs and our RWV model. Our RWV model for polythermal glaciers refined the volume estimation and enhanced the precision in mass change study. And the difference between different models could raise an error up to 10% of the volume results. Moreover, the fixed RWV usually used was probably larger than the actual one in those polythermal glaciers.

## Spatio-temporal modelling of Antarctic mass balance from multi-satellite observations

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Constraining past ice mass changes, identifying their cause(s) and determining rigorous error estimates, is important for closing the sea level budget and as an input for and test of numerical models. For the Antarctic ice sheet, considerable uncertainty remains between different methods and groups. Estimates obtained from altimetry, gravimetry, and mass-budget methods can yield conflicting results with error estimates that do not always overlap, while the, commonly adopted, use of different forward models to isolate and remove the effects of glacio-isostatic adjustment (GIA) and surface mass balance (SMB) processes introduces another source of uncertainty which is hard to quantify. To address both these issues, we present a statistical modelling approach to the problem. We combine the observational data, including satellite altimetry, GRACE, GPS and InSAR, and use the different degrees of spatial and temporal smoothness to constrain the underlying geophysical processes. This is achieved via a spatio-temporal Bayesian hierarchical model, employing dimensionality reduction methods to allow the solution to remain tractable in the presence of the large number ( $> 10^6$ ) of observations involved. The resulting trend estimates are only dependent on length and smoothness properties obtained from numerical models, but are otherwise entirely data-driven. The statistical methods are presented elsewhere and here we focus on the results of the combination.

We present annually-resolved spatial fields for i) dynamic ice loss, ii) SMB anomaly, iii) firn compaction and iv) GIA, using a combination of GRACE, ICESat, ENVISat, and GPS vertical uplift rates, for 2003-2009. The elastic flexure of the crust is also determined simultaneously. We estimate that, between 2003 and 2009, there has been an acceleration in dynamic ice loss, from close to balance in 2003/2004 to a rate of  $-200\text{Gt/yr}$  by 2009. This was predominantly driven by losses in West Antarctica and the Antarctic Peninsula. These dynamic losses have been partially compensated by an overall positive trend in SMB over the whole continent. We conclude that there was no statistically significant net imbalance in the seven year period. Other data are being included to allow extension of the time series back to 1995 and forward to the present day using, for example, CryoSat 2, ice core records and accumulation radar data.

## The role of refreezing meltwater beneath the Antarctic and Greenland Ice Sheets

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Meltwater can influence ice flow by lubricating the base or by freezing-on new warm ice that changes ice sheet strength. In East Antarctica water in subglacial networks along the valleys of the Gamburtsev Mountains refreezes along the high ridge producing large bodies of basal ice. Basal ice units thicken along flow and deflect the overlying stratigraphy upward up to 1000m. In Antarctica, basal units are characterized by an upper reflector and often emerge from the bright, water-filled ice sheet bed. Basal freeze-on in the Dome A region must have persisted in the same locations through the last glacial-interglacial transition to produce the 60km long features. While the surface accumulation, surface slope and bed morphology vary on the north and south of Dome A, a quarter of the ice sheet base consists of ice freeze-on from the bottom. Similar structures are present within the Greenland Ice Sheet. In Greenland, both surface and basal meltwater refreeze to the bottom of the ice sheet producing distinct ice units up to 1100m thick. In Greenland, it is clear the units consist of a core of refrozen water commonly surrounded by 100's of meters of heavily deformed ice. Beneath Petermann Glacier, Greenland refrozen ice units coincide with the onset of fast flow and continue downstream where they correspond to locations of rapid melting of the floating ice tongue. Refreezing can modify the temperature structure and rheology of an ice sheet, influencing both deformation and discharge of ice into the global oceans. In Antarctica, refrozen ice has been sampled over Lake Vostok and imaged downstream of Lake Vostok, over Lake Concordia, close to Dome C and on both sides of Dome A. The basal freeze-on modifies the fundamental structure of ice sheets, thickening the ice column from the base. Widespread freeze-on can change the rheology and modify the flow of the Antarctic and Greenland ice sheets. Inclusion of these basal processes is essential to produce robust predictions of future ice sheet change and to accurately predict the location of the oldest ice.

## Area changes and frontal ablation of glaciers on James Ross Island

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The glaciers of James Ross Island have shown considerable retreat since many years. Some of them even show dramatic changes after the disintegration of the ice shelf in Prince-Gustav-Channel. Using multi-spectral imagery from various mission back to 1975, we document and quantify these area changes on a catchment basis. From 1975 to 1988 (12.4 years) the glacier area decreased by 22.8 Km<sup>2</sup>, at a rate of 1.8 Km<sup>2</sup>/a, and from 1988 to 2009 (21 years) the decay more than doubled to 58.5 Km<sup>2</sup>, at an increased rate of 2.8 Km/a. This is coincident with the regional warming trend. During period 2001-2009, 101 Km<sup>2</sup> of shelf ice within Röhss Bay were lost. Using repeat acquisitions of ALOS PALSAR we additionally derive surface velocity fields and estimate the ice discharge. Ice thickness was provided from BEDMAP project.

## Flow and ice discharge of tributary glaciers of Larsen-C Ice Shelves

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Using repeat acquisitions of various SAR satellite sensors we derive surface velocity fields and estimate the ice discharge of the tributaries of southern Larsen-C Ice Shelf. We analysed various acquisitions of ALOS PALSAR as well as ERS/ENVISAT as well as TerraSAR-X data takes. While the L-Band data provided very accurate results, the X-Band data showed some temporal decorrelation. Combining the velocity fields with ice thickness data from the NASA Icebridge missions provides an estimate of ice discharge for selected outlet glaciers.

## Changes in ice dynamics of tributary glaciers of former Larsen-A and Prince-Gustav-Channel Ice Shelf (Antarctic Peninsula)

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During the last decades numerous ice shelves along the Antarctic Peninsula retreated, have started to break-up or disintegrated completely. The loss of the backstress caused tributary glaciers to accelerate and an increased ice discharge is reported for the Antarctic Peninsula. Quantification of the mass changes is still subject to considerable errors although numbers are converging from the different methods.

We provide detailed analysis of glaciers former draining into Larsen-A and Prince Gustav ice shelves. The aim is to study its response to the ice shelf disintegration in the end of the 1980 and 1995 as well as to better quantify the ice mass loss over time. Using feature tracking we analyse time series of different SAR satellites (ERS-1/2, ENVISAT, Radarsat-1, ALOS PALSAR, TerraSAR-X/TanDEM-X) of the last 20 years in regard to glacier surface velocity changes. Ice front position changes are recorded in conjunction with the velocity data. From high resolution bi-static TanDEM-X satellite data, ASTER and SPOT stereo images changes in surface elevations are determined. Airborne laser scanning, ground penetrating radar (AWI Polar-5/6, NASA operation ice-bridge) and differential GNS data from field campaigns support the analysis to estimate the ice discharge. For example at the Dinsmoore-Bombardier-Edgeworth glacier system results show an increase in surface velocity from 0.9 m/d in 1996 up to 3.3 m/d in 2007 close to the terminus. Subsequently, surface velocities decreased to 1.6 m/d in 2010 and kept nearly constant. The changes in flow velocities are coinciding with changes in front position. Furthermore, the estimates of surface elevation changes indicate a lowering of ~24m on Bombardier and Edgeworth Glacier between 2003 and 2013. Finally, ice discharge estimates are calculated by combining all datasets. These will support the imbalance calculation in the research area and the interpretation how ice shelf disintegration effects the tributary glaciers.

## Glacier mass balance and glacier changes in the north-eastern Antarctic Peninsula

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Climate warming during last decades is affecting the glaciers on north-eastern Antarctic Peninsula. In particular, “Glaciar Bahía del Diablo” and “Glaciar Cabo Lamb” on Vega Island have been subject to a mean surface lowering of 1.0 m/year since 1984. “Glaciar Bahía del Diablo” mass-balance results from 1999 up to date also show a negative trend. Annual net mass balance results are directly related with the mean summer air temperature. Field data obtained by several DGPS surveys during field campaigns were used to improve the Digital Elevation Models of the glacier, to re-assess the glacier boundary and to calibrate the mass-balance series by means of a geodetic volume-change determination for a similar period.

## Spatio-temporal analysis of a 32-years time series for surface melt and runoff on the Antarctic Peninsula

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The present study estimated a 32-years time series for Surface Melt (SM) and Runoff (R) on the Antarctic Peninsula (north of 71°S), comprising the 1980-2012 period. A Positive Degree Days gridded-based model was used, in daily resolution, to calculate annual sums of SM and R. The model was fed with surface air temperature data obtained by the ERA-Interim reanalysis project, which was interpolated to a 200 m resolution grid using a multivariate regression method. For the SM estimation, the highest and lowest melt factors (MF) for snow found in literature were applied ( $2.17$  and  $6.00 \text{ kg m}^{-1} \text{ } ^\circ\text{C}^{-1} \text{ day}^{-1}$ ), while R was considered to be the difference between the total SM and the amount retained by capillarity, refreezing and porosity. Differences of up to  $50.96 \text{ Gt/a}$  and  $35.13 \text{ Gt/a}$  for SM and R, respectively, were found by applying both MF, which is considerable for the magnitude of the data, but both are extreme high and low factors. Hereafter, all analysis considered the median time series between both extreme MF.

SM and R showed maximum and minimum peaks in the 2002/2003 and 1986/1987 years, respectively ( $\overline{SM} = 20.86 \text{ Gt/a}$ ,  $\overline{R} = 7.08 \text{ Gt/a}$ ). The most remarkable characteristic is the high interannual variability ( $\overline{SM}^{\text{std}} = 10.77 \text{ Gt/a}$ ,  $\overline{R}^{\text{std}} = 5.29 \text{ Gt/a}$ ), which is also observed in sea ice extent and surface air temperature time series of the same region. The geographical distribution of both variables is strongly dependent on the elevation, almost restricting the occurrence of R to the coastal zones and ice shelves. A wavelet analysis indicated a 3 to 4 years periodicity in the time series, with an energy peak between 1998 and 2007.

Comparing visually the total melt extent area time series with the one obtained by Liu *et al.* (2006) through passive microwave imagery, a good agreement is observed, although we obtained lower values. The best accordance occurred in the post 1998 period. As the microwave signal decays exponentially with liquid water content, the lower accordance in the pre-1998 period may be due to the low resolution (whole  $25 \times 25 \text{ km}$ ) of the passive microwave imagery. As the air temperature rises, so will the time series agreement. The same explanation may be valid for the smaller melt area estimated by our model. The estimative of a statistically significant temporal trend for the time series was unfeasible, in part due to the high annual variability even considering the median time series, but the presence of superimposed climatic cycles should also be considered. The strong SM and R over the Larsen C ice shelf supports the high relevance of these variables to the Larsen A and B disintegrations processes.

## Quantifying surface mass balance estimates over Antarctica using ice penetrating radars and ice cores

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Accurate quantification of surface snow-accumulation over Antarctica is important for mass balance estimates and climate studies based on ice core records. Large uncertainties exist in current compilations of Antarctic surface mass balance (SMB), particularly in East Antarctica. Using airborne radar, lidar and thresholds of surface slope, modeled SMB and wind fields, we have predicted continent-wide distribution of wind-scour zones over Antarctica. These zones are located over relatively steep ice surface and controlled by bedrock topography. The near-surface winds accelerate over these zones and erode and sublimate the snow. This results in numerous localized regions ( $\leq 200 \text{ km}^2$ ) with reduced surface accumulation. Each year, tens of gigatons of snow on the Antarctic ice sheet are ablated by persistent near-surface katabatic winds over these wind-scour zones. Near the coast, winds often blow significant amounts of surface snow from these zones into the ocean. SMB estimates over Antarctica rely on sparse point measurements or coarse atmospheric models that do not capture these local processes and overestimate the net mass input by more than 40 Gt/yr.

The snow mass eroded over the wind-scour zones are either sublimated, redistributed downslope in topographic depressions or blown out into the ocean. While these processes of surface mass loss are known, it is harder to quantify the amount of total mass lost. To constrain the regional SMB, we use Operation IceBridge's snow radar, ice core dielectric and depth-density profiles, and ice penetrating radars from the Norwegian-U.S. Scientific Traverse of East Antarctica over the Recovery Ice Stream catchment to estimate the amount of snow redistributed at the topographic depressions downslope of the wind-scour zones. Accurate quantification of regional SMB will reduce the imbalances observed between mass-budget methods and mass balance estimates from GRACE observations.

## Modelled glacier response to centennial temperature and precipitation trends on the Antarctic Peninsula

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The northern Antarctic Peninsula is currently undergoing rapid atmospheric warming. Increased glacier-surface melt during the Twentieth Century has contributed to ice-shelf collapse and the widespread thinning, acceleration and recession of glaciers. Glaciers peripheral to the Antarctic Ice Sheet currently therefore make a large contribution to eustatic sea level rise, although future melting may be offset by increased precipitation. The future behaviour of Antarctic Peninsula glaciers consequently depends on whether air temperature or precipitation is the primary control on glacier mass balance. Here we present glacier-climate relationships during the Holocene, using ice core and geological data and numerical model simulations focussing on Glacier IJR45, James Ross Island, northeast Antarctic Peninsula. Our modelling experiments show that this representative glacier is sensitive to temperature change, but relatively insensitive to precipitation change. Consequently, the most recent glacier expansion occurred during late Holocene cooling and not during the warmer and potentially wetter mid-Holocene, as previously hypothesised. Increases in precipitation are unlikely to offset high glacier melt over the coming century. Modelling experiments, spanning a range of past, present and future time intervals, together strongly suggest that future increases in precipitation are unlikely to offset atmospheric warming-induced melt of glaciers peripheral to the Antarctic Peninsula.

## Antarctica's potential contribution to future sea-level rise

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A hybrid ice sheet-shelf model with freely migrating grounding lines is improved by accounting for 1) surface meltwater enhancement of ice shelf calving; and 2) the structural stability of thick (>800 m), marine-terminating (tidewater) grounding lines. When coupled to a high-resolution atmospheric model with imposed or simulated ocean temperatures, the new model is demonstrated to do a good job simulating past geologic intervals with high (albeit uncertain) sea levels including the Pliocene (3Ma; +20 ±10m) and the Last Interglacial (130-115ka; +4-9m). When applied to future IPCC CMIP5 RCP greenhouse gas forcing scenarios with ocean temperatures provided by the NCAR CCSM4, the same model shows the potential for massive ice and freshwater discharge beginning in the second half of this century. In both RCP2.6 and 8.5 scenarios considerable retreat begins in the Pine Island Bay region of West Antarctica. In the more aggressive (and arguably more likely) RCP8.5 scenario, Pine Island Bay retreat is followed by more massive retreat of the entire WAIS, and eventual ice retreat into deep East Antarctic basins. During peak rates of retreat, freshwater discharge exceeds 1 Sv and exceeds 0.2 Sv for several centuries with potential to disrupt ocean circulation in addition to contributing between 2m and 9m sea level rise within the next 500 yers. Here, we demonstrate that large portions of the Antarctic Ice Sheet (in West and East Antarctica) can retreat on relatively short (decadal-centennial) timescales, posing a serious threat to global populations.

## **'Unlocking the archive': Using photogrammetry of historic aerial photographs to extend the record of glacier change on the Antarctic Peninsula**

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Changes to glacier fronts and ice shelves and glacier acceleration on the Antarctic Peninsula are well documented, but there is almost no data on mass changes for the more than 400 glaciers in the region. Forecasting the future impacts of the Antarctic Peninsula ice sheet on sea level will require a much improved understanding of 20<sup>th</sup> Century and contemporary glacier mass changes. Satellite data has been used to measure recent changes, but methods to quantify changes over decadal time scales have eluded researchers. However, there is an archive of aerial photography of the Antarctic Peninsula dating back to the 1940s, but this has been largely ignored due to the technical problems associated with deriving quantitative data from historic aerial photographs. Modern advances in photogrammetric processing and capture of GPS-supported aerial photography now allow this archive to be 'unlocked'.

Accurate photogrammetric reconstruction from aerial photographs traditionally requires known ground control points surveyed in the field; in remote and inaccessible areas, such as the Antarctic Peninsula, this is often impossible and so has restricted the use of photogrammetric analysis of the available aerial photography. Our project provides control for historic photos without fieldwork on the ground, by 1) linking them to a newly acquired, highly accurate photogrammetric model adjusted through direct kinematic GPS positioning of the camera, or 2) adjusting DEMs derived from the historic photographs to a reference surface extracted from ASTER stereo satellite imagery.

Our methods will allow accurate measurements of surface elevation change for about 50 glaciers on the Antarctic Peninsula over a time-span of up to 65 years, enabling detection of both spatial and temporal patterns of change and improving understanding of glacier response in this area. The use of this technique opens up possibilities for 'unlocking the archive' in other remote glacial areas where historic aerial photography exists but the collection of ground control points is limited.

This presentation will outline the photogrammetric workflow and associated errors with examples from the Antarctic Peninsula region and summarise initial findings from the research.

## A stochastic model for dynamic ice loss

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Quantifying ice sheet reduction on a timescale of decades to centuries is highly challenging due in large part to the episodic and highly non-linear nature of rapid dynamic ice loss. Deterministic approaches are progressing but still need considerable development before they can make reliable projections for whole ice sheets. The most convincing deterministic models are at the scale of individual glacial systems and require scaling up in some way to estimate whole ice sheet contributions to future sea level rise. In parallel, new discoveries concerning the complexity of different ice sheet systems continue as observations increase and improve. In response to the challenges of modelling ice sheets, there have been calls to adopt alternative approaches to estimating the potential upper bounds to the ice sheet contributions to future sea level rise. Here we develop and apply an approach based on a recurrence interval model governing Dynamic Ice Loss (DIL) for individual marine outlet basins. Our stochastic approach integrates paleo and instrumental data and can account for the stochastic nature of ice sheet discharge. Intermediate size ice streams contribute most to DIL on a century time scale. This work makes a strong case for collecting more paleo-proxy data to better understand larger marine outlets with longer recurrence intervals and the focused modelling of specific, intermediate size ice-streams with sophisticated ice-stream models.

## Ice dynamic and related records at Union Glaciar, Heritage Range, West Antarctica

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Several sectors of Union Glacier (79°45.66' S / 83°15.89' W) area are being studied by a joint Brazilian–Chilean program since December 2011. The central ice basin is characterized by the feeding of several tributary glaciers descending from surrounding Edson Hills, Buchanan Hills, Collier Hills and Enterprise Hills, parts of southern east section of Heritage Range in the Ellsworth Mountains. A program to study the ice mass balance, snow properties, and the interactions of climate and ice dynamic was initiated in the Criosfera Glacier site, one of these tributaries. Records are based on DGPS surveys, snow stratigraphy sampling, GPR sounding, Glacier Ablation Sensor System probe logging, automatic weather station installation and analysis of multi-sensor remote sensing data. At Criosfera Glacier the bamboo stakes array report an annual snow accumulation of  $31.5 \pm 54.6$  cm. The surveying of additional ground control points for the generation of a larger scale digital elevation model of the area was initiated to create a map with larger spatial resolution in order to geocode multisensor satellite data. Observation of epiglacial melt water and subsequent vigorous water run-off has been recorded at the end of December 2011 and 2012, lasting for short time periods. These events were recorded in days with cloud-free skies and with warmest air temperatures (ca.  $-2^{\circ}$ ), being located close to dark rock outcrops covering slopes with northward exposition. Evidence of semi-frozen ponds with a thin-frozen layer surface were detected in the upper part of the southern moraines suggesting warm conditions that last for several weeks every season.

## **CryoSat-2 observations in Antarctica: Quantifying uncertainties by calibration and validation utilizing different satellite, airborne and ground-based techniques**

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ESA's CryoSat-2 mission with its radar altimeter system SIRAL has been designed in order to determine fluctuations in the mass of the vast ice sheets that overlay Greenland and Antarctica and marine ice floating in the polar oceans.

To fulfill the main goals of the CryoSat-2 mission it is necessary to validate the different CryoSat-2 products against independent measurements. The objective of the CryoSat Validation Experiments (CryoVEx) is to collect and analyse airborne and ground-based measurements in order to get such independent data sets.

In 2008/09 and 2010/11 the Institut für Planetare Geodäsie of TU Dresden successfully realised CryoVEx campaigns in the blue-ice area south-east of Schirmacher Oasis, Dronning Maud Land, East Antarctica. Since altimetric returns at blue ice are dominated by surface reflection, such areas are particularly suited for calibration/validation activities. The surface heights have been observed utilizing kinematic GNSS measurements. Extensive ground-based observations along traverses covering the blue-ice area have been carried out since 1991 in order to determine long-term surface-height changes and surface velocities. The two Antarctic CryoVEx campaigns provide an excellent continuation of the long-term observations.

In the presentation we will discuss the results of the accomplished CryoVEx campaigns, comparisons to the former measurements and possible inferences. Up to 2008 the repeated measurements yielded a decrease of the surface height of up to -15 ... -20cm/a in this area. In contrast to this, the rates of the surface-height change based on the results of the two CryoVEx campaigns, which cover even 2 years, register a positive trend in the same magnitude. We detected the anomalous trend change on basis of the repeatedly observed traverse covering the blue-ice area as well as of several kinematic test grids. Additionally, we will compare our ground-based results with coordinated airborne measurements carried out by AWI including a collection of radar (ASIRAS) and laser altimeter data.

In order to classify the anomalous and probably temporary trend change it is planned to proceed with the validation activities in the blue-ice region and to carry out an additional CryoVEx campaign during the upcoming Antarctic season. These additional observations will help to clarify the further development of the long-term height-changes of the surface within the area of investigation.

## Sensitivity of the Weddell Sea sector ice streams to sub-shelf melting and surface accumulation

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A recent ocean modelling study indicates that possible changes in circulation may bring warm deep ocean water into direct contact with the grounding lines of the Filchner-Ronne ice streams, suggesting the potential for future ice losses from this sector equivalent to ~0.3 m of sea-level rise. Significant advancements have been made in our knowledge of both the basal topography and ice velocity in the Weddell Sea sector, thus enabling an assessment to be made of the relative sensitivities of the diverse collection of ice streams feeding the Filchner-Ronne Ice Shelf. Here we use the BISICLES ice sheet model, which employs adaptive-mesh refinement to resolve grounding line dynamics, to carry out such an assessment. The impact of perturbations to the surface and sub-shelf mass balance forcing fields from our 2000 year 'reference' model run indicate that both the Institute and Möller Ice Streams are highly sensitive to changes in basal melting either near to their respective grounding lines, or in the region of the ice rises within the Filchner-Ronne Ice Shelf. These same perturbations have little impact, however, on Rutford, Carlson or Foundation ice streams, while Evans Ice Stream is found to enter a phase of unstable retreat only after melt at its grounding line has increased by an order-of-magnitude from likely present-day values.

## Surface mass and heat budget of snow cover and blue ice in the western Dronning Maud Land

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The surface heat balance of an ice sheet depends on the surface reflectance and the thermal properties of the glacial surface layer. Dry snow and blue ice areas represent extreme cases in this question. Field investigations have been made on the surface mass and heat balance of both these surfaces in the western Dronning Maud Land based on automated station and manual data collection, including Aboa and AWS5 weather stations, FINNARP snow stations, and field campaigns in two austral summers (2009–2011). With both atmospheric layer data and glacial data the surface heat balance could be closed to gain a significant improvement on the accuracy of the total heat flux. The surface heat balance was governed by the radiative fluxes with occasional strong turbulent fluxes in connection with cyclonic activity and catabatic winds. Due to the low relative humidity latent heat transfer was also significant. In the snow site the air temperature ranged from near 0°C to –30°C. The air temperature ranged from 0°C to –30°C, and the snow temperature at a depth of 54 cm revealed three distinct cycles shorter than annual: the daily cycle, the synoptic scale cycle, and a long cycle of 2–4 months. The average density was 390 kg m<sup>-3</sup> at the surface and at 1.5-m depth it was 460 kg m<sup>-3</sup>. The blue ice site was located at Basen nunatak, its size being about 5 km<sup>2</sup>. The albedo was 0.4–0.6 according to the manual field measurements, and in summer a supraglacial lake formed at the site. The summer heating of the ice penetrated deep, at 3-m depth the temperature was still at the freezing point. The lake body consisted of two layers, each around 1 m thick: an upper layer with a thin ice layer on top and main body of liquid water, and a lower layer containing slush and hard ice sub-layers. The light attenuation coefficient of the lake body was 0.5–0.7 m<sup>-1</sup>. The lake freezes up in winter in the present climatic conditions. The monthly sublimation varied between 2.2 mm (July) and 19.9 mm (December). Thermally active surface layer is deeper over blue ice due to the higher reflectance, optical thickness and thermal conductivity. The snow-covered site reached the melting point in a very thin subsurface layer, but in the blue ice site a 1-m layer of liquid water was produced. The method of closing the surface heat balance using ice and snow data is a highly important addition since the integral heat flux can be obtained instead of getting lost with a several independent errors and uncertainties in the atmospheric data.

## Understanding the response of the Ecology Glacier to climate change

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The glacier complex on King George Island in the South Shetland Islands has been exhibiting accelerated rates of retreat over the last decade. Several studies have investigated the response of the upper parts of the ice cap, but the outlet glaciers have received less attention. The Ecology Glacier is a polythermal outlet glacier of the Warzawa ice field, which is located in the southern quadrant of King George Island. This glacier has been retreating at a relatively high rate, such that it has changed from being a marine-terminating glacier, to a land-terminating glacier during the last few years. This change to a deglaciating environment has implications for the biological systems downstream of the Ecology Glacier (which includes an Antarctic Protected Area). In this project we investigate the hydrological role of the Ecology Glacier under current and future climatic conditions through a monitoring and modelling effort. This presentation features data from the first of three monitoring seasons and from existing meteorological datasets and remote sensing products. Using daily MODIS imagery from 2003 to present, we have reconstructed snow coverage and albedo patterns, and we use this as input data to give a preliminary look at mass balance changes through the last decade.

## **GRACE Antarctic ice mass change: Trends and accelerations from different methodologies with uncertainties based on autocorrelation**

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Several methodologies are employed to extract time series of Antarctic ice mass change from GRACE level 1b positioning, K band range rate data, and accelerometer and attitude data. These include global spherical harmonics, mascons and spherical cap harmonics. In this study we use these methodologies to extract Antarctic ice mass change for 2003-2013 inclusive. A comparison of the solutions based on the different methodologies is undertaken with particular reference to the spatial scale. Time series analysis based on linear regression under the assumption of Gaussian noise has been shown to underestimate the trend and acceleration uncertainties. This underestimation will lead to erroneous conclusions on the spatial distribution of locations where accelerated ice mass change is observed. Here, we utilise autocorrelation and infer the appropriate stochastic noise model for each time series. We will discuss the differences in the stochastic properties of the time series as derived from the three methodologies as well as differences in the spatial distributions of significant trends and acceleration. A further complexity in time series analysis concerns deterministic versus stochastic variations. By utilising the appropriate stochastic models for each methodology we can infer the spatial extent for which we are confident that the observed GRACE signatures are deterministic and unlikely to be a result of stochastic variation.

## On the Use of Spherical Cap Harmonics for GRACE Ice Mass Change

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We consider Antarctica ice mass change using spherical cap harmonics and GRACE data. Unlike global harmonics, spherical cap harmonics utilise associated Legendre functions of non-integral orders. Furthermore, two types of spherical cap harmonics are defined depending on the boundary conditions. In this study we describe and develop the theory of spherical cap harmonics as applied to GRACE. The surface mass change is defined over a polar cap of half angle  $\theta_0$  by representation of the surface mass in terms of gravitational spherical cap harmonics. By utilising positioning, K band range rate data and accelerometer and attitude data for short arcs across the Southern Hemisphere time series of Antarctica ice mass change is recovered from GRACE data. We will discuss the relevance of the spherical cap size, and the truncation of the spherical cap harmonic expansion. Comparisons of Antarctica ice mass change from spherical cap and global spherical harmonics will be presented.

## A simulated comparison of level-1b GRACE analysis techniques

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Temporal mass anomalies from GRACE have been obtained using a number of different approaches including; conventional spherical harmonic and the mascon approach, which applies a constraint matrix between mascon parameters that share geophysical similarities. The resulting temporal gravity fields are frequently obtained using different codes and algorithms and are produced by different groups, making it hard to directly compare any subsequent mass flux analysis.

To assess the errors and the ability of each technique to resolve basin-level mass changes at a variety of spatial scales we undertake a comparison of solutions generated through the estimation of mascon and spherical harmonic coefficients. We use simulations to provide an accurate assessment of each technique and quantify the capability to resolve basin-level mass changes at a variety of spatial scales while using simulations to understanding how each methodology handle the noise inherent at higher degree and order.

Through a simulated recovery of a GLDAS anomaly with added noise in the form of 'stripes' we will show the advantage of the mascon solution over a spherical harmonic recovery. We will show how the addition of a constraint between mascon parameters that share geophysical similarities result in a reduction of the signal lost at all degrees and an improvement in the recovered signal. We will validate the use of the mascon methodology in Polar Regions by subsequently extending the simulation to the recovery of an Antarctic mass signal.

## Evolution of 27 individual Svalbard glaciers over the 21st century

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Sea-level rise is one of the major challenges for mankind in the oncoming decades. The Arctic glaciers and ice caps are known to play a major role in this respect due to their large surface area and their location in the region of highest predicted air temperature increases over the 21st century. One of the most heavily glacierized archipelagos in the Arctic is Svalbard. It holds about 36,000 km<sup>2</sup> of glaciers and ice caps. What is known about the future evolution of Svalbard's ice masses so far suffers rather high uncertainties as future mass balance and volume change assessments have only been performed as part of global-scale studies.

We here present a high-resolution modelling study of the climatic mass balance and related changes in ice volume for 27 individual glaciers spread throughout Spitsbergen, the largest island of the archipelago. Our model calculates glacier mass balance and area/volume changes using a temperature-index approach in combination with a surface elevation change parameterization. The initial glacier topographies and volumes have been assessed from extensive ground-penetrating radar measurements that have been carried out in recent years. The calculations are performed for the 21st century and are forced by statistically downscaled output of ten different global circulation models representing the four SRES RCP scenarios 2.6, 4.5, 6.0 and 8.5.

Results indicate a strongly decreasing ice volume over the 21st century, especially for smaller glaciers. However, substantially different magnitudes of ice volume evolution are evident over the entire set of glacier size classes and dependent on the climate-change scenarios used. Based on statistical upscaling of the results from our individual glaciers we are able to extrapolate them to the entire set of smaller ice bodies on Spitsbergen and present an estimate of 21st century sea level rise originating from these glaciers.

## Ice shelf dynamics of the Princess Ragnhild Coast, Dronning Maud Land, Antarctica

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The ice shelves of the princess Ragnhild Coast, Dronning Maud Land, are laterally confined by large ice rises, and at several places pinned on the ice-shelf front by small ice rumpled. Both ice rises and rumpled significantly buttress the ice flow from large outlet glaciers (such as West Ragnhild Glacier, east of the Sør Rondane Mountains) flowing into these ice shelves. Potential unpinning of the shelves could lead to ice shelf acceleration and thinning, but more importantly, an acceleration of outlet glaciers at the upstream entrance of the ice shelf.

Over the last years, we carried out an extensive geophysical survey, comprising low and high frequency radar and differential GNSS, across the Roi Baudouin ice shelf, the ice rumple and the two ice rises that buttress the flow. The Derwael ice rise (to the east of the ice shelf) is characterized by a well-developed Raymond effect, i.e. an upwarping of internal ice reflectors due to the high effective viscosity underneath the ice divide, which is a characteristic of steady ice flow over long time scales. Forward and inverse ice shelf models were then developed and applied to interpret the geophysical observations.

Based on this evidence, our understanding of the ice-shelf systems shows that:

1. Ice flow across the ice rises has been local over longer (thousands of years) time scales, demonstrating that they are stable features.
2. Basal melt rates at the grounding line are of the order of tens of centimeters, but significantly higher within sub ice shelf channels and at the grounding line of the major outlet glaciers feeding in the ice shelf.
3. The outlet glaciers feeding the ice shelf are dominated by ice flow due to basal sliding, probably over unconsolidated sediment; their ice flux across the grounding line shows that they are amongst the primary discharge features of the whole Dronning Maud Land.
4. The speed of the ice shelf flow is significantly reduced by local pinning of small ice rumpled that show a great variability in response to the tidal signal; unpinning inevitably leads to ice shelf speedup.
5. Sub-shelf marine ice accretion is a common feature of the ice shelf, pointing to a vigorous ocean circulation across the continental shelf.

All observations show that, despite the apparent stability of the ice shelf system in Dronning Maud Land, outlet glaciers and ice shelves control the discharge of the East Antarctic ice sheet in this area and that small perturbations in this system may lead to significant ice flow acceleration as observed elsewhere in West Antarctica.

## The velocities of the primary tributary glaciers of the Amery Ice Shelf, 2004-2012

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The Amery Ice Shelf is one of the primary drainage basins for the East Antarctic Ice Sheet. Monitoring its response to climate change is an important step in determining what role the East Antarctic Ice Sheet may play, positive or negative, in sea level rise. This study calculates the velocity of the southern portion of the Amery Ice shelf and its tributary glaciers by measuring the displacement of features on the ice surface over a sequence of visible spectrum Landsat 7 images separated by one year intervals spanning 2004 to 2012. The displacements undergo a geo-rectification correction before being converted into velocities. No changes in surface velocity are observed above the uncertainty level over this period, indicating that the ice velocity has been stable over our study region. Accordingly we use the spatially incomplete velocity fields from each image pair between 2004 and 2012 to synthesise an average velocity dataset of the Amery Ice Shelf region (VAIS). The VAIS dataset is compared to previous velocity measurements from the RAMP-MAMM and MEaSUREs velocity datasets, as well as the limited *in situ* GPS data in the region. The velocities in the VAIS are higher than MEaSUREs across the region, but differ regionally from RAMP-MAMM with higher velocities on the grounded ice and slower velocities on the floating ice. The few GPS velocity measurements are higher than all three remotely sensed velocity datasets. Monitoring the rate of ice flow into ice shelves is vital to understand how, where and when changes occur in Antarctica, and to quantify their impact on sea level rise.

## Converging glacial flows in an idealised model

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The Fisher, Lambert and Mellor glaciers are the primary tributary glaciers of the Amery Ice Shelf and converge over the southern grounding zone. This region experiences complex stresses as each flow has variations in velocity and thickness, coupled with complex topography and spatially varying basal traction. This study develops an idealised topography to investigate both the physical controls on ice flow in this scenario, as well as the importance of model resolution and ice flow physics. The model being used is BISICLES, which has two different ice physics modes: a) Shallow Shelf Approximation and b) Higher order model. This study will investigate how the two different physical approximations over a range of resolutions represent flow dynamics and evaluate them based on our physical knowledge of the physics from observations.

## A new scientific traverse in an unexplored area of East Antarctica

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Laboratory Glaciology

During the 2013-2014 summer field campaign, a scientific traverse was performed from Cap Prud'Homme (CP) to GC40 location in the Aurora Basin North (ABN, East Antarctica), via the D85 station. The scientific expedition is a new French contribution to the international SCAR program ITASE (International Trans-Antarctic Scientific Expeditions). This project was associated to a larger initiative from the Australian Antarctic Division (AAD), and in close collaboration with Denmark, USA and France, to perform an intermediate ice core drilling (400 m) at GC40 (71°36'10, 111°15'46). The site located 1250 km from Dumont d'Urville, 600 km from Casey and 550 km from Dome C. Because the access to the site was limited, a traverse was realized to GC40 where >a skiway was grooved to allow planes to land deliver the material and the drilling team. This was an excellent opportunity to pursue scientific activities in this poorly explored sector of Antarctica. The main scientific objectives of the "traverse" was to extend our vision on the distribution of accumulation and on the related processes, to estimate past and current snow accumulation changes (last 50-100 years) in the central regions of east Antarctica. A continuous Snow Ground Penetrating Radar signal was retrieved along the traverse. This signal allows interpolation of accumulation data obtained from firn / ice cores collected at selected locations. Here we present the first results from this traverse.

## Modeling interactions between Antarctic instability and Surface Mass Balance

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In the context of future global warming, Antarctic contribution to sea level rise (SLR) depends on several processes leading to opposite impacts. First, under a warming climate, precipitation is supposed to increase, inducing a plausible negative impact on SLR. Contrary to the Greenland ice sheet case, ablation should stay a marginal process at least on grounded ice. Second, oceanic warming and/or surface ponding on ice shelves may trigger a Marine Ice Sheet Instability by reducing the back force they exert on outlet glaciers. Once engaged on such a self-entertained retreat a large positive contribution to SLR may be expected. This dynamic process is already going on in the Amundsen sea sector. Although these two processes (surface mass balance -- SMB -- and ice dynamics) have been modeled separately to infer sea level contribution, little work has been done to study their interactions.

In this presentation we focus on how grounding line retreat can affect estimation of SMB in the future and the related contribution to sea level change. To evaluate the shift of precipitation pattern while the steep surface slope region migrates inward due to the grounding line retreat, we simulate surface mass balance on various surface topographies of the Antarctic ice sheet. Each ice sheet topography is obtained with an ice sheet model (GRISLI) in which grounding line retreat is parameterized according to glaciological considerations. Because we are looking at coastal changes, a high resolution is needed for the atmospheric model.

We use the regional circulation model MAR with a resolution of 40 km. The SMB is further downscaled on fast-retreating areas with SMHiL (a fast-computing surface mass balance downscaling model) and MAR to take into account scales as small as 10 km. Comparing the performance of MAR and SMHiL indicates in which range of grounding line retreat SMHiL is sufficient to capture the interaction between ice dynamic changes and SMB.

This work constitutes an important step toward asynchronous coupling between atmospheric and ice sheet models improving our ability to perform SLR projections

## Internal structure and subglacial characteristics of the triple ice divide between Pine Island, Rutford and Institute Ice streams in West Antarctica

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In January 2014, a new oversnow traverse was conducted by CECs to the triple ice divide between Pine Island, Institute and Rutford ice streams in the West Antarctic ice sheet. The main aims of the campaign were to: (1) map the surface and subglacial topography of the region; (2) identify the internal structure of the ice; and (3) investigate surface mass balance and ice dynamics. West Antarctica has been considered potentially unstable. This is especially true for Pine Island Glacier which is the most dynamic in the region and has been recently considered as experiencing irreversible changes. In spite of these changes, little is known about present or past dynamic at its ice divide with nearby ice streams. Is the ice divide experiencing a migration in response to the high rates of thinning and ongoing acceleration? Is there evidence in the ice divide internal structure of the ice of past dynamic changes? To answer these questions, two different radars operating on a synchronous basis were used throughout the traverse. The first radar was a VHF coherent system with high output power (200 W) and was employed to map the bedrock. This radar used the pulse-compression method at central frequency of 155 MHz and a bandwidth of 20 MHz. The second radar was a frequency modulated continuous wave (FM-CW) system transmitting in the UHF band, between 203 and 1019 MHz. All radar data was geo-located using dual GPS receivers.

The traverse convoy, pulled by a Prinoth tractor, comprised of a scientific fiber glass module specially designed to allocate up to 6 scientists with all needed scientific sensors, and a logistic module including kitchen and bathroom. Both modules were installed onboard lehmann sledges. In total, the traverse covered near 1100 km since leaving the summer base camp at Union glacier (79.8°S/83.4°W). Apart from the extensive radar and GPS data collection, a network of stakes was installed for mass balance and ice dynamic purposes.

The scientific instruments performed very well during the whole campaign and allowed for the detection of ice thickness up to a maximum of 3100 m. The detected subglacial topography surrounding the triple ice divide was much rougher and deeper than previously estimated by the BEDMAP 2 data set. The internal structure of the first 200 m of snow/firn was clearly mapped, showing a complex pattern of isochronous layers. In addition, the bedrock returns allowed for the identification of a new subglacial lake with an estimated area of near 18 km<sup>2</sup>.

The results obtained during the traverse and a preliminary analysis of the data will be presented.

## Present-day changes of the Antarctic Ice Sheet by satellite gravimetry, satellite altimetry and ground-based GPS

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Currently, the Antarctic Ice Sheet is in the main focus of interdisciplinary research with respect to climate change. Special attention is given to the investigation of ice height and velocity changes, of ice-mass balance and, closely related to these, of ice-sheet dynamics. We utilize satellite observations of the Gravity Recovery and Climate Experiment (GRACE) and of the Ice, Cloud, and Land Elevation Satellite (ICESat). Using GRACE RL05 data analyses were carried out for the entire period 2003 to 2012 as well as for the period 2003 to 2009 covered by ICESat data in order to facilitate a consistent cross-comparison. Both satellite sensors provide independent estimates of the ice-mass change, although the GRACE estimate is a direct one and the ICESat results have to be converted from height resp. volume change to mass change adopting reasonable assumptions on the density pattern. The main error sources of the present-day ice-mass balance will be discussed. For GRACE the largest source of uncertainty originates from the glacial-isostatic adjustment (GIA). Mass-change predictions by current GIA models will be examined and discussed. For ICESat the determination of the biases between the different laser operation periods is a crucial issue. To accomplish this analysis step we make use of the region of the subglacial Lake Vostok which provides an almost flat, near-zero accumulation area which has been also investigated by ground-truth observations with respect to height and height change. Furthermore, the volume-mass conversion step has to be examined in detail to come up with a reasonable error measure for the inferred ice-mass change. Finally, we will update our results of Groh et al. (2012) where a combination of GRACE and ICESat results was utilized to commonly estimate ice-mass balance and GIA mass effect. These results can be checked by independent GPS observations of the induced vertical deformation where the largest uplift rates in Antarctica were detected for the first time by Groh et al. (2012) in the region of the Amundsen Sea embayment. Hence, it is shown that present-day models considerably underestimate the GIA effect in this area. This gives a further indication for the ongoing discussion how to best capture the GIA effect by models. There are many issues still to be investigated like major differences in the solid earth characteristics between West and East Antarctica, laterally variable rheology, timing of the glacial history (e.g. Holocene events), ice volume at last glacial maximum, and, eventually, the coupling of GIA and ice-sheet dynamics.

## Non-trivial dynamics of Antarctic ice sheet resulted on borehole, geodetic and radar observations

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As the result of analysis of recent research in ice boreholes, geodetic and radar observations, a number of the Antarctic ice sheet flow features were observed, which do not fit to the traditional concept of ice sheets dynamics. For many years four boreholes were logged on the traverse between Vostok and Mirny stations, East Antarctica: at Vostok station to the depth of 1920 m (25-years monitoring), Vostok-1 and Mirny stations to 450 m, Pionerskaya station to 350 m. The data of borehole directional survey were compared with the data of surface radar profiling, and some general conclusions from experimental observations can be made: (1) the entire Antarctic ice sheet has a layered structure of the flow and the flow direction of each sub-layer is changed in the 'fan' manner; (2) the upper snow-firn layer's flow direction greatly differs (by 30...80°) from the underlying layers flow direction; (3) the flow rate of lower layers is faster than the upper layers. Recently the complicated folded structures were recorded by radar survey at the lower part of Antarctic ice sheet which in accordance with the morphological geotectonic geology may be interpreted as not-laminar ice flow ('glacial diapirs'). The results of surface and astronomic-geodetic observations revealed that the Antarctic ice sheet is flowing generally outward from the central part to the periphery but it can be divided into local streams. These streams have individual features similar to the nature of mountain glaciers and are varied for different local domes and glacier trunks.

## Marine ice sheet profiles and stability under Coulomb basal conditions

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Basal sliding of ice sheets and ice streams is of critical importance for explaining high glacial surface velocities and ice sheet stability. The vast majority of studies parameterize basal sliding by assuming that the basal shear stress is proportional to a power of the basal velocity. Recent laboratory measurements suggest this may be a poor representation of the actual sliding physics. In this work we instead consider the case of a Coulomb rheology, which is more consistent with some recent experiments on Antarctic till. Under this assumption, the basal shear stress may not exceed a linear function of the effective pressure at the ice sheet base, and is therefore substantially reduced close to the grounding line. We explore the consequences of this modification by calculating steady ice sheet profiles and stability conditions in a one-dimensional ice sheet model. We find that if water pressures are low, the model recovers classical results. With high water pressures, a different regime can be achieved in which highly pressurized till results in a modified steady-state ice sheet profile as well as different conditions for grounding line stability. Numerical model results suggest that our revised solution can exist under certain conditions for which the approximations made in the analytical solution are appropriate. Work is ongoing to evaluate which Antarctic ice streams meet the criteria necessary to transition to this different behavior.

## Evaluation of modeled Antarctic surface mass balance by RACMO2

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Regional atmospheric climate models are commonly used to estimate the Antarctic surface mass balance (SMB) since observations are too sparse for continent wide estimates. Evaluation of modeled SMB is essential since climate models do not provide a priori uncertainty ranges. Given the limited number of direct observations, this model evaluation is not trivial.

In the results presented we compare SMB estimates of two versions of the regional atmospheric climate model RACMO2: RACMO2.1 and its successor RACMO2.3. The most relevant model change in RACMO2.3 is the parameterization of super-saturation in ice clouds. In RACMO2.1, super-saturation was not allowed. The expected improvement in modeled SMB reflects into a better agreement with SMB observations and these improvements are most outspoken in the interior of East Antarctica where RACMO2.1 was too dry. The improved agreement also leads to lower uncertainty ranges in the modeled ice sheet integrated SMB. A similar pattern of improvement arises when balance velocities based on the modeled SMB fields are compared with InSAR ice-surface velocities.

## Holocene changes in relative sea-level in the Lützow-Holm Bay region, East Antarctica

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Compared to the other continental ice masses, the East Antarctic Ice-Sheet (EAIS) has few field data to constrain its past volume and contribution to global sea-level changes since the Last Glacial Maximum. We developed a new relative sea-level (RSL) curve for Lützow Holm Bay by using marine to freshwater transitions in sediment cores from four isolation lakes and <sup>14</sup>C-dating of macrofossils in raised beaches. These data were combined with radiocarbon dating of the transitions from glaciogenic to organic-rich sediments in three glacial lakes to obtain the minimum age of deglaciation and the maximum sea-level high stand. Our results were integrated with published raised beach data and records from two isolation lakes. In West Ongul Island, the maximum marine limit was 17 m at 10,500 <sup>14</sup>C yr BP. RSL fall was relatively rapid (15 mm/yr) between c. 5000 cal. yr BP and 4800 cal. yr BP. The uplift rate equaled 2.1 mm/yr during the past c. 4800 cal. yr BP, which was similar to that in Skallen (2 mm/yr during the past 4690 ± 100 cal. yr BP). In Skarvsnes, the maximum marine limit was 32.7 m at 5410 ± 40 <sup>14</sup>C (5265 - 4653 cal. yr BP). RSL fall was very rapid (14.5 mm/yr) between c. 3670 and 1905 cal. yr BP. Between c. 1905 and 1500 cal. yr BP, RSL fall dropped to 2.1 mm/yr and from c. 1500 cal. yr BP onwards, it was c. 1 mm/yr. The RSL changes on West Ongul Island and Skallen are in agreement with previous findings from the region. By contrast, the RSL curve for Skarvsnes differs in shape and maximum marine limit from previous reconstructions and those from nearby regions and elsewhere in East Antarctica. These regional differences are likely related to neotectonic faulting, and complicate estimations of the contribution of this part of the EAIS to past sea-level changes.

## Dynamics and mass flux of Denman Glacier, East Antarctica

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Denman Glacier is a long, well-defined glacier stream draining ice from a basin in the East Antarctic ice sheet. This stream discharges through the Shackleton Ice Shelf, during which it essentially retains its speed and form rather than merging with other out-flows that cross the adjacent sections of the coastline. The tongue of the ice stream progressively extends outwards and calves episodically to form a large iceberg. The most recent calving episode occurred in 1985. Each of the latest iceberg, and previous one, grounded off-shore for periods of around 20 years before drifting away.

Early estimates of glacier velocity were derived from a pair of Landsat-1 images, as well as aero-photo surveys. Now new estimates of velocity have been derived from various satellite images. Detail surface topography has been derived from analysis of a combination of ICESat GLAS data and CryoSat SIRAL data, and stereo images. The Digital Elevation Model shows discrete steps in slope related to variations in the derived strain rates. Estimates of ice thickness are used to define the driving stresses and spatial variation of mass flux.

Shear strain rates at the outer margins of the stream are large consistent with the stream passing through the ice shelf, while longitudinal strain rates along the section where the stream passes through the shelf are small indicating the restraining effect of the slower ice of the shelf to each side of the stream.

## S04: PAST ANTARCTIC ICE SHEET DYNAMICS (PAIS)

### Lateglacial-Holocene ice sheet thinning and retreat in southern Victoria Land, Antarctica

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Retreat of the East Antarctic Ice Sheet (EAIS) since the Last Glacial Maximum (LGM) has been associated with sea-level rise and ocean warming on the ice sheet margins, but the significance and relative contribution to eustatic sea-level rise since this time has been difficult to quantify. Here we present new constraints for the timing and retreat for EAIS in the Ross Embayment and Ross Sea Ice Sheet (RSIS). Using two nunataks, Escalade and Tate peaks as a gauge for past EAIS levels, glacial geologic evidence and cosmogenic-nuclide exposure ages indicate the ice surface of the Skelton Névé was between 50 and 106 m thicker than present during the LGM. The ice surface elevation remained close to its maximum ice level until at least 17.3 ka and has thinned by at least 50 m to the present-day level since ~13.5 ka. Much of the thinning occurred prior to 8.7 ka, and then thinning slowed until it reached the present-day ice level post 3.2 ka. This lateglacial-Holocene ice-surface lowering is asynchronous from other sites in the Transantarctic Mountains where increased snow accumulation caused thickening up glacier. These results suggest that the first phase of significant thinning and retreat in the Skelton Névé occurred during or most likely just after meltwater pulse 1A (MWP-1A), a period of abrupt sea-level rise of up to 20 m that occurred between ~14.7 ka and 14.3 ka. Thus it is unlikely that this part of the EAIS made any significant contribution to eustatic sea-level rise at this time. Exposure ages from large (>1 m) boulders in southern McMurdo Sound show that the RSIS had an ice surface elevation ~520 m asl on the eastern side of Mount Discovery during the LGM and ice surface lowering took place after 13.6 ka. The ice surface retreated from 520 to 205 m elevation between 13.6 and 8.9 ka; and from 205 m elevation to the present ice shelf between 8.9 and 5.4 ka. Our late-glacial and Holocene chronology from southern McMurdo Sound is consistent with other records in the Ross Embayment, and implies the RSIS responded to ocean warming and sea-level rise during the early to middle Holocene. We conclude that while components of both the EAIS and WAIS that drained into the Ross Sea contributed to lateglacial-Holocene sea-level rise; it was in response to warming of the Southern Ocean and sea-level rise from the melting of the Northern Hemisphere ice sheets.

## On the duration of West Antarctic Ice Sheet grounding events in Ross Sea during the post-LGM retreat

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A back-stepped grounding zone wedge (GZW) on the middle shelf of the Glomar Challenger Basin paleo trough is usually assigned to the time that elapsed since the West Antarctic Ice Sheet (WAIS) began a rapid but apparently pulsed retreat beginning at ~11 ka <sup>14</sup>C BP. In the marine environment, GZWs are constructed at the marine termination of ice streams. Detailed seismic and multibeam mapping revealed the extent and volume of the GZW in the paleo trough. This volume estimate is of interest because it can be used to estimate the duration of the WAIS grounding event that constructed the middle shelf GZW. The paleodrainage basin for the middle shelf GZW had an area of  $10.105 \times 10^{11} \text{ m}^2$ . Only a few data based estimates of modern sediment yield and/or flux have been obtained for Antarctic ice streams because these erosion and deposition sites are below thick and fast flowing ice cover. We infer that the retreat mode flux is estimated to be  $2.424 \times 10^8 \text{ m}^3/\text{a}$ . Given our GZW volume estimate of  $3.5716 \times 10^{11} \text{ m}^3$ , the duration of the grounding event is estimated to have been 1.47 ky. This duration estimate is of interest because it provides some perspective on the potential duration of the modern grounding event.

## The Recovery ice stream, East Antarctica: Tectonics, lakes and the onset of fast flow

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The Recovery Ice Stream drains a large catchment covering 8% of the East Antarctic Ice Sheet. The Recovery Ice Stream, East Antarctica extends over 800 km inland and widens a broad 400 km wide onset region. Within this broad onset region the fast flow is organized into multiple branches, each with different onsets. Here we use new airborne and ground based geophysics to constrain the physical setting of the onset region in order to advance our understanding of the controlling mechanisms for the onset of fast flow. The 400 km wide Recovery onset region is characterized by a crustal boundary, a change in roughness, a topographic step, and four topographic basins (A,B,C,D). The crustal boundary controls both the 500-1000m high topographic step and the regional change in roughness. This crustal boundary is between the elevated Recovery Highlands underlain by thicker crust and the low-lying smooth Recovery Lakes region underlain by thinner crust. Of the four topographic basins aligned along this boundary, three contain water and form the Recovery Lakes (A,B,C). In Lakes B and C the subglacial water is located in basins with sharp downstream ridges in contrast to the gradual slopes on the downstream margin of Lake A. The fastest flowing branch of the ice stream reaches to the margin of Recovery Lake A, the only lake basin with a shallow slope that may allow the water to escape. The presence of multiple potential triggers along the four Recovery Lakes onset, indicates basal water is a dominant trigger for the onset of fast flow but only if it is stored in a shallow-sided basin where it can lubricate the flow downstream. Relative minor topographic barriers appear to trap the water within the basins and inhibit the onset of streaming out of Lakes B and C. Other proposed triggers, such as topographic steps, changes in roughness, changes in geothermal flux and lubricating sediments have a lesser influence.

## Assessing sea ice dynamics and paleoceanography of the Oligocene Southern Ocean using organic-walled dinoflagellate cyst assemblages from the Wilkes Land Margin, east Antarctica

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The Oligocene Epoch (33.9-23 Ma) is the time interval in the Cenozoic that saw the establishment of a continental-scale Antarctic ice-sheet. Some numerical modeling studies suggest that this continental-scale ice sheet inhabits many positive feedbacks which make large ice sheets require a large climatic forcing to decrease in size. In contrast, deep-sea oxygen isotope records suggest a highly dynamic East Antarctic Ice sheet during the Oligocene, in contrast to these numerical models. Other numerical modeling studies simulating continental ice buildup suggest that alongside continental ice, first sea-ice conditions may have started along the East Antarctic Margin. The sea ice itself is an important climatic feedback as it provides a powerful source for salty, cold bottom water formation. Furthermore, sea ice concentrates primary productivity to a short season, which enhances export productivity and adds to carbon drawdown in the Southern Ocean. Integrated Ocean Drilling Expedition 318 drilled the Wilkes Land Margin in 2010, which provided the direct sedimentary archives required to evaluate the robustness of the results of the numerical models with field data. Particularly the sediments recovered from Site U1356 yield a thick and relatively complete (albeit compromised by core gaps) Oligocene succession that is chrono-stratigraphically well-calibrated with use of nannoplankton- dinocyst- and magnetostratigraphy. Notably, this record yields well-preserved dinoflagellate cysts (dinocysts). Dinocysts are the fossilisable remains of dinoflagellates, some of which are today specifically linked to the high (seasonal) productivity of the ecosystems associated with sea-ice and oceanic fronts.

In the earliest Oligocene, just after the onset of Antarctic glaciation, we document the installation of dinoflagellate cyst assemblages that bear remarkable similarity with those of the present-day Southern Ocean. We interpret this as a regime-shift in plankton communities in response to the installation of the seasonally highly productive sea-ice ecosystem. Following this initial installation, we document variable dinocyst assemblages during the remainder of the Oligocene. These patterns argue that changes in sea-ice extent, and/or the intensity of the vertical mixing of the water column occurred in response to the waxing and waning of the Antarctic ice sheet.

I will present a paleoceanographic reconstruction of the Oligocene Southern Ocean surface waters offshore the Wilkes Land Margin, inferred from dinocyst assemblages from U1356. This provides a first image of the evolution of Southern Ocean surface water ecosystems in response to an apparently quite dynamic Oligocene East Antarctic Ice sheet.

**Glaciated scoria cones as climate and erosion indicators: morphometric analysis of Erebus Volcanic Province, Antarctica, using high-resolution digital elevation data**

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Polar desert environments are generally presumed to have minimal effects on landscape change and polar dry-based glaciers are considered to be ineffective agents of erosion. Morphologic studies of dated cinder cones in the Erebus Volcanic Province, Antarctica, test these presumptions by documenting the signatures of wet-based and dry-based Neogene and Quaternary glaciation activity on cinder cones and by determining effective erosion rates for polar desert environments from diffusion modeling of degrading cones across an age spectrum that encompasses the types of glaciation addressed. Differences in erosion rates beneath polar and polythermal glaciers can be established using these results and the conclusions of previous authors. Interpretations of conditions during glaciated periods from ANDRILL core data are combined with reconstructions of past glacial extents to correlate morphologic history of cinder cones with periods of wet-based and dry-based glaciation.

Morphologic study of cinder cones is also used to establish an age-calibrated rate of surface change in a polar desert environment. Establishment of a relative age classification based on the degree of cone slope degradation can potentially be used to assign ages to the hundreds of undated cones in Antarctica, and may also prove applicable as a dating tool for volcanism in other cold-desert environments, such as those on Mars and other terrestrial planets.

The principal methods applied are quantitative morphometric analysis and modeling using ArcGIS tools with digital elevation models (DEMs) derived from Airborne Laser Scanning (ALS) data and high-resolution stereo satellite imagery. Cinder cones provide ideal subjects for this analysis because they form consistently as simple, radially symmetrical landforms with approximately constant slopes. DEMs are used in tandem with satellite images to characterize landforms and surface properties of both glaciated and non-glaciated polar desert volcanic terrain. LiDAR and DEMs from satellite imagery are compared to determine the most accurate visual two- and three-dimensional representations of partly snow-covered, high-contrast surface environments.

## **A fully coupled 3-D ice-sheet - sea-level model: A focus on the variability of Antarctic ice volume during the past glacial cycles**

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Relative sea-level (RSL) variations during the late Pleistocene cannot be reconstructed independent of the estimates of ice-volume fluctuations. For the latter, however, the knowledge of regional and global relative sea-level variations is necessary as sea level is a forcing variable for ice-sheet variations. Overcoming this problem of circularity demands a fully coupled system where ice sheets and sea level vary consistently in space and time and dynamically affect each other. Here we present results for the past 410,000 years from the coupling of a set of 3-D ice-sheet-shelf models to a global sea-level model based on the solution of gravitationally self-consistent sea-level equation. The sea-level model incorporates all the Glacial Isostatic Adjustment feedbacks for a Maxwell viscoelastic and rotating Earth model with variable coastlines. Ice volume is computed with four 3-D ice-sheet-shelf models for North America, Eurasia, Greenland and Antarctica. With an inverse approach, ice volume and temperature are derived from a benthic d18O stacked record.

We show the dynamical response of the ice sheets to changes in RSL, the latter including both the deformation of the bedrock to ice and water loading and the geoidal deformations. Especially for the West Antarctic ice sheet, ice volume is lower during glacial periods relative to an uncoupled simulation that uses eustatic sea level. Earth model parameters, i.e. the viscosity profile and lithosphere thickness have been varied to test the importance for the glacial-interglacial variability of the Antarctic ice sheet. Additionally, ice-sheet model parameters have been varied accordingly. In such a way we come up with a suite of different modelling results for the Antarctic ice sheet and accompanying global RSL and Northern Hemisphere ice volume over the past glacial cycles. Subsequently, we compare our results with RSL reconstructions derived from geological and archaeological paleo sea-level indicators over the globe, and present the set of model parameters that best depict the variations of Antarctic ice volume in coherence with observational evidence.

## Simulating the Antarctic ice sheet in the Late-Pliocene warm period: PLISMIP-ANT, an ice-sheet model intercomparison project

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In the context of future climate change, understanding the nature and behaviour of ice sheets during warm intervals in Earth history is of fundamental importance. The Late-Pliocene Warm Period (also known as the PRISM interval: 3.29 to 2.97 million years before present) can serve as a potential analogue for projected future climates, with a global annual mean surface-air temperature warming of 1.76 °C. Although Pliocene ice locations and surface extents are still poorly constrained, a significant contribution to sea-level rise should be expected from Greenland and West and, possibly, East Antarctica based on palaeo sea-level reconstructions. Here, we present results from simulations of the Antarctic ice sheet by means of an international Pliocene Ice Sheet Modeling Intercomparison Project (PLISMIP-ANT). We include an overview of the 6 ice-sheet models used and how specific model configurations influence the resulting Pliocene Antarctic ice sheet. For the experiments, ice-sheet models including the shallow ice and shelf approximations have been used to simulate the complete Antarctic domain (including grounded and floating ice). We compare the performance of the ice-sheet models in simulating modern control and Pliocene ice sheets by a suite of sensitivity experiments. Ice-sheet model forcing fields are taken from the PlioMIP results incorporating at least 4 coupled atmosphere-ocean general circulation models (AOGCM). We show that ice-sheet models simulate a present-day ice sheet, which is comparable to the observations, and find no systematic biases introduced when using different AOGCM forcing relative to observational climate forcing. This project includes multiple ice-sheet models forced with multiple climate model output, from which a comprehensive assessment can be made as to the uncertainties of ice-sheet extent on Antarctica. These results may eventually serve as a new constraint on the extent of the Antarctic ice sheet during the Late-Pliocene Warm Period for use in climate modelling experiments.

## Seismic stratigraphy and tomography in the outer shelf and slope of the Central Basin, Ross Sea, Antarctica

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The Ross Sea, located between Victoria Land and Marie Byrd Land in Antarctica, is one of the main drainage of the Antarctic Ice Sheet (AIS). Reflection seismic data acquired by many countries during several decades have provided insights into the history of the Ross Sea and the AIS evolution. However the majority of the existing seismic data are concentrated in the shelf area, where hiatus formed by grounding ice sheet erosion by multiple events prevent to fully reconstruct the sediment stratigraphic record. On the outer shelf and upper slope, where the sediments were discharged by grounding ice, the geological record is more continuous. The main purpose of this study is the investigation of the Cenozoic Antarctic Ice Sheet evolution through the seismic sequence analysis of the outer shelf and slope of the Central Basin, in the Ross Sea. The data used are the new multi-channel seismic data, KSL12, that were acquired on the outer shelf and upper slope of the Central Basin, in February 2013 by Korea Polar Research Institute. The reflection seismic data, previously collected by the Italian Antarctic Program (PNRA) and other data available from the Seismic Data Library System (SDLS) are also used for velocity tomography and seismic sequence mapping. The seismic data were processed by a conventional processing flow to produce the seismic profiles. Preliminary results show well-developed prograding wedges at the mouth of glacial troughs, eroded by a major glacial unconformity, the Ross Sea Unconformity 4 (RSU-4), correlated to a main event between early- and mid-Miocene. The velocity anomalies shown along KSL12-1 can be interpreted as showing the occurrence of gas and fluids, diagenetic horizons and sediment compactions. The isopach maps of each sequence show the variation of thickness of the sediments depocenter shift. The seismic sequence stratigraphy and acoustic facies analysis provide information about different phases of ice sheet's advance and retreat related to the AIS Cenozoic dynamics.

## **Late Neogene geomorphological and glacial reconstruction of the Northern Victoria Land coast, western Ross Sea, (Antarctica)**

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OGS Istituto Nazionale di Oceanografia e Geofisica Sperimentale

This study is a contribution to the reconstruction of the geomorphology and the glacial history of the northern Victoria Land coastal and East Antarctic Ice Sheet (EAIS) outlet glaciers.

A grid of high-resolution single-channel reflection seismic lines, collected in Wood Bay and Lady Newnes Bay, north to Cape Washington (western Ross Sea, Antarctica), provides evidence of overdeepened marine subglacial valleys, more than 1 km deep and 1-2 km wide, formed along the seaward extension of the Tinker, Aviator, Fitzgerald and Icebreaker glaciers and converging into the major SW-NE Drygalski ice stream system.

The existence of an ice cap seaward of north Victoria Land (NVL), possibly in the early Pliocene, or earlier since 8.2–7.5 Ma, was inferred by spatial distribution and geometry of seismic facies, as well as the direct correlation with the Northern Basin seismic glacial units.

The expansion of the dynamic NVL ice cap would be corroborated by the wide and uniform distribution of clinoforms up to the shelf edge and their direction of deposition seaward of a broad, grounding-line, subglacial system prograding from the coast eastward and northward. The inferred initial possible scenario of the ice cap was followed by the development of EAIS outlet glaciers that cut sea valleys near the Victoria Land coast, onto the shelf, and their successive deviation toward the NE by ice streams coming from the south western Ross Sea.

The transition from a thick ice cap covering the NVL to the NVL valley glaciers advancing and retreating up to about 100 km from the coast, during the Neogene would represent a significant environmental change, possibly from interglacial conditions more temperate than today and gradually cooling to a cold and dry coastal regime

## Successful implementation of an operational vibroseismic system

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After the first application of the vibroseis technique on firm within the seasons 2009/10 we now established an operational vibroseis system that allowed the longest vibroseismic traverse with continuous data acquisition in Antarctica. We followed a route from the Ekströmisen over the grounding line onto the ice sheet, covering about 500 km distance within three weeks.

The seismic data was collected using a vibroseis Buggy 'EnviroVibe' in combination with a 1.5 km long snow streamer towed behind a Pistenbully. The vibroseis on Mattracks was set onto a polyethylene sled to distribute the load of the vibroseis on the surface and allow flexibility on rough surfaces. The highest production was reached for an operation speed of 6 km/h ensuring minimal damage to the 1.5 km streamer, consisting of 60 channels with 8 geophones each. Still the setup allowed for the measurement of 20 km of seismic 6-fold data per day or 40 km/day for 1-fold data.

Hence, within three weeks of survey time 407 km seismic profile were acquired, including 110 km of 6-fold data with 125 m shot spacing and 25 km of 3-fold data with 250 m shot spacing. The remaining distance was covered with 1-fold data. This survey allowed covering the bathymetry below the Ekströmisen, the bed topography within the catchment area of the Ekstömisen as well as englacial features. Especially, the imaging of deepenings within the bed topography and their steep sidewalls shows the advantages and the additional information that can be gained from these seismic surveys compared to airborne or ground-penetrating radar data. We present the overall characteristics of different vibroseis sources and mounting set-ups investigated over the last six years and provide recommendation which set-up to use for which scientific questions and areas of interest. Our surveys demonstrate the potential to help increase our understanding of subglacial and englacial properties by the application of such an operational vibroseismic system, which is a main target of the PAIS program.

## Neogene Antarctic climate and oceanographic reconstructions using molecular and isotopic biomarker proxies

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Atmospheric CO<sub>2</sub> reconstructions ranged between 500 and 300ppm across intervals of significant climate and environmental change during the Neogene, indicating that major climate thresholds were passed during periods of relatively modest CO<sub>2</sub> variation. This implies the Earth's climate system is highly sensitive to feedbacks associated with changes in global ice sheet and sea-ice extent, as well as terrestrial and marine ecosystems. In particular, moderately elevated CO<sub>2</sub> (350- >400 ppm) levels were present during the Mid-Miocene Climate Optimum (MMCO, ~17-15 ma) and the Pliocene Warm Period (~5-3 Ma). Modelling of global climate, vegetation, and ice sheet extent has tried to reconcile the various feedbacks that led to a global warming of 3°C, and up to 6°C of warming at the poles, during these periods. Advances have been made regarding the timing and extent of ice sheet and oceanic variability from studies on continental margin drill cores offshore of Antarctica, such as those provided by ANDRILL and the Integrated Ocean Drilling Program. However, better reconstructions of past hydrology, land and sea surface temperature using geological proxies are required to understand marine-terrestrial climate linkages at the Antarctic margin, and to reconcile data-model comparisons.

This study will produce new proxy climate reconstructions using terrestrial and marine organic biomarkers from Antarctic drill cores and outcrop samples that span the MMCO, the Pliocene warm period, and the subsequent rapid cooling events that followed (14-13.5 Ma and 3-2.5 Ma respectively). A range of sample sets sourced from existing repositories and from field work undertaken in Antarctica in 2012 will be used. Variations in *n*-alkane abundances and concentrations will be used to identify changes in the distribution of terrestrial vegetation. These and other biomarkers will be analysed to determine biomarker syngeneity and abundances across a range of lithologies. Bacterial ether-lipids will be analysed to determine terrestrial mean annual temperatures and soil pH (via the methylation and cyclisation indexes of branched tetraethers – MBT and CBT, respectively). Tetraether-lipids of crenarchaeota found in marine sediments sampled from continental shelves around Antarctica will be used to derive sea surface temperatures using the TEX<sub>86</sub> index.

## Determining basal boundary conditions for assessments of East Antarctic ice sheet evolution and stability in the Wilkes Subglacial Basin

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The Wilkes Subglacial Basin (WSB) extends for ca 1,400 km into the interior of East Antarctica and hosts several major glaciers that drain a large sector of the East Antarctic Ice Sheet (EAIS). The region is of major significance for assessing the stability of the EAIS, as it lies well below sea level and its bedrock deepens inland, making it potentially more prone to marine ice sheet instability. It has become a focus of research within IODP Leg 318 that aims to better comprehend the initial stages of glaciation and the history and longer term stability of the EAIS.

Understanding geological boundary conditions onshore is important to assess their influence on ice sheet dynamics and interpret the paleo-ice sheet record. Early geophysical models inferred a major extensional sedimentary basin beneath the WSB that could potentially help maintain enhanced glacial flow and may be linked to inferred but strongly controversial Neogene deglaciation in the region. Later geophysical models proposed that the WSB is a Cenozoic flexural basin with little or no Cenozoic infill. A joint Italian-UK aerogeophysical exploration campaign is super-seeding these earlier geophysical views of the WSB (Ferraccioli et al., 2009, *Tectonophysics*): i) Precambrian and Paleozoic basement faults can be recognised as providing structural controls on the topographic margins of the basin and its deep sub-basins; ii) the crust beneath the basin is thinner compared to the Transantarctic Mountains, but is unlikely to be strongly affected by Cretaceous or Cenozoic rifting (Jordan et al., 2013, *Tectonophysics*), iii) its bedrock is composed of rocks of different ages and composition, including Proterozoic basement, Neoproterozoic and Cambrian sediments intruded by Cambrian arc rocks and cover rocks formed primarily by Beacon sediments intruded by Jurassic Ferrar sills.

A new collaborative Italian-US and UK initiative is underway to analyse and model the variable geological boundary conditions in the WSB using previous and new geophysical data that now includes four new campaigns over the region since IPY. We will present initial interpretations of the potential field signatures and radar over the northern and central parts of the basin to help analyse tectonic and lithological influences on the subglacial topography and on EAIS flow regimes within the WSB.

## Mechanisms driving abrupt shifts in West Antarctic ice stream direction during the Holocene

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Determining the behaviour of the marine-based West Antarctic Ice Sheet over millennia is critical to place recent rapid changes in context and better predict Antarctic's future contribution to sea-level rise. Here, we reconstruct the geometry of two major ice streams entering the Weddell Sea over 20,000 yrs, using terrestrial geologic constraints and high-resolution ice-sheet simulations, to understand the effect enhanced flow has on regional ice dynamics and mass balance.

We reconstruct terrestrial ice surface elevations through time by measuring multiple cosmogenic nuclides (*in situ* <sup>14</sup>C and <sup>10</sup>Be) in glacially transported erratics from four sites – the Flower Hills and Union Glacier, and the Patriot and Marble Hills – to record elevation changes in catchments of the Rutford and Institute ice streams. Glacial erratics sampled from steep exposed bedrock surfaces serve as 'dipsticks' that allow us to reconstruct past surface elevation changes in the Rutford and Institute ice streams as they decayed from their proposed extent at the Last Glacial Maximum (LGM) to their modern configuration. To test the dynamic glaciological changes predicted by our geological interpretation we assessed the changes to geometry and ice-flow pattern triggered by post-LGM increases in oceanic heat flux and sea level as predicted from high-resolution ice sheet modelling using the Parallel Ice Sheet Model (PISM). In our simulations of the whole LGM Antarctic ice sheet we implement PISM at 5 km resolution in order to resolve at a fine scale the geometry and dynamics of the ice sheet and to predict its response to sea-level rise and ocean warming.

We demonstrate that changes at the marine margin of the expanded ice sheet triggered ice-stream instability in the Rutford and Institute ice streams, which led to an asynchronous local response. This effectively decoupled these ice streams from climate forcing and resulted in the Institute Ice Stream migrating, switching flow from the Rutford Trough into the Thiel Trough, changing regional ice dynamics markedly during the mid Holocene. Given predictions of ocean warming in the Thiel Trough at the grounding line of ice streams that are sensitised to marine ice-sheet instability in the Weddell Sea, these results have important implications for future West Antarctic Ice Sheet stability.

## Antarctic bedrock topography and ice sheet hysteresis during the Cenozoic

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There has been a long standing disagreement regarding the stability of the East Antarctic ice sheet during the Oligocene, Miocene and Pliocene, the period after a continental sized ice sheet formed at the Eocene-Oligocene transition (EOT). Indirect evidence from large variations in benthic  $\delta^{18}\text{O}$  records and from sequence stratigraphy has been used to suggest large fluctuations in the volume of the Antarctic ice sheets during this interval. Provenance studies based on sediments recovered offshore of the east Antarctic continent suggest that there was significant ice retreat into the Wilkes Subglacial Basin during the Pliocene and possibly the Miocene. This is coupled with relatively low (typically <750 ppmv) atmospheric  $\text{CO}_2$  during this interval as suggested by proxy records.

Until recently, ice sheet models have struggled to achieve significant ice loss from the East Antarctic ice sheet due to a strong hysteresis effect. Recent improvements in ice shelf physics and the addition of an ice cliff failure mechanism has helped to reconcile some of this disagreement, with significant ice loss simulated from the marine basins of east Antarctica under Pliocene boundary conditions.

Here we present a number of sensitivity experiments to determine how the bedrock topography affects this failure mechanism. Reconstructions of the bedrock topography of Antarctica at the EOT suggest that the marine basins were less pronounced than. Our results suggest that although there is some retreat of the ice sheet into the marine basins under Eocene/Oligocene boundary conditions, this would have a limited impact on sea level change (<10 m).

## Documenting past retreats of the West Antarctic Ice Sheet - Upcoming drilling in the Amundsen Sea Embayment

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The West Antarctic Ice-Sheet (WAIS) is likely to have been subject to very dynamic changes during its history as most of its base is grounded below modern sea-level, making it particularly sensitive to climate changes. Its collapse would result in global sea-level rise of 3-5 m. The reconstruction and quantification of possible partial or full collapses of the WAIS in the past can provide important constraints for ice-sheet models, used for projecting its future behaviour and resulting sea-level rise. Large uncertainties exist regarding the chronology, extent, rates as well as spatial and temporal variability of past advances and retreats of the WAIS across the continental shelves. By using the seafloor drilling device MeBo during an RV Polarstern cruise scheduled for early 2015, a series of sediment cores will be drilled on the Amundsen Sea Embayment (ASE) shelf, where seismic data show glacially-derived sequences covered by only a thin veneer of postglacial deposits in some areas. From analyses of seismic data, we infer that interglacial sediments can be sampled which may have been deposited under seasonally open water conditions and thus contain datable microfossil-bearing material. A shallow basin near the Pine Island Glacier front will be one of the prime targets for the drilling. The near-horizontal seismic reflection horizons may represent a sequence of continuously deposited, mainly terrigenous material, including ice-rafted debris, meltwater deposits and hemipelagic sediments deposited rapidly during the last deglaciation and Holocene or a series of unconformities caused by erosion resulting from grounding line oscillations through many glacial cycles. Subglacial bedforms imaged in multibeam bathymetric data indicate fast glacial flow over some shelf areas of the ASE, where seismic profiles show acoustic basement near the seafloor. It is unknown, whether fast ice-flow in these areas was facilitated by water-lubricated sliding over bedrock or presence of a thin layer of deformable till (perhaps less than a metre in thickness). The nature of this layer holds important clues for understanding the processes that operated beneath the margin of the ice-sheet, beneath ice-flows and on ridges between ice-streams during the Last Glacial Maximum. Grounding zone wedges (GZWs) are widely thought to be important in stabilising grounding line positions during ice-sheet retreat, but hypotheses about the processes and duration of their formation and their composition, are mainly based on conceptual models. Drill sites on and near GZWs are aimed to establish the nature of their sediments, their formation processes, their rates of growth and the palaeo-environmental conditions in their surroundings.

## Antarctic meltwater pulses from a positive ice-ocean feedback mechanism

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Global mean sea level at the last glacial maximum (c. 21 ka) was 130 m lower than at present (Austermann et al., 2013), with the equivalent ice volume locked up in ice sheets in both hemispheres. Melting of these ice sheets took place episodically (Carlson & Winsor, 2012), with at least two periods of abrupt sea-level rise - 'meltwater pulses' - taking place (Clark et al., 2009; Stanford et al., 2011). Although the timing and magnitude of these events is increasingly well-constrained (Deschamps et al., 2012), the sea-level contribution from Antarctica remains vigorously debated (Carlson & Clark, 2012). Here we use a data-constrained ice-sheet model, driven with timeseries-forcings from empirical proxies and from an intermediate complexity Earth system model (Menviel et al., 2011), to reconstruct the pattern and timing of Antarctic ice-sheet recession from 25 ka to present. Our suite of transient simulations indicates that ice-sheet mass loss peaked during two periods broadly coincident with meltwater pulses 1A and 1B (Stanford et al., 2011), contributing to sea-level at rates of up to 1 m per century at c.14 ka. Together with global oceanic proxies, our results offer compelling evidence that Antarctica may have contributed to MWP1A as a consequence of reduced Southern Ocean overturning following Heinrich Event 1, when warmer subsurface water thermally eroded grounded marine-based ice and instigated a positive feedback that further accelerated ice-sheet retreat.

## The glacial geomorphology of the Antarctic Ice-Sheet bed

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In 1976 David Sugden and Brian John developed a classification of Antarctic landscapes of glacial erosion based upon exposed and eroded coastal topography, providing insight into the past glacial dynamics of the Antarctic Ice Sheets. We extend this classification to cover the continental interior of Antarctica by analysing the hypsometry of the subglacial landscape using a recently released dataset of bed topography (BEDMAP2). We use the existing classification as a basis for first developing a low-resolution description of landscape evolution under the ice sheet before using this to build a more detailed classification of patterns of glacial erosion.

Our key findings are that a more widespread distribution of ancient, preserved alpine landscapes may survive beneath the Antarctic ice sheets than has been previously recognised. Furthermore, landscapes of selective erosion are suggested to exist further inland than might be expected from the beds of northern hemisphere ice sheets, and may reflect the presence of thinner, less extensive ice in the past. Much of the selective nature of erosion may be controlled by pre-glacial topography, and especially by the large-scale tectonic structure and fluvial valley network. These interpretations are supported by existing Radarsat and Modis data of the ice surface in which the characteristic valley spacing of subglacial landscapes can be traced and inferred.

The age of selectively eroded landscapes cannot be directly determined, but they probably pre-date the cessation of warm-based glaciation at the coast. We suggest the ages of glacial landscapes are likely to get progressively older towards the center of East Antarctica. This reflects the likelihood of the ice margin retreating into the continental interior during Cenozoic ice sheet fluctuations, and the increased potential for long-term cold-based ice conditions to be maintained in the upland core of East Antarctica.

## Glacial history and behaviour of Mackay Glacier, Transantarctic Mountains

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The configuration of Antarctic ice sheets is inherently linked to changes in climate and the encircling oceans. Direct observations of the ice sheet have shown that changes are possible on the timescale of years to decades (Pritchard et al., 2012), but ice sheets also respond on longer timescales. Understanding the changes that occurred in Antarctica since the Last Glacial Maximum (LGM) is therefore vital for evaluating longer-term drivers of ice sheet changes.

The Ross Sea embayment drains both the marine-based West Antarctic Ice Sheet (WAIS) as well as some of the East Antarctic Ice Sheet (EAIS) through the Transantarctic Mountains. At the LGM, grounded ice extended to the outer continental shelf (Anderson et al., 2002). Deglaciation in the Ross Sea Embayment initiated at ca. 14 ka (Licht et al., 1999), continued during the Holocene and slowed and/or stopped in recent millennia. To the east of the Ross Sea Embayment in West Antarctica, surface-exposure dating indicates thinning was underway by 11 ka (Stone et al., 2003) and in a similar manner to the Ross Sea, continued throughout the Holocene.

A very rapid and large global sea level rise, known as Meltwater Pulse 1a, occurred during the last global deglaciation, between around 15 and 14 ka. Existing chronologies appear to indicate that Antarctic deglaciation slightly post-dated this event (e.g. Stone et al., 2003; Bentley et al., 2006; Mackintosh et al., 2011). In contrast, relative sea level evidence (Deschamps et al., 2012) and reinterpretation of geological data (Carlson & Clark, 2012) suggest that Antarctica was a significant contributor. Further direct constraints on the timing of deglaciation from Antarctica are required to test these competing hypotheses.

This project aims to better reconstruct the configurations of the EAIS and WAIS in the Transantarctic Mountains at the LGM, specifically of the Mackay Glacier system which has not previously been studied. Mackay Glacier is important because its response on glacial-interglacial timescales is likely modulated by changes in grounded ice volume in the western Ross Sea. We present >50 cosmogenic surface-exposure dates collected from elevation transects at 3 locations beside Mackay Glacier. The data record early thinning after the LGM that continues into the late Holocene. Rapid thinning occurs during the mid-Holocene after grounded ice in the Ross Sea retreated past Mackay Glacier. The deglacial thinning chronology is being used, together with a series of mapped offshore grounding-zone wedges, to constrain a 1-dimensional numerical flowline model investigating the time-transgressive glacial dynamics. The model will help to evaluate the mechanisms that forced ice sheet retreat between the LGM and present-day.

## New age constraints for Paleogene sediments in the Ross Sea and implications for Coulman High

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Chronostratigraphic data from Deep Sea Drilling Project (DSDP) Site 270 in the Ross Sea provide important temporal constraints on regional stratigraphy. Importantly, much of the sequence cored at Site 270 correlates with the upper section targeted by the ANDRILL Coulman High Project. Biostratigraphic data in the upper section of DSDP 270 are rare, but the occurrence of the diatom *Kisseleviella tricornata* at 105 mbsf provides an age constraint of 24–21 Ma for this stratigraphic level. The sample falls within a reversely magnetized interval that we correlate to either Chron C6Cr or C6Cn.2r. Planktonic foraminifera diagnostic of late Oligocene age occur at 310 mbsf and greensands at 385 mbsf indicate a minimum age of 26 Ma based on K-Ar dating of glauconite. We have used these tie points to guide correlation of magnetozones in the core to the Global Polarity Timescale, producing two possible age models. Here we report new chronostratigraphic results that provide additional age constraints, including new results from Ar-Ar dating on the glauconite from the greensands and foraminifera biostratigraphy. In addition, samples have now been analyzed for calcareous nannofossil biostratigraphy. The presence of nannofossil *Chiasmolithus altus* (last appearance datum [LAD] 26.10 Ma) at 345.29 mbsf, together with the presence of *Dictyococcites bisectus* (LAD 23.9 Ma) at 280.25 mbsf and absence of the species at 123.05 mbsf support the younger age model. This interpretation suggests that a complete Oligocene/Miocene boundary is preserved at Site 270 and offers an ice-proximal marine record of the Mi-1 glaciation. These latest results enhance the Ross Sea chronostratigraphic model and indicate that drilling at Coulman High will recover an upper Oligocene and older section. Site 270 provides insight into late Oligocene ice-sheet dynamics, but recovery was relatively poor and key high-resolution datasets were not acquired. We would benefit from new records through this interval with more complete recovery to which we could apply a full suite of modern measurement techniques (e.g., physical properties measurements, X-ray fluorescence, etc.), making drilling at Coulman High a high priority.

## Evidence for a cool temperate ice-free coastal environment at high southern latitudes (78°S) during the Middle to Late Eocene

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Much of Antarctica's Cenozoic geological record is hidden beneath the thick ice sheets and fringing ice shelves that cover the continent. Glacial erratics of sedimentary rocks present in coastal moraines at Minna Bluff and Mount Discovery, McMurdo Sound, western Ross Sea, Antarctica contain middle and late Eocene plant and marine fossils that were deposited in a range of marine settings along the Antarctic coastline. This suite of sedimentary rocks were likely deposited at the margin of a narrow (c. 100 km wide), relatively deep (up to 1000 m) marine seaway that was bound by the proto-Transantarctic Mountains to the west and a topographic high to the east. Although these Eocene "McMurdo Erratics" lack stratigraphic integrity, they are significant as they offer a rare glimpse into Antarctica's climate during global greenhouse conditions at high latitudes (c. 78°S). Fossils recovered from the rocks are diverse and include marine and terrestrial palynomorphs, diatoms, molluscs, wood, leaves and other macrofauna and flora. Bioclimatic analysis of pollen assemblages suggests minimum mean annual temperatures ranged from from ~15°C to ~8°C. Geochemical temperature proxies derived from the sedimentary rocks include organic biomarkers (TEX86) and fish tooth  $\delta^{18}\text{O}$  that indicate coastal sea surface temperatures were at least 15°C in the late Middle Eocene. While rare limestones occur in several sandstone erratics, we find no conclusive evidence for glaciation at the coast.

The fossil-bearing coastal moraines also contain a suite of igneous and metamorphic erratics that are comparable to lithological units exposed in the Transantarctic Mountains between the Skelton and Mulock glaciers. This suggests that the Eocene erratics were eroded from the north-eastern portion of a large sub-glacial basin behind Minna Bluff and/or from grabens in a basement high immediately south-east of Minna Bluff. Importantly, the northeastward extension of this basement high is a target for stratigraphic drilling during the proposed ANDRILL Coulman High Project. Drilling on the Coulman High has an excellent chance of recovering correlative Eocene marine strata, providing stratigraphic context for the fossiliferous erratics and providing new constraints on polar environmental conditions under high atmospheric CO<sub>2</sub> concentrations.

## Provenance approaches to reconstruct Antarctic ice sheet history through time

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Provenance studies of both marine and terrestrial glacial deposits have provided key constraints on Antarctica's ice sheet history. The tools applied to Antarctic glacial sediment provenance include mineralogy/petrography, elemental compositions, radiogenic isotope compositions, geochronology and thermochronology. Our analyses show that single-method approaches typically produce the same provenance interpretation in supraglacial and subglacial debris, but that more distal deposits may require a multi-proxy approach to reach unambiguous provenance interpretations. For instance, sand/pebble petrography, Nd, Sr and Pb isotopic values of the <63  $\mu$  fraction, detrital zircon geochronology, and  $^{40}\text{Ar}/^{39}\text{Ar}$  of hornblendes independently show that lateral and medial ice cored moraines along TAM outlet glaciers contain locally derived material, whereas some nunatak moraines contain subglacially-derived erratic material. These same approaches were applied to the provenance of LGM tills on the Ross Sea continental shelf and all lead to similar LGM ice flow reconstructions showing that East and West Antarctic ice converged in the central Ross Sea. Broad ice flow patterns can be refined using detrital zircons, which show distinctive age distributions for individual ice streams that can be traced to LGM tills.

In contrast, published circum-Antarctic surveys of fine sediment radiogenic isotopes (Nd, Hf, Sr isotopes) and dispersed mineral grains show that each has potential for distinguishing different ice sheet sectors, but the combination is most powerful. A clear distinction is found between West and East Antarctic contributions with eNd ranging from +1 to -5 for <63  $\mu$  sediments from along the west side of the Antarctic Peninsula and West Antarctica and from -11 to -21 for samples around East Antarctica. The Ross and Weddell Seas have intermediate compositions (-3 to -7 and -8 to -10 respectively) reflecting the mix of West and East Antarctic sources. Hf and Sr isotopes follow similar patterns, with Hf isotopes co-aligned with Nd on the global terrestrial array, and Sr isotopes <0.715 along West Antarctica, >0.72 along East Antarctica and intermediate in the Ross and Weddell sectors. Published evidence from dispersed sand grains is mostly  $^{40}\text{Ar}/^{39}\text{Ar}$  ages of hornblendes. East Antarctica in general has a very large Ross/Pan African signature, with subordinate Grenville ages. The exception is the Wilkes Land/Adelie Land margin where a large fraction of the grains are in the 1.2 or 1.5 Ga range. Thus, while the Wilkes Land margin overlaps in its eNd with the Prydz and Dronning Maud Land sectors, the  $^{40}\text{Ar}/^{39}\text{Ar}$  ages clearly distinguish it. Likewise while the Prydz Bay and Dronning Maud Land sectors have largely overlapping Ross/Pan African  $^{40}\text{Ar}/^{39}\text{Ar}$  ages, their eNd is not overlapping and thus all three major East Antarctic sectors can be distinguished from each other with this combination of tools.

## Seeking for the sedimentary records of behavior of east Antarctic ice sheet during the Pliocene warmth epoch

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The Pliocene Warmth Event has been influenced globally, including Antarctica. But behavior of Antarctic continent is still unclear. The Grove Mountains emerge as a group of 64 isolated nunataks scattered over an area of ~3 200 km<sup>2</sup> within the EAIS (72°20'S to 73°10'S, 73°50'E to 75°40'E). Land based multi-disciplinary study of past ice surface elevations in Grove Mountains, including the glacial geology, the cold desert soils, the depositional environment of moraine sedimentary boulders and their spore pollen assemblages, and the bed rock cosmogenic nuclide exposure ages, implies a significant shrinkage of the ice sheet at Pliocene Epoch, with its margin retreated back to the Grove Mountains, ~400 km southern from its present coastal position. Such a dramatic history of the EAIS should be proved by the sedimentary drilling core from sub-glacial basins. During the Pliocene collapse of the EAIS, it should left a set of frontal outwash basins system along its paleo-margin of the EAIS at the Grove Mountains where the key records describing such scenario just be hidden up today. The survey of snow-ledge ice-radar for the sub-glacial topography has been carried out in the Grove Mountains, with the preliminary results showing the distribution trends of such paleo-sub-glacial sedimentary basins. The ice-geological core drilling at basins (a different sort of sub-glacial lake) in the Grove Mountains will be actualized for next step of CHINARE.

## Seismic echo-characters and sedimentary distribution on the South Shetland Islands continental margin, Antarctica

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The present work consists in characterizing the sedimentary distribution on the South Shetland Islands continental margin, Antarctica Peninsula, through the interpretation and correlation of high-resolution seismic profiles and geological samples. The characterization was made through echo-characters, maps of seismic amplitudes and its correlation with the collected samples, filling the gap in scientific research about the sedimentary coverage at this location. Five different echo types have been identified and classified. Echo types I and II have good seismic resolution and are characterized by continuous sharp bottom echoes with sub-parallel reflections. Echoes III and IV are characterized by diffuse and very prolonged bottom echoes with no sub-bottom reflectors. Echo V is associated to glacial deposits on the upper slope in response to deglaciation and the transport of coarse grains in a muddy matrix and is characterized by diffraction hyperbolae.

Echo I has medium-high amplitudes and indicates silty sand and sandy silt (AM-02 and AM-14), respectively, and presents the highest sand content among the samples. Echo II, with numerous sub-parallel reflections, demonstrates the lowest amplitudes and high percentages of mud, approximately 90% of mud (AM-17). Echos III and IV, located on the shallowest portions of South Shetland's continental margin, showing prolonged and diffuse echoes with medium-low amplitude values, are related to samples AM-01 and AM-04, both classified as sandy-silt with approximately 35% of sand.

The echo-characters showed good correlation with geological samples collected along the Bransfield Strait and bays of the King George Island, but not completely with the amplitudes map.

At this point, the best indicators of small lithological variations are the echo-characters, whereas seismic amplitudes proved to be good indicators of the deposits present in Echo V. These glacial sediments were brought by glaciers to the mouth of the fjords and are identified on the seismic records as large overlapping diffraction hyperbolae with high seismic amplitudes (Echo V).

The results indicate a strong influence of the sedimentary process on the seismic signature of sedimentary deposits with similar grain size characteristics. Peak amplitudes were able to detect only sedimentary deposits with different geological nature.

## Early Holocene retreat of the marine-based ice sheet in the central Ross Sea

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Establishing a reliable chronology for the retreat of marine-based ice sheets in the Ross Embayment since the Last Glacial Maximum (LGM) has proved challenging, in large part due to an absence of carbonate material in marine sediment cores from which precise radiocarbon chronologies can be obtained. Here, we report a lithofacies-based retreat history from the ANDRILL Coulman High drill site in the Central Ross Embayment. This site was located within the paleo-drainage path of the Byrd Glacier, the largest East Antarctic Ice Sheet outlet glacier draining in to the Ross Sea at the LGM. Planktic and benthic foraminiferal-based radiocarbon dates from a laminated-diatom- and ice-rafted debris-bearing glaciomarine mud constrain the retreat history of the Last Glacial Maximum (LGM) ice sheet in the Ross Embayment. This establishes that the modern-day calving line location of the Ross Ice Shelf was established by 9.5 ka BP, indicating that the majority of ice sheet retreat in the Ross Sea occurred prior to this time.

During post-LGM retreat of the ice sheet margin in western Ross Sea, and prior to the first open marine conditions at Coulman High, it is hypothesized that the grounding and calving line were in relative close proximity to each other. As the calving line became "pinned" in the Ross Island region, the grounding line likely continued its retreat toward its present day location, although if this occurred rapidly or gradually throughout the Holocene remains unknown.

We examine our results in the context of oceanic drivers and marine instability mechanisms for the LGM retreat of the ice sheets in the Ross Embayment. This will be achieved through comparison with recently published chronologies derived from marine sediment cores in the Amundsen Sea and Wilkes Land margin. Our results imply that the majority of post-LGM ice sheet retreat occurred in unison in all three sectors, which is consistent with the strong oceanic connections between the Amundsen and Ross Sea and Wilkes Land, via the Ross Sea Gyre and Antarctic Slope Current.

## Paleoclimate perspectives on present and future polar amplification

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Polar amplification occurs when the magnitude of zonally-averaged surface temperature change at high latitudes exceeds the globally-averaged temperature change. It is of global concern due to the potential effects of future warming on ice sheet stability, and therefore, global sea level and carbon cycle feedbacks linked with permafrost melting. In this talk I will describe different feedbacks operating in both polar regions, and then contrast polar amplification depicted for past high CO<sub>2</sub> (mid-Pliocene, Early Eocene) and low CO<sub>2</sub> (LGM) climates with present and projected temperature patterns for future greenhouse gas emission scenarios.

In the Arctic, the sea ice/ocean surface albedo feedback plays an important role. Since 1875, the Arctic has warmed at a rate of 1.36°C per century, approximately twice as fast as the global average, and since 1979, Arctic land surface has warmed at an even higher rate of 0.5°C per decade. In contrast the transient response of Antarctic and Southern Ocean temperatures appears more complex. Mixed-layer depths in the Southern Ocean typically exceed several hundreds of meters, which has allowed the ocean to take up vast amounts of heat and damp the temperature response to external forcing. This process, and the presence of the ozone hole over the Antarctic ice sheet is suppressing amplified surface warming in southern high-latitudes. While, the Antarctic Peninsula is experiencing one of the strongest regional warming trends (0.5°C per decade over the past 50 years), more than twice that of the global mean temperature, and central West Antarctica may have also experienced a similar strong warming trend, zonal mean Antarctic surface warming has been modest at 0.1°C per decade over the past 50 years.

For past high CO<sub>2</sub> time periods, reconstructions and simulations reveal Arctic and Antarctic surface temperature amplification of up to two times the global mean. This relatively symmetrical bipolar amplification appears to be a robust feature of the long-term equilibrium Earth system response to changes of CO<sub>2</sub> concentration, and explains in part why Greenland Ice Sheet and the West Antarctic Ice Sheet appear to be highly sensitive to relatively small increases in CO<sub>2</sub> concentration and global mean temperature. For example, global sea level during the mid-Pliocene warm period may have been up to +20m higher than present day when atmospheric CO<sub>2</sub> concentrations were ~350 to 450 ppm and global mean surface temperature was 2°C to 3°C above pre-industrial levels.

In response to rapid atmospheric CO<sub>2</sub> changes, climate models project an asymmetric transient warming, with an earlier response in the Arctic and a delayed response in the Southern Ocean. For the RCP8.5 scenario, annual mean Arctic warming is expected to exceed the global average by 2.2 to 2.4 times for the period 2081–2100 compared to 1986–2005, which corresponds to the higher end of polar amplification implied by paleo-reconstructions. Whereas polar amplification in the Southern Ocean and Antarctica is much smaller in magnitude than the equilibrium response implied from paleo-reconstructions for a high-CO<sub>2</sub> world.

## Dynamic to persistent transition of East Antarctic Ice Sheet (EAIS) during early Pliocene and cycles of waning and waxing of EAIS inferred from clay minerals and carbon content of ocean sediments

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Ocean sediments from site U1359 of IODP expedition 318, collected from the continental rise off the coast of Wilkes Land, east Antarctica are analysed for clay mineralogy and carbon content.

The Total Organic Carbon (TOC) contents of the sediments show an inverse relationship with the rate of sedimentation. Total inorganic carbon values are generally very low consistent with high depth of water column. However, coincident with the seismic unconformity WL-U8 significantly high values of Total Inorganic Carbon (TIC) possibly correspond to change in glacial regime from dynamic to a persistent ice sheet (EAIS) at ~4.9 Ma (Tauxe et. al 2012).

The temporal variation of the clay mineralogical data shows a dominance of illite with chlorite, smectite and kaolinite in decreasing concentration. Illite is negatively correlated with smectite which shows enrichment during 6.2-6.8, 5.5-5.8, 4.5 and 2.5 Ma. The mineralogical analyses on the silt size fraction (2-53  $\mu\text{m}$ ) of some selected samples were also carried out. The combined results of clay and silt size fractions show presence of chlorite and illite in both size fractions and smectite and kaolinite restricted only to the clay size fraction (<2  $\mu\text{m}$ ). The crystallinity and chemistry of illite in both fractions are similar. This suggests negligible role of sorting probably due to the deposition from the waxing ice sheet. During times of ice growth nearby cratonic east Antarctica shield provided biotite rich sediments to the depositional site. On the other hand, the presence of smectite, only in the clay size fraction suggests the effective role of sorting probably due to the deposition from distal source in ice retreat condition. During times of ice retreat smectite rich sediment derived from Ross Orogen is transported to the sampling site through surface or bottom water currents (Gordon and Tchernia, 1972) (Bellanca et al., 1998; Ehrmann, 1998, Damiani et al., 2006). Poor crystallinity of illite due to degradation further corroborates the ice retreat condition (Hambrey and Barrett, 1993). Thus, the enrichment of smectite/illite reflects the waning /waxing of ice sheet respectively.

References available on request

## Orbital forcing of the East Antarctic Ice Sheet during the Pliocene-Early Pleistocene

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Geological reconstructions of global ice volume and sea-level during the Pliocene and Early Pleistocene (5 to 2 Ma) display regular glacial-interglacial cycles predominantly paced every 41-kyrs, paced by variations in Earth's axial tilt (obliquity). The absence of a strong ~20-kyr precession signal challenges our fundamental understanding of how ice sheets respond to orbital forcing because precession should impart the greatest influence on high-latitude summer insolation intensity, and therefore have an influence on polar ice volume. While a number of hypotheses have been proposed, reconciliation of this conundrum remains hampered by a lack of observational evidence from the Antarctic ice sheet. Here, we present an orbital-scale time-series of ice-berg rafted debris and continental rise sedimentation from a well-dated sediment core (Integrated Ocean Drilling Program site U1361) adjacent to the Wilkes Land margin of the East Antarctic Ice Sheet (EAIS). Our data reveal ~40-kyr cyclic variations in the extent of the EAIS paced by obliquity between 4.3-3.3 Ma during the warmer-than-present climate of the Pliocene, as has previously been demonstrated for the West Antarctic Ice Sheet (WAIS). Under a warmer climate state, mean annual insolation (paced by obliquity) had more influence on Antarctic ice volume, than insolation intensity modulated by precession. However, a transition to 20-kyr precession cycle dominance at 3.3 Ma preceded the development of a more stable EAIS marine margin at ~ 2.5 Ma, reflecting the declining influence of oceanic forcing as the high latitude southern ocean cooled and a perennial summer sea-ice field developed. Furthermore, this transition from obliquity to precession dominance occurs when the benthic  $\delta^{18}\text{O}$  stack displays an abrupt loss of the 40-kyr signal and becomes dominated by the 100-kyr eccentricity frequency. Our data implies an eccentricity-modulated, precession-paced response of EAIS, under a colder climate state, may account for the variability observed in the benthic  $\delta^{18}\text{O}$  reconstruction of ice volume, and lends support to the hypothesis that anti-phased polar ice-volume cancels out on a precession time scale.

## Modeling Antarctic ice sheet variations: past calibration and future ensembles

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Several recent studies have used large-ensemble techniques in modeling Antarctic Ice Sheet retreat from last glacial maximum extents over the past ~20,000 years. Here we use similar techniques in a 3-D hybrid continental ice-sheet model, assessing model simulations of ice retreat during the Last Interglacial period (~125 ka) and the middle Pliocene warm period (~3 Ma). For the latter, recently added mechanisms of melt-enhanced calving and tidewater-cliff failure allow major retreat into East Antarctic sub-glacial basins, in better agreement with (albeit uncertain) proxy sea-level data.

Large-ensemble techniques are used to objectively constrain ranges of model parameters, using algorithms to quantitatively score each model run vs. geological data. The sets of large-ensemble runs are extended into the future (centuries to millennia), with atmospheric and oceanic forcing based on IPCC AR5 scenarios. The goal is to produce calibrated probabilistic envelopes of Antarctic response and associated sea-level rise to future anthropogenic warming, which include the relatively speculative but serious possibility of drastic retreat due to the newly added enhanced-calving and cliff-failure mechanisms.

## Eocene - Oligocene terrestrial palynology of the CIROS-1 drillhole, McMurdo Sound, Antarctica

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Fifty six new pollen samples from the Late Eocene – Early Oligocene of the CIROS-1 drill hole below the ~9 million year disconformity at 366m reveal a number of stratigraphic and paleoenvironmentally important *in situ* taxa.

The coastal vegetation of the Late Eocene (below 550m in the core) consisted of podocarps, beeches, various Proteaceae, and a variety of other tree and shrub species indicative of a beech-dominated rain forest. A subtle loss of key taxa is apparent in the 366-550m interval, mainly characterised by a loss of Proteaceae pollen diversity. Bioclimatic analysis of these pollen assemblages suggests a decrease in the minimum range of possible mean annual temperature at this interval, from ~13-15°C to ~8°C. However, low diversity assemblages, and some uncertainty in assigning modern analogues allows the possibility that mean annual temperatures remained relatively steady at 19-20°C over this interval.

The possible cooling signal appears to precede a marked decrease in dinoflagellates cyst diversity at ~450m, and a cooling inferred from clay mineralogy at ~430m. Initial results, subject to an increase in the size of the pollen dataset, suggest that terrestrial vegetation records high-latitude Eocene – Oligocene cooling earlier than proxies of continental weathering and the coastal marine environment. Three new strontium dates obtained from shells from the same interval are consistent with the possibility that the Eocene – Oligocene boundary lies below 450m in the core. If so, these climatic deterioration events could all occur within C13n, and would likely slightly postdate the Oi-1 oxygen isotope event.

## A long-term history of Antarctic grounding line change from ice divides

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Layering in ice divides stores a record of ice dynamics going back centuries to millennia and can tell us whether today's rapid change is normal or exotic.

Currently, rapid grounding-line retreat is underway along several sections of the Antarctic ice sheet margin, forced by the arrival of warm water at the coast and leading to the continent's significant ongoing contribution to sea level rise. Even an ice sheet stable to grounding line perturbations will continue to lose mass if this forcing is sustained, but the forcing is poorly understood: is it unusual? Will it continue or increase? We can start to answer these questions by looking for evidence of coastal dynamic change stored within the ice itself.

Fortunately, a record of flow dynamics along the ice sheet margins – the glacial response to grounding line change - is preserved within ice divides. 'Raymond bumps' in the internal ice stratigraphy form over a long (and calculable) time under an unmoving divide, hence their presence indicates a sustained, unchanging flow regime. A present-day divide that is offset from its underlying Raymond bump indicates a long spell of unchanged flow perturbed at some time in the more recent past. I present here a map of this Antarctic flow history spanning centuries to millennia, derived from both ground and satellite radar remote sensing, that serves as a proxy for changes at the grounding line. This reveals a surprising picture of prolonged stasis where we now see rapid and recent change, implying a new and exotic shift in the coastal regime.

## Oligocene-Miocene East Antarctic ice sheet history from Wilkes Land sediments: IODP Site 1356.

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IODP Expedition 318 drilled seven sites in two transects across the Wilkes Land (WL) margin of Antarctica to obtain a long-term record of the Cenozoic Antarctic glaciation in response to climatic changes, including major transitions. Our study focused on nearly 300 meters of Oligocene-early Miocene sediments from Site 1356 (cores 42R to 72R) located on a channel levee in the lower continental rise. Magnetostratigraphic and biostratigraphic age control at Site 1356 constrains the timing for three well-differentiated depositional environments. Hemipelagic and bottom current deposition dominated during the late early to late Oligocene. Debris flows with interbedded turbidite deposits characterized sedimentation during late Oligocene to early Miocene. Turbidite and hemipelagic sedimentation dominated during the early Miocene. Based on correlations with the regional grid of seismic lines, early to late Oligocene deposits are characteristic of abyssal plain sedimentation under the influence of bottom currents. The sharp transition from abyssal plain facies to distal debris flows during the late Oligocene coincides with the deposition of large mass transport deposits at the base of the continental slope and erosion of large channels on the continental rise. The distal mass transport deposits are recovered in our cores and are mixed with levee turbidites from the nearby channel. The Oligocene to Miocene transition marks the disappearance of debris flows in our cores and the start of turbidite and hemipelagic deposition that characterizes levee sedimentation of the early Miocene environment.

The changes in seismic and sediment facies document the evolution of the East Antarctic Ice Sheet on the Wilkes Land margin, with debris flow and channel-levee development during the late Oligocene to earliest Miocene indicating significant East Antarctic Ice Sheet expansion during the climate cooling leading to the Mi-1 glaciation. During this cooling, highly erosive wet-based ice sheets transported large volumes of sediment to the continental shelf edge, triggering widespread debris flows and turbidite deposition along the Wilkes Land margin.

## Subglacial sediment provenance and transport from the Whillans and Kamb ice streams: New micropaleontological, biomarker and $^{10}\text{Be}$ results

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We report preliminary micropaleontological and geochemical analyses of Subglacial Lake Whillans (SLW) sediments, recovered in 2013 by the WISSARD Project, augmented by new analysis of sediments previously recovered from beneath the upstream sectors of the Whillans (WIS) and Kamb (KIS) ice streams. Siliceous microfossils (notably diatoms and sponge spicules) and organic-walled palynomorphs (pollen, spores, dinoflagellates) in these sediments provide insights into West Antarctic rift basin paleobiogeography, subglacial sediment transport, and ice sheet history. Absolute abundance (particles per gram dry sediment) of identifiable diatoms and diatom fragments in different size classes were calculated to compare and contrast physical conditions and sediment provenance at each setting. Sponge spicules are analyzed for taphonomic effects from subglacial transport and microbial bioerosion. Palynomorphs are analyzed for abundance, diversity, and source rock ages. Biomarkers for marine algae (Brassicasterol & Dinostanol) and land plants (leaf wax *n*-alkanes) independently assess terrestrial and marine contributions to these glacial sediments. Cosmogenic  $^{10}\text{Be}$  in the sediments provides an assessment of post-Miocene contribution to the diamictos.

No statistically significant stratigraphic variation in microfossil and fragment abundance or taphonomy is noted in SLW diamictos, in agreement geochemical and geological data. Low abundance and poor preservation of diatoms and spicules at SLW suggests relatively long distance transport from marine sediment sources, with evidence of high shear strain. Upper Miocene diatoms dominate all samples analyzed, though older and younger diatoms are present. WIS samples exhibit the highest diversity of diatoms, including Pleistocene marine and Paleogene freshwater taxa. KIS sediments have the highest abundance of whole diatoms, but they are characterized by low diversity, indicating local erosion of an Upper Miocene deposit. Palynomorphs in all samples demonstrate a sizable contribution of Eocene terrigenous material. Initial biomarker analyses strongly corroborate the micropaleontological data.  $^{10}\text{Be}$  in SLW samples are significantly higher than typical WIS and KIS sediments, indicating different potential input sources, including (1) young sediments deposited during deglacial intervals, (2) input from sub-ice shelf oceanic sources, or (3) concentration of basal ice melt sources.

## Testing the role of Milankovitch forcing on global sea-level change using a continuous Late Pliocene shallow-marine sedimentary record from the Wanganui Basin, New Zealand

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Milankovitch Theory directly links the waxing and waning of ice sheets to orbital forcing. These cyclic variations in insolation are widely thought to cause significant changes to global ice volume (and therefore sea-level) at frequencies of ~21,000 years (precession) and ~41,000 years (obliquity). Classical Milankovitch Theory implies both signals should be present in globally-integrated records of ice volume/sea-level change. However, the global marine oxygen isotope ( $\delta^{18}\text{O}$ ) record during the Late Pliocene (3-2.5 Ma) consists of distinctly obliquity dominated signals, with a notable absence of precession. This observation has led to a number of hypotheses concerning the global and hemispheric influence of orbital forcing on glacial-interglacial cycles. Well-dated, high-resolution shallow-marine sediment records provide a method independent of the  $\delta^{18}\text{O}$  record to reconstruct the frequency of Late Pliocene glacial-interglacial variability, via its effect on global sea-level recorded as cyclical water depth changes. While the amplitude of these water depth changes may reflect local factors such as sediment supply and tectonics, their frequency should reflect global glacio-eustatic sea-level changes. The Wanganui Basin, New Zealand, contains a high-resolution and well-dated Neogene shallow-marine sedimentary succession, making it an ideal location to examine sea-level/ice-volume change. We propose to investigate the magnitude and timing of changes in sea-level and ice volume during the Late Pliocene. This will be achieved through a coordinated integrated study of sediment grain size (a proxy for paleo-water depth), oxygen isotopes (a proxy for ice volume), and a quantitative census of benthic foraminifera (another proxy for paleo-water depth) in the Mangaweka Mudstone (~3-2.6Ma), where it is exposed in a continuous sequence along the Rangitikei River in the Wanganui Basin. Geochemical fingerprinting, correlation and absolute ages of rhyolitic tephras within a well-established magneto-stratigraphic framework will form the basis of an age model. It is anticipated that water depth changes corresponding to precession, obliquity and/or eccentricity forcing on global sea-level will be resolved in the Late Pliocene record and will provide insights into the relative responses of both polar ice sheets during the transition from a unipolar to a bipolar world.

## **Subsidence and tilting of a pre-25 Ma wave-cut platform in Ross Sea, Antarctica**

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Publications using analysis of oxygen and calcium isotopes in deep sea cores indicate an earliest Oligocene Antarctic ice sheet of larger volume than today. Recent publications explain this by a higher, and thus less marine, West Antarctica at that time. We use all available seismic reflection profiles in the Seismic Data Library System, correlated to Deep Sea Drilling Program sites, to interpret the Oligocene to Middle Miocene seismic stratigraphy of most of Ross Sea. A planar unconformity was cut into eroded basement rocks before 25 Ma across Central High. We interpret this unconformity to be planar because of sub-aerial and wave erosion. Late Oligocene sedimentary rocks aggraded above basement everywhere on Central High soon after it subsided through paleo-sea level, although deposition at DSDP-270 may have been at 300 m depth after a hiatus. The eroded basement surface tilted down into the neighboring sedimentary basins through Oligocene and Miocene time, resulting in a Central High antiform.

Tilting suggests that flanking basins continued to subside faster than the Central High basement ridge during Oligocene through Miocene time. At -76.7 degrees latitude, the wave-cut platform antiform crest is below 0.8 km depth, and, 110 km to the east, its eastern edge is near 2 km depth. Subsidence of the crest through paleo-sea level occurred just before 25 Ma, and subsidence of the eastern edge of the planar basement unconformity through sea level occurred before an inferred age of ~30 Ma. Planar progressively-tilted Oligocene-Miocene stratigraphic horizons suggest that the increase in subsidence rate can be projected 60 km east of the basement platform edge. The post-30 Ma extrapolated subsidence of the edge of deep Eastern Basin would thus be 2.5 km. This supports published interpretations for 3 km of post-RSU6 unconformity subsidence of the middle of Eastern Basin, and near sea level formation of this unconformity, inferred to be ~30 Ma. Restoring this subsidence supports an end Eocene emergent West Antarctica as well as large land or shallow areas within Ross Sea.

The isotopic record supports major ice retreats and advances through Oligocene time. Once in place, the high elevation of much the East Antarctic Ice Sheet makes it unlikely to have greatly retreated at expected CO<sub>2</sub> levels. Oligocene to Middle Miocene deposition rates were rapid enough to keep up with subsidence and maintain a shallow Ross Sea except in the northeast. A shallow Ross Sea may have facilitated advances and retreats of a dynamic West Antarctic Ice Sheet.

## East Antarctic deglaciation and the link to global cooling since the Quaternary: Evidence from glacial geomorphology and $^{10}\text{Be}$ surface exposure dating of the Sør Rondane Mountains, Dronning Maud Land

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Reconstructing past variability of the Antarctic ice sheets is essential to understand their stability and to anticipate their contribution to sea level change as a result of future climate change in a high- $\text{CO}_2$  world. Recent studies have reported a significant decrease in thickness of the East Antarctic Ice Sheet (EAIS) during the last several million years. However, the geographical extent of this decrease and subsequent isostatic rebound remain uncertain and a topic of debate. In this study, we reconstruct magnitude and timing of ice sheet retreat at the Sør Rondane Mountains in Dronning Maud Land, East Antarctica, based on detailed geomorphological survey, cosmogenic exposure dating, and glacial isostatic adjustment modeling. Three distinct deglaciation phases since Pliocene for this sector of the EAIS are identified, based on rock weathering and  $^{10}\text{Be}$  surface exposure data. We estimate that during the Plio-Pleistocene the ice sheet thinned by at least 500 m. This thinning is attributed to the reorganization of Southern Ocean circulation associated with the global cooling into the Pleistocene, which reduced the transport of moisture from the Southern Ocean to the interior of EAIS. The data also show since the Last Glacial Maximum the ice surface has lowered less than ca. 50 m and probably started after ca. 14 ka. This suggests that the EAIS in Dronning Maud Land is unlikely to have been a major contributor to postglacial sea-level rise and Meltwater pulse 1A.

## Early glaciation already during the Early Miocene in the Amundsen Sea, Southern Pacific: Indications from the distribution of sedimentary sequences

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The distribution and internal architecture of seismostratigraphic sequences observed on the Antarctic continental slope and rise are results of sediment transport and deposition by bottom currents and ice sheets. Analysis of seismic reflection data allows to reconstruct sediment input and sediment transport patterns and to infer past changes in climate and oceanography. We observe four seismostratigraphic units which show distinct differences in location and shape of their depocentres and which accumulated at variable sedimentation rates. We used an age-depth model based on DSDP Leg 35 Site 324 for the Plio/Pleistocene and a correlation with seismic reflection characteristics from the Ross and Bellingshausen Seas, which unfortunately has large uncertainties. For the period before 21 Ma, we interpret low energy input of detritus via a palaeo-delta originating in an area of the Amundsen Sea shelf, where a palaeo-ice stream trough (Pine Island Trough East, PITE) is located today, and deposition of this material on the continental rise under sea ice coverage. For the period 21-14.1 Ma we postulate glacial erosion for the hinterland of this part of West Antarctica, which resulted in a larger depocentre and an increase in mass transport deposits. Warming during the Mid Miocene Climatic Optimum resulted in a polythermal ice sheet and led to a higher sediment supply along a broad front but with a focus via two palaeo-ice stream troughs, PITE and Abbot Trough (AT). Most of the glaciogenic debris was transported onto the eastern Amundsen Sea rise where it was shaped into levee-drifts by a re-circulating bottom current. A reduced sediment accumulation in the deep-sea subsequent to the onset of climatic cooling after 14 Ma indicates a reduced sediment supply probably in response to a colder and drier ice sheet. A dynamic ice sheet since 4 Ma delivered material offshore mainly via AT and Pine Island Trough West (PITW). Interaction of this glaciogenic detritus with a west-setting bottom current resulted in the continued formation of levee-drifts in the eastern and central Amundsen Sea.

## Ice-sheet and sea-level history of the Weddell Sea

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As the southern extension of the Atlantic Ocean, the Weddell Sea is a key area to study Earth's past climate variability. It constitutes a major source of Antarctic Bottom Water formation, which influences the Atlantic Meridional Overturning Circulation. Moreover, the Weddell Gyre is an important cyclonic circulation system for water-mass communication between the Antarctic Ice Sheet and the Southern Ocean. One of the world's two largest ice shelves, the Filchner-Rønne Ice Shelf, drains into the Weddell Basin.

Marine data from the southeastern Weddell Sea indicates that the advance to and retreat from the maximum extent of this sector of the Antarctic Ice Sheet (AIS) was, within dating uncertainties, synchronous with most sectors of Northern Hemisphere ice sheets. Our modeling studies indicate that AIS dynamics in the Weddell Sea sector of the EAIS are highly susceptible to far-field changes in sea level, likely forced from the Northern Hemisphere. Also, changes in North Atlantic Deep Water formation and attendant heat flux to Antarctic grounding lines were able to synchronize the hemispheric ice sheets.

Despite the paramount scientific importance that has, over the last two decades, identified the Weddell Sea as a key area to study past and present climate change, there has been no deep scientific drilling for high-resolution reconstruction of the Plio-Pleistocene. Therefore, IODP proposal 848 (Weber et al., 2013) proposes to continental margin sites to address critical questions of EAIS and WAIS stability, the interhemispheric phasing of ice-sheet and climate events, ocean circulation, and bottom-water production.

### Literature

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## A way forward to discover Antarctica's past: Results of the 2013 U.S. Antarctic geologic drilling workshop

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54 geoscientists met in November 2013 at the NSF-sponsored Antarctic Geological Drilling Workshop to discuss geologic drilling goals in areas from the South Pacific to the South Pole and from Precambrian time to modern day. Much knowledge of past climate changes, and inferred ice sheet history, has been obtained from drill cores taken in low-latitude oceanic settings. Such far-field proxies offer a general outline of ice sheet behavior, but cannot show which part of the ice sheet changed, or what ocean currents, temperatures, or other controlling parameters were in proximal settings. Drilling in Antarctica can yield samples of rock that were influenced directly by glacial processes and that provide access to Antarctica's ice-covered geology. Limited outcrops, short gravity cores, and drill cores with partial recovery have been studied from many locations, but such records cannot give the *continuous temporal record* needed to determine timing and rates of ice sheet change, boundary conditions controlling that behavior, or model future behavior. *Spatially distributed records*, including transects from onshore to distal far-field records from each major ice drainage basin, are needed to resolve the individual histories of each area, which have large differences that are only now being realized. *High quality seismic data* linking drill sites can increase the impact of individual sites by extending the details over a broader area and tightening the time constraints at each site. Over-ice seismic capabilities offer a means to identify future drilling targets in the Antarctic interior. New approaches to sample bedrock beneath the ice sheet and measure conditions beneath the ice will help refine basal-bed boundary conditions that are vital to reconstructions of ice sheet behavior. *Numerical modeling*, with an eye toward the integration of model output with geological records, can test data-driven hypotheses and link Antarctic climate and ice sheet history with distant latitudes. In workshop discussions, two general themes rose to highest priority. One is the study of mid-Cenozoic-Pliocene ice sheet history during times when climate forcing of *high atmospheric CO<sub>2</sub>* was comparable to estimates for the next century, but when tectonic and ocean circulation boundary conditions were not the same as today. The other priority, is on *late Quaternary interglacials*, when Earth and ocean boundary conditions were similar to today and ice retreated landward of its current position, although atmospheric CO<sub>2</sub> levels were lower than at present. Combinations of records of ice sheet behavior during these two time intervals, and under these two sets of boundary condition and greenhouse gas forcing scenarios, will yield information needed for studies of near and long-term future behavior of the Antarctic Ice Sheet.

## Regional versus local ice retreat histories in Prydz Bay, East Antarctica: deglaciation chronology of Rauer Group

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Investigation into the ice extent during the Last Glacial Maximum (LGM) and timing of the last deglaciation has been completed at a handful of widely separated sites scattered around East Antarctica. Widely divergent ice sheet retreat histories have been reported, complicating generalization of the nature and timing of ice retreat.

Prydz Bay is one such area with conflicting evidence. Estimates of ice extent during the LGM vary from almost no expansion compared to the present in Larsemann Hills to 700 m of thinning and 40 km of post LGM margin retreat in Vestfold Hills, although the latter is highly debated. The Rauer Group, a 300 km<sup>2</sup> archipelago of ice free islands lies between these two sites. We investigated former ice extent using <sup>10</sup>Be and <sup>26</sup>Al dating in conjunction with geomorphic evidence to resolve the controversy surrounding the nature and timing of ice retreat along this coastline since the Last Glacial Maximum.

Our new cosmogenic exposure dates provide evidence for a relatively slow uncovering of the Rauer Group during the late Pleistocene and early Holocene, followed by a stable ice margin during most of the Holocene. The ice margin retreated eastwards from the outer islands to near to within 1 km of the modern ice margin between ~14 and 10 ka BP. Further retreats of ~ 0.5 km occurred at ~ 6 ka and within the last few hundred years.

Ice retreat at Rauer Group corresponds closely to the larger retreat histories proposed at Vestfold Hills, suggesting that substantial retreat occurred along much of the Princess Elisabeth Land coastline following the LGM. We suggest that the ice sheet surface elevation near the Larsemann Hills was kept low by an extension of an ice stream occupying Svenner Channel and the Amery Depression that drained ice from the hinterland through the Dâlk Glacier, thus enabling ice free conditions to persist in the eastern part of Larsemann Hills throughout the LGM.

## Greenhouse to icehouse Antarctic paleoclimate and ice history from George V Land and Adélie Land shelf sediments

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The George V Land and Adélie Land continental shelf of East Antarctica contains a record of Antarctica's climate and ice history from the lush forests of the Eocene greenhouse to the dynamic ice sheet margins of the Neogene. Short piston cores and dredges have recovered Early Cretaceous and Eocene organic-rich sediment at the seabed, and in 2010, IODP Expedition 318 recovered earliest Oligocene and early Pliocene subglacial and proglacial diamictites at shallow drilling depths. However, challenging ice and drilling conditions from the JOIDES Resolution on the shelf resulted in poor core recovery and sites had to be abandoned before the main stratigraphic targets could be reached. Therefore, in IODP Proposal 813, we plan to use an ice-strengthened research vessel for easier access to the shelf, and to use the MeBo sea bed drill for improved core recovery in two stratigraphic transects of shallow (~80m) holes. In February 2014, high-resolution seismic reflection, bathymetry and grab sample data were collected on Palmer expedition NBP1402 in the Mertz Glacier area. These new data will provide context and aid in selecting drill sites.

Along the Cretaceous and Eocene "Greenhouse" transect of sites, marine and terrestrial temperature proxies and palynological records will provide information on high-latitude paleoenvironments and pole-equator temperature gradients, and their evolution through time. The "Icehouse" transect will investigate the evolution of the Antarctic ice sheet in this sector by targeting strata above and below regional erosional and downlap surfaces to date and characterize major episodes of ice sheet advance. These direct records of ice extent on the shelf can be set in the context of Southern Ocean records of temperature, ice-rafted debris (IRD) and latitudinal fluctuations of the opal belt, and hence we can relate ice sheet evolution to paleoclimate conditions. Targets include possible late Eocene precursor glaciations, the Eocene/Oligocene boundary erosion surface, and ice extents in the Oligocene, Miocene, and Pliocene. The ice and climate history of the George V Land and Adélie Land margin can provide warm-world scenarios to help to understand ice sheet instability and Antarctic climate under future global warming.

## Rexamination of lithospheric flexure induced by volcano loads in McMurdo Sound, West Antarctica, and implications for regional lithospheric strength

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Lithospheric flexure induced by extrusive volcanism plays an important role in regional scale basin evolution. Examining flexural features, in turn, help us understand regional lithospheric strength. Ross Island volcano loading provides a natural experiment to examine the lithospheric strength of McMurdo Sound region, Antarctica. Previous researchers have examined flexural loading in the region using spatially limited seismic and gravity data. In this study, a more comprehensive data set of marine seismic and gravity profiles are investigated. The data set includes lines that show the complete flexural architecture across McMurdo Sound to the west of Ross Island, and shorter profiles on the north and south sides of Ross Island. The seismic profiles clearly show unconformities representing flexure surfaces induced by loading. Age constraints for these unconformities are derived from ANDRILL project results. Improved digital topographic data for the volcanoes are used to model applied loads. Elastic thin plate models were built according to Vening Meinesz's isostatic flexure model. A set of effective elastic thicknesses ( $T_e$ ) was tested, by comparing misfit between the modeled flexure surfaces and the flexure surfaces observed in regional seismic lines, and by comparing misfit between the modeled free air anomalies and the free air anomalies observed in regional gravity lines. The selected 'best fit'  $T_e$  is compared with  $T_e$  estimated by previous researchers for the region. New constraints on  $T_e$  are important, because this parameter controls the spatial extent and depth of flexural basins formed around the volcano loads. Neogene sediments deposited in the accommodation space provided by the flexural basins are important targets for new ANDRILL-style drilling in the McMurdo Sound region.

## S05: SOLID EARTH RESPONSES AND INFLUENCES ON CRYOSPHERIC EVOLUTION

### Crustal deformation in Northern Victoria Land: results from the VLNDEF GPS network

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GPS measurements are the core of the Italian geodetic activity in Antarctica. During the 1999-2000 expedition, Italian geodesists began the establishment of a large GPS network devoted to the detection and monitoring of crustal deformations in the Northern Victoria Land (NVL). Nowadays, 28 markers are monumented on rocky outcrops and form the VLNDEF (Victoria Land Network for DEformation Control) network. VLNDEF extends over 500 km North-South and 300 km East-West, and its markers can be accessed by means of helicopter from MZS or, more conveniently, planning remote camps in the North and or South of NVL.

A permanent GPS station (TNB1) was installed in 1998 at MZS with DOMES N. 66036M001. In addition, to increase redundancy in the long term observations at MZS, an additional permanent GPS station TNB2 was installed in 2008 on a marker materialized a couple of years earlier and a few meters apart from TNB1. During 2008 three markers of the network were converted into semi-permanent remote stations, namely VL01 (Cape Hallett), VL05 (Cape Philips) and VL18 (Starr Nunatak). They are powered by a set of batteries and solar panels and provide a few months of data every year. Since its establishment, VLNDEF has been surveyed ten times, of which three are surveys of the whole network.

The remarkable amount of GPS data collected so far can be used to shed some light on the ongoing crustal deformations, their pattern and the presence of any neo-tectonic activity. We present the results obtained using the Bernese V.5.0 and the GIPSY-OASIS software, adopting a common analysis strategy, models and parameters. We compare and critically comment the results.

## Hot rocks in a cool place - sub-glacial heat flow in east Antarctica

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Numerical models are the primary predictive tools for understanding the dynamic behaviour of the Antarctic ice sheet. But a key boundary parameter – the magnitude of sub-glacial heat flow – is controlled by geological factors and remains poorly constrained. We show that variations in the abundance and distribution of heat-producing elements (U, Th and K) within the Antarctic continental crust give rise to higher (by a factor as much as 2-3), and considerably more variable, regional sub-glacial heat flows than that assumed in many ice modelling studies. Such elevated, and variable, heat flows would fundamentally impact on regional ice sheet behaviour and predict higher localized basal melt production and enhanced ice surging and streaming. We also note that, prior to the breakup of Gondwana, much of the East Antarctic continental crust was contiguous with southern Australia where extensive high heat-producing Proterozoic-aged rocks, and correspondingly elevated regional heat flows, are well documented and such crustal rocks almost certainly extend beneath the modern east Antarctic ice sheet. We also present an example from Prydz Bay, where the presence of high heat producing Cambrian granites, with elevated Th contents, fundamentally modifies local and regional heat flows. Such fundamental geological controls on sub-glacial heat flow must be considered to accurately model ice dynamics, and would allow more refined predictions of ice mass balance and sea level change, particularly in the context of anthropogenic climate change.

## The mantle transition zone beneath Antarctica from P-wave receiver functions

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Several exposed, sub-glacial, and submarine volcanoes exist throughout West Antarctica in the vicinity of the West Antarctic Rift System; prior work has suggested that a mantle plume beneath the region influences the observed rifting and volcanism. However the existence of a mantle plume has not been verified, because models from recent seismic tomography results are not well resolved at mantle transition zone depths. We use P-wave receiver functions (PRFs) from all Antarctic seismic stations, including recent 2007-2012 Antarctic POLENET, permanent GSN, and the 2000-2003 TAMSEIS seismographs to explore the depth to and the thickness of the mantle transition zone throughout Antarctica. We calculate PRFs for all earthquakes occurring at 30-90° with Mb>5.5 using a time-domain iterative deconvolution method filtered using a Gaussian-width factor of 0.5 and 1.0, corresponding to frequencies less than ~0.24 Hz and ~0.48 Hz, respectively. Using this method, we check stability of the deconvolution by convolving the vertical component with the final radial receiver function, rejecting all receiver functions that did not recover at least 80% of the original trace. Results for P receiver functions stacked by station and migrated to depth using the ak135 1-d velocity model indicate subtle changes in the thickness of the transition zone throughout West Antarctica, although deviating only slightly from the global average thickness. In addition to transition zone thickness variations that could reveal the presence of a mantle plume, we detect the presence of prominent negative peaks which may reveal melts produced in response to plume upwellings through a water-rich mantle transition zone. In two regions of West Antarctica a faint 720' peak is detected, which is also thought to become more prominent in the presence of hot mantle. The 520' discontinuity is detected beneath most of West Antarctica; in the vicinity approaching the Transantarctics, the 520' appears to split into two positive peaks. Future work is planned to incorporate data from the 2-3 year AGAP survey in order to resolve whether the transition zone is normal beneath the anomalously high topography of East Antarctica. Additional analysis will use three-dimensional regional seismic velocity models to migrate receiver functions in West Antarctica to more clearly resolve whether regions with subtle transition zone thinning are significant features.

## The Gamburtsev Subglacial Mountains in East Antarctica: a shut case or still enduringly enigmatic?

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The Gamburtsev Subglacial Mountains (GSM) played a key role in the initiation of the Antarctic ice sheet. Despite recent advances in understanding their subglacial landscapes and their underlying crustal and lithospheric architecture, the origins and evolution of the GSM remain enduringly enigmatic and increasingly controversial.

Aerogeophysical data reveal a major Paleozoic to Mesozoic rift system in East Antarctica surrounding the GSM and a thick high-density lower crustal root beneath the range that may have formed during the Proterozoic assembly of East Antarctica. Continental rifting may have triggered phase changes at deep crustal levels, perhaps restoring some of the latent root buoyancy, as well as causing more classical lithospheric flexure and rift-flank uplift.

The Permian to Cretaceous rift-flank uplift model for the Gamburtsevs (Ferraccioli et al., 2011 *Nature*) is appealing because it links intraplate mountain-building to the geodynamic processes that led to the separation of India from East Antarctica. However, while Permian rifting is well-established in both the Lambert Rift and India, recent detrital thermochronology results suggest that Cretaceous rift-related exhumation in interior East Antarctica may not have been as significant as previously proposed. This raises the question of whether the modern Gamburtsevs may instead have been uplifted solely in response to changes in Cenozoic erosion (e.g. during the early stages of East Antarctic Ice Sheet development), superimposed upon a Permian rift flank or via other mechanisms (e.g. dynamic topography).

To address this question we are combining analyses of the GSM landscapes with 2D & 3D flexural models of peak uplift caused by the isostatic responses to fluvial and glacial valley incision. The advantage of this approach is that outputs of geophysical relief and isostatic modelling can be compared with estimates of erosion rates since the Oligocene and the total amount of incision estimated in the Lambert rift region (Thomson et al. 2013, *Nature Geoscience*). Modelling outputs can also be compared against the present-day elevations of up to 1500 m a.s.l of uplifted Oligocene-early Miocene glacial-marine sediments in the Lambert Glacier (Hambrey et al., 2000, *Geology*). These new models provide more quantitative means of assessing the possible range of pre-incision elevations of the "Gamburtsev plateau", which is a key constraint when modelling East Antarctic ice sheet nucleation and evolution.

## Airborne geophysics in the Recovery Lakes region, East Antarctica

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Long-range airborne geophysics measurements were carried out in January/February 2013 in hitherto unexplored parts of Interior East Antarctica (the Recovery Lakes region), supplementing earlier surveys over the interior Dronning Maud land region Jan/Feb 2011. The 2013 measurement programme provided for the first time a regional coverage of gravity, magnetics and ice penetrating radar for major Dronning Maud land ice stream systems from the grounding line up to the Recovery Lakes drainage basin. The campaign was carried out with a BAS Twin-Otter, operating from the UK Halley and Argentina Belgrano II stations, as well as a field camp on Recovery Lake B, with camp logistics provided by the Norwegian Polar Institute.

The gravity measurements were the primary driver for the mission, with two airborne gravimeters (L&R and Chekan) providing measurements at accuracy levels of 2 mGal, supplementing the GOCE satellite mission with fill-in data in a major void of Antarctica, in support of global gravity field modelling. The combined 2011-13 airborne gravity data show, together with the magnetic data and ice-penetrating radar data, hitherto unknown geological features in deep interior Dronning Maud Land, as well as provide new data on the sub-ice structures of the major ice streams and the underlying sediments. Ice radar data further provide detailed insights into the nature of the subglacial Recovery Lakes, the second-largest in Antarctica, confirming that the lakes are real lakes, with more water stored in 2013 than earlier suggested. The success of a survey like this, in one of the most inaccessible areas on Antarctica, highlights the possibility of rapidly closing the last data void of Antarctica around the pole, especially important for global gravity field mapping, where the GOCE gravity field mission has not provided any data south of 83 S.

## Relation of positive gravity anomalies of sedimentary basins of the Ross Sea to the Antarctic Ice Sheet

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The extensional basins of the Ross Sea are paradoxical in that positive gravity anomalies overlay the Victoria Land Basin, Central Trough, Northern Basin and Northern Central Trough while basement highs are associated with negative gravity anomalies. A number of studies have attributed the positive gravity anomalies across the depocenters to high-density volcanics deep within the basins or magmatic intrusions within the region of the thinned crust or upper mantle (Edwards et al., 1987). Karner et al. (2005) had regarded that there is no clear correlation between known volcanic outcrops in the western Ross Sea region and the Bouguer gravity anomaly. According to the conclusion from Karner et al. (2005), the observed anticorrelation of gravity anomalies with sediment thickness can be reproduced if the flexural strength of the lithosphere during rifting is significantly lower than the flexural strength of the lithosphere at the time of sedimentation. In contrast, the younger Terror Rift has a negative gravity anomaly, a simple consequence of comparable syn-rift and post-rift rigidities and a relatively narrow width. But in fact, in the main part of the Victoria Land Basin apart from the Terror Rift and the Central Trough there are some outcrops of alkali basalts or magmatic intrusions indicated by the Werner deconvolution solutions of magnetic data, corresponding to those peaks of positive gravity anomalies. Thus, either the Ross Sea sediments or the basement may have unusual densities that might produce these positive anomalies. The flexural isotatic model based on a normal density relationship between sediment infill and basement would not be an exclusive selection to solve the paradox. Interpretations advancing the concept of high density material in the lower crust or upper mantle and general gravity studies of the Ross Sea basins have tended to ignore the constraints offered by isostasy in mapping the density distributions in the lithosphere (Davey and Cooper, 1987). For example, Tre'hu et al. (1993) underscore the non-uniqueness of gravity modeling when isostasy is not taken into account. In particular, the modeled gravity does not laterally integrate to zero, indicating the existence of unbalanced forces and thus untenable geological models. If both the Ross Sea and the Antarctic Ice Sheet or the Transantarctic Mountains are treated as one system, we may get rid of this dilemma. As the Antarctic Ice Sheet or the Transantarctic Mountains had been developing, the local crust would gradually subside and its underlying anthenosphere would flow outwards. Along weak belts or faults at the depocenters of the Ross Sea, compressed magma were likely to upwell and underplate, and then cooling magma in crust and the negative buoyancy of anthenosphere would lead to increase gravity anomalies within the extensional basins.

## Significance of enigmatic blue ice moraine gypsum, Sør Rodane, East Antarctica

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During the international GEA-II expedition to Sør Rondane (East Antarctica), large aggregates of crystalline gypsum were found within blue-ice moraines on the south side of the Sør Rondane Mountains at an elevation of ca. 2000 m and ca. 250 km inland of the present coastline. Gypsum aggregates reach one meter in diameter with individual crystal length up to 20 cm. Apparently, the gypsum grows in-situ and as a result of sublimation of the blue ice on the gravel of the moraine. Individual cobbles and sand are incorporated into the gypsum aggregates. The gypsum does not show signs of transport. In thin section, the gypsum shows an irregular growth zoning and in part bent cleavage planes. Abundant primary fluid inclusions are present parallel to the growth zoning as well as parallel to cleavage plains. This type of gypsum formation is enigmatic and has never been described before. It might indicate an important and thus far unknown process, characterising a special way of interaction between the lithosphere and the cryosphere. Preliminary Sr-isotope data indicate relatively high values and suggest crustal affinities. A preliminary set of sulfate sulfur ( $\delta^{34}\text{S}_{\text{SO}_4}$ ) and oxygen ( $\delta^{18}\text{O}_{\text{SO}_4}$ ) isotope data reveals values ranging from +7.0 and +29.6 ‰ ( $\delta^{34}\text{S}_{\text{SO}_4}$ ) and between -16.7 and +0.3 ‰ ( $\delta^{18}\text{O}_{\text{SO}_4}$ ). Samples display a positive correlation between  $\delta^{34}\text{S}$  and  $\delta^{18}\text{O}$ . Thus, Sulfur isotope values are highly variable and offer different conclusions with respect to potential sulfate sources. None of the gypsum samples displays a sulfur isotopic composition reflecting a pure seawater sulfate (i.e. sea spray) origin. Two samples yielded  $\delta^{34}\text{S}_{\text{SO}_4}$  values of +7.0 and +9.0 ‰, most others are distinctly more positive than modern seawater sulfate (i.e., above +21.0 ‰), with a maximum value of +29.6 ‰. In general, the sulfur isotope values more positive than modern seawater sulfate suggest bacterial sulfate reduction. The low  $\delta^{34}\text{S}_{\text{SO}_4}$  values are comparable to values measured previously for continental sulfate and are similar to a single pyrite sample from a black schist sample, ca. 150 km to the W, Steingarden area (this study). The oxygen isotopic composition for the blue ice gypsum samples is also characterized by rather variable including strongly negative  $\delta^{18}\text{O}_{\text{SO}_4}$  values. Negative sulfate oxygen isotope values possibly reflect an  $^{18}\text{O}$  depleted continental source such as Antarctic glacial waters that could have fostered the oxidative weathering of sulfide sulfur. The observed variability could reflect different stages of bacterial sulfate reduction.

## Bedrock elevation, crustal thickness, and Inferred upper mantle temperatures for Antarctica

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Previous analyses of surface elevations and crustal thickness for North America has revealed distinct trends for cratonic and Cordilleran regions, with mountain belts being elevated relative to cratonic regions (Hyndman, 2010). The higher elevations in mountain belts for crustal thicknesses similar to or smaller than cratonic regions were inferred to be a consequence of thermal expansion of the asthenosphere. The relationship between crustal thickness and surface elevations was explored for Antarctica with the CRUST 2.0 and BEDMAP digital compilations of crustal thickness and bedrock topography. Bedrock elevations were corrected for crustal density and for isostatic loading using the IJ05 glacial isostatic adjustment model. Antarctica was divided into six broad structural elements: Antarctic Peninsula, East Antarctica, Ellsworth Land, Marie Byrd Land, Transantarctic Mountains, and West Antarctic Rift System. For each region, the crustal thicknesses and corrected bedrock elevations were evaluated and compared to the trend lines developed for North America. Broadly speaking, Antarctic regions were concordant with North America, with East Antarctica lying on the cratonic trend and Marie Byrd Land, which is hypothesized to lie on a mantle hotspot, lying close to the Cordilleran trend. Most other regions are intermediate to the two trends. These results are consistent with previous analyses based on seismic wave speeds which inferred high mantle viscosities beneath East Antarctica and low viscosities beneath West Antarctica. A prominent exception, however, was the West Antarctic Rift System (WARS), which lies on the cratonic trend. It may be a consequence of the WARS region having an average crustal thickness in CRUST 2.0 that is larger than expected for a rift environment. This may reflect the paucity of constraining observations for the region. An analysis of a limited number of crustal thicknesses directly constrained by seismological observations also finds that East Antarctica lies on the cratonic trend and Marie Byrd Land lies close to the Cordilleran trend. With the exception of the WARS, the Antarctic analysis is consistent with the trends found for North America, but more direct observations of crustal thickness are needed for Antarctica before independent relationships can be developed.

## Long-term detectability of teleseismic events and their relation to surface environment at Syowa Station, Antarctica

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Phase identifying procedure for teleseismic events at Syowa Station (69.0°S, 39.6°E; SYO), East Antarctica have been carried out since 1967 after the International Geophysical Year (IGY; 1957-1958). From the development of INTELSAT telecommunication link, digital waveform data have been transmitted to the National Institute of Polar Research (NIPR) for utilization of phase identification. Arrival times of teleseismic phases, P, PKP, PP, S, SKS have been reported to the International Seismological Centre (ISC), and published by "JARE Data Reports" from NIPR. In this paper, hypocentral distribution and time variations for detected earthquakes are demonstrated over the last four decades in 1967-2010. Characteristics of detected events, magnitude dependency, spatial distributions, seasonal variations, together with classification by focal depth are demonstrated. Besides the natural increase in number for occurrence of teleseismic events on the globe, a technical advance in observing system and station infrastructure, as well as the improvement of procedure for reading seismic phases, could be efficiently combined to produce the increase in detection number in last few decades. Variations in teleseismic detectability for longer terms may possibly by associate with meteorological environment and sea-ice spreading area around the Antarctic continent. Recorded teleseismic and local seismic signals have sufficient quality for many analyses on dynamics and structure of the Earth's as viewed from Antarctica. The continuously recorded data are applied not only to lithospheric studies but also to Earths deep interiors, as the significant contribution to the Federation of Digital Seismological Network (FDSN) from high southern latitude.

## Characteristic cryoseismic waves associated with surface environments around the Lützow-Holm Bay, East Antarctica

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In an international geoscience prospect at the IPY, the 'Polar Earth Observing Network (POLENET)' was the largest contributions in establishing a seismic and GPS network in Antarctica. Several kinds of environmental signals associated with the atmosphere - ocean - cryosphere - solid earth systems are detected in the continent and surrounding oceans. Ice-related seismic motions for small magnitude events are generally named 'ice-quakes' ('ice-shocks') and can be generated by glacially related dynamics (Kanao et al., 2012). Such kinds of cryoseismic sources are consisted from the movements of ice sheets, sea-ice, oceanic tide-cracks, oceanic gravity waves, icebergs and the calving fronts of ice caps. Nettles and Ekstrom (2010), moreover, determined the hypocenter and magnitude of several large ice-quakes (glacial earthquakes) around Antarctica by using the long period surface wave data. These hypocenters locate mainly at the outlet of the large glaciers, otherwise the edge of ice shelves. Cryoseismic and oceanic waves are likely to be influenced by the variations in environmental conditions, including lower atmosphere, and the continuous study of their time-space variation provides indirect evidence of climate change. In this presentation, several characteristic features of cryoseismic waves observed the stations around the Lützow-Holm Bay (LHB) region are introduced, involving the surface environmental variations in vicinity of the area from continental coastal to the southern ocean. Hypocenters of local events, waveforms involving discharge of sea-ice, tide relating signals, as well as the tremor signals with characteristic frequency contents are demonstrated. As the glacial earthquakes are the most prominent evidence found recently in the polar region, these new innovative studies of polar seismology has been achieved on the basis of observational experiments and long-term monitoring under the extreme conditions of the polar environment.

## Rheology of the Antarctic Peninsula from rapid ice unloading and change in rates of bedrock uplift

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Commencement of large glacial unloading in the Antarctic Peninsula since 1995, and especially 2002, resulted in rapid bedrock uplift. The ice unloading and the bedrock response are both well observed, since 2001 and 1998, respectively. The observed uplift increase cannot be explained by an elastic response only, but modelling based on a viscoelastic (linear Maxwell) rheology closely reproduces the observations. Strong preference is found for a low value of upper mantle viscosity, but with little sensitivity to the modelled thickness of the elastic lithosphere.

However, wider geophysical and laboratory studies suggest that a more complex rheological model may be required to correctly interpret the observed deformation. This well observed event offers a rare opportunity to constrain the rheology of the upper mantle using post-glacial rebound data and without large ambiguity in the ice history. Here, we discuss such constraints.

## GPS crustal motions show 3D earth models are needed to understand Antarctic ice mass change

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GPS observations of crustal motion in the Antarctic interior appear to be driven by changes in ice mass, and provide essential constraints for models of glacial isostatic adjustment (GIA). While vertical displacement patterns are commonly used to assess GIA model accuracy, efforts to develop more realistic 3D earth models have shown that horizontal motions are more important for characterizing GIA on a laterally varying earth. This phenomenon is especially significant for Antarctica, where a strong boundary in crustal thickness and mantle viscosity separates East and West Antarctica.

We present GPS-derived horizontal crustal motion data from Antarctica acquired by the Antarctic Network (ANET) component of the Polar Earth Observing Network (POLENET). Observed displacements validate predictions from models that GIA-induced horizontal motions across an extreme earth properties boundary can be reversed, resulting in motion toward, rather than away from former ice mass centers. Specifically, horizontal crustal motions are consistently near-perpendicular to the very strong gradient in mantle viscosity mapped by seismology, with motion toward the weaker, West Antarctic side from the stronger, East Antarctic side. This correlation suggests that the disagreement between observed and predicted horizontal motions derived from 1D GIA models is a result of the strong influence of heterogeneity in earth structure on solid earth deformation. Comparison to 3D GIA models shows a close agreement between observed and predicted motions, indicating 3D laterally-varying earth models are necessary to produce reliable predictions of GIA for Antarctica. Both horizontal and vertical displacements due to GIA are impacted by lateral variations in earth structure, therefore this result further indicates the importance of using 3D GIA models to correct for GIA-induced uplift and associated gravity signals to estimate Antarctic ice mass balance from satellite gravity and altimetry measurements.

## Cenozoic stress field evolution in King George Island from mesofault population analysis

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A study on palaeostresses was performed in King George Island (South Shetland Islands) in order to establish the Cenozoic plate tectonic evolution in the southwestern Scotia Arc and Bransfield Strait. 254 faults were measured at 13 sites on Upper Cretaceous and Eocene igneous and sedimentary rocks in Fildes (9 sites), Barton (1 site), Potter (1 site) and Keller (2 sites) peninsulas. Fault data were analyzed with the Etchecopar,  $\gamma$ -R and Right Dihedra methods.

In Fildes Peninsula palaeostress analysis was performed on 168 faults. Fault planes dip between 30° and vertical. Directional fault analysis shows a NE-SW orientation maximum and a relative maximum striking N-S. Orientation of  $\sigma_1$  shows two main axes trending NE-SW and NW-SE, whereas the  $\sigma_3$  direction is N-S, NE-SW and E-W. The R relationship is normal to radial normal and wrench regimes. In Barton Peninsula 16 faults have been measured. Most faults show dips between 50°-80°. Faults show NNW-SSE, NE-SW and ESE-WNW orientations. Results of our palaeostress analysis indicate NW-SE  $\sigma_1$  horizontal stress direction and ESE-WNW  $\sigma_3$  horizontal stress directions and the R relationship point to wrench and normal regime, respectively. In Potter Peninsula 8 faults have been measured. Faults show subvertical dips and they exhibit N-S and ENE-WSW orientation. Results of our palaeostress analysis indicate a main compressional regime with N-S direction and the R relationship shows a wrench regime. In Keller Peninsula palaeostress analysis was performed on 62 fault planes. Fault planes dip between 30° to vertical. Directional fault analysis indicates a NE-SW and ENE-WSW orientation maxima and a relative maximum striking NE-SW. From the orientations of stress axes, it can be observed that  $\sigma_1$  present two main axes trending NE-SW and NW-SE, whereas the  $\sigma_3$  direction is NE-SW. The R relationship mainly indicates a wrench regime.

According to our interpretation, NW-SE maximum horizontal stress is related to the Mesozoic-Cenozoic oceanic subduction of the Former Phoenix Plate under the Pacific margin of the Antarctic Plate along the South Shetland Trench. The NE-SW compression could be connected with late Miocene to present-day sinistral transcurrent movement along the South Scotia Ridge and the South Shetland Trench. The NE-SW extensional stress field could be associated to the Oligocene opening of the Powell Basin. Finally, the E-W extensional stress field could be related to the Pliocene to present development of the Bransfield Basin.

## Antarctic seismic sources recorded by recent large-scale seismograph deployments

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With the advent of year round seismic installations, we find the apparent lack of seismicity in Antarctica is actually a limitation in instrumentation. Continuous data recorded by POLENET/ANET (+/- 38 stations in West Antarctica) and GAMSEIS (+/- 30 stations in East Antarctica) since 2007 record many sources of seismicity in Antarctica, including a new source of cryoseismicity.

We observe a shallow cryoseismic source located on the East Antarctic plateau. Only strong surface waves (always Rayleigh and in most cases Love waves as well) are recorded, and even the nearest stations record no body waves. Modeling indicates the source must be very shallow, within the upper 30-50 m, in order for no body wave energy to be observed above the noise. We calculate a Rayleigh wave group velocity dispersion curve and then invert for S-wave velocity structure with the best recorded events. The structure, which shows a 100-200 m thick lower velocity firn layer overlaying a relatively constant ice layer, becomes the input model for reflectivity synthetics as we test what source mechanism and depth are required to produce the observed waveforms. A pure double-couple mechanism is insufficient and therefore an expansion or contraction component is necessary. Some form of crack formation in the firn layer is most likely the source of these newly discovered events.

POLENET/ANET also records seismic activity associated with volcanism in the Executive Committee Range (ECR) in 2010-2011. Over 1,300 deep long period (DLP) events are located below what we assume to be the current location of volcanic activity in the linear ECR chain. The events are 25-40 km deep and cannot be resolved with a glacial source. The cluster of events correlates with a subglacial topographic high, possibly a volcanic construct, and magnetic anomalies indicative of volcanic material. Ash layers ~8,000 years old attributed to nearby Mount Waesche indicate volcanism more recent than any dated eruptions. Together a swarm of volcanic seismic events associated with geologic evidence of volcanism and a very young ash layer indicate volcanism in the ECR is continuing to migrate southward. These observations invite the question of the impact of an eruption and the subsequent melt to the subglacial system. An eruption is unlikely to breach the 1.2-2 km thick ice sheet but the large volume of melt water introduced to the subglacial system could increase the velocity of overlying ice.

## Network of absolute-gravity stations in Western and Central Dronning Maud Land

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There are now five absolute-gravity (AG) stations in Western and Central Dronning Maud Land between longitudes 14 deg W and 12 deg E. The oldest station is at the Finnish base Aboa, with 5 measurements by the Finnish Geodetic Institute (FGI) starting with the FINNARP 1993 expedition. Measurements at Maitri (India) and Novolazarevskaya (Russia) were first performed in 2004 by the National Geophysical Research Institute (NGRI) of India, and by the FGI, respectively. In the season 2010/11 a new station was constructed at Troll (Norway). In the season 2011/12 the aforementioned four stations were occupied by the FG5-221 absolute gravimeter of the FGI. At Sanae IV (South Africa) there are two previous occupations by the FG5-221, in 2003/4 and 2005/6.

AG stations are important for Antarctic geodynamics. They provide accurate starting values for gravity surveys performed for geophysical and geological investigations. Observed gravity change from repeated AG measurements can be compared with vertical motion from continuous GNSS observations, predictions from models of Glacial Isostatic Adjustment (GIA) and with solid Earth deformation from estimated variation in contemporary ice load. Given sufficient joint coverage with International Terrestrial Reference Frame (ITRF) sites, gravity rates at high latitudes could in principle provide an independent check of the geocentricity of the  $\dot{z}$  (velocities in the direction of the rotation axis of the Earth) of the ITRF.

All the AG sites mentioned have continuous GNSS stations. Numerous supporting measurements have been made at them: microgravity networks, levelling and GNSS ties to excentres etc., for controlling the stability of the stations. At some sites, nearby glacier elevations were surveyed to monitor the attraction of the variable close-field snow and ice masses. We give a description of the sites and the measurements performed at them. The work benefited from the co-operation in the COST Action ES0701 "Improved Constraints on Models of GIA".

**Time series of absolute gravity measurements at the Finnish Antarctic Station Aboa, Dronning Maud Land: comparison with observed vertical motion, models of Glacial Isostatic Adjustment, and variation in contemporary ice and snow mass**

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The gravity laboratory at the Finnish Antarctic Research Station Aboa in Western Dronning Maud Land was constructed by the FINNARP 1993 expedition, and the site was first occupied by the JILAg-5 absolute gravimeter (AG) of the Finnish Geodetic Institute (FGI) in January 1994. Repeat measurements were performed with the JILAg-5 in FINNARP 2000, and with the FG5-221 in FINNARP 2003, 2005, and 2011. The station has thus one of the longest absolute-gravity time series in the Antarctic:

The continuous GPS (CGPS) station at Aboa started operations during FINNARP 2002 in February 2003. The receiver works unattended during the austral winter. The data is stored in the memory card of the receiver and recovered by summer expeditions to Aboa. The CGPS station is part of the POLENET. A broadband seismometer of the Institute of Seismology of the University of Helsinki occupies the laboratory pier whenever AG is not there. The seismometer data is collected and recovered in the same way as that of the CGPS receiver.

The gravity laboratory and the CGPS antenna close to it are on exposed bedrock on the nunatak Basen. The expectation was that the primary signals of time-dependent gravity would be (i) viscoelastic gravity change due to Glacial Isostatic Adjustment and (ii) elastic gravity change due to contemporary variation in regional ice load. In other words, signals that should show up as vertical deformation in the GPS coordinate time series. However, it was soon recognized that the close-field attraction of the variable snow and ice masses on the slopes of Basen and on the glacier Plogbreen below Basen could have a large influence on observed gravity. Monitoring of local snow mass started during FINNARP 1999 in cooperation with several institutions and has been pursued ever since, now using mainly RTK-GPS methods.

We describe the results and discuss the contributions of the different phenomena to the absolute gravity record and to the coordinate time series from the CGPS.

## **Absolute gravity time series at Aboa, Dronning Maud Land: influence of near-field snow masses revisited**

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The absolute gravity station at the Finnish Antarctic Research Station Aboa (Western Dronning Maud Land) has been occupied in 5 FINNARP expeditions since 1993/1994, at time intervals of 2 to 6 years. We have previously found that the campaign-to-campaign variation in the snow mass within 100 m of the station can cause a gravity effect of some microgals. It thus can mask gravity signals related to vertical deformation, e.g., due to Postglacial Rebound (PGR) or variation in contemporary ice load. At this close-range the snow surface heights were mapped on foot in a dense grid using Real Time Kinematic GPS (RTK-GPS) methods.

Here we extend the analysis to a distance of 3 km from the station, using repeated RTK-GPS profiles measured by antennas mounted in sledges, towed by snowmobiles. Technical details of the method are described. The variation in snow surface heights can in this area be up to 5 m between campaigns and is primarily caused by wind accumulation and ablation. We have sampled extensively the mean density of the top 1 m snow layer; it shows lateral variations of tens of percent. We discuss the appropriate density modelling for transforming variation in surface heights to variation in mass.

## Antarctica's hypsometry and crustal thickness: Implications for the origin of anomalous topography in East Antarctica

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The hypsometry of Antarctica revealed by BEDMAP2 data is characterised by deglaciated modal elevations of ~450 m and ~650 m for West and East Antarctica, respectively, and an East Antarctic plateau that is topographically anomalous by ~400-600 m with respect to global continental modal elevation estimates. Superimposed on the East Antarctic plateau are the Gamburtsev Subglacial Mountains, the Dronning Maud Land Mountains and the Vostok Highlands with modal elevations ~400 m in excess of the East Antarctic mode. To ascertain whether East Antarctica's anomalous topography can be attributed to Airy-type crustal compensation, a continental-scale crustal thickness model was derived from the inversion of GOCO03S satellite gravity data constrained by seismic crustal thickness estimates. The average crustal thickness of East Antarctica is ~40 km (for West Antarctica ~24 km), a value typical of continental shields, and while crustal thicknesses of >50 km locally beneath the Gamburtsev Subglacial Mountains and Dronning Maud Land can account for their differential modal elevation above the plateau, crustal thicknesses elsewhere across East Antarctica offer no suggestion of crustal-level continental-scale support for the broader plateau. Enderby Land, for example, resides on the plateau and is characterised by a modal elevation of ~750 m and crust ~40 km thick, whereas off the plateau in East Antarctica, the Aurora and Wilkes Subglacial Basins have modal elevations of ~-50 m and ~-50 m, respectively, yet similarly thick crust. The lack of crustal support for the elevated broader East Antarctic plateau, coupled with seismic images showing fast upper mantle velocities beneath the plateau, suggest a mid-to-lower mantle source for East Antarctica's anomalous topography.

## **P-wave velocity structure beneath Mt. Melbourne in the northern Victoria Land, Antarctica**

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The P-wave velocity structure of the shallow upper mantle beneath Mt. Melbourne was modeled from the double precision teleseismic inversion method [VanDecar, 1991]. The teleseismic events used in this study were obtained from the Korea Polar Seismic Network at Terra Nova Bay (KPSN@TNB), which consisted of five broadband seismic stations deployed from 2001. The 1501 relative P-wave traveltimes residuals were computed from 402 events using the multichannel cross correlation (MCCC) method [VanDecar and Crosson, 1990]. The inverted velocity model reveals two separate low-velocity regions; one is beneath Mt. Melbourne and trending N-S direction between 40 - 90km depths, and the other is beneath the KP03 station and extending to NW direction. The low velocity anomaly smeared downward along the raypaths in the model space of the outside the KPSN@TNB. However, several resolution tests confirmed that our model is reasonably good for the model space within the network. The low velocity anomaly beneath Mt. Melbourne is associated the uplift of and volcanic center.

## Volcanotectonic deformation models for Deception volcano and its environment: update and time evolution (1992-2014)

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The region defined by the South Shetlands Islands, the Bransfield Sea and the Antarctic Peninsula represents one of the most interesting geodynamic regions in Antarctica due to the convergence of several tectonic plates. The South Shetland archipelago is a volcanic arc formed as a consequence of the Phoenix micro-plate subduction under the Antarctic plate. A close to 1.0 cm/year velocity has been measured and attributed to the NW-SE Bransfield basin extension and the Phoenix micro-plate shortening or subduction, after the Phoenix-Antarctic opening finished at about 3.3 Ma. The slow subduction rate is favorable to the roll-back motion of the subducted slab, producing the extension of the overriding plate and giving way to the back-arc Bransfield basin formation, and therefore to the separation of the South Shetland block. To the north, the South Shetland trench ends at the left-lateral Shackleton fracture zone near Elephant Island, and to the south, ends at the Hero fracture zone. Within the Bransfield Basin, Deception Island presents active volcanism manifested in seismic, thermal and surface deformation activities, which recent eruptive processes took place in 1967, 1969, and 1970. Two seismic crisis were detected along the 1991-1992 and 1998-1999 austral summers with hypocenters located in Fumaroles Bay. Deception Island presents two major geodynamic behaviors of distinct origins: the tectonic regime of the Bransfield Basin and its own volcanic activity.

The presented work focuses on both the regional tectonic study and the monitoring of the volcanic activity of Deception Island, based on GNSS observations registered in the geodetic benchmarks located in the region. An evaluation of the surface deformation gives the displacement velocities of each benchmark from GNSS observations made between 1992 and 2014. From the velocity field of the Spanish Antarctic Geodynamic Network (RGAE) benchmarks a regional tectonic model was assessed. This model supports an ongoing subduction process at the South Shetland trench and presents a singular geodynamic behavior of Byers Peninsula in Livingston Island. From the velocities of the three geodetic benchmarks with permanent GNSS observations each austral summer campaign, near the "Gabriel de Castilla" Spanish Antarctic Station, in Fumaroles Bay and in Pendulum Cove, the analysis of the volcanic activity of Deception Island is presented. In the 1992-2014 time window, periods of expansion and uplift interchanged by periods of compression and subsidence were identified. Also the seismic crisis registered in this time window were correlated with the periods of expansion and uplift.

## Bransfield basin's strain marker: Insights from Deception's GNSS-GPS benchmarks' enhanced sub-daily surface deformation analysis

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Deception island is the most prominent active volcanic center situated in the Bransfield basin between the South Shetland islands to the west and the Antarctic peninsula to the east, whose main volcano-tectonic feature is a central flooded depression. This central caldera has been described as a collapse caldera originated after one or more voluminous eruptions, or by progressive passive normal faulting along a nearly orthogonal fault system. This fault system results from the Phoenix slab roll back along the South Shetland trench, the Phoenix-Antarctic subduction zone, and its additional left-lateral component consequence of the Antarctic plate regional northeastwards movement that also promotes the southwestward propagation of the South Scotia ridge, the Antarctic-Scotia boundary.

A methodology for near real time surface deformation analysis was developed and applied along Deception island's austral summer campaigns for volcano surveillance purposes. It relies on a minimum of three strategically deployed benchmarks position variations at sub-daily rates determined through GNSS-GPS (Global Navigation Satellite Systems – Global Positioning System) geodetic techniques. The benchmarks' positions were computed every 30 minutes with the Bernese GPS Software 5.0. Multipath and residual loading and meteorological effects were dealt with a discrete Kalman filter. The method 1 sigma position accuracy was assessed at 1 mm in the northing and easting components and 2 mm in the height component, when applied to baselines ranging up to 300 km with a reference benchmark that is far away from the volcano's dynamic influence. Supported on accurate benchmarks' positions, a normal vector analysis was applied to the triangle covering the monitored surface determining instantaneous strain and inclination.

Deception island deformation general trend is of compression. However, Deception movement relatively to the South Shetland block suggests a southeastwards general trend following the Bransfield basin opening, also reflected in the lesser southeastwards relative movement of the benchmark closest to the South Shetland block. That is only possible if the NW-SE extension rate is usually inferior to the NE-SW compression rate, that at times may also be NW-SE, further reflected in Deception's elliptic shape. Those are respectively the Bransfield extension, the Antarctic-Scotia left-lateral compression and the South Shetland trench compression directions. Nevertheless, Deception's NE-SW extension processes identified in 1996-1999 and 2004-2008 are inferred to be driven by volcano dynamics or by normal faulting consequence of the left-lateral component of the South Shetland trench. Hence, Deception Island acts as a strain marker in the Bransfield basin volcano-tectonic setting.

## **Modular Volcano Monitoring System (MVMS) for the deception volcano (Antarctica): Seismicity, ground deformation and soil temperature parameters**

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The multidisciplinary scientific field of Volcanology uses mainly geological, geophysical and geochemical surveying techniques and methods. To determine the risk and degree of danger of an impending volcanic eruption, it is essential to evaluate the state of the currently-existing volcanic activity. The geodetic and geophysical parameters commonly used for volcanic monitoring and surveillance include seismic activity, gravity anomalies, analysis of volcanic gases, geomagnetic anomalies, thermal anomalies, and ground deformation parameters. Volcano monitoring requires realtime or quasi real-time evaluation. The complexity of a volcanic process involves the simultaneous evaluation of two or more of these parameters; mainly, seismicity and ground deformation. Through the analysis of these parameters the start, energy, location and behavior of the process can be inferred. The main aim is to carry out a temporal and spatial forecast of its short term evolution.

The multiparametric condition of the system and the need to evaluate the volcanic parameters in real-time, together with the increasing storage capacity and logging rate of the geodetic and geophysical instrumentation make necessary the design and development of systems that have to be faster, more efficient, more robust, more scalable, and easily deployed. Due to the different characteristics of the behavior of each volcano, it is necessary to design multiparametric systems with a modular structure (MVMS). The system MVMS is sufficiently flexible to quickly incorporate any sensor (seismometers, GNSS-GPS receiver, inclinometers, thermistors, infrasound, gas, MINIDOAS, etc.) and change the settings and applications, adapting it to the available sensors and environmental conditions and activity.

This job presents a MVMS system designed for volcanic monitoring on Deception Island (Antarctica). In this case the following modules have been incorporated: Ground Deformation Module (IESID); Thermometric Sensor Module (TSM); y Seismic Sensor Module (SSM).

The TSM and SSM modules are managed by an embedded ARM system. The observations of these parameters are sent via WiFi to a control center located in the BAE Gabriel de Castilla. In this control center the mentioned observations are jointly processed, analyzed and evaluated with the aim of establishing forecasts about the immediate evolution of the volcanic system. The developed system has provided data from these parameters in a continuous, uninterrupted way throughout the Spanish campaigns in the southern summer.

This modular design MVMS developed on Deception Island, with appropriate modifications and adjustments, has been used in the eruptive process occurred in October 2011 on the island of El Hierro (Canary islands).

## Study of the crust in East and West Antarctica based on S-wave receiver functions

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In regions with thick ice cover, seismic reverberations within the ice layer create strong multiples that can be observed in P-wave receiver functions. The P-to-S (Ps) conversion from the crust-mantle boundary is often masked by these ice multiples. S-wave receiver functions (SRF) are an alternate way to estimate the crustal structure using the S-to-P (Sp) conversions, which do not interfere with the ice multiples. We analyzed broadband data from the TAMS, AGAP and POLENET temporary networks encompassing 78 stations. Moho Sp arrivals are clearly seen at ~4-6 seconds for the TAMS stations, ~6-8 sec in the AGAP stations and at ~3-4 sec for the POLENET stations. A grid search approach was used to obtain Moho depths constrained by both receiver functions and Rayleigh wave phase velocities on all three of the networks. Using this methodology, we were able to constrain the Moho depths and average crustal S-wave velocity for all three of the networks stations. We found Moho depths with an average of 30 km in West Antarctica, 43 km for the TAMS station and 52 km for the AGAP stations.

## Near field dynamic, co-seismic and post-seismic deformations associated with the 2013, M7.8, and 2003, M7.6, South Scotia Ridge Plate Boundary earthquakes observed with GPS

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The South Scotia Ridge (SSR) left-lateral transform fault defines the Scotia plate's (SP) southern boundary separating it from the Powell Basin (PB), South Orkney Microcontinent (SOM), and the Weddell Sea sections of the Antarctic plate (AP). The SP developed as a space filling accommodation zone for S. America-Antarctica relative motions, mostly during the last 40 m.y. The SSR also hosts several restraining and releasing bends. The SP, PB and SOM have complex evolution histories including large-scale displacement and stretching of the SOM, as well as other continental fragments within the SP, all of which were incorporated into a background of changing sea floor spreading geometries.

The SOM defines an ~300 km segment of the SSR opposite a section of the SP that is primarily oceanic crust with a few small, stretched continental fragments. Two large earthquakes, M7.6 and 7.8, with aftershock zones largely confined to the northern SOM boundary, occurred on the SSR in 2003 and 2013. Moment tensor solutions show they occurred on faults dipping ~30 and 45° to the south. The 2013 event was almost pure, left-lateral strike-slip, while the 2003 event was oblique but predominantly strike-slip. This is an unusual combination of fault dip and slip direction for a strike-slip plate boundary. The half duration of both events is also relatively long.

A continuous GPS station on Laurie Island is located immediately west of the rupture zone of the 2003 event and at the approximate center, and close to the surface projection, of the finite fault models for the 2013 earthquake. We present co-seismic static offsets and post-seismic transients for both earthquakes from GPS daily position estimates. In addition, the GPS station now records at 1 Hz and we present the GPS displacement seismogram for the 2013 event. This record contains a complex signal that includes the passage of the Love and Rayleigh surface waves, with max displacements of ~70 cm, over an ~80 second time interval during which a ~50 cm static offset developed.

## Inception and variability of the Antarctic Ice Sheet across the Eocene-Oligocene transition

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Climate cooling throughout middle to late Eocene triggered the transition from hot-house to ice-house conditions. Based on deep-sea marine  $\delta^{18}\text{O}$  values, a continental-scale Antarctic Ice Sheet (AIS) developed across the Eocene-Oligocene transition (EOT) in two ~200 kyr-spaced phases between 34.0 and 33.5 Ma.

Geochemical data and ice-sheet modelling show that AIS glaciation initiated as atmospheric  $\text{CO}_2$  fell below ~2.5 times pre-industrial values. AIS likely reached or exceeded present-day dimensions. Quantifying the magnitude and timing of AIS volume variations by means of  $\delta^{18}\text{O}$  records is hampered by the fact that the latter reflect a coupled signal of temperature and ice-sheet volume. Furthermore, bathymetric variations based on marine geologic sections are affected by large uncertainties and, most importantly, reflect the local response of relative sea level (rsl) to ice volume fluctuations rather than the global eustatic signal.

AIS proximal and Northern Hemisphere (NH) marine settings show an opposite trend of rsl change across the EOT. Consistently with central values based on  $\delta^{18}\text{O}$  records, a  $60 \pm 20\text{m}$  rsl drop is estimated from NH low-latitude shallow marine sequences. Conversely, sedimentary facies from shallow shelfal areas in the proximity of the AIS witness an 50 - 150m rsl rise across the EOT. This contrast clearly stems from glacial isostatic adjustment (GIA). Accordingly, we solve the gravitationally self-consistent Sea Level Equation for two different and independent AIS models both driven by atmospheric  $\text{CO}_2$  variations and evolving on different Antarctic topographies. In particular, minimum and maximum AIS volumes, respectively of ~55m and ~70m equivalent sea level, stem from a smaller and a larger Antarctic topography.

Minimum and maximum GIA predictions at the NH rsl sites respectively correspond to the lower limit and central value of the EOT rsl drop inferred from geological data. In general, the departures from the eustatic trend significantly increase southward toward Antarctica, where the AIS growth is accompanied by a rsl rise. Accordingly, the cyclochronological record of sedimentary cycles retrieved from Cape Roberts Project Drillcore CRP-3 witness a deepening across the EOT. Furthermore, CRP-3 record shows that full glacial conditions consistent with the maximum AIS model dimensions were reached only at ~32.8 Ma, while AIS volume fluctuations around the minimum model volume persisted during the first million years of glaciation.

## Sensitivity of present-day uplift rates to ice thickness changes in the late Holocene

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Uplift and gravity rates caused by changes in past ice thickness depend on the variation of viscosity beneath Antarctica. For low viscosity, the uplift rates become sensitive to more recent changes in ice thickness and vice versa. We use information from seismology and geology to estimate 3D viscosity. The viscosity estimates are inserted in a finite element model for GIA to enable us to study sensitivity of present-day uplift rates to ice loading changes.

First, global tomography models are combined with regional seismic data to provide information about the upper mantle beneath Antarctica. Second, shear velocities are converted to temperature for a typical mantle composition. Finally, the temperature estimates are inserted in olivine flow laws, which results in lateral variations in viscosity by orders of magnitude, and low viscosity beneath West Antarctica. To infer plausible flow law parameters we compare model predictions to GPS uplift rates and relative sea level histories at locations where the ice model is thought to be reliable. The preferred model is used to study how sensitive uplift rates at various locations are to ice thickness changes in the late Holocene.

## Using dense GPS records to constrain the ice history of the Antarctic Peninsula

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Global Positioning System (GPS) measurements of present-day land surface motions in glaciated or formerly glaciated regions can be used to infer the history of ice thickness and extent. The geologically recent glacial history of the Antarctic Peninsula is relatively poorly understood but can provide an insight into the evolution of ice sheets during deglaciation. Knowledge of deglacial load changes in the Antarctic Peninsula is required to correct observations from the GRACE satellite mission for the contribution of Glacial Isostatic Adjustment (GIA) to changes in Earth's gravity field. The uncertainties in this correction propagate into estimates of the Antarctic Ice Sheet contribution to modern globally averaged sea-level rise.

We present a study of land surface motion on the Antarctic Peninsula based on a comparison of GPS measurements with high resolution forward models of GIA. GPS data were collected from Austral summer 2010-2014 in Palmer Land, Antarctic Peninsula. The GIA models apply a suite of established and novel ice histories to a spherical Earth with visco-elastic rheology and produce predictions of present-day surface motion. This model output was used to understand the sensitivity of the observed land surface motion to changes in ice load and to assumptions concerning the deep geologic structure of the Antarctic Peninsula. We found that significant uncertainty in the modelled GIA in the Antarctic Peninsula arises from the assumed structure of the solid Earth, thus we adopted a plausible range of Earth model parameters guided by independent lines of evidence, such as studies based on seismic tomography. The results of our data-model comparison provide an evaluation of the critical timescales and magnitudes of ice sheet evolution that influence GPS observations in the Antarctic Peninsula.

## **GIA and GPS: How does 3D Earth structure influence the pattern of horizontal deformation across Antarctica?**

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Lateral variations in Earth structure have been shown to play an important role in determining the solid Earth response to ice loading and unloading, particularly with reference to horizontal deformation. The pattern of present-day horizontal deformation across Antarctica, as measured by GPS receivers, is currently poorly understood, and does not match predictions derived from Glacial Isostatic Adjustment (GIA) models that only consider radial variations in Earth properties.

In this study we investigate the effect of including 3D variations in Earth structure on predictions of present-day horizontal deformation across Antarctica. Seismic data collected as part of the POLENET program are used in combination with global seismic data to define a 3D model which forms the solid Earth component of a GIA model. The model is forced using the W12 and ICE-5G deglaciation models, which are implemented within the sea-level equation to determine surface load changes throughout the last glacial cycle. We explore the sensitivity of model predictions to choices made during the construction of the 3D Earth model, and compare our results with the present-day pattern of horizontal deformation across West Antarctica as observed by the POLENET GPS network.

## New Antarctic seismic structure models and implications for solid-earth ice sheet interactions

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The structure of the earth beneath ice sheets controls many factors influencing ice sheet dynamics, including geothermal heat flow into the base of the ice sheet and the timescale and amplitude of isostatic response to ice mass change. Recent broadband seismic deployments, including the AGAP/GAMSEIS array of 26 broadband seismographs in East Antarctica and the POLENET/ANET deployment of 34 seismographs in West Antarctica, reveal the detailed crust and upper mantle structure of Antarctica for the first time. The seismographs operate year-around due to insulated boxes, power systems, and modified instrumentation developed in collaboration with the IRIS PASSCAL Instrument Center. We use Rayleigh wave phase velocities at periods of 20-180 s determined using a two-plane wave decomposition of teleseismic Rayleigh waves to invert for the three dimensional shear velocity structure. In addition, Rayleigh wave group and phase velocities obtained by ambient seismic noise correlation provide constraints at shorter periods and shallower depths.

The new results show that the Gamburtsev Mnts in East Antarctica are supported by 55 km thick crust, and are underlain by thick Precambrian continental lithosphere that initially formed during Archean to mid-Proterozoic times. The absence of lithospheric thermal anomalies suggests that the mountains were formed by a compressional orogeny during the Paleozoic, thus providing a locus for ice sheet nucleation throughout a long time period. In West Antarctica, the crust and lithosphere are extremely thin near the Transantarctic Mountain Front and topographic lows such as the Bentley Trench, which represent currently inactive Cenozoic rift systems. Slow seismic velocities beneath Marie Byrd Land at asthenospheric depths suggest a major thermal anomaly, possibly due to a mantle plume. We investigate several different parameterizations for inferring heat flow, lithospheric thickness and mantle viscosity from seismic velocity models and apply them to the 3D shear velocity models of Antarctica. Extremely high heat flow is predicted for much of West Antarctica, consistent with recent results from the WAIS ice drilling. We find large variations in lithospheric thickness, with East Antarctica showing thick lithosphere and the West Antarctic Rift System (WARS) showing almost no lithosphere. Older geological regions that were reactivated during the Phanerozoic, such as the Ellsworth-Whitmore mountains, show intermediate lithospheric thickness. We also infer several orders of magnitude difference in viscosity between East and West Antarctica, with lowest viscosities found beneath Marie Byrd Land and the WARS. Realistic glacial isostatic adjustment models must take these large lateral variations into account.

## The POLENET-ANET integrated GPS and seismology approach to understanding glacial isostatic adjustment in Antarctica

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The POLENET-ANET project is simultaneously resolving crustal motions, measured by GPS, and earth structure and rheological properties, mapped by seismology. Measured vertical and horizontal crustal motion patterns are not explained by extant glacial isostatic adjustment (GIA) models. These models have ice histories dominated by ice loss following the Last Glacial Maximum (LGM) and rely on 1D earth models, with rheological properties varying only radially. Seismological results from POLENET-ANET are revealing significant complexity in lateral variation in earth properties. For example, crustal thickness variations occur not only across the East-West Antarctic boundary, but also between crustal blocks within West Antarctica. Modeling of mantle viscosity based on shear wave velocities shows a sharp lateral gradient from high-to-low viscosity in the Ross Embayment, a much more gradual gradient in the Weddell Embayment, and very low viscosities below Marie Byrd Land and the Amundsen Sea Embayment (ASE).

Remarkable vertical and horizontal bedrock crustal motion velocity magnitudes, directions and patterns correlate spatially, in many aspects, with earth property variations mapped by seismology. Within the ASE, extremely high upward velocities are flanked by subsiding regions – neither predicted by GIA models. Given the thin crust and low mantle viscosity, it is likely that this is not an LGM signal, which would have already relaxed, and uplift modeled as the elastic response to modern ice mass change can't explain measured rates. As in other regions where rapid GIA-induced uplift has been measured, the crustal velocities in the Amundsen Embayment likely record a viscoelastic response to ice loss on decadal-centennial time scales. Along the East-West Antarctic boundary in the Ross Embayment, GIA-induced horizontal crustal motions are *toward*, rather than away from, the principal ice load center, correlating spatially with the strong lateral gradient in mantle viscosity. In the Weddell Embayment region, where crustal thickness is intermediate between East and West Antarctica and mantle viscosity values are moderate, crustal motions show the best match with predictions of GIA models. It is clear that lateral variations in earth properties fundamentally control the isostatic response to ice mass changes in Antarctica. Ongoing, integrated seismic-GPS studies are critical to developing the next generation of GIA models.

## Seismic observations of Beardmore Glacier, Antarctica

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We report initial results of our project to determine the dynamic sensitivity of outlet glaciers to forcing at the grounding lines in order to assess the contribution of East Antarctica to sea-level rise when the surrounding ice shelves collapse. In this project, the specific focus is Beardmore Glacier, an outlet glacier that discharges into the Ross Ice Shelf. Goals are to address the following: What is the magnitude and spatial pattern of basal resistance? What are the bed conditions? Does basal motion occur through sliding over a hard bed or deformation of basal sediments? What controls the spatial and temporal patterns of sliding and basal drag? How will collapse of the Ross Ice Shelf affect the flow of outlet glaciers? How fast and how much ice could be drawn down from East Antarctica? In this presentation, we focus on initial active source seismic observations. First results from seismic measurements revealed that ice in the vicinity of camp is up to 3100 m thick. Surface elevation of the camp is 910m; the bed of the glacier there is more than 2200 m below sea level. Surface velocities in this region are ~300 m/yr. Such a deep trough has also been detected on Byrd Glacier by a recent CReSIS airborne radar survey. These deep troughs exert strong influence on the dynamics of outlet glaciers. In contrast, ice thickness on the slow-moving (~50 m/yr), "sticky spot" is only 900- 1000 m. Change in ice thickness is the primary control in the observed pattern of surface velocity.

## Observations of normal mode coupling below 4 mHz at the South Pole

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Strong coupling of free oscillations, between fundamental spheroidal and toroidal modes (S-T coupling), below frequencies of 3 mHz is mainly caused by Earth's rotation. Significant rotational S-T coupling should not occur at QSPA, a permanent IRIS/USGS station located at the South Pole, as Coriolis force comes near zero at the polar region. However, we have found that strong S-T coupling are occasionally observed in the early period (less than 24 hours) following some recent large earthquakes. One typical example is significant coupling of 0S11-0T12 observed at QSPA after the 2011/03/11 Mw=9.1 Tohoku earthquake. The coupling is also observed at P061, a temporary station close to South Pole, but it is not identified at global stations located along the great circle paths connecting QSPA and the epicenter, suggesting that the strong coupling is caused by a local structure beneath the polar region. It is noted that non-rotational coupling 0S24-0T24, 0S25-0T25 and 0S26-0T26 are also identified at QSPA after some recent large earthquakes. Our extensive observations suggest that the local azimuthal anisotropy beneath the South Pole may be the main cause for strong S-T coupling at QSPA.

## Structure of the Marie Byrd Land crustal province from GIMBLE aerogeophysics

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Coastal Marie Byrd Land (MBL) represents a region of elevated terrain associated with the West Antarctic Rift System, which underlies the West Antarctic Ice Sheet (WAIS). It likely provides a key point for both the inception and the stabilization of the generally marine based WAIS during the Neogene, however, the nature and evolution of MBL are still unclear.

The presence of subaerial volcanos and geological evidence for bed rock elevation increase over the late Cenozoic have lead to the interpretation of MBL as a Neogene hotspot dome analogous to that seen in East Africa. An alternative explanation is that MBL is the northern rift flank of the Mesozoic WARS that originated during the Cretaceous extension and lead to the detachment of New Zealand from this sector.

Discerning between these interpretations and testing the hotspot hypothesis is especially important for understanding geothermal heat flow under WAIS, and therefore key for understanding melt water production and ice sheet lubrication.

For these reasons, MBL has been a target of POLENET investigations.

Here we present results of the first aerogeophysical survey targeting MBL specifically, integrated into reprocessed regional aerogeophysical data. The first season of the GIMBLE survey took place in January 2013. Ice penetrating radar demonstrate evidence for deep tectonic and erosional dissection of the Marie Byrd Land massif, and locate evidence for recent volcanic activity in MBL from bright layers within the ice, and subglacial edifices. Magnetics data combined with the radar data provide further evidence for local subglacial volcanism. Finally, airborne gravimetry interpreted in the context of POLENET results indicate that the crustal structure of MBL is complex but distinct from that of the broader WARS. No clear bounding fault can be identified, which provides a line of evidence against the rift flank hypothesis

The second season of GIMBLE will take place in December 2014, and will specifically target the proposed rift flank region at high resolution.

## **S06: STATUS AND TRENDS IN ANTARCTIC SEA ICE AND ICE SHELVES**

### **Antarctic sea ice and ice shelves: status, trends, processes and interactions**

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The overall circumpolar extent of Antarctic sea ice has increased over the last three and a half decades while, over the same period, many Antarctic ice shelves have thinned, and some have collapsed completely. But with both sea ice and ice shelves there are significant regional differences in the changes around Antarctica. For example, the maximum extent of sea ice and its seasonal duration have increased in some sectors but decreased in others. Some of the regional differences appear to be driven by atmospheric and oceanic processes and interactions which are also regional.

Ice shelves and floating ice tongues fringe more than 70% of the Antarctic coastline and buttress the flow of grounded ice from the margin of the Antarctic ice sheet. Most of those ice sheet drainage basins which are currently losing mass, and contributing to global sea level rise, drain to the ocean via ice shelves that are thinning. In many of these cases there is also evidence that the grounding line is retreating inland. Antarctic ice shelf thinning is predominantly a result of enhanced submarine basal melting, driven by warmer ocean waters circulating beneath the shelves. The changes to ocean properties and circulation within ice shelf cavities may in turn be driven by changes in the atmosphere, as well as by associated changes in sea ice production. Inter-annual to decadal variability in the size and rate of sea ice production in latent-heat polynyas around the Antarctic coast is one important influence on the properties and seasonality of oceanic circulation and basal melt within ice shelf cavities. This and other close links and feedbacks between atmosphere, ocean, sea ice, ice shelves (and ultimately ice sheet mass loss) in the Antarctic coastal margin will be explored and reviewed in this presentation.

## Sedimentary geochemical markers to identify deglaciation of the South Shetland Islands Ice Cap

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A 2.5m long core collected from Admiralty Bay on King George Island, one of South Shetland Islands, West Antarctica were used to reconstruct the environmental conditions of the bay and to link the marine record with deglaciation of the South Shetland Islands Ice Cap. The core, sampled every 2 cm, were analyzed for %COT,  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ , %CaCO<sub>3</sub>, metals and biomarkers compounds (*n*-alkanes, steroids, and *n*-alcohols). Based on the results the core can be divided in two sections: unit I below 156 and unit II above 156 cm. Unit I has lower values of COT and *n*-alkanes (averages 0.04% and 810 ng g<sup>-1</sup>), but higher values of %CaCO<sub>3</sub> (average 11.6%), while Unit II has higher values of TOC and *n*-alkanes (averages 0.29% and 1385 ng g<sup>-1</sup>), but lower values of %CaCO<sub>3</sub> (average 9.6%). The low values of COT and *n*-alkanes in Unit I suggest low surface-water productivity probably due to glacial advance at that time. The higher values of CaCO<sub>3</sub> in Unit I can be associated to the presence of surface ice that would limit CO<sub>2</sub> exchange between ocean and atmosphere. Thus, dissolution of CaCO<sub>3</sub> in sediment would be minimal. The increase of COT and *n*-alkanes levels in Unit II can be an indicative of deglaciation when the melt water inflow rise and increased surface production. Also due to a possible deglaciation, the exchange of CO<sub>2</sub> between ocean and atmosphere would increase as indicated by decrease in CaCO<sub>3</sub> values.

## Changes in ice dynamics of Wilkins Ice Shelf

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Wilkins Ice Shelf has undergone dramatic changes since the beginning of the 1990's. Several break-up events occurred resulting in considerable area loss and changes in backstress. The ice shelf is characterized by a very distinct geometry and a large number of ice rises partly stabilizing, but also partly nuclei for fracture and rift development. We investigate the adjustment of surface velocities to changes in frontal positions using data from various SAR satellite missions (ERS-1/2 SAR, ENVISAT ASAR, ALOS PALSAR, TerraSAR-X). Flow fields were derived using intensity feature tracking on various concatenated scenes along a track. Masking of sea areas, fast flowing and rapidly changing areas increased coregistration accuracy of the data and considerably improved the velocity products. While the L-band data from ALOS PALSAR provided repeat coverage with mostly very reliable results, the C-Band data showed strong decorrelation effects. Nevertheless, we could derive a set of velocity fields that support further analysis of the break-up event and the investigation of potential mechanisms.

## Continuing changes in Ross Sea Temperature, salinity and $\delta^{18}\text{O}$ : Evidence for Accelerating Glacial Melt

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The Ross Sea, Antarctica, lies adjacent to the world's largest floating ice shelf, the Ross Ice Shelf (RIS), that forms from continental ice drainage from both East and West Antarctica. There are conflicting views regarding whether (and where) the Ross Ice Shelf may be losing mass. Physical and isotopic observations from the Ross Sea water column extend back into the 1960's, providing a long and rich data set against which to compare recent observations. Here we focus on properties that allow evaluation of the contribution of melting glacial ice to the changing salinity of the Ross Sea. Seawater  $\delta^{18}\text{O}$  values, paired with precision measurements of Salinity and Temperature extend back to 1977 some of which are summarized in Jacobs et al. (1985, 2002). Here we present 2 new data sets collected by hydrocast in the Ross Sea during cruises aboard the RVIB Nathaniel B. Palmer in 2006/2007 and 2014. We produced over 800 new seawater  $\delta^{18}\text{O}$  measurements, all from samples that were independently measured for Salinity using the shipboard AutoSal or PortaSal systems. We compare these new data sets to previously published  $\delta^{18}\text{O}$  values along with T and S. We observe continued freshening and slight warming of many of the Ross Sea subsurface water masses identified by Jacobs et al. and particularly in High Salinity Shelf Water (HSSW). Mean salinities observed in HSSW decreased by about 0.06 between the 1970's and 2006/2007. We observed a further decrease in S of about 0.04 between 2006/2007 and 2013. Declining HSSW Salinity is accompanied by continuing declines in seawater  $\delta^{18}\text{O}$ , from mean values of  $\sim -0.42\text{‰}$  in the 1970's to  $\sim -0.55\text{‰}$  in 2006/2007 to  $\sim -0.72\text{‰}$  in 2013. Examination of water mass evolution pathways involving mixing of Circumpolar Deep Water with shelf water masses and with low salinity waters derived from precipitation and glacial ice melt suggests a large and increasing contribution of freshwater derived from melting glacial ice, most likely from the RIS. We also compare stable isotopic composition, T, and S profiles recorded at a long time series station north of Ross Island as well as several transects from along the front of the Ross Ice Shelf. This work suggests continuous and accelerating freshening of the Ross Sea water column in part due to melting continental ice, despite the observation of increased sea ice extent during the past decade.

## Long-term statistics of coastal polynyas in the Weddell-Sea using satellite-based thermal infrared thin-ice retrievals

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We derived long-term statistical polynya parameters such as polynya area and ice-production rates from thin-ice thickness composites that were derived from high-resolution infrared MODIS imagery. So far, only short-term investigations were done using infrared spaceborne measurements, while this study is based on a twelve year investigation period (2002-2013) in the Weddell Sea region. The focus lies on the coastal polynyas which are important hot spots in new-ice formation. They influence the bottom-water formation and also act as biological habitats. The here used MODIS data has the capability to resolve even very narrow coastal polynyas which would stay otherwise undetected in comparison to coarse resolution passive microwave imagery. Its major disadvantage is the sensor limitation due to cloud cover. We present simple pre- and post-processing steps to account for missing spatial coverage as a result of cloud covered areas. Our findings are discussed in comparison to recent studies based on passive microwave imagery as well as model-based studies investigating polynya areas and ice-production rates in different parts of the Weddell Sea.

## Polynya formation and ice production in the Weddell Sea

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The Weddell Sea is known as one of the most active regions of polynya developments around the Antarctic continent. Low temperatures are prevailing particularly in winter and lead to strong ice production and the formation of high salinity shelf water. The Ronne Ice Shelf polynya is was found to be the most important polynya for these processes. It is generally recognized that polynya formations are primarily forced by offshore winds and secondarily by ocean currents. Many authors have addressed this issue previously at the Ross Ice Shelf and Adélie Coast and connected polynya dynamics to strong katabatic surge events. Such investigations of atmospheric dynamics and simultaneous polynya occurrence are still severely underrepresented for the southwestern part of the Weddell Sea and especially for the Ronne Ice Shelf. Due to the very flat terrain gradients of the ice shelf katabatic winds are of minor importance in that area. The forcing by synoptic systems or atmospheric processes therefore play a crucial role in polynya developments at the Ronne Ice Shelf.

High-resolution simulations have been carried out for the Weddell Sea region using the non-hydrostatic NWP model COSMO from the German Meteorological Service (DWD). For the austral autumn and winter (March to August) 2008 daily forecast simulations were conducted with the consideration of daily sea-ice coverage deduced from the passive microwave system AMSR-E. These simulations are used to analyze the synoptic and mesoscale atmospheric dynamics of the Weddell Sea region and find linkages to polynya occurrence at the Ronne Ice Shelf.

Seven significant polynya events are identified for the simulation period, three in the autumn and four in the winter season. It can be shown that in almost all cases synoptic cyclones are the primary polynya forcing systems. In most cases the timely interaction of several passing cyclones in the northern and central Weddell Sea leads to maintenance of a strong synoptic pressure gradient above the Ronne Ice Shelf. This strong synoptic forcing results in a moderate to strong offshore surface wind. It turned out that these synoptic depressions lead to strong barrier winds above the northwestern Ronne Ice Shelf and along the eastern flank of the Antarctic Peninsula. The fact, that these barrier winds often appear prior or during the initial break up of sea ice at the shelf ice edge, suggest that this mesoscale wind phenomenon plays a crucial role for polynya development. Furthermore, mesoscale cyclones contribute to the break-up of the sea-ice under large-scale stationary weather conditions.

## Tidal bending and strand cracks at the Kamb Ice Stream grounding line, West Antarctica

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An extensive set of shore-parallel fractures are observed at the grounding line of Kamb Ice Stream (KIS) in West Antarctica. The cracks are far more pervasive at the KIS grounding line than at the nearby Whillans Ice Stream (WIS) grounding line. Fracture propagation is heard (and felt) at the KIS grounding line during the falling tide. We use field observations together with models of elastic bending and fracture propagation to establish that bending on the falling tide favors propagation while bending on the rising tide suppresses propagation, and that only near the grounding line is the combination of stresses associated with viscous deformation and tidal bending large enough to produce strand cracks. Differences in basal boundary conditions across the KIS and WIS grounding line transitions (stagnant to floating vs. fast-flowing to floating) are likely the cause for differences in strand crack appearance at the two locations.

## Storm-induced sea ice breakup and the implications for ice extent

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Energy propagation from large storm-driven waves through sea ice has previously been unmeasured. Here we present the first set of concurrent observations at multiple locations in Antarctic sea ice. These show that storm-generated ocean waves propagating through sea ice are able to transport enough energy to break first-year sea ice hundreds of kilometres from the ice edge. This is further than was previously believed possible. We observed the wave height decay for large waves, those with a significant wave height greater than 3 m, to be linear. This implies a more prominent role for large ocean waves in sea ice breakup and retreat than previously thought. We examine the relevance of this by comparing observed Antarctic sea ice edge positions with changes in modelled significant wave heights for the Southern Ocean between 1997 and 2009, and find the sea ice edge retreat (expansion) correlates with mean significant wave height increases (decreases). It also captures the spatial variability found in the Ross and Amundsen-Bellinghousen Seas. Our results highlight that with climate models failing to capture changes in sea ice in both polar regions, the absence of either explicit or parameterized ocean wave-sea ice interaction models within a climate scale model is a significant omission.

## **An integrated physical and biological study on land-fast sea ice: the effects of proximity to an ice shelf**

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Land-fast sea ice (fast ice) forms adjacent to the coast. During winter it surrounds most of the Antarctic continent and greatly affects energy and material fluxes between the ocean and the atmosphere. It is held in place by the land, an ice shelf or other feature, and generally increases in thickness due to loss of thermal energy to the atmosphere. However in regions where it abuts an ice shelf there is also a contribution to thickness from the very cold water that emerges from deep in the ice shelf cavity. The dependence of fast ice upon these purely thermodynamic processes means that its maximum thickness is likely to be a sensitive indicator of climate change. Fast ice is also an important structural component of Antarctic coastal ecosystems, providing a habitat for diverse microbial communities.

In some cases fast ice is accessible from research stations that may be staffed throughout the year. Consequently studies are usually restricted to small geographic regions, providing location-specific knowledge. To broaden our understanding of fast ice, international coordination was inaugurated in 2007 through the Antarctic Fast Ice Network (AFIN). The aim of AFIN is to monitor land-fast sea ice around Antarctica and to make these observations available to a larger community. In this contribution to AFIN we seek improved understanding of the seasonal formation of Antarctic fast ice at remote sites in the New Zealand and Australian sectors, which include a variety of physical settings. Based on these *in situ* physical measurements, we will ultimately develop an observation-based algorithm for estimating land-fast sea ice algal biomass. By collating our results with historical measurements, the ultimate aim is to recognise the early signs of the response of fast ice to climate warming.

Mass balance stations, supplied by New Zealand and Australian scientists, will make simultaneous measurements at Scott Base in the Ross Sea and at Mawson and Davis stations in East Antarctica. They will provide the seasonal evolution of a vertical temperature profile, from atmosphere to ocean. Such measurements allow us to derive sea ice growth rate, and atmospheric and oceanic heat flux from the time the buoys are deployed in mid winter. Here we describe initial measurements from this study and compare them with measurements made in previous years at Australian and New Zealand sites.

## Continuous GPS measurements on the Drygalski Ice Tongue, Antarctica

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Velocity and thickness variations of the Drygalski Ice Tongue on the west side of the Ross Sea were analyzed from two AMIGOSs (Automated Meteorology-Ice/Indigenous species-Geophysics Observation System) and Landsat images. The continuous GPS measurements since early 2012 present the ice velocities of ~705 m/yr at KA1 (near the ice front) and ~697m/yr at KA2 (25 km upstream of KA1) site. The ice tongue is stably flowing with residual displacements in the range of 5m. We found small motions related with the drag by wind force and irregular transverse motion with several meters amplitude in August 2012 and January 2014. According to the analysis of past Landsat images, there was a big change of flow direction in 2007. The flow direction change may imply the variation of ocean circulation or sea ice near the ice tongue.

The elevation observed by GPS is gradually lowering for two years. The snow accumulation, firm compaction, dynamic deformation by strain, and basal melt affect the elevation of the surface on which the AMIGOS was installed. We removed other effects except for basal melt using the accumulation rate observed from the continuous camera images of a stake on snow, the strain rate determined from the velocities at two AMIGOSs, and the previous estimates of firm compaction. The basal melt rates beneath the KA1 and KA2 are about 3 m/yr and 2m/y respectively. The new basal melt estimates beneath the Drygalski Ice Tongue are significantly larger than the basal melt in a steady state (~0.76 m/yr). The accelerated basal melt is a quite recent event because the ICESat elevation measurement from 2003 to 2009 does not show a significant thinning as our in-situ measurement.

## Seasonal variation of double frequency microseisms and its application to monitor sea-ice variability in the Ross Sea, Antarctica

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Korea Polar Research Institute has been operating a broadband seismic network in the Terra Nova Bay, Antarctica, since 2011. Examining ambient seismic noise level using power spectral analysis for the period of 2011-2013, we observed a seasonal pattern at 4-10 s period. The amplitude of double-frequency (DF) microseism reaches an annual minimum in July. Correlation of the DF energy and Sea-Ice Concentration (SIC) information obtained from the AMSR-E (Advanced Microwave Scanning Radiometer for EOS Aqua), we found a strong negative correlation. The result implies that as the SIC becomes higher, i.e. more sea-ice in the ocean, the DF power decreases, which is coincident with the hypothesis of 'sea-ice damping effect'. We also determined the lag time as almost zero from the cross correlation indicating that the DF energy responses immediately to the sea-ice condition nearby. In this study, we propose that a long-term observation of the DF microseisms should be necessary to monitor local climate change in Polar Regions, which contributes extra benefits to the satellite remote sensing.

## Snow precipitation, accumulation, and redistribution on Antarctic sea ice

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Snow plays a critical role in Antarctic sea ice mass balance, yet there have been very few measurements of snow accumulation and the processes that control its distribution on sea ice. We present data on snow accumulation, distribution, and blowing snow from two recent cruises to the East Antarctic and Weddell Sea ice pack. To examine the three-dimensional distribution of snow and its relationships with ice surface morphology, snow depth and surface elevation were measured through a combination of high-resolution terrestrial lidar scanning and gridded snow depth surveys at 1-3m resolution. These data allow relationships between surface roughness features and snow accumulation to be examined in unprecedented detail. Contemporaneous with these data, weather stations were installed on the ice to monitor wind profiles, precipitation, and blowing snow, providing information on driving forces controlling the snow distribution. To extend these time series of snow accumulation and redistribution, autonomous weather stations capable of monitoring accumulation, precipitation, blowing snow, and meteorological data were deployed alongside ice mass balance buoys and snow depth buoys on five floes – two in the East Antarctic in October-November, 2012, and three in the Weddell Sea in June-August, 2013. These data are compared to estimates of precipitation from atmospheric reanalyses. These observations show that precipitation is not necessarily a good estimator for snow accumulation, with the latter depending strongly on local surface morphology and meteorological conditions. This suggests that treatment of blowing snow must be included before sea ice models will accurately simulate Antarctic snow and sea ice mass balance.

## **A remote sensing based ice-shelf crevasse detection and analysis: a case study on the Amery Ice Shelf, East Antarctica**

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There is an increasing need to understanding calving process due to iceberg calving as one of the major mass loss paths. However, not enough measurements of crevasse properties are provided for a calving model. A cross-interferometry-based digital elevation model (DEM) of ice shelves at a resolution of 25 m derived from highly coherent ERS-ENVISAT data pairs provides a possibility to detect detailed properties of crevasses using remote-sensing. We present a remote-sensing method to detect crevasse location, width, length, depth, orientation and strain rate, and have a case study on the Amery Ice Shelf (AIS). The results show that the complexity of crevassing on the AIS is beyond expected: (1) The occurrence of strike-slip motion proposed a mixed-mode of the tensile and sliding. (2) Three types of crevasses identified suggest basal topography and strain rate are two key factors to the ice-shelf crevasse formation. (3) Interactions exist between older re-existing crevasses and newly formed crevasses. (4) The spacing between crevasses formed at a fixed place is likely to be used for tracking the history of velocity or strain rate field. (5) The suture zones have important impact on the crevassing. (6) The relationship between crevasses and breakups at ice-shelf front indicates that the great threat to breakups of the Amery ice shelf only comes from the crevasses formed by ice flowing over basal obstructions near the ice-shelf front. The other crevasses formed far from the ice front have little impact on the ice-shelf breakup and limited contribution to the propagation of rifts. This investigation can be used to test crevasse-depth models and improve a calving law for an ice shelf or ice sheet model.

## Climate driven enhanced calving of retreating Antarctic ice shelves

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Iceberg calving from Antarctic ice shelves occurs both for ice sheet-shelf systems in balance and for systems undergoing change. Rapid changes to calving rates can result from the episodic nature of long-term stable ice sheet-shelf systems, or can be caused by changing forcing, in which case they may be indicative of ongoing change and possibly a regime shift. Quantification of iceberg calving styles and spatial distribution can identify vulnerable ice shelves and help to establish links between calving and climate-related forcing, such as ocean-induced ice shelf melt. Here we use multi-source satellite data and model derived products to provide a first direct empirical estimation of iceberg calving rates, classified according to two distinct styles, and thence the mass balance of all Antarctic ice shelves. Between 2005 and 2011 we estimate an iceberg calving rate of  $755 \pm 24$  gigatonnes per year (Gt/yr), and derive a basal melt rate of  $1516 \pm 106$  Gt/yr. Net Antarctic ice shelf mass balance is slightly positive, as giant ice shelf advance dominates retreat of smaller systems. For ice shelves in negative mass balance, loss mainly due to melt-induced calving (302 Gt/yr) is as important as from basal melting (312 Gt/yr), underlining that climate forcing is causing this retreat.

## Cloudiness and sea ice mutual variations in the Antarctic and Arctic

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Mutual changes of clouds and sea ice extent in polar latitudes based on observations and reanalyses for last decades and CMIP5 multi-model simulations are analyzed. Different datasets are used, including satellite data ISCCP, PATMOS-x, CM SAF for clouds.

We performed a comparative analysis of the relationship of clouds and sea ice extent in the annual cycle and interannual variability in the Antarctic (55-70°S) and Arctic (70-90°N) with the use of cross-wavelet analysis.

In addition, we assess possible tendencies of change in the relationship of clouds and sea ice extent in the Antarctic and Arctic from multi-model simulations with the RCP scenarios for the 21<sup>st</sup> century.

## Antarctic sea ice response in ensemble CMIP5 historical and ozone perturbation simulations

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Antarctic sea-ice trends from three CMIP5 modelling systems are compared with observations. Several hypotheses advanced to explain the recent small positive trend in overall extent are investigated. In the CSIRO Mk3.6 system, area-weighted trends match the observations in some of the ensemble members. Whilst the CSIRO results with ozone forcing are more realistic, with regional patterns being enhanced in the Bellingshausen and Weddell seas and East Antarctica, we do not exclude the hypothesis that the current positive trend is due to natural variability. The regional patterns of ice advance and mid-winter ice maximum are well represented in the ACCESS modelling system and are driven by atmospheric pressure, air and ocean temperature trends; inclusion of ozone forcing did not have a discernible signal. The results do not support a hypothesis for regions of positive ice concentration trends being driven by increased stratification from sea-ice melting.

## Seismic constraints on the glaciology, oceanography, and geology of the Pine Island Glacier ice shelf region, West Antarctica

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Pine Island Glacier exhibits some of the largest ice mass loss in all of Antarctica, even though it is currently buttressed by a small ice shelf. Warming ocean waters are potentially threatening the future of the ice shelf, which could lead to even greater ice mass loss from this sector of the West Antarctic Ice Sheet in the future. However, the ability to accurately model how these warm waters will interact with the ice shelf is dependent on constraining ocean circulation patterns beneath the ice shelf, which requires detailed information on the shape of the sub-ice-shelf ocean cavity. We present new constraints on the geometry of the ocean cavity beneath the Pine Island Glacier Ice Shelf, Antarctica, from seismic measurements collected across the ice shelf.

During the 2012/13 Antarctic field season, the first active seismic observations of the ocean cavity and seafloor geology beneath the Pine Island Ice Shelf were made in an effort to better constrain the geometry of the ocean cavity beneath the ice shelf and improve ice-ocean modeling studies. 55 point observations were made across the ice shelf and approximately 14-line-kilometers of seismic reflection data were collected across the ice shelf. These data point to an ocean cavity ranging in thickness from <200 m along a seafloor high beneath the ice shelf to >600 m in some localities. The seismic reflection profile data also reveal bands of internal water reflectors that likely arise from temperature and salinity variations due to ocean circulation patterns. The three-dimensional shape of this cavity, coupled with the seismic profile data and oceanographic measurements made at three locations across the ice shelf, will provide modelers with the ability to model ocean circulation beneath the ice shelf and predict its fate in a warming climate.

## **The influence of the largescale atmospheric circulation on Antarctic sea ice during ice advance and retreat seasons**

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Using observed sea ice concentration data this research isolates distinct regions of sea ice variability around Antarctica and determines advance and retreat seasons for each of them. The latter are then statistically linked with observed geopotential height data to determine the atmospheric circulation mechanism most closely associated with the sea ice seasons. The Amundsen Sea Low, the Southern Annular Mode, Zonal Wave Three and ENSO, are shown to influence different regions of sea ice around the continent. The timing of their influences vary and these influences maybe of similar or opposing signs. The results clarify which atmospheric circulation mechanism is of primary importance to sea ice variability in the different regions around Antarctica. As these circulation mechanisms respond to a changing climate, sea ice variability around Antarctica will also change.

## Antarctic sea ice seasonality - an EOF and trend analysis

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There have been distinct and contrasting regional changes in Antarctic sea ice seasonality (day of advance, retreat and subsequent duration) since 1979/80: larger total duration in the Ross Sea, by approximately 2 months, and smaller duration in the Bellingshausen and Amundsen Seas, by approximately 3 months. Here we examine modes of variability in satellite-derived sea ice seasonality for the period 1979/80-2013/14, employing an empirical orthogonal function (EOF). We compare these modes with trends of sea ice extent and concentration, and of large-scale atmospheric indices and variables such as the Southern Annular Mode (SAM), the Southern Oscillation Index and ozone concentration. Distinct trends are found in the time series of the second principal component of advance and retreat, compared to high variability in trends for the other modes and duration. The first principal component of retreat is found to be closely related to the SAM. This study supports and enhances recent studies of others connecting trends in sea ice with dynamic atmospheric changes.

## Sensing under the ice: a strategy for sustained observations in the sea-ice zone of the Southern Ocean

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Polar regions play a critical role in setting the rate and nature of global climate variability and change through their moderation of the earth's heat, freshwater and carbon budgets. Recent studies suggest that some of the strongest climate change signals are already underway in the high latitudes. The Southern Ocean is warming more rapidly than the global average. Both the Arctic and Southern Oceans are experiencing widespread changes to water mass properties, circulation and the distribution of sea ice. Routine, sustained observations are required in order to detect, interpret and understand polar climate change. The under-ice polar oceans are some of the least well sampled and understood regions on earth and remain a 'blind spot' in the global ocean observing system.

The Southern Ocean Observing System organised an international workshop to develop a strategy for sustained observing in the Antarctic sea ice zone. The workshop was motivated by increasing evidence for rapid change at high latitudes, growing recognition of the widespread consequences of changes in the polar ocean, and advances in ocean observing technology.

A strategy for sustained observations of the ocean beneath the sea ice and in the sub-ice shelf cavity was developed. Broad-scale measurements are needed to assess heat and freshwater budgets. These observations will be provided by ice-capable profiling floats (including acoustic navigation in some regions), instrumented mammals, and ship-based sampling. As additional biogeochemical sensors become proven, a subset of the floats will include measurements needed to track the evolving ocean inventory of carbon and oxygen. A combination of tools will be used to provide the observations and understanding needed to assess the vulnerability of the Antarctic ice shelf to changes in ocean temperature and circulation: moorings and acoustically-navigated gliders will be used to measure exchange with the sub-ice shelf cavity; autonomous submarines will sample the ocean cavity directly; instruments will be deployed through boreholes at key locations to provide time series of ocean properties beneath the ice shelf; and ship-based measurements will be needed to sample the full range of water mass tracers. Acoustics are likely to play an increasingly important role, for instrument navigation, data transmission, and acoustic tomography in the sub-ice shelf cavity.

Many of these technologies are being used now, and the talk will highlight recent scientific advances enabled by under-ice observing.

## Antarctic land-fast sea ice: ice shelf influence on sea ice structure and growth rates

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More than half of Antarctica's coastline is fringed by ice shelves. Land-fast sea ice forming near ice shelves can be influenced by supercooled sea water originating from ice shelf basal melt. Although the ice shelf influenced water is only marginally less saline and the supercooling slight (of the order of 0.01 K), the effects on sea ice structure (through platelet ice formation) and growth rates are dramatic. In this presentation, a method to reconstruct changes in water masses using oxygen isotope measurements from sea ice cores is examined. Direct measurements of sea ice growth rates are used to validate the output of a sea ice thermodynamic model driven with Modern-Era Retrospective Analysis for Research and Applications (MERRA) reanalysis data, along with observations of snow depth and freeze up dates. The output of that model is used along with sea ice oxygen isotope measurements and fractionation equations to determine changes in sea water isotope composition over the course of the ice growth period. For McMurdo Sound, Antarctica in 2009, the method is at the limits of resolution for determining the presence of ice shelf influenced surface waters, and improvements to the methods are suggested for that region.

## The role of floating glaciers in interrupting Antarctic buoyant coastal currents

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One of the unique features of Antarctic coastal waters is the interjection provided by floating glaciers entering the coastal ocean. Buoyant melt water-influenced currents, bound by Coriolis, must negotiate these ephemeral structures. Recent ocean data from two floating glaciers in the Ross Dependency will be presented and contextualised using computational results from an adaptive mesh fluids solver. The two glacier tongues examined are the Erebus Glacier Tongue (EGT) and the Drygalski Ice Tongue (DIT). The two are different in scale by an order of magnitude, with the DIT as wide as the EGT is long. They both are influenced by their proximity to the Ross Ice Shelf Cavity and the evolution of the ice shelf water plume that exits this cavity in the Western Ross Sea and so forming a component of the so-called Victoria Land Coastal Current.

The observations show that, whilst the high latitude will strongly influence propagation of internal waves, there are still clear oscillation-like responses in the near-field water column to tide-glacier interaction. This, along with interaction with complex bathymetry influences local turbulent mixing. The numerics reveal the complexity of the system whereby there is a clear downstream wake zone. The recirculating wake, three-dimensional effects and sub-ice internal waves are all observed in the numerical results. While there is a clearly a flow-distortion effect in the near-field, changes to regional energetics are also influenced. Estimates of integrated dissipation suggest that these floating extensions of the Antarctic ice sheet may alter energy budgets through enhanced dissipation, and thus influence coastal near-surface circulation. Furthermore, the glaciers have the potential to influence ice shelf water by (i) modifying the transport, and/or generating new ISW water through (ii) melting at depth or (iii) through influence on the pressure history experienced by any given parcel of fluid. These all likely serve to influence the influence of the shelf cavity on sea ice production.

## The increasing extent of Antarctic sea ice

Turner J

British Antarctic Survey

Over the satellite era beginning in 1979 the extent of Antarctic sea ice has increased throughout the year, with the annual mean extent having increased at a statistically significant rate ( $p < 0.01$ ) of 1.2% per decade. However, such figures mask large regional variations, and in particular the observed decrease of ice in the Bellingshausen Sea and increase in the Ross Sea. But the increase in the Ross Sea has been critical to the overall Southern Ocean positive trend and accounts for ~84% of the net Antarctic sea ice extent increase. Between the Bellingshausen and Ross Seas sea ice anomalies are strongly correlated with changes in the near-surface wind field, although other processes, such as freshwater injection from basal ice shelf melting, oceanic change and ice-ocean feedback processes have also been suggested as controlling factors. In this area the dominant atmospheric feature is the climatological Amundsen Sea Low (ASL), with changes in the winds around the low correlating highly with changes in the sea ice. The ASL has deepened since 1979, increasing the near-surface wind speeds over the Ross Sea, especially during the spring. The climate in the region of the ASL is affected by a number of factors, including sea surface temperatures across the tropical Pacific Ocean and the phase of the El Niño – Southern Oscillation, ocean conditions in the Atlantic and the loss of stratospheric ozone. However, the ASL also has a large natural/intrinsic variability. This talk will consider the relative importance of these different factors in increasing the extent of Antarctic sea ice using observational data and model output.

## Sea-ice production estimated from under-ice floats on the Antarctic continental shelf

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Ocean and sea ice observations of the Antarctic continental shelf are sparse and consequently the physical processes and dynamics of this region are not well understood. Most historical observations are from hydrographic surveys during ice-free summers, with very few observations from under the ice during winter. The Argo program has successfully used profiling floats to observe the global ice-free oceans to a depth of 2000 m over the past 15 years. Advances in float design now give us the capability to deploy profiling floats in the seasonal ice zone. In this study, we describe the first results from polar profiling floats deployed on the Antarctic continental shelf in the Mertz polynya, Adélie Land. We use the floats in a novel way, deliberately grounding floats between profiles, in order to obtain full-depth water column profiles and to increase their residence time in a poorly observed region. The seasonal cycle of salinity reflects the formation and melt of sea ice and water mass formation. Using a salinity budget, sea-ice production is estimated monthly and seasonally over two full annual cycles (2012-2013). Sea ice production peaks in March in both years. The mean winter (March to October) ice formation rate was 2.4 cm/day in 2012 and 1.5 cm/day in 2013. These rates are lower than some previously published estimates for the Mertz Polynya, likely reflecting the decrease in polynya area and ice formation following the calving of the Mertz Glacier Tongue in 2010. The float provided the first full water column sampling in an Antarctic coastal polynya through the complete annual cycle, increasing our understanding of sea ice production and water masses and circulation in the Mertz polynya. Widespread deployment of similar floats would allow further insights into ocean – ice interaction, circulation and seasonality of the Antarctic continental shelf.

## Numerical investigation of the Ross Sea water masses with thermodynamically active sea ice/ice shelves

Tonelli M, **Wainer I**

University of Sao Paulo

Dense water formation around Antarctica plays a critical role modulating the climate, since that's where the linkage between the upper and lower limbs of MOC takes place. Assessing whether these processes may be affected by rapid climate changes and all the eventual feedbacks may be crucial to fully understand the ocean heat transport and to provide quality future projections. Applying the Coordinated Ocean-Ice Reference (CORE) interannual forcing we have run a 60-year simulation (1948-2007) using ROMS with a new sea-ice/ice-shelf thermodynamics module. Another 100-year simulation forced with CORE normal year was previously run to provide stable initial conditions. The normal year consists of single annual cycle of all the data that are representative of climatological conditions over decades and can be applied repeatedly for as many years of model integration as necessary. The 60-year forcing has interannually varying data from 1948 to 2007, which allows validation of model output with ocean observations. Both experiments employed a periodic circumpolar variable resolution grid reaching less than 5 km at the southern boundary. By performing OMP water masses separating scheme, we were able to identify the main Ross Sea water masses: Antarctic Surface Water (AASW), Circumpolar Deep Water (CDW), Antarctic Bottom Water (AABW) and Shelf Water (SW). Results are consistent with previous observational studies (Budillon et al., 2003; Orsi & Wiederwohl, 2009). From the interannual simulation we were able to estimate the freshening of the shelf and bottom waters at rates of  $\sim 0.03/\text{decade}$  and  $\sim 0.01/\text{decade}$ , respectively, consistent with the observed trends found by Jacobs & Giulivi (2010). We believe that this freshening is caused a greater flux of warm waters from the Antarctic Circumpolar Current onto the shelf of the Ross Sea, leading to glacial melting due to changes in the sea ice and ice shelf dynamics.

## The role of Antarctic sea ice in heat absorption by the Weddell Sea

Mas M, Ferrero B, **Wainer I**

OC2 – IOUSP

The Southern Ocean, especially the Weddell and Ross seas, play an important role on the exchanges between the atmosphere and the deep ocean, once these are regions of subsurface water formation, where the ocean interacts with the atmosphere and sea ice to form subsurface water masses. These regions act as a gateway that enables the deep ocean to store an enormous amount of heat with no direct contact with the atmosphere, and heat fluxes at these regions are controlled by atmospheric temperature and sea ice, which acts not only as a leading mechanism in the formation of bottom waters but also as an insulator agent between the ocean and the atmosphere.

Climate models are a powerful tool to better understand the responses of such regions in relation to interactions with the atmosphere and ice, and consequently their role in climate change. For IPCC's Fifth Assessment Report (AR5), WRCF's Working Group on Coupled Modelling has launched the fifth phase of the Coupled Model Intercomparison Project (CMIP5), which consists of a series of different models with different setups that are run with the same goal: to assess what drives the changes in climate. This is done by evaluating how realistic are model simulations of the past, analyzing future projections both in short and long time scales and understanding the differences in projections results by different models.

In this context, the aim of this study is to intercompare heat content time series of the CMIP5 climate models and try to correlate their values at different layers (surface to 300, 700 and 3000 meters) with variations in sea ice concentration and extension as well as surface atmospheric temperatures at the Weddell Sea region, in an attempt to infer if these variables may be influencing or being influenced by the increase in ocean heat content.

## Multi-year / multi-decade ice about Mertz Glacier, East Antarctica, and its temporal evolution

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Large areas of multi-year and multi-decade sea ice occur to the east of the Mertz Glacier Tongue [MGT] in East Antarctica. Measurements of the free-board height of this ice obtained by satellite-borne laser and radar altimeters indicates that the ice is many metres thick and in places tens of metres thick. Visual observations from ships of the above water layers of thick floes from the region suggest that the free-board is composed of snow. Snow accumulation rate for the region is estimated at around 1 m/y from firn core data retrieved from the large iceberg B09B when it was grounded to the east of MGT. So the primary process contributing to the large thickness of the floes appears to be accumulation of snow at the surface and flooding to create snow-ice.

The thick ice in the region has been described as land-fast, however long fractures do form through the ice-field and allow the ice to diverge somewhat and move. But, the ice floes typically remain in place. They converge again, and export of ice appears to occur rarely. Re-location of iceberg B09B and calving of MGT in early 2010 brought about major changes. Large sections broke-up and drifted out to the west through what was the location of the Mertz Glacier polynya. The breakup and melting of the snow cover introduced a fresh-water pulse into the upper layers of the ocean in the region. We derive the temporal evolution of the spatial distribution of this thick ice and its growth through analysis of time series of SAR images and altimeter data from ICESat and CryoSat-2.

## S07: DEVELOPMENTS IN THE UNDERSTANDING OF SUBGLACIAL AQUATIC ENVIRONMENTS

### Preliminary results of chemical analyses of Lake Vostok water refrozen in borehole 5G-1 following the unsealing of the lake

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One year after the lake's unsealing, the first samples of refrozen lake water have become available. A new, 122m-long ice core taken from a depth of 3415-3543m was obtained in spring 2013. Drilling stopped at 227m above Lake Vostok. The top of the refrozen material was represented by a foam-like hydrate compound. This was identified as a mixed clathrate hydrate of lake gases and hydrofluorocarbon densifier. The secondary ice had a heterogeneous, radial-beam texture, with the concentration of gaseous and liquid inclusions increasing towards the borehole axis.

A few horizontal thick sections of the secondary water ice were analysed using chromatography and GC-MS, with focus on the modified organic species of drilling fluid, which may give additional information on the properties of the lake water.

It was shown that ice core samples of the secondary water ice selected on its vertical profile, contain minor inclusions of drilling fluid, and the presence of this fluid means that we unfortunately cannot obtain authentic data about the initial chemical composition of the lake water. Essential variations in structure of drilling fluid components were established during studying the central channel of the core. It is assumed, that reactions which have led to similar transformations, can be connected with the high content of oxygen in lake water.

Elemental analysis of the cleanest samples showed increased concentrations of some elements. But because the samples were contaminated with drilling fluid, it is not possible to come to any firm conclusions about the composition of the lake water.

## **Subsurface imaging reveals aquifer beneath an ice-sealed Antarctic lake**

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We use ground penetrating radar (GPR) and a helicopter borne time-domain electromagnetic (TDEM) survey to interpret the presence of highly saline brine beneath Lake Vida, in the McMurdo Dry Valleys, East Antarctica. The GPR signals penetrated 20 m into lake ice and facilitated bathymetric mapping of the grounded ice. The TDEM survey revealed a low resistivity zone 30-100 m beneath the lake basin. Based on previous knowledge of brine chemistry and local geology, we interpret this zone to be an isolated and confined aquifer situated in unconsolidated sediments with a porosity of 23-42%. Our results facilitate the modeling of hydrologic processes in an ice-sealed environment, provide a better understanding of historic conditions in the Dry Valleys, and reveal a system where liquid water may act as microbial refugia beneath a cold, desert environment.

## Subglacial lakes and estuaries – geophysical observations of subglacial hydrology beneath Whillans Ice Stream

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Water beneath Whillans Ice Stream flows through a system of active subglacial lakes via a poorly-known drainage system before discharging across the ice sheet grounding zone into the sub ice-shelf cavity. Here we present active source seismic and radio echo sounding data recently acquired as part of the Whillans Ice Stream Subglacial Access Research Drilling (WISSARD) program. WISSARD geophysics focussed on Subglacial Lake Whillans (a small active lake) and on the downstream location of subglacial water discharge across the Whillans Grounding Zone. Active source seismology and surface elevation data indicate that Subglacial Lake Whillans is a perennial, albeit shallow, lake, with sometimes discontinuous water bodies. Drilling into the lake revealed a water depth of approximately 2 meters. Downstream at the grounding zone, water is hypothesized to flow both up and down glacier in an estuarine zone, contrary to the traditional one-way view of water crossing from beneath an ice sheet into the ocean. At both the lake and grounding line location subglacial sediments are thought to play a role. At the lake, erosion and deposition of imaged sediments may lead to episodic lake generation and demise as hydropotential traps are generated and destroyed. At the grounding line, subglacial sediments are imaged but are not observed to be forming the asymmetric wedge deposits that are thought to mark stable grounding line positions elsewhere.

## The nature of microparticles found in frozen water after unsealing of Lake Vostok

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After unsealing of Lake Vostok by drilling in 2012 (at depth of 3769.3 m), the lake water was risen few hundred meters into the borehole and then has been frozen. The deepest ice core of the accreted ice (3768.4–3769.3 m), retrieved from the well was covered with brownish film-like deposit which formed as a result of lake water penetration between the drilling bit and the ice core. Visual and optical studies showed that this deposit consists of mineral particles of up to 50 mkm across. For definition of nature and origin of these particles they were studied using SEM and X-ray microprobe analyses. More than 100 particles with determinations of their elemental composition have been explored. Based on this study, it was established that most of particles (c. 90%) are ferrous oxides (often with the impurity of nickel, copper and zinc) as well as iron-zinc alloys, reduced iron (4 particles) and organic matter. Other particles (c. 10%) are represented by silicates (clay-mica minerals) and clasts of quartz, corundum and ilmenite which range from 10 to 70 mkm in size.

Detected compositions clearly evidence that the most of the observed deposit is of technogenic origin and associated with metal oxidation after the contact of lake water with the drilling bit. The oxidation was supposed to be very fast indirectly confirming assumption about a high concentration of oxygen in Lake Vostok. The mineral clasts (20-70 mkm in size) found in the water frozen on the deepest ice core are more intriguing. If these clasts are not the result of contamination they can indicate the existence of fine-grained suspension at least in the uppermost lake water layer. Contamination could come from the drilling fluid (artificial contaminant) and/or from walls of the borehole which drilled through the accreted ice containing mineral clots/aggregates in the layer between 3538 m and 3608 m (natural contaminants). The analysis of drilling fluid (microscopy of filters after fluid filtration) did not show mineral microparticles as artificial contaminants and examination of accreted ice cores suggests vanishing field of outcropped mineral inclusions in borehole walls.

In 2013 season, the frozen water was sampled by drilling but it proved to be heavily polluted with kerosene. This fact severely restricted the study of biomarkers and primary water composition but SEM and microprobe analyses discovered amorphous quarts and crystals of calcite (with faces of up to 10 mkm long). All these minerals are considered to be rather authigenic in nature, i.e. formed in lake water. If found mineral particles came from the water, it can be evidence of the relatively strong water circulation in the lake (i.e. a circulation which supports aleurite-sized material in the water as a suspension).

## Antarctic subglacial exploration - highlights from recent investigations of subglacial Lake Whillans and Blood Falls

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Subglacial environments are one of the most difficult portions of the cryosphere to access. Recently, in collaboration with innovative and often large-scale drilling projects, ecologists are beginning to explore the subglacial biome. Understanding the persistence of life in extended isolation and the evolution and stability of subglacial habitats requires an integrated, interdisciplinary approach. Here we highlight how drilling and exploration come together with results from a recent Antarctic drilling project that sampled Subglacial Lake Whillans, a fresh water lake under the Whillans Ice Stream. We also discuss a new approach to subglacial exploration with investigations of a ferrous, saline subglacial ecosystem below the Taylor Glacier in East Antarctica, known as Blood Falls. Both of these ecosystems appear to persist independent of photosynthetically derived carbon inputs. This is supported by molecular data and biogeochemical measurements that indicate chemoautotrophic activity is present with energy derived in part by cycling iron and sulfur compounds. Comparing these two distinct subglacial ecosystems will provide important insight into microbial community structure and function, as well as elucidate unique adaptations for cold, dark life. The collaborative efforts of exploring these isolated microbial habitats help enable the development of relevant tools for geomicrobiological examination of other subglacial environments on Earth and prepare us for the exploration of icy extraterrestrial targets.

## Environment and processes of Subglacial Lake Whillans, West Antarctica

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Subglacial Lake Whillans (SLW) lies 800m below the low gradient, Whillans Ice Plain West Antarctica, upstream from where Whillans Ice Stream goes afloat into the Ross Ice Shelf. During 2013-14 season the WISSARD project made measurements in, and collected water and sediment samples from SLW. Sediment is typical subglacial till; a homogenized, structureless diamicton. Debris from local basal ice is likely not contributed to SLW by rainout because ice is theoretically below pressure melting. So lake floor diamicton likely was transported to SLW by deformation while the ice stream was grounded at the drill site both prior to lake formation and during lake "lowstands". Satellite altimetry has shown SLW experiences short (~7 month) discharge events, lowering the ice surface and lake water level by between 1-4m. Lake lowstands are separated by longer periods of gradual recharge, but over the period of many lowstands the ice stream is suspected to touch down and couple with the lake floor, potentially shearing new till into SLW. Subglacial hydrological diversions also may play a role in SLW history; if water is captured by another drainage basin, then the bed at SLW will also act as a till. The lack of sorted sediment (apart from a lamina of mud at the sediment-water interface) and erosional lags within sediment cores indicate water flow during discharge/recharge events has had a low current velocity with quiescent conditions in the lake. Although important volumes of water are moved during such events, water velocities are not those of classic "floods" due to low hydropotential gradients on the ice plain and wide channels. Sediment source indicators (particle composition, form and surface texture, geochemistry (XRF, XRD, <sup>10</sup>Be), fossils, biomarkers) show sediment is recycled from older Cenozoic sediments and bedrock. Biologists show  $\delta^{18}\text{O}$  values of lake water likely from up-stream ice sheet melt; however, Cl and Br ion concentrations indicate a seawater source likely recycled from older marine sediments. Chemolithoautotrophs dominate an active microbial community, indicating they play a role in breakdown of subglacial particulates. The most notable variability in cores is a weak, critical porosity horizon down to ~50cm depth above more consolidated till. We interpret the weak upper horizon as a product of shear deformation and decreasing effective pressure experienced during final stages of grounding prior to a lake recharge event. The presence of this weak layer illustrates the importance of hydrology in modulating till rheology and is an example of how subglacial sediments can preserve archives of hydrologic conditions at the ice-bed interface. All results show till is being subglacially deformed and sheared from up-ice-stream into SLW and beyond. That appears to be the main sediment transport mechanism rather than fluvial transport. We cannot yet constrain basal/englacial debris transport.

## Concentrated englacial shear over rigid basal ice, West Antarctica: implications for modelling and ice sheet flow

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Basal freeze-on, deformation and ice crystal fabric re-organisation have been invoked to explain thick, massive englacial units observed in the lower ice column of the Antarctic and Greenland ice sheets. Whilst recognised as having very different rheological properties to overlying meteoric ice, studies assessing the impact of basal units on the large-scale flow of an ice sheet have so far been limited.

We report the discovery of a previously unknown, extensive (100 km long, >25 km wide, and up to 1 km thick) englacial unit of near-basal ice beneath the onset zone of the Institute Ice Stream, West Antarctica. Using radio-echo sounding, we describe the form and physical characteristics of this unit, and its impact on the stratigraphy and internal deformation of overlying ice.

The lower englacial unit, characterised by a highly-deformed to massive structure, is inferred to be rheologically distinct from the overlying ice column. The overlying ice contains a series of englacial 'whirlwind' features, which are traceable and exhibit longitudinal continuity between flow-orthogonal radar lines. Whirlwinds are the representation of englacial layer buckling, so provide robust evidence for enhanced ice flow. The interface between the primary ice units is sharp, abrupt and 'wavy'. Immediately above this interface, whirlwind features are deformed and display evidence for flow-orthogonal horizontal shear, consistent with the deformation of the overlying ice across the basal ice unit. This phenomenon is not a local process, it is observed above the entirety of the basal ice, nor is it dependent on flight orientation, direction of shear is consistent regardless of flight orientation.

These findings have clear significance for our understanding and ability to realistically model ice sheet flow. Our observations suggest that, in parts of the onset zone of the Institute Ice Stream, the flow of the ice sheet effectively ignores the basal topography. Instead, enhanced ice flow responds to a pseudo-bed, with internal deformation concentrated and terminating at an englacial rheological interface between the upper ice sheet column and the massive basal ice.

Our results demonstrate that we may need to: (i) adapt numerical models of those parts of the ice sheet with extensive and thick basal ice units; and (ii) carefully reconsider existing schematic models of ice flow, to incorporate processes associated with concentrated englacial shear.

## WISSARD at Subglacial Lake Whillans: Scientific operations and initial results

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Antarctic subglacial lakes represent important targets for scientific exploration because they may harbor unique microbial ecosystems, help determine ice sheet dynamics, and contain sedimentary paleoenvironmental and paleoclimatic records. There are already several hundred known subglacial lakes in Antarctica, including so-called active lakes experiencing fill-and-drain cycles. The glaciologic, geologic, and hydrologic settings of these lakes are likely to be variable and may result in large differences in subglacial lacustrine conditions.

Subglacial Lake Whillans (SLW) is located beneath the Whillans Ice Plain (WhIP), which is fed by Mercer and Whillans Ice Stream on the upstream end and discharges into Ross Ice Shelf. SLW belongs to a group of active subglacial lakes discovered beneath WhIP based on ice elevation change anomalies by Fricker and others (2007). It was targeted for drilling by the Whillans Ice Stream Subglacial Access Research Drilling (WISSARD) project.

The WISSARD project includes an extensive geophysical component, whose major part is focused on monitoring active subglacial lakes using a network of continuous Global Positioning System (cGPS) stations. One of these cGPS units was placed on SLW in December 2007 and captured one filling-draining cycle in 2008-09 with amplitude of ~3m. After this event the cGPS on SLW has shown only minor uplift, indicating that the lake was close to its most drained state at the time of drilling, in late January 2013. As part of direct preparations for site selection and drilling, an extensive geophysical survey of SLW was conducted in austral summer of 2010-11. Detailed kinematic GPS and ice-penetrating radar surveys revealed that SLW corresponds to a ~15m depression in ice surface topography and >80kPa low in the regional subglacial water pressure field, as estimated from ice surface and bed topography data (Christianson and others, 2012). Active-source seismic investigations over SLW confirmed that the basal reflection coefficient is consistent with the presence of a subglacial water reservoir and revealed a sub-ice reflector interpreted as lake bottom (Horgan and others, 2012).

Based on the geophysical results summarized in the previous paragraph, the WISSARD science team selected the site with the thickest inferred subglacial water column thickness as the SLW drilling location for the 2012-13 field season at 84.240° South and 153.694° West. We will describe the scientific operations which took place in the SLW borehole in the course of ~3 days at the end of January 2013. We also report selected preliminary results describing conditions encountered in SLW water column and underlying sediments.

## Microbial nutrient cycling and physiology in Subglacial Lake Whillans, Antarctica

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Recent recognition of the widespread nature of liquid water beneath the Antarctic ice sheet has generated international interest in subglacial aquatic environments as functional microbial ecosystems that play a role in global elemental transformations. Subglacial Lake Whillans (SLW) lies 800 m beneath the ice surface of Whillans Ice Stream, West Antarctica. Remote sensing data indicate that the lake is situated near the end of a hydrological flow-path and periodically flushes into the sea under the Ross Ice Shelf. We report here on the collection of the first bulk liquid water samples from SLW and provide the first direct evidence for active microbial life and elemental cycling in a subglacial lake.

Epifluorescent microscopy showed that water collected cleanly from SLW contained  $\sim 10^5$  cells mL<sup>-1</sup>. Cellular viability and metabolic activity were measured as (i) cellular ATP concentration, (ii) respiratory electron transport activity, and (iii) cellular incorporation and/or respiration of <sup>14</sup>C-bicarbonate, <sup>14</sup>C-leucine, <sup>3</sup>H-thymidine, and <sup>3</sup>H-leucine. The fluorescent portion of dissolved organic matter (DOM) in the water column and surficial sediments was analyzed via excitation emission matrix spectroscopy (EEMS).

ATP levels (avg +/- SD = 3.7 +/- 0.4 pmol L<sup>-1</sup>) in the lake samples were significantly (p<0.05) greater than levels in drill borehole water and blanks. Dark incorporation of <sup>14</sup>C-bicarbonate, which we assume to represent chemoautotrophic activity, provides  $\sim 33$  ng C L<sup>-1</sup> d<sup>-1</sup> to the SLW water column, which meets  $\sim 15\%$  of the heterotrophic carbon demand (BCD) estimated from the incorporation and respiration of <sup>14</sup>C-leucine in SLW water. More conservative estimates of BCD based on <sup>3</sup>H-thymidine, and <sup>3</sup>H-leucine incorporation rates reveal that chemoautotrophic activity is sufficient to supply between 30% and 150% of BCD. Fluorescence, humification, and freshness indices calculated from EEMS data indicate that DOM in the SLW water column and surficial sediments are the products of microbial activity, and that water column DOM was produced more recently than surficial sediment DOM. <sup>14</sup>C-dating and  $\delta^{13}\text{C}$  characteristics of the particulate organic carbon component of the SLW water column provide further insight into sources of and processes affecting organic matter in subglacial environments.

Collectively, our data show that SLW is a microbially dominated ecosystem driven by chemoautotrophy that transforms carbon and other key biogeochemical elements beneath the Antarctic ice sheet.

## Development and validation of biogeochemical sensors for subglacial aquatic ecosystems

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Subglacial runoff from glaciers and ice sheets has the potential to influence global biogeochemical cycles, via the export of bioavailable carbon and nutrient. However, measuring such biogeochemical parameters in subglacial aquatic environments and in bulk runoff is challenging. Manual sampling cannot provide continuous datasets and relies on the presence of personnel in the field, which is frequently impossible outside of the summer season. Collection of samples from more remote subglacial aquatic environments, such as ice stream sediment porewaters and subglacial lakes, is logistically difficult and expensive. Sensors provide an alternative for monitoring *in situ* conditions and are available for many analytes, but they are frequently unsuitable for deployment in icy environments. Low temperatures, freeze-thaw cycles, remote locations, low concentration and low ionic strength meltwaters challenge technologies designed for temperate aquatic systems. In order to overcome these limitations, the UK Natural Environment Research Council has funded the DELVE project, which will DEvelop and VaLidate the first miniaturised biogeochemical sensor suite for glacial Environments. The DELVE initiative will assemble a suite of sensors with the goal of monitoring dissolved oxygen (DO), pH, nitrate, H<sub>2</sub>S and iron/manganese in glacial meltwaters. Where possible, commercially available sensors were employed or re-developed (DO, pH and H<sub>2</sub>S). If no commercial alternative was suitable, bespoke lab-on-chip microfluidic sensors (developed at National Oceanography Centre, Southampton) were designed and manufactured (nitrate, iron/manganese). All sensors were subject to comprehensive performance evaluation at low temperatures, including freeze-thaw cycling, and the response to low concentration and low ionic strength was quantified. Sensors which performed well throughout the laboratory testing process were deployed in glacial meltwaters in south Greenland, where they collected high resolution, continuous data on the evolution of meltwaters during a summer season. We present the results of this testing, and demonstrate a suite of sensors suitable for monitoring biogeochemical species in the cryosphere, including subglacial lakes.

## **Instrumentation of recoverable autonomous sonde RECAS for environmental exploration of Antarctic subglacial lakes**

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Nowadays it is generally recognized that a vast network of lakes, rivers, and streams exists thousands of meters beneath Antarctic Ice Sheets. The subglacial water most likely contains life, which must adapt to total darkness, low nutrient levels, high water pressures and isolation from atmosphere. It is obvious that in situ investigations should not contaminate these subglacial aquatic systems. This criterion makes sustainability of subglacial environment of chief importance. The proposed RECoverable Autonomous Sonde 'RECAS' will allow analysis and sampling of subglacial water while the subglacial lake would stay isolated from the surface. The wire for the transmission of electric power to it and signals from it is twisted on the coil inside the sonde, paid out of the advancing sonde and became fixed in the refreezing melt-water above it. The sonde is equipped by two hot-points with heating elements located on the bottom and top sides of the sonde and able to move down and upwards. While the sonde melts down to the ice sheet bed and up to the ice sheet surface, it is vitally important to control melting-drilling operating parameters (rate of penetration, bit load, true vertical depth, measured depth, temperature of electrically heated melting tip and lateral housing heaters, power consumption by different energy users, borehole inclination and diameter) and to identify environmental conditions (pressure, temperature), because in the case of RECAS fail its recovery would be impossible. Some of the registered parameters (e.g. bit load and borehole inclination) have limits. When parameters are going out the limits, the system is adjusted manually or automatically. When the sonde enters into the subglacial lake, it samples the water and examines water parameters: pressure, temperature, pH, oxygen concentration, sound velocity, and conductivity. Video cameras and sonar provide additional information on the lake environment. The first laboratory tests of the RECAS components are scheduled for 2014. Field tests of the RECAS in Antarctica are planned as soon as the project gets full financial and logistical support.

## **S08: ANTARCTIC PERMAFROST, PERIGLACIAL, SNOW, FIRN & ICE-FREE ENVIRONMENT & SNOW AND FIRN OF ANTARCTICA**

### **Rates and landscape implications of soil transport on hillslopes by patterned ground processes in Taylor Valley, McMurdo Dry Valleys, Antarctica**

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Cryoturbation and formation of patterned ground are important processes for organising the microtopography and surface characteristics of Antarctic ice-free areas. On flat topography, development of polygonal patterned ground is associated with a convection-like motion of sediment from sand wedges beneath the troughs defining polygon boundaries to the centre of polygons. Some return movement of sediment occurs near the surface. This sense of motion implies an inflating polygon centre with a stable surface.

This study aimed to determine how patterned ground processes are modified by gravitational stresses on hillslopes. We trenched across one 8-sided, 12 m-wide polygon between the upslope and downslope contour-parallel troughs. We measured electrical conductivity (EC) and pH of the soils and dated sediments by single-grain luminescence techniques. Trenching exposed a sand wedge centred on the upslope trough and extending beneath the downslope side of the trough. From this zone, 10 cm-thick lenses of well-sorted sand emerged at low angle from beneath the ice-cemented permafrost at 30 cm depth to become closer and parallel to the surface within the active layer further downslope. A 40 cm-thick cell of well-sorted gravel formed the downslope wall of the trough and extended downslope about 1 m. The pattern of alignment of clast long axes suggested a rotating motion – downslope at depth, and return to the trough at the surface. A thinning wedge of the well-sorted gravel extending downslope from the gravel cell suggested rafting atop the downslope-extruding layers of sand. Adjacent to the downslope trough, a plug of diamicton, presumed to be deformed Ross Sea Drift, deflected extruding sand lenses steeply upward.

Luminescence ages showed that sand grains making up the extruding layers comprised multiple cohorts of grains. The cohorts became progressively older in a downslope direction, confirming the inference of extrusion at the upslope sand wedge and ongoing downslope motion. The oldest cohorts were ca 29 ka, which presumably date the Ross Sea Drift. Soil pH and EC increased in a downslope direction, indicating a corresponding increase in residence time for surface soil layers. By calculating sand layer velocities and measuring soil depths above the sand layers, we estimated soil flux rates that suggested hillslope diffusivities similar to that of temperate regions. Polygon dimensions and soil flux rates determine soil turnover times and limit the extent to which soil salinity and pH can increase. These are important soil chemical attributes for structuring soil microbial communities. Our results suggest that McMurdo Dry Valley hillslopes may be as responsive as temperate hillslopes to climatic forcing, and reaffirm the importance of abiotic processes in structuring soil ecosystems.

## Geoenvironments of the Potter Peninsula, King George Island, Maritime Antarctic

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The aim of this work was to identify and map the geoenvironments of Potter Peninsula, King George Island, Maritime Antarctica. Multi-criteria based analysis of geomorphology, landforms, vegetation, susceptibility to wind action and incident solar radiation was used to cluster the environmental characteristics of Potter Peninsula. By means of that, seven geoenvironments were identified and mapped: marine terraces, outwash cones with sporadic vegetation, raised marine terraces with accentuated anthropic influence, marine terraces with high biodiversity of flora, moraines in recent ice-free areas, surface with rocks predominance, and glacial. The ice-free area of Potter Peninsula has 6.68 km<sup>2</sup> and comprises six geoenvironments, with a predominance of terrains with convergent and concave forms and little or inexistent susceptibility to wind action. In general, geoenvironments located on marine terraces have more diversity of flora, while geoenvironments in the inner part of the peninsula showed predominance of old and young moraines, exposed rocks and lakes.

## Aeolian dust in Terra Nova Bay Polynya, Antarctica

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Aeolian dust derived from the Transantarctic Mountains is transported by katabatic winds across the surface of the Nansen Ice Sheet (NIS) and into Terra Nova Bay (TNB) Polynya in the western Ross Sea. Intense phytoplankton blooms occur in the polynya each summer which influence an important biogeochemical cycle that draws-down atmospheric CO<sub>2</sub>, alters the oceanic food web and contributes biogenic sediment to the seafloor. Despite many studies suggesting that aeolian dust is an important source of iron (Fe) critical for triggering the blooms, the flux of Fe-bearing dust remains poorly constrained. Understanding these fundamental modern processes is essential for understanding how the Fe-driven biogeochemical cycle operates in the Ross Sea and also for interpreting records of past environmental change in the region and predicting how they might change in a warming Antarctic and Southern Ocean.

We present new data from a network of custom built dust traps and snow samples from the surface of the NIS combined with reanalysis of local wind field data from automated weather stations in the TNB region to quantify the dust flux into the polynya. The dust dispersal pattern combined with X-ray fluorescence analysis of dust provenance shows that the distribution is strongly related to the occurrence of limited rock and moraine outcrops in zones of katabatic airflow. We suggest that most aeolian sediment entering the TNB polynya is funneled through a narrow 'dusty corridor' ~2 km wide on the northern part of the ice shelf between the Northern Foothills and Inexpressible Island in an area known as Hells Gate. Future work will focus on relating these insights on the dust flux with bloom intensity as measured by satellite images of chlorophyll-a concentration and also with records of sea floor sedimentation. This will contribute to an improved understanding of the impact of dust on primary productivity and biogeochemical cycling in the region.

## New insights into the long-term dynamics of the Victoria Valley Dune-Field, Antarctica

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The Victoria Valley dune-field is the largest in Antarctica, occupying an area of ~8 km<sup>2</sup>, within which there is a range of permafrosted dune-types including transverse, reversing, barchanoid and whaleback dunes. High-resolution ground penetrating radar (GPR) imaging of selected dunes reveal sets of cross strata and low-angle bounding surfaces that indicate dominant and changing wind speed and direction during sand accretion and deflation. GPR images from the western-most Vida dune, the largest in the dune-field, demonstrated that the Vida dune is in excess of 70 m-thick and comprised of undeformed lee-side dipping strata suggesting sand accretion under dominantly westerly katabatic winds sourced from the East Antarctic Ice Sheet. Conversely, the Packard and whaleback dunes several km to the east are little more than 8 m thick and display complex stratigraphies reflecting the bi-modal wind regime that dominates modern dune morphodynamics at the eastern-end of the dune-field. Optically-stimulated luminescence (OSL) ages were obtained from sand packages identified from the GPR imagery, with the OSL ages ranging from modern to ca 1.3 ka suggesting that the dunes are latest Holocene features in their present configuration. Selected sand samples dated by OSL were also analysed for their terrestrial cosmogenic nuclide (TCN) concentrations (<sup>10</sup>Be and <sup>26</sup>Al) to assess the long-term migration history of the sand grains. The TCN exposure ages suggest a residence time of at least 500 ka that most likely reflects continual deflation and mixing of the sand. Furthermore, the dual nuclide banana plot suggests it is possible that sand dunes in some form may have been present for at least 6 Ma. However, it is unclear whether we are dealing with sand grains that are being continually re-exposed/buried, or have spent much of their time buried. Consequently we are presently analysing a third and stable nuclide, <sup>21</sup>Ne, to enable us to determine a mean age for the sand and hence infer the likely period that the dunes can have persisted in the Victoria Valley landscape.

## Monitoring of climate variability and permafrost active layer on James Ross Island, Maritime Antarctica

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Permafrost and glaciers belong to key indicators of climate change as they react sensitively to climate variations. Monitoring the climate variability, thermal regime and thickness of the permafrost active layer is especially important in polar regions, which experience a rapid increase in average temperature of the air. The largest warming in the Southern Hemisphere over the last 50 years was reported from the western side of Antarctic Peninsula. However, field evidence of meteorological and cryospheric environmental variables is limited due to difficult accessibility and expensive logistics. The Ulu Peninsula in the northern part of James Ross Island represents a suitable locality for investigations of these variables and their interrelationship, as it is one of the largest deglaciated areas along the Antarctic Peninsula. Since 2007, an integrated multidisciplinary study of terrestrial ecosystems has been carried out at the Johann Gregor Mendel Station (63°48'S, 57°53'W). In this contribution, preliminary results of microclimate measurements and active layer monitoring on the Ulu Peninsula are presented. Climate conditions of this region are characterized by a short summer (December-February) with positive air temperatures up to 8°C and annual mean air temperature around -7°C. In spite of high cloudiness (daily means of 80–90%), global solar radiation can reach the maxima as high as 30 MJ.m<sup>-2</sup> on clear sky days around summer solstice. Mean annual ground temperatures (MAGT) range from -6.2°C (200 cm) to -6.6°C (5 cm) near by the Mendel Station. MAGT at Johnson Mesa (~320 m a.s.l.) varies from -8.0°C (50 cm) to -8.5°C (5 cm), which confirms the strong dependence of the sites on altitude. The active layer thickness was recorded at the depth of about 55-60cm (Mendel Station) and/or 25-30 cm (Johnson Mesa) at the end of January. The effect of air temperature and global radiation on ground temperature was studied with respect to the site characteristics and snow occurrence. The correlation analysis showed that the highest influence of the air temperature on the ground temperature was observed in days without snow cover during winter season. Conversely, the significant decrease of the air temperature influence was found in days with snow cover higher than 7 cm and/or in days without snow cover during summer. Acknowledgements: The authors thank CzechPolar infrastructure for providing facilities.

## Sources of phosphorus to ponds of the McMurdo Ice Shelf, Antarctica

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Meltwater ponds are a common habitat for terrestrial biota on continental Antarctica. The productivity of benthic cyanobacteria (the dominant biomass) requires availability of phosphorus (P), but sources of P and factors limiting its bioavailability are poorly understood. Consequently it is difficult to predict how productivity will be affected by changes in pond size that may result from a warming climate. As part of a larger research programme to determine the P biogeochemical cycle for meltwater ponds in Victoria Land, this study has explored P distribution and speciation in ponds of the McMurdo Ice Shelf to develop a conceptual model of the P cycle in this area.

Over three visits between 2011 and 2013; soil, soil salts, sediment, water and biological material was collected from 5 ponds at the study site, as well as data on the structure of the ponds. The ponds sit above a layer of sediment ca. 40 cm deep, which lies on an ice cement, with the water table around the ponds extending ca. 30 cm above the pond water level. The major reservoir of P in the ponds is contained within the microbial mats, which can hold 100 times the amount of P present in the water column. The speciation of water column P had variable composition, but was most often dominated by organic P species. Pond sediments contain 10-20 % less total phosphorous than surrounding soils, which have up to 11 mg/kg of water soluble phosphorous, and up to 2 g/kg of total phosphorous. This suggests that recently flooded soils have a major role as an immediate source of phosphorous to newly formed ponds, and that leaching of sediments is a key process for some time thereafter. A conceptual model for a P cycle is proposed for a typical pond in this environment, identifying the microbial mat as the major P reservoir in the pond, and the sediment as the major source of P over time. These relatively P rich coastal systems on the McMurdo Ice Shelf will be compared and contrasted with P poor inland pond environments in the McMurdo Dry Valleys.

## The presence of photosynthetic organisms in Potter Peninsula, King George Island, estimated from Landsat images

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The aim of this work was to map snow free areas with photosynthetic organisms cover, such as grasses, lichens or algae in the Potter Peninsula (King George Island, South Shetland Islands), in two different years, selected by the occurrence of El Niño (2004) and La Niña (2008) events. For this investigation, we classified Landsat 7/ETM+ sensor data to generate a binary map with two classes: snow free areas with photosynthetic organisms and other areas.

The images were co-registered (RMSE = 0.024), using as reference the image from 2004, which was georeferenced using the WGS84 and a Polar Stereographic projection. Only the near infrared band (0.78 - 0.90  $\mu\text{m}$ ) was used in the classification process, since all the photosynthetic organisms have a reflectance value increase (even though small for lichens) in this wavelength, allowing discriminating areas with this kind of organisms. The classification was made using the ISODATA algorithm (which is implemented on the ENVI software), configured for ten interactions and for discriminating no more than ten classes. The algorithm was able to separated areas with ice, snow, water and snow free areas with and without photosynthetic organisms.

A binary map showing the snow free areas with photosynthetic organisms and other areas in Potter Peninsula was produced for both years. The calculated areas with a photosynthetic organisms cover were 24.5  $\text{km}^2$  in 2004 and 21.1  $\text{km}^2$  in 2008. These results are limited by the spatial resolution of satellite images, probably these areas are overestimated, since each pixel is 30 x 30 meter (or 900  $\text{m}^2$ ). Results for other years, using high resolution images (like the ones from the Ikonos sensor) "vegetation" smaller than our results. Neither ENSO nor air temperature in Potter Peninsula can explain the difference of about 3,4  $\text{km}^2$  between 2004 and 2008, since the mean, maximum and minimum air temperatures for the 2004 Austral summer was lower than the ones for 2008 (1.6, 3.5, -0.9°C for 2004 and 1.9, 4.2, 0.1°C for 2008).

## Three years of electrical resistivity monitoring in a CALM site in Livingston Island (Maritime Antarctica)

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With the objective of detecting and studying the spatial and time distribution of permafrost in a Circumpolar Active Layer Monitoring (CALM) site near the Bulgarian Antarctic Station St. Kliment Ohridski in the Hurd Peninsula of Livingston Island, several geoelectrical surveys using the electrical resistivity tomography (ERT) method were used during the summer season of the years 2009, 2012, and 2013. The ERT profiles (profiles 7, 8, and 9) were made along three different directions, crossing approximately at the center of the CALM site; however, only profiles 8 and 9 were done in 2009, 2012, and 2013; profile 7 was done in 2009 and never repeated because of snow accumulation along some portions of the profile during 2012 and 2013. Each ERT profile consisted of 40 electrodes equally spaced 2 m apart. Since it was expected to have permafrost structures that should be approximately horizontal, a Wenner configuration was used. The apparent electrical resistivity sections obtained along each ERT profile were transformed into electrical resistivity models using a 2-dimensional inversion code (RES2DINV). The geoelectrical models obtained for the 78 m long profiles 8 and 9 represent the distribution of the electrical resistivity of the ground to depths of about 13 m. In some models electrical resistivities as high as 10,000 ohm.m were obtained. During the field work some portions of the ground traversed by profiles 8 and 9 were covered with snow; some of those snow covered areas coincide with very high electrical resistivity patches below the ground surface which are interpreted as frozen ground or sporadic permafrost. As a first interpretation, the snow that was not melted yet during the field work was acting as an insulating cover to the ground maintaining the temperature below the values it would reach if there were no snow; to a certain extent, this could explain the existence of some of the frozen ground patches.

## High-degree snow metamorphism in the Allan Hills, Antarctica

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Snow metamorphism is a primary driver of the transition from snow to ice. High-degree snow metamorphism, which results in major structural changes, is little-studied but has been identified in certain places in Antarctica. Albert et al. [2004] and Courville et al. [2007] described the structural properties of such metamorphosed snow in the megadunes of East Antarctica. Here we report on a 5-m firn core collected adjacent to a blue-ice field in the Allan Hills (-76.67°, 159.23°) in January 2011. This entire core showed a high degree of snow metamorphism, and little densification. We determined the physical properties of the snow using computer tomography and measured the isotopic composition of  $\delta\text{H}$  and  $\delta^{18}\text{O}$ , as well as  $^{210}\text{Pb}$  activity. The micro-CT measurements show a homogenous and stable structure throughout the entire core as opposed to the more variable structure pattern of seasonal snow observed elsewhere in Antarctic and in alpine regions. This implies that the snow has undergone high-degree metamorphism, which is likely to have been caused by decades of temperature-gradient driven metamorphic growth in the near surface due to prolonged exposure to seasonal temperature cycling. Such metamorphism is likely to be accompanied by altered isotopic compositions and chemical species concentration.  $^{210}\text{Pb}$  has a short half-life of 22.3 years and can thus be used to detect changes in accumulation rates that occurred within the last century. Except for the top 0.3 m, our 5-m core has no detectable  $^{210}\text{Pb}$  activity. This implies that most of the snow is older than 100 years. The measured isotopic compositions require high vapor transport and can thus also be linked to prolonged exposure of snow to seasonal temperature cycling and very low accumulation rates. For ice core research, this means that cores from near-zero accumulation areas can help better understand the ranges of isotopic composition during ice ages, when accumulation rates were lower than today.

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Courville, Z. R., M. R. Albert, M. A. Fahnestock, L. M. Cathles IV, and C. A. Shuman (2007), Impacts of an accumulation hiatus on the physical properties of firn at a low-accumulation polar site, *Journal of Geophysical Research*, 112(F2), 1–11, doi:10.1029/2005JF000429.

## **The origin of buried ice and permafrost sediments in Victoria Valley, Antarctica**

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Massive ice and ice-cemented sediments lie beneath the surface of most areas in the McMurdo Dry Valleys (MDV). While the origin of this ice and sediment remains poorly understood, their occurrence in Victoria Valley clearly relates to the past advance and retreat of cold-based glaciers in the valley. The spectrum of ice and sediment ranges from clear massive ice, to sediment-rich ice and displays variable degrees of deformation. We suggest that the massive ice forms from stranded remnants of ice aprons and frozen melt-water ponds at the margin of the previously expanded cold-based Victoria Lower Glacier. These isolated 'pods' of ice may then become buried by fluvial sediments, which act to protect them from further melting as the glacier retreats. Multiple advances and retreats of the Victoria Lower Glacier not only repeat this process but the overriding of previous deposits generates extreme deformation and complex ages of the relict sediment-rich ice.

In several stream cuts we find highly deformed bodies of massive ice and ice-cemented sediment buried beneath a cover of glacial debris in the Victoria Valley. This includes both ductile and brittle deformation of ice-cemented sediment and sediment rich ice. Ages of these sediments from optically stimulated luminescence (OSL) and C-14 range from 5 ka to 40 ka and show no recognizable patterns. This attests to the complexity of deposition through repetitive events. We conclude that much of the buried ice and ice-cemented sediments throughout the Dry Valleys formed by similar processes over millions of years.

## Soil diversity in Thala Hills oasis (Enderby Land, East Antarctica)

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The Thala Hills oasis is located in the western part of Enderby Land. It consists of two parts—Molodezhny and Vecherny sites—with a total area of 20 km<sup>2</sup>. The Thala Hills and other coastal oases of Enderby Land are related to polar desert soil zone of Bockheim and Ugolini (1990) and Blume et al. (1997). In our opinion coastal oases of Enderby Land should be allocated to Mid-Antarctic snow-patch cryptogamic barrens (Goryachkin et al., 2011; Balks et al., 2013). Melt water from snow patches enhances soil development, and pedogenesis of soils in wet valleys have features of more humid soils than are common to Antarctic, including pervection, cryoturbation, biochemical weathering, podzolization, and peat accumulation. At the same time soils of well drained and wind-affected habitats may have some features of pedogenesis which are characteristic of a more arid climate, including desert pavement, desert varnish, salinization, and calcification. Wet valley oasis should be regarded as the closest analogues of the wet valleys oasis "Larsemann Hills" (Mergelov, 2011). Organo-mineral soils (first centimeters depth) with micro profiles on fine earth under algae, lichen and moss are well represented. Soils with macro-profiles are associated with the receipt of the organic material from the ocean («ornithogenic» и «post-ornithogenic») and from lakes - «amphibia» soils (Abakumov, Krylenkov, 2011). The most "succulent" vegetation of oases is related to wind shelters on colluvium in hollows formed in hard rock. It creates thick moss and lichens cover; the organo-mineral soil with peat and raw humus horizons is formed. Close analogues of such soils are Spodorthels in the Grearson Hills oasis, Wilkes Land (Beyer, Bölter, 2000). The dominant soil taxa along the coast are Haploturbels/Haplorthels, Aquiturbels/Aquorthels, and previously unclassified ornithogenic soils and endolithic microsoils. Lithic subgroups both for Haploturbels and Gelorthents (permafrost > 1 m without cryoturbations) are predominant in the territories with shallow rock contact.

## **Radiocarbon distribution in lake waters and streams of the McMurdo Dry Valleys, East Antarctica: implications for lake history and ecology**

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The water of the permanently ice-covered lakes of the McMurdo Dry Valleys is derived primarily from glacial melt streams and to a lesser extent permafrost seeps and subglacial outflow. The result is a mixture of radiocarbon ages that reflect both the source and the biogeochemical processing of waters as they migrate to the lake water column. Samples were collected from various locations within the dry valley lakes, and the streams that feed them, and analyzed for radiocarbon abundance of organic and inorganic carbon. Stream gradient and length were shown to affect the degree of equilibration of water with the modern atmosphere prior to entering the lakes. Stream microbial mats assimilate inorganic carbon flowing over them. Seasonal ice free 'moat' water dissolved inorganic carbon (DIC) is largely dependent on the amount of meltwater input from streams (modern) vs. that from direct glaciers input (old). Under the ice-cover, radiocarbon ages of lake water DIC and organic matter are dependent on lake history, composition, and quantity of particulate matter fallout. Bottom waters of the west lobe of Lake Bonney have a DIC age of ~27,000 <sup>14</sup>C yr before present which we believe are the most radiocarbon deficient lake waters on earth. Comparison of the radiocarbon profiles in the two lobes of Lake Bonney, along with previously published geochemical data, provides a new chronology of the evolution of these two water bodies and shows that currently deep saline water is being displaced over the sill separating them.

## Geomorphic-biological interactions in the Ahlmannryggen and Jutelsessen areas of Western Dronning Maud Land, Antarctica

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Interactions between abiotic variables and community structure in Antarctica are poorly understood. Research is, therefore, required to elucidate the patterns of biodiversity that exist and the factors that influence them, particularly under changing climates. Landscape processes affect environmental heterogeneity, which in turn affect patterns of biodiversity. Nine nunataks in the Ahlmannryggen and Jutelsessen areas were investigated to determine the potential impact of abiotic variables on some ground fauna and flora at intra and inter-nunatak scales. Lichen was found to colonise small-scale topographical features that result from rock weathering. Topographical depressions were also found to provide sites for snow accumulation. The availability of moisture from snow melt provides preferential habitats for biota. In the Jutelsessen area, invertebrates and microbes were found to inhabit the cracks of thermal contraction polygons where snow, and, therefore, moisture is available. Two nunataks, Veseleskarvet and Robertskollen, were specifically targeted for comparison of ground temperature, ground moisture and air temperature as clear differences in biodiversity were found, despite being only 25 kilometres apart. The two nunataks serve as excellent laboratories that can potentially be used as proxies for investigating the possible impacts of climate change. The surface ground temperatures recorded on Robertskollen were often in excess of 15°C warmer than those recorded on Vesleskarvet.

## Digital Mapping of total organic carbon in Cryosols of the Keller Peninsula - King George Island - Maritime Antarctic

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The aim of this study was to evaluate different digital mapping methods for the prediction of total soil organic carbon in Cryosols and provide maps and data that can support an understanding of key processes involved in pedogenesis and landscape evolution in the Keller peninsula, King George Island, Maritime Antarctic. Soil samples were collected in 55 points in a semiregular grid pattern to cover most of the ice-free area of the peninsula. Samples were collected at depths of 0-5, 5-10 and 10-30 cm.

Total organic carbon (TOC) was quantified according to YEOMANS and BREMEMER (1988) and 0.5g of air-dried fine soil samples were weighed, crushed and passed through a 60-mesh sieve. Subsequently, 5ml of  $K_2Cr_2O_7$  and 7.5 ml  $H_2SO_4$  were added and heated at 170°C for 30 min. A total of 0.3 ml of phenanthroline was used and titrated with ferrous ammonium sulphate solution 0.2 mol.L<sup>-1</sup>.

Three spatial distribution methods were tested: multiple linear regression (MLR), ordinary kriging (OK) and kriging with external drift (KED). For models MLR and KED, 12 terrain covariates were generated using a digital elevation model (DEM) with 5 m resolution. For covariate selection, a stepwise process was used based on the Akaike Information Criterion, followed by correlation analysis between the selected covariates to avoid effects of multicollinearity. The same covariates used in MLR were used in KED for prediction of the corresponding variables. A terrain attribute called K\_5 was also used, which is Kernel density estimation based on the occurrence points of bird nests and plant species fields in the peninsula.

The total organic carbon (TOC) variable was only spatially distributed at a depth of 5-10 cm. because it was the only variable with normal data distribution among the studied depths. For the prediction of total organic carbon (TOC), the K\_05 elevation covariates were selected. Both positively correlated with the TOC variable.

This model was chosen directly by stepwise and no alterations were needed, considering that the model presented few covariates and no redundant covariates that should require removal. The fact that stepwise selected K0\_5 and this covariate positively correlates with TOC indicates that the method was effective in constructing the model, showing that at the locations with more nests and plant cover there is a greater contribution of organic carbon in the soil. The elevation covariate also had a positive correlation with TOC due to the high levels of carbon found in the north peak (highest peak of the peninsula), where there is a large field of *Usnea antarctica*.

Evaluation of the RMSE index, by means of relative improvement, showed that KED had a better performance than the other tested methods, with values 2.2% better than ordinary kriging and 3.3 % over MLR. Analysis of minimum and maximum values observed and predicted by the three methods showed that prediction by KED presented values that were more similar to the observed values. The map generated by KED revealed the direct influence of locations with nests and plant species.

## Catastrophic Release of an Ice-Dammed Lake. A trigger of rapid geomorphic change

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The McMurdo Dry Valleys are considered a geomorphically stable landscape due to its cold and dry environment. Comparisons between current photographs and those that date to Scott's visit in 1903 indeed show an unchanging valley. In this context we were surprised to note the sudden disappearance of the Garwood River into the subsurface in about 2003, only to become revealed a few years later when the overlying abandoned stream channel collapsed >2 m into the subterranean thermokarst channel. This event may be related to the bank erosion further down valley that exposed a massive layer of Pleistocene ice and to the formation of an extensive flood plain.

Investigations upstream suggested the trigger for these events may be the catastrophic release of ice-dammed Buddha Lake. Terraces around the lake and abandoned deltas adjacent to inlet streams indicate the lake has filled and drained multiple times in the past. Our observations over the past two years show that the formation and drainage of the lake may be an annual event. To monitor the process we deployed two automatic cameras and installed a stage recorder on the outlet stream during the 2013-14 austral summer. Results showed that the lake rapidly filled during a three-week period in December prior to an abrupt drainage (15 hours) in early January. The timing of release roughly coincided with a release the previous year.

The drainage of the lake appears to be controlled by a thin, ~2 m, ice dam. The lake outflow is constrained between the Joyce Glacier and a valley wall composed of bedrock/colluvium, which forms an ice-walled channel positioned against a steeply sloping bedrock/colluvium surface. A mixture of refrozen glacial melt and ice debris from the glacier cliff, an accumulation commonly found around many glaciers in this environment, appears to fill the channel. In addition, a small, intermittent, lake outflow may form auf-ice that also helps to fill the channel. Initial field observations after lake drainage in the previous season suggest a subsurface pathway along the ice/bedrock contact. We hypothesize that a subsurface leak develops and quickly enlarges by thermal erosion that rapidly drains the lake. As such, ice-dammed lakes in Antarctica are possible agents for rapid geomorphic change in an otherwise stable environment.

## Thermal diffusivity and modelling of temperature and humidity of the active layer in the Keller Peninsula

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The estimation of thermal properties of soil in areas with permafrost using energy balance models is essential for studying the effects of climate changes in periglacial environments, considering that these properties regulate heat transfer from the active layer and, thus, influence annual freeze and thaw depth.

The aim of this study was to compare data of six different soil temperature and humidity monitoring sites in the Keller peninsula, King George Island and adjust the predictive models of these two variables. The study period was 2008 to 2011 and the sensors were located at different depths, according to the variation of soil horizons. For soil temperature modelling, the Fourier Transform was used to generate a sine curve. Parameters obtained from adjusting the soil temperature model were: average, amplitude, damping depth, phase shift and thermal diffusivity. To estimate soil temperature versus soil humidity, the Ligand-Bilding model was used, which generates the sigmoid growth curve. Models were validated using statistical tests.

In all sites, thermal amplitude diminished with depth due to soil properties that buffer the heat wave along the profile. The site near the Ferraz Station showed the highest soil temperature average and lower thermal amplitude, given its greatest proximity to the station. Sites in the Tyrrell Plateau and near the Ipanema refuge presented the lowest temperatures and amplitude. As depth increased, the heat wave in summer tended to be buffered, as shown by increase in diffusivity with increase of depth. In winter, the inverse occurred resulting in higher temperatures at the deeper layers, due to changes in flow direction of heat that the soil stored during the hottest seasons. Thermal diffusivity exponentially increased with depth of soil. The thermal regime of the active layer in Keller was closely related to water volume of the soil, being that thermal diffusivity reached a maximum value between 20 and 25% of soil humidity.

Adjustments of soil humidity models according to temperature in all depths and sites was statistically significant by variance analysis ( $p < 0.05$ ), that is, model estimates did not present significant differences in relation to the observed soil temperature data. The model for monthly soil humidity averages *versus* temperature was satisfactory, with regression coefficients ( $r^2$ ) between 0.95 and 0.97.

Estimated thermal diffusivity showed that organic matter considerably influenced the thermal regime of the active layer near the Ipanema refuge. In the other sites, diffusivity was mainly influenced by soil texture. Model adjustment was satisfactory and showed that the freezing point of water in the soil shifted up to  $-0.92^\circ\text{C}$  due to the amount of salts present in the soil solution and thermal isolation of some sites.

## "Soils" of Antarctic ice-free environment - input to change the global pedology

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The International Polar Year and the ANTPAS project especially activated the study of Antarctic permafrost and permafrost-affected soils very much. The scientific community gained the data from the latitudes of Middle Antarctic between previously better studied Dry Valleys and Antarctic Peninsular. The data on permafrost were published earlier (Vieira et al., 2010), however the materials on soils have been only prepared for publishing (Bockheim et al., in print). The data on "soils" of Antarctic show that these natural bodies are usually described and classified as natural soils of other parts of the globe in spite of their great specificity. Most of Antarctic "soils" do not fit criteria of the scientific definition of a soil as the differentiation of their profiles related to interaction of an atmosphere with a parent material without any influence of macro-organisms. Even under such macrobiota as mosses and lichens we could have no result of organic-mineral interactions in Antarctica – no humus *sensu stricto* but a mixture of poorly decayed organic remnants and mineral fine-earth. On the other hand, some results of biomineral interactions take place within fractures of a hard rock (e.g. euholothic soils – Mergelov et al., 2012) but these "microsoils", fitting absolutely all criteria of the scientific definitions of soil, are ignored by pedologists and they are studied in biogeochemistry. As for soil-forming factors – the usual climatic characteristics: mean air temperatures (MAT), annual precipitation are not appropriate, as the soil temperature can be +30°C when the MAT is negative, and 200 mm and 1000 mm of precipitation can have the same effect on soil because solid precipitation is blown away. The lateral processes usually are predominant in this conditions and the perception and understanding of soil processes is possible only on the landscape level. Surely, all these natural bodies in which we can see the interaction between biota and a rock and/or between climate and a rock should be the objects of the global pedology. However, many concepts and elements of the pedology should be changed on the base of knowledge on Antarctic "soils". The new special chemical and biological methods should be developed to study "evercold" soils not only because their temperature, as they never "knew" the usual laboratory conditions of 20°C, but also because of their tiny horizons and features. The use of not only mean climatic characteristics but also of their diurnal, seasonal and inter-annual amplitudes is very important. New approaches to a classification of Antarctic "soils" are needed. The "soil cover" of Antarctic is so specific that it has its own type of geographical zonality – the insular one. Some of particular proposals for these and other elements of "Extremal pedology" is elucidated in the paper.

## Seasonal effects on ice-wedge thermal variation in East Antarctica: a time series approach

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This research aims at studying the thermal variation of ice wedges at various depths. In particular, the analysis of ice-wedge top and bottom, ground surface and air temperatures are undertaken. The active layer depth is calculated through seasons and years using hourly data at three sites in northern Victoria Land: Baker Rocks, Boomerang Glacier and Mount Jackman. The recording period is from 2004 to 2013 at Baker Rocks and Boomerang Glacier, and from 2006 to 2013 at Mount Jackman.

Daily mean ground surface temperatures (DMGST) and daily mean air temperatures are highly correlated at Baker Rocks ( $r^2=0.96$ ), Boomerang Glacier ( $r^2=0.95$ ), and Mount Jackman ( $r^2=0.92$ ) sites. This shows that the ground surface temperature at measurement sites responds strongly to air temperature. Moreover, hourly ground surface temperature and DMGST are generally lower than the air temperature in the winter season, which shows the absence of a significant snow cover.

Standard deviations of the hourly temperature show that high temperature variability can exist over one month, with higher variability in winter than in summer. Frequent and large temperature fluctuations are common throughout winter with either a sharp drop or a rapid increase both in air and ground surface temperature. Variations of 25°C to 30°C were recorded over periods of one to four days.

The overall variability of temperatures is decomposed using spectral analysis in order to isolate seasonal effects from cycles and long term trends. Moreover, spectral analysis is also applied to the long term temperature data (26 years) from six automatic weather stations, located in northern Victoria Land, to compare the temperature series recorded over different time spans and to identify possible fitting trends. The time series approach in the frequency domain is quite new in this field and it represents therefore the main contribution to the existing literature.

## Perennially Frozen lakes and frost mounds analyses through GPR investigations in Terra Nova Bay area (Northern Victoria Land, Antarctica)

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Perennially frozen lakes are widespread in Victoria Land and represent one of the less known component of the hydrogeology in this cold desert. In the coastal sector of the Northern Victoria Land these lakes are particularly frequent with a wide range of size. Many of the perennially frozen lakes show icing blisters and debris-covered mounds that seemed to be related each other. These features were hypothesized of hydrostatic origin related to closed talik although in some cases hydraulic origin linked to open talik can be not excluded. To analyze the relationships among icing blisters, frost debris-covered mounds, frozen lakes and the surrounding hydrogeology a site close to MZS station was chosen to carry out a 3D reconstruction through ground probing radar investigation. A GPR dataset made by 15 profiles acquired with an irregular grid within an area of about 15000 m<sup>3</sup> was recorded with two sets of antennas having central frequencies of 400 and 900 MHz, respectively. The total length of the profiles is of about 2000 m and the trace spacing has a mean value of 2 cm, in order to reach very high lateral resolution.

Data have been processed applying the following flow: DC removal; time drift correction; background removal; bandpass filtering; spherical divergence correction and exponential amplitude recovery; velocity analysis through diffraction hyperbola fitting and depth conversion. Migration algorithms have been also tested in order to both focus scattered events and to reconstruct the real reflector morphology.

We found that the depth of the lake reaches 3.5 m showing a very irregular morphology. Within the frozen body there are several internal reflection showing often high lateral continuity and various dips; they are probably related with the contacts between different glaciological units. Internal debris has been also imaged, as well as horizontal reflectors located close to the lake bottom in its deepest parts. These levels can be interpreted as the top of a melted layer of diluted brine. The profiles crossing both frost mounds and frost blister show that such structures are larger than at the surface and that all the internal reflectors are strongly deformed with pull-up shapes. Moreover, we notice that the signal attenuation of the materials constituting the frost mounds is higher than in the other areas possibly due to either some free water content or different ice composition.

Quantitative analyses performed allow us to evaluate the density of the frozen materials, which span from snow to firn and ice. Further efforts will be addressed to try to discriminate between possible fresh, brackish and salt water units and to validate the interpretation with borehole data.

## Permafrost warming and vegetation changes in Continental Antarctica

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High latitude areas of both Hemispheres are expected to be highly sensitive to climate change impacts. Vegetation, the active layer, and the underlying permafrost are key environmental components of terrestrial ecosystems.

Since 2000 we started a long-term monitoring of climate, permafrost, active layer and vegetation at Victoria Land, continental Antarctica. In particular, here we presented the ground temperature, active layer thickness and vegetation data monitored along a transect between Apostrophe Island (73°30' S 167° 50' E) to Prior Island (75° 41' S 162° 52' E).

Our data confirm the stability of mean annual and summer air temperature, of snow cover, and an increasing trend of summer incoming short wave radiation. The active layer thickness is increasing with a rate of 0.3 cm/y.

The active layer is characterized by large annual and spatial differences. The latter is due to scarce vegetation, patchy and very thin organic layer and large spatial differences in snow accumulation.

The active layer thickening, probably due to the increase of incoming short wave radiation, produced a general decrease of the ground water content due to the better drainage of the ground.

The resultant drying may be responsible of the decline of mosses in xeric sites, while it provided better conditions for mosses in hydric sites, following the species-specific water requirements.

An increase of lichen vegetation was observed where the climate drying occurred. This evidence emphasizes that the Antarctic continent is experiencing changes in total contrast to changes reported from maritime Antarctica.

## **An evaluation of high-altitude and -latitude diurnal frost environments**

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Geomorphology is considered a multivariate scientific field, where a number of processes may yield similar forms or particular processes yield specific forms. While specific processes need to be investigated, it is often challenging to isolate these in geomorphic regimes. It has long been thought that climatic zones control specific geomorphological processes and features. Climatic geomorphologists believe that processes inherent to each climate zone will engender characteristic regional patterns and landforms. However, criticism has arisen regarding the premise of climate geomorphology and the paper discusses azonality/zonality in a variety of environments. Three study sites of varying altitudes, latitudes and climates are investigated, allowing for an investigation into said azonality/zonality. These sites include Western Dronning Maud Land of the Antarctic, Marion Island in the sub-Antarctic and the Eastern Cape Drakensberg of mainland South Africa. Continental Western Dronning Maud Land is a polar desert, Marion Island has a hyper-maritime climate and the Drakensberg is an alpine region. Climatic Geomorphology would consider that the three study sites each have characteristic geomorphological features. However, it was found that common landforms existed in each, showing a convergence of form, or equifinality. Despite widely disparate climates, common to all three areas are diurnal frost cycles. This paper considers the role of frost cycles in on landform evolution at each study site. It is argued that the concept of zonality cannot be universally applied investigating landforms.

## The Geomorphology of a rock glacier, near Troll Station in the Jutulsessen, Antarctica

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Rock glaciers are known to occur in a number of environments across the globe, yet they remain poorly understood geomorphic features and are not well documented in the Antarctic. The composition of ice and sediment found across these landforms has the potential to improve our understanding of past climates, their dynamics and morphology. A rock glacier in the vicinity of the Norwegian research station, Troll (72°01'S, 02°32'E), in the Jutulsessen of Dronning Maud Land, Antarctica was studied during the 2013/14 Austral summer season to characterise its structure and monitor slope movement. The study offers new research to this region of the Antarctic, and contributes to the existing knowledge of rock glaciers. Sediment samples were collected to determine moisture content, particle distribution and sorting. Clast characteristics and orientation were measured and slope movement monitoring transects set up. Near-surface temperature was recorded at 17 sites across the glacier and rock hardness measured at 30 sites using an Equotip 3™. The geology of the region is predominantly gneiss and partially metamorphosed granites that have been weathered down into larger clasts of feldspar and quartz. The upper reaches of the rock glacier are characterised by random sediment sorting with an absence of significant amounts of fines. The basal lobe is characterised by larger boulders with an increased portion of fines. Rock hardness is variable, as are ground temperatures. Liquid water accumulations found on the basal lobe indicate melt water as a source, rather than precipitation. The presence of lichen and advanced weathering of rock surfaces on the basal lobe suggest an absence of movement. Current observations suggest this to be a relict rock glacier, which could potentially be a resource of palaeoclimatic information.

## **An investigation into morphology and dynamics of thermal contraction crack polygons found at Mimelia in the Jutulsessen, Antarctica**

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Rhodes University

Thermal contraction crack polygons in the permafrost found at Mimelia in the Jutulsessen were identified and measured. The spatial extent of the polygon field was delineated, as was the morphology of randomly selected polygons. Data on soil moisture, polygon dimension and shape, temperature regimes, as well as sediment samples were collected. The spatial progression of polygons and their morphology across the study site is discussed, as are high-frequency temperature dynamics for polygon centres in comparison to polygon borders (cracks). The features occur on slopes ranging from 8°-27° and are variable in size, ranging from 18m to more than 60m in perimeter. Ground moisture at the borders is marginally higher than the centre of the polygons. Overall, polygons have very low moisture contents (<1%). Temperatures stabilise with depth, with near surface readings the most variable and extreme. High-frequency, as well as annual low-frequency temperature regimes are shown to be statistically different. In addition, sediment samples are shown to be significantly different for centres versus borders of polygons. Given polygon dimensions and crack propagation, it is suggested that the polygon field is not yet mature and that polygons fall within a developmental stage.

## Rapid thermokarst erosion in Garwood Valley, McMurdo Dry Valleys: multi-year observations of ground ice thaw

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Thermokarst, a land surface lowered and disrupted by melting ground ice, is a major driver of landscape change in the Arctic, but has long been considered to be a minor landscape process in Antarctica. We report on multi-year (2001-2014) observations of buried ice deposits in Garwood Valley, McMurdo Dry Valleys (MDV), that combine airborne and ground-based LiDAR with time lapse imaging and continuous meteorological measurements. These long term observations show that 1) thermokarst formation accelerated in Garwood Valley from 2001-2013 and has subsequently slowed, suggesting polycyclic melting behaviour similar to that observed in Arctic retrogressive thaw slumps; 2) the rate of thermokarst erosion had reached up to ~10 times the average Holocene rate; and 3) the rapid rate of thermokarst formation is driven most strongly by increasing insolation and sediment/albedo feedbacks, but is in competition with burial of ice by overlying, dry sediment.

Stranded ice sheet deposits filling the valley floor is capped by 0.1-1 m of glacial till and (in places) fluvial sediments deposited during the late-Pleistocene/early-Holocene. Repeat LiDAR measurements of the valley have been made in 2001 (December), 2009 (November), and 2010-2014 (November and January). These measurements show that the ice melt and sediment removal along the "ice cliff" (an exposed outcrop of sediment-capped ice, ~15 m tall and ~400 m long) have accelerated from a long-term average of  $1150 \pm 20 \text{ m}^3/\text{year}$  (since 6.3 ka, the last recorded date of sediment deposition above the ice cliff), to  $\sim 5,000 \text{ m}^3/\text{year}$  (2001-2010), to  $\sim 6,700 \text{ m}^3/\text{year}$  (2010-2011), and  $\sim 11,300 \text{ m}^3/\text{year}$  from 2011-2012. Since austral summer of 2012, rapid erosion has continued at the ice cliff, however, slumping of overlying sediment has buried much of the exposed ice, resulting in slower rates of erosion. Undercutting of ice-cored talus cones by the Garwood River during 2013-2014 may lead to removal of this sediment cover and renewal of rapid thermokarst erosion.

The physical factor most strongly correlated with ice cliff retreat by melting is total net radiation. Integrated net radiation closely tracks ice cliff range, even when air temperatures are below  $0^\circ\text{C}$ . Increased insolation provides an explanation for accelerating ice cliff retreat since 2001: since 1990, summer incoming solar radiation in the Dry Valleys has increased  $\sim 35 \text{ W m}^{-2}$  ( $\sim 1.7 \text{ W/m}^2/\text{yr}$ ,  $R^2 = 0.33$ ,  $P < 0.01$ ). This is a large percentage of summer average insolation ( $\sim 220 \text{ W/m}^2$  from 1990-2009), and represents a departure from the 1957-1994 continental trend of decreasing insolation in Antarctica. Net radiation at the ice cliff on sunny summer days is  $\sim 1.7\text{-}1.8 \times 10^7 \text{ J/m}^2$ , approximately double the latent heat required to maintain the melt rates at the ice cliff (2-4 cm/day) in the absence of sensible and turbulent heat fluxes from adjacent air.

## Relief analysis in periglacial environments on selected ice-free areas of the South Shetland Islands

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The ice-free areas in the South Shetland Islands suppose less than 10 % of the archipelago's surface. Therefore these areas offer a great interest in particular for geological and ecological studies, as well as evidences of past and current environmental changes. A quantitative geomorphic analysis of the largest ice-free areas of the South Shetlands archipelago, Byers Peninsula (Livingston Island) and Fildes Peninsula (King George Island) has been carried out in order to study the drainage basins, the relief evolution and to provide insight on the glacial history, the periglacial and fluvial processes and on possible climatic and neotectonic influences. The general relief and in particular the drainage basins have been mapped and studied by means of GIS spatial analysis using several data sources: aerial photographs, RADARSAT-2 satellite images, digital elevation models and field work. Fluvial drainage systems play an important role in the landscape evolution and can also contribute to a better understanding of the relief history. Shape and relief distribution for both basins and drainage networks have been characterized by a series of morphometric parameters analyzed on hierarchically selected watersheds in both peninsulas. Results of morphometric parameters reveal an elongated shape of basins, and a limited hierarchical network, common of a youthful stage of landscape evolution models. The use of different fluvial morphometric indexes allows us to propose different models of ice cover retreat and fluvial system development in the studied peninsulas. The hypsometric integrals and the T-Factor index have been the most relevant indexes implemented to detect recent and past changes in the glacial and fluvial evolution of ice-free areas in the studied region. The melting process is not continuous in time and can be understood as a succession of moments of relative stability along with others of high activity, following ice retreat, so that it leaves a mark on the earth surface and more specifically in the morphology of river basins that the application of morphometric indexes is able to capture, and from the results interpretation of relief evolution and spatial discrimination are possible. Ultimately, the morphometric analysis has revealed itself as a useful tool for acquiring knowledge on ice cover retreat processes and fluvial development, and can also contribute to outline scenarios connected to changes produced by glacial melting in recently deglaciated areas.

## The Geochemistry of McMurdo Dry Valley Streams: How Do They Compare to other Glacial Derived Melt Waters?

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In seminal reviews Tranter (2004) and Anderson (2007) summarized our understanding of the geochemistry of glacier melt streams. The geochemistry of most glacial streams is dominated by carbonate dissolution, carbonation, sulfide oxidation and selective biotite weathering. Glacial meltwater streams in the McMurdo Dry Valleys (MDV) originate from glaciers that are frozen to the substrate. Because of the differences in water flow paths subglacial sulfide oxidation and carbonation are not significant processes in the MDV streams. The major processes controlling the biogeochemistry of the MDV streams occur in the extended stream channel or hypohoric zone where changing water residence times, seasonal flow dynamics and variations in size play important roles. Our analysis of seasonal comparisons of the concentrations of weathering products, dissolved Ca, Mg, K, and Si, suggest that the MDV streams behave like temperate streams in regards to their concentration-discharge relationship, reflecting “chemostatic” behavior. All these data support the notion that MDV streams are not typical of other glacial systems. We suggest that water fluxes control the solute fluxes in MDV streams.

## The diversity and activity of methanogens in Antarctic periglacial sediment

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Antarctic periglacial regions are largely anoxic, contain plenty of organic carbon overridden by glacier ice during periods of advance, and are recognized as a suitable environment for methanogens to habitat. However, the in situ microbial activity and the responses of main microbial players during periods of glacial retreat are yet insufficient investigated. In this research, we present new data on the abundance, diversity and activity of methanogenic archaea from Antarctic periglacial sediments. Low archaeal diversity was detected and clones of Methanosarcinales, Methanomicrobiales and Methanocellales were identified in clone libraries. We employed long-term laboratory incubations to quantify the CH<sub>4</sub> production potential in different substrates. Results showed CH<sub>4</sub> production was more evident when H<sub>2</sub>+CO<sub>2</sub> were supplied as substrates and the order of magnitude of McrA copy numbers reaches 10<sup>6</sup>. These results suggest that hydrogenotrophic methanogens dominate in Antarctic periglacial sediments. In addition, this finding is helpful to estimate the potential effect of methanogenesis on the climate change in Antarctica.

## Oxygen isotopic ratios in the snow surface along a traverse from the Geographic South Pole to Patriot Hills

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This work examines the results of an oxygen isotopic profile formed by 104 snow samples collected in the austral summer of 2004 – 2005 along a traverse of the Antarctic ice sheet. The traverse was a joint Chilean - Brazilian work and was carried out as part of the ITASE (International Trans-Antarctic Scientific Expedition) program. It started at Geographic South Pole (altitude 2,840 m) and went to the Tenente Parodi Chilean station at Patriot Hills (80°18'S; 81°22'W, altitude 720 m) collecting superficial snow samples (upper 0.30 m) at every 10 km. The mean local annual temperature was determined at 6 points spaced approximately 220 km apart, at a depth between 10 and 15 m. We determined the O18/O16 ratios with 0.05‰ precision, using a GSMS - Gas Source Mass Spectrometer coupled with a Micromass Multiprep device, at the Climate Change Institute, University of Maine. Data are presented in delta ( $\delta$ ), relative to VSMOW. The  $\delta$  values for the oxygen isotopes vary from 52.6‰ to 30.0‰. As expected, results show a strong correlation of  $\delta^{18}\text{O}$  with local temperature (positive correlation), latitude, altitude and distance to the coast (all negative correlation). The  $\delta^{18}\text{O}$ /Elevation gradient is 0.08‰/100m and the  $\delta^{18}\text{O}$ /Temperature is 0.743‰/°C. Results agree with bibliography, which show an isotope ratio decrease with distance from the coast (0.0323‰/ km). We found an anomalous area, where in less than 20 km (from 87°30'S and 86°44'S) the isotopic ratio increases rapidly with distance from the coast, from -45.0 to -34.5‰, and then, after about 100 km, goes back to the general decreasing trend. HYSPLIT air trajectory models were run to examine if an orographic effect caused by the Transantarctic Mountains could be the origin of this anomalous area. After further examination, we attributed this anomaly to post-depositional processes, such as wind-driven sublimation.

## Active-layer dynamics of Western Dronning Maud Land, Antarctica

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Permafrost is one of the controlling factors of Antarctic terrestrial ecosystems, and the role it plays in the cryosphere is not well understood. There is much still to be learnt about the thermal state, physical properties, thickness and age of permafrost in Western Dronning Maud Land. Active layer dynamics and observed change over time have the potential to improve our knowledge of climate change. Understanding the effects of a warming climate on permafrost can also be of benefit to infrastructure, especially in areas with a large amount of frozen ground such as Scandinavia, Canada and Russia. The paper discusses the observed active layer and permafrost dynamics of Western Dronning Maud Land (WDML), Antarctica, using data from nine study sites. Ground and ambient air temperature, as well as ground moisture data were collected for each site. An inventory of active layer and permafrost landforms was compiled, as were the frequency of frost cycles and the depth of the active layer. Furthermore, mapping of periglacial features was conducted at each study site by use of an unmanned Autonomous Aerial Vehicle (UAV).

## Landscape processes and the active layer environment in Western Dronning Land

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Rhodes University

A paucity of past Geomorphology research in the Antarctic makes current investigations into active layer dynamics in this sensitive environment critical to understanding climate-landscape-biology interactions. The findings presented are from research that commenced during the 2007-2008 International Polar Year to investigate Geomorphology and Environmental Change in Western Dronning Maude Land. The project has been extended to include biological interactions with the landscape in a project titled *Landscape Processes in Antarctic Ecosystems*. The research and findings presented serves as a summary as well as an introduction to other papers in this session, where the initial findings of research during eight Austral Summers are discussed.

It is argued that the active layer environment is vital to investigating Antarctic and, by extension, global environments. Small changes in location produce significant differences in ground-level climate and these are ideal proxies for showing landscape and biological responses to climate change. The responses of both the Biology and Geomorphology to environmental changes, and associated feedbacks, can then be studied in the environment that probably has the fewest outside influences on Earth.

Ground climates in the study show expected strong seasonal patterns, with winters being substantially cooler than the warmer summers. The diurnal, inter-annual, and long-term trends are more difficult to interpret, but are critical to the survival of the colonising biodiversity and landscape development. Ground temperature differences of over 20°C have been recorded at two sites only 25km apart.

It is also not only the thermal environment that is critical to both the Geomorphology and Biology, but also moisture. The more moisture available, the more diverse is the landscape and the biodiversity. Climate driven changes in the region have already been shown to be, and are further predicted to be, dramatic.

## Soils of the Princess Elizabeth Land (East Antarctica)

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The soil cover of ice-free areas of the Princess Elizabeth Land (including Larsemann and Vestfold Hills) could generally be described as an alternation of three major clusters: 1) soils of wet inter-hill valleys – the hot spots of organo-mineral interactions in oases with the highest bio- and pedodiversity due to seasonal superficial and ground water sources; 2) soils with no signs of macrobiotic life (“ahumic”) formed on dry watersheds and elevated boards of the valleys with loose substrates and only atmospheric moisture source; 3) endolithic and epilithic soils on rocky exposures. Saturation by meltwater in wet valleys does not decrease the redox potential of soil solution and thus gleyic features are not expressed. Downward migration of silt and sand particles and cryoturbation are common. Cryptogamic biota originates mostly in epilithic, endolithic or hypolithic forms. Organo-mineral microhorizons of the wet valley soils show low degree of humification and the mineral matrix is not disguised by dark humus. However most coarse fragments (sand particles, gravel) and rocks do contain translucent organo-mineral coatings on their external and inner (in fissures) surfaces. In the absence of “classical” soil horizons such coatings are often the most distinct product of pedogenesis as well as the medium recording external factors change. Organo-mineral coatings are produced by interaction in situ of biofilm-like organized biota and mineral matrix in subaerial conditions.

Despite noticeable diversity of soils and microhorizons the wet valleys do not provide the most spacious environment to soils in oases. “Ahumic” soils together with endolithic and epilithic profiles occupy the largest areas in oases of the Princess Elizabeth Land.

The first data on endolithic soils suggest that their profiles are diverse. The products of endolithic pedogenesis include not just the fine earth formed in situ but also numerous microhorizons in a form of organo-mineral coatings (average of  $0.037 \pm 0.19$  g C/cm<sup>2</sup>). Certain types of rock varnish coatings were recognized as the products of endolithic pedogenesis.

The other, less extensive but still repetitive clusters, are the “amphibious” soils of lakeshores with pulsating regime and ornithogenic soils. In case of external organic matter contribution from lakes and the ocean (by birds) the larger amount of organic matter can be accumulated in the soil but still with low connection to the mineral matrix.

## Strontium isotopic signatures of the Torrent Valley streams, Monolith and Phormidium lakes on James Ross Island, Antarctica

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Czech Geological Survey

The Antarctic Peninsula and adjacent islands is the third-most warming site worldwide and the fastest warming in the Southern Hemisphere. This warming is not only accelerating retreat of glaciers (leaving fresh rock surfaces exposed to extreme weather conditions) but also the rate of rock weathering. In order to understand processes of chemical weathering we are using strontium isotopes ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) which provide natural fingerprint of rock-water interaction.

Sampling on the Northern part of the James Ross Island was performed during the 2011 and 2012 field campaigns by a team of Czech Geological Survey. Sampling sites were selected in respect to bedrock lithology, consisting of two main geological domains (palagonitized basalts and Mesozoic sediments). Isotopic analyses were performed at Czech Geological Survey using ion exchange chromatography separation and TIMS.

Data for water samples from Torrent Valley and Brandy Bay (Phormidium Lake and Monolith Lake basins) fall within two isotopically distinct groups. Water samples taken within Torrent Valley have less radiogenic  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios than samples from Brandy Bay. In Torrent Valley the  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios of the stream profile from the glacier to the sea shore become less radiogenic with increasing distance from the glacier. Torrent Valley is dominated by volcanic rocks and the isotopic composition of waters is close to their previously published isotopic data ( $0.7033 \pm 0.0002$ ), thus implying major contribution of volcanic source of the Sr in the water.

Water samples collected within Phormidium Lake basin have  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios close to marine sediments ( $0.7085 \pm 0.0006$ ) which are in good agreement with the geological situation on site. There are significant isotopic variations in the stream data. Some of the small streams entering Phormidium Lake are more radiogenic and some are less radiogenic than the waters of the lake itself. The  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of the Phormidium Lake lies on the mixing line between the stream waters. If the assumption that the  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of the sea water in Brandy Bay is equivalent to the modern-day seawater composition value is true, it seems that the sea spray aerosol contribution is not significant here, even the Phormidium Lake is in the close proximity to the bay shore. Data for Monolith Lake basin show  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios as a mixture between marine sediments and volcanic rocks as volcanoclastic breccias are quite abundant at this site. Our preliminary results imply that strontium isotopic composition can be successfully used as a tool to discern the proportions of geological materials undergoing chemical weathering at periglacial environment of JRI.

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## **TerraSAR-X high resolution snow patch mapping in high cloudiness environments: results from King George, Livingston and Deception islands (South Shetland Islands, Antarctica)**

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Snow plays an important role in controlling ground thermal regime and thus influencing permafrost distribution in the lower areas of the South Shetlands archipelago, where late lying snowpatches protect the soil from summer warming. However, summer snow distribution is complex in the mountainous environments of the Maritime Antarctica and it is very difficult to obtain accurate mapping products of snow cover extent and also to monitor snowmelt. Field observations of snow cover in the region are currently based on: i) thickness data from a very scarce network of meteorological stations, ii) temperature poles allowing to estimate snow thickness, iii) and time-lapse cameras allowing for assessing snow distribution over relatively small areas. The high cloudiness of the Maritime Antarctic environment limits good mapping results from the analysis of optical remote sensing imagery such as Landsat, QuickBird or GeoEye. Therefore, microwave sensors provide the best imagery, since they are not influenced by cloudiness and are sensitive to wet-snow, typical of the melting season.

We have used TerraSAR-X spotlight scenes with ca. 1m pixel resolution for mapping snow in different test sites in the South Shetlands. Scenes have been acquired in January 2012, and January/February 2014 for Fildes Peninsula (King George Island), Hurd Peninsula (Livingston Island) and Deception island. Close to acquisition time, snowpits were dug in order to characterize snow stratigraphy, grain size, grain type and snow density and to evaluate its effects on radar backscattering. A DGPS system was used to map snow patch borders at the exact same dates of the images, as well as other water surfaces, such as lakes, and also bare ground areas. This information was used as ground truth for assessing the classification potential of the scenes. The results indicate that TerraSAR-X, especially with HH polarization can be used for mapping snow cover and to monitor snowmelt during spring and summer allowing classifying the ice-free areas according to the length of the snow-covered period. Such map would be extremely useful for permafrost modelling. This approach is currently being conducted in the framework of the project PERMANTAR-3 (Permafrost monitoring and modelling in Antarctic Peninsula – PTDC/AAG-GLO/3908/2012 of the FCT and PROPOLAR).

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## Surface sediments and the Late Quaternary history of the western Vestfold Hills

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A striking feature of the western Vestfold Hills are the boulder fields draped over the landscape. Boulders are commonly greater than 1 m in diameter and reach up to 4 m across. Interpretations of these deposits have ranged from "ground moraines", beach ridges and intertidal boulder pavements and concentration of boulders at the surface by cryoturbation. All suggestions have merit in places. The understanding of these sediments bears on interpretations of glacial history for the region. Some studies suggest ice covered the area during the Last Glacial Maximum (LGM), but others suggest that the last glaciation may be as old as Pliocene. We use high resolution aerial photos, topographic LIDAR, surface levelling with Real Time Kinematic Differential GPS, multibeam bathymetric data, test pit stratigraphy, and boulder transect surveys to interpret the uppermost sedimentary units in the area.

The boulders form part of two sedimentary units exposed at the surface. The lower one is a silty to clayey diamict which is overlain by a boulder sand unit up to 2 m thick but which is discontinuous (Dingle Sand), forming ridges and terraces in the valleys and discontinuous drapes across bedrock hills. Pit stratigraphy indicates this unit has been found up to 23 m above Mean Sea Level (MSL). The highest boulder concentrations and the largest clasts are found on the sand unit. Excavations in this sand have found bivalves in growth position and as fragments. The lower diamict includes shell fragments (Vestfold Formation). The sandy unit forms ridges and terraces in the valleys with no strong orientation relative to potential palaeo-ice flow or palaeo-shoreline positions and the same topography continues below modern sea level. The size of boulders suggests emplacement by glacial ice. The morphology and elevation of the sand unit suggests initial deposition as a discontinuous boulder sand by cold ice which was then submerged by the Holocene transgression, colonized by marine organisms and then, in the case of the deposits below 9 m MSL, reworked in the coastal zone. The surface boulder concentrations on land have then been increased by deflation of the surface. Thus, the Vestfold Hills stratigraphy is comprised of the Vestfold Formation (an older, clayey till, possibly as old as Pliocene), overlain by the Dingle Sand (a unit which started as a deposit of a cold glacier, and has since been reworked during marine transgression and regression). The glaciation that initiated the deposition of the Dingle Sand could have been LGM age, though the shelly fossils date the inundation, not the genesis of the unit.

## Geomorphological processes in the ice-free area of Elephant Point (Livingston island, South Shetland)

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The retreat of Rotch dome glacier during the Holocene has originated the largest ice-free environment in the South Shetland Islands in the western tip of Livingston Island, Byers Peninsula (60 km<sup>2</sup>). The deglaciation process has also exposed the land surface in several other smaller peninsulas along the margins of this island. One of these environments is Elephant Point, an area of 1 km<sup>2</sup> located 3 km eastwards from the westernmost fringe of Byers Peninsula.

In late January 2014 we carried out a detailed geomorphological mapping of the landforms and processes occurring in Elephant Point. We also conducted measurements of the active layer thickness using a probe along three transects covering the entire peninsula.

Periglacial processes are widespread in the ice-free area in Elephant Point. From the present-day glacier front to the coast four main areas were identified:

- Proglacial environment. Small area recently deglaciated affected by thermokarst processes.
- Moraine complex. The moraine is 20-50 m height and 1 km length. It is composed by a sequence of arches running from the W to the E along the peninsula. The sediments of the moraine are intensely reworked by periglacial slope processes (mudflows, solifluction), more active on the north facing slope. Nival processes are very active on the southern slope of the moraine, generating several névé moraines.
- Bedrock plateaus, with heavily lichenized surfaces and patterned ground forms in areas where cryosols are present.
- Marine terraces. Up to 5 different raised beaches were identified (2, 3, 5, 7, 10 m asl). Cryoturbation processes are very intense in the oldest marine terraces (mudboils, sorted circles).

As in other ice-free environments in the Maritime Antarctica, permafrost conditions are widespread in Elephant Point. Visual observations of ice-rich permafrost were observed along the mudflow scars existing on the moraines, even at elevations of 5 m asl. Measurements of the thickness of the frozen ground reported an average of 56 cm depth. The deepest thickness was found at the moraine ridges (70-80 cm) and near the coastline (80-90 cm).

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## The influence of climate changes on interaction between the atmosphere - snow cover - permafrost in Antarctica and Arctica

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On the base of analyses of climate changes for the whole period of observation and for the last several years at Barentsburg (Svalbard, Norway) and Bellingsausen (Antarctic Peninsula) meteorostations and experimental studies an evolution of possible degradation of permafrost is given.

Linear trends of positive ( $T_{th}$ ) and negative ( $T_f$ ) mean daily air temperature at meteorostation Bellingsausen (1970-2012) showed their increase by 0,18°C and 0,8°C accordingly. We can see quite other situation for the last ten years – since 2003 to 2012. Trends of positive ( $T_{th}$ ) and negative ( $T_f$ ) mean daily air temperature were reduced by 0,043 and 0,138°C/year. The amount of solid precipitations was annually increase approximately by 28 mm within the last 10 years.

At the meteorostation Barentsburg (Svalbard, Norway), increase of mean annual air temperature and negative ( $T_f$ ) mean daily air temperature is 3,0°C within the last 27 years (0,11°C/year). This dynamics is kept at the expense of increase of negative air temperature during the last years.

Increase of value  $T_{th}$  (2003-2012) is about 0,026°C/year, and increase of value  $T_f$  (2003-2012) is about 0,24°C/year. Average thickness snow cover increase by 1,7 cm/year (2003-2012).

Calculations show, that thawed layer of ground approximately freezes within 3 months, when maximum thickness of snow cover is 1, 5 m, and mean long-term  $T_f$  value is -8,8° C. In the warmest winter of 2005-2006, when  $T_f$  = -4,9°C, the time of freezing was about 4 months.

However, mean long-term climate conditions don't lead to degradation of permafrost on Antarctic peninsula and archipelago Svalbard (Arctica).

## A seismic analysis of the firn across Antarctica

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Mapping the structure of polar firn is key to improving our understanding of current fluctuations in near-surface ice conditions that contribute to the future evolution of a glaciological system. The observed thickness and densification of the firn provides details on recent surface accumulation, temperature, and local ice dynamics; thus, observations of the firn from multiple locations can highlight how climate and ice dynamics may vary across a glacier or ice sheet. Seismic observations of the firn provide a simple means for imaging the physical properties of the firn, as the firn column can be imaged seismically in a matter of hours at a given location. Previous seismic studies, though limited to a handful of sites across Antarctica and Greenland, have also demonstrated that firn densification can be correlated to the seismic velocity structure of the firn.

Here I present the results from a series seismic observations of the firn across Antarctica and derive relationships between the seismic structure of the firn and its physical properties (density, accumulation, mean annual temperature). Co-located density and seismic sites are used in this study, spanning a broad range of elevations (<50 m to ~3500 m), accumulation rates (<5 cm a<sup>-1</sup> to >30 cm a<sup>-1</sup>), and temperatures (<-50°C to >-20°C), thus allowing a new and robust seismic velocity – density relationship to be determined. The effects of accumulation and temperature on seismic velocities are also explored. This analysis highlights a novel methodology for exploring the physical structure and variability of the firn across a glacier or ice sheet, and provides a simple means for capturing firn structure, without the logistical constraints of firn coring, storage, and analysis.

## Soil and air temperature along an altitudinal gradient in Keller Peninsula, King George Island, Maritime Antarctica

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Soil temperature depend on several factors, such as atmospheric factors (for example, air temperature, precipitation and solar radiation), soil surface conditions (snow cover and vegetation), soil properties (structure, chemical composition, humidity). However, in periglacial environments the presence of permafrost is the key factor in defining the soil thermal regime. In Antarctica, the soil temperature is related to various environmental attributes and therefore it is an effective indicator of climate change effects in that region. While the weather conditions influences the soil temperature on a global scale, locally the soil temperature is mainly influenced by topography and soil properties. In periglacial environment, the active layer thickness is inversely proportional to altitude. So, along an altitudinal gradient, the permafrost is closer to ground surface at site of altitude highest. This study analyzed the soil and air temperature on three sites with different altitudes (34, 89 and 259 m) and little vegetation in Keller Peninsula, King George Island, Antarctica. The study period was March 2009 to February 2010. Monthly and daily averages of soil and air temperature were calculated. Soil temperature data were obtained by sensors installed in different soil depths (10, 30 and 80 cm). Air temperature data was measured by a thermometer located about 1 m height from the soil surface. Data were measured every hour and recorded in data logger. Air temperature average (-3.2, -3.7 and -4.5°C) was inversely proportional to altitude, which was expected, but the average soil temperature did not appear of this same way. Soil temperature average was higher (-1.2°C) at site with the lowest elevation (34 m) and colder (-2.3°C) at site where the altitude is intermediate (89 m). In site with 259 m the soil temperature was around -1.9°C. This occurred in 89 m because of other environmental factors, as solar radiation blocking by higher adjacent areas. Besides, in this site the surface soil has a soft slope, which decreases amount of snow deposited and facilitates of water flow, decreasing the thermal conductivity in defreezing period. Also, the zero curtain period was more short in this site, probably because the heat exchange between air and soil are facilitated by little snow cover. In conclusion, altitude and air temperature are important environment factors for soil temperature, but local conditions, as ground slope and snow cover, are also.

## Recent glaciological and geomorphological changes in King George Island glaciers

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This paper investigates changes in glaciers from the Kraków Ice Field (Admiralty Bay) and in the Collins Glacier (Fildes Peninsula), King George Island (KGI), South Shetland Islands, off the Antarctic Peninsula. Glaciological and sedimentary data analysis, from fieldwork carried out in the summers of 2007, 2010, 2011 and 2013, point to fast environmental changes. We used COSMO-SkyMed (Constellation of Small Satellites for Mediterranean Basin Observation) images in spotlight mode (1 m spatial resolution) with HH and VV polarization for recognition of geomorphological features in the Martel Inlet (Admiralty Bay) ice-free areas. In this area, temperate glaciers have an extended proglacial front as a consequence of their recent retreat. To monitor recent changes, we determined terminus and snow line altitude fluctuations. We used topographic data to generate transverse and longitudinal sections and a three-dimensional model (DSM) of the Wanda Glacier (Admiralty Bay) surface. From 1979 to 2011, this glacier lost 0.71 km<sup>2</sup> of its ice front (about 31% of the 1.5 km<sup>2</sup> total surface area); the nearby Viéville Glacier lost 4.48 km<sup>2</sup> of its ice front. Due to their small size and thermal conditions, these glaciers respond rapidly to climatic changes. The Collins Glacier suffered a greater retreat and snow line elevation change in its north sector. The current continuous and fast retreat phase is attributed to the recent regional warming. A geomorphological map of the recent proglacial areas showed several types of glacial deposits, such as frontal and lateral moraines, flutes, meltwater channels and erosional features like rock moutonnés, striations and U-shaped valleys. Some glacial linear features in the Wanda Glacier proglacial area, such as lateral moraines, flutings, and arêtes are better identified with COSMO-SkyMed VV polarization, while supraglacial debris, debris flow, and shorelines are better discriminated with HH polarization. Meltwater channels, lakes, and lagoons were easily distinguished under both co-polarizations. These ice-free areas were susceptible to rapid post-depositional changes.

## Genesis of polar desert soils from Edson Hills Glacial Valley, Ellsworth Mountains, East Antarctica

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Knowledge on Antarctic soils from the Ellsworth Mountains (Ells. Mts.) are patchy comparatively with Dry Valleys soils from the Transantarctic Mountains, and could help understand the genesis of cryogenic soils under extreme dry, cold desert conditions. The Ells. Mts. are a slightly arcuate 350-km-long north-northwest-trending mountain chain is bordered on the west by the polar plateau of West Antarctica and on the east by Ronne Ice Shelf. The range is as much as 90 km wide and constitutes one of the largest areas of exposed bedrock in West Antarctica. Edson Hills is a rocky glacial valley located within the Union Glacier. Is formed by a sequence of three formations: Hyde Glacier Formation (greywacke, argillites and conglomerates); Union Glacier Formation (volcanic tuffs and lahars) and Kosco Peak Member (marble-conglomerate) from the Cambrian. We characterized soils from Ells. Mts. regarding their morphological, physics and chemical properties. Soil samples were air dried and passed through 2 mm sieves. After removal of water soluble salts, the samples were submitted to chemical and physical analyses such as: pH in water, potential acidity (H + Al), exchangeable bases, total organic carbon, electric conductivity, soil texture and color. The soils classify, for the most part, in weathering stages 1 to 2. Only in the upper parts of ridges were there traces of soils at weathering stage 3. This indicates that much of the present icefree topography has been overridden by ice within the last few hundred thousand years. Cryoturbation is a widespread phenomenon in this area resulting in intense cryoclastic weathering and patterned ground, forming sorted circles, stripes and gelifluxion lobes. The soil show low horizontation, discrete patches of salt on the surface, and salt crusts beneath the rock fragments. Despite of the low weathering stage of the soil, they have yellowish hue and high chroma values from influence by sulfide material. Boulders on moraines show staining, pitting, spalling, and some striations. All soil are alkaline in reaction, with pHs at the range between 7.5-9.2. Cryptogamic (lichens or mosses) crusts are absent, and the organic matter contents were invariably very low, ranging between 0.13 and 0.38 %. Permafrost is continuous and occurs close to the surface, at between 5-15 cm down the top. The available P background is also very low (< 5.3 mg/kg), exchangeable K and Na levels are surprisingly low for Polar Desert soils. Soils are all skeletal, with a predominance of coarse materials. CEC is medium to high, and Ca-dominated, as a result of a strong limestone influence in the moraine parent materials. The main salts present are Ca and Na-sulphate forms, and less chloride forms, and clay sized materials are dominated by salts in all soils, especially below 5 cm depth.

## Active-layer temperature regime in Keller Peninsula, King George Island, from 2008 to 2011

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Temporal datasets may be seen as a combination of periodic or semi-periodic components, which are obtained in a long term trend and alleatory high-frequency noises, in different applications. The periodic components are assumed to be fix or that their amplitudes and phases vary smoothly along the period of registration (WILKS, 2006). Seeking to identify the most frequent (patterns) active-layer temperatures in the 2008 to 2011 period for six monitoring sites in Keller Peninsula, different techniques of temporal dataset analyses were used (harmonic and spectral). The annual period was the most frequent, followed by the intra-annual (seasonal) and inter-annual (climatic mode) periods. In sites with highest soil temperatures (Cruzes, VLF, Refuge and Yellow Point), the intra-annual frequency was marked by three periods of four months, where two of them correspond to winter and summer. The third period is composed by spring and autumn seasons, each with a two-month duration. The coldest sites (Tyrrel and Ipanema) presented a intra-annual variation of six months composed of two periods: warm and cold. The spectral analysis allowed the identification of a significant interannual period, in which anomalous soil temperatures occurred, with temperature slower than expected, which possibly corresponds to the influence of the Anular South Climatic Mode (ASM), which occurred in this region from 2009 to 2010. The results demonstrate the potential of soils temperatures as a tool for environmental monitoring in a changing climate scenario.

## Soil formation and pedodiversity in Maritime Antarctica

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Although recent publications highlight interesting and novel aspects of soil genesis in Antarctica, there has not been a comprehensive regional approach to describe the soils from Maritime Antarctica. The region experiences high air temperature increases and growing impact of human activities, due to the presence of many scientific stations and tourism activities. In this work, we summarize the existing information on soils of the South Shetland (SSI) and South Orkney Islands (SOI). We compiled data from existing soil studies with focus on pedogenesis and soils geography. Data were collected from 365 pedons.

The presence of permafrost, intense cryoclastic weathering and cryoturbation under a periglacial regime leads to a predominance of turbic soils (Turbels). Chemical weathering has a distinct role in soil formation in the SSI and SOI, notably in soils under bird guano influence and in sulfide-bearing rocks, where acid-sulfate soils form. Clay formation, phosphatization and organic matter accumulation occur in stable areas where vegetation exists, allowing long-term stability, illuviation (podzolization), and soil horizonation. Cryptogamic vegetation, despite its low biomass and the dominance of saxicolous lichens and mosses, strongly acidifies the topsoil, generating organic acids that enhance chemical weathering; the volcanoclastic nature of the regional bedrock further facilitates chemical dissolution and clay formation.

Soils of the SOI and SSI have a combination of unstable primary minerals and secondary minerals in the clay fraction, attributed to intense physical weathering and moderate chemical transformation. The amount of stones, gravels and cobbles are normally high in this part of Antarctica and is directly related to the sedimentary/lithological nature of the bedrock. Tuffs, ashes, closely jointed volcanics, volcanic breccia and sandstones are usually shattered into small fragments, whereas igneous rocks of plutonic origin are more resistant. Sulfide-bearing rocks are those which promote a greater clay formation and are dominated by poorly crystalline minerals (jarosite, ferrihydrite).

The suite of soil forming processes in the SOI and SSI are varied: acidification, podzolization, gleying, cryoturbation, sulphurization, phosphatization, brownification – all suggesting a variety of soils according to the landscape position and the composition/nature of parent material.

## Defining Permafrost Research Priorities over the next ten years: An ICARP III contribution

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The Third International Conference on Arctic Research Planning (ICARP III) provides a framework to identify Arctic science priorities for the next decade, to coordinate various Arctic research agendas, to inform policy makers, people who live in or near the Arctic and the global community and to build constructive relationships between producers and users of knowledge.

The permafrost community, through the International Permafrost Association (IPA), has assembled a core team to coordinate ICARPIII activities. The Permafrost Research Priorities (PRP) process is coordinated by the IPA and the Climate and Cryosphere project (CliC) and aims at identifying the top priorities in permafrost research. The IPA specifically mandated the group not to limit its focus to the Arctic but to define research priorities for the whole of permafrost research.

The process will span much of 2014 engaging the research community and will result in a short publication listing and putting into context research priorities. The document shall become the benchmark against which permafrost research should be gauged starting in 2015. The final document of priorities will be sent to national and international funding agencies, international organizations, policy makers, and others with interests in supporting permafrost research. It will form one of the outputs of ICARP III.

ICARP III is governed by a Steering Committee established by the participating organizations. It will be structured along scientific themes and include a series of events, culminating in a final conference at the Arctic Science Summit Week 2015.

The permafrost community will engage its members over the year 2014 to produce a statement specific to permafrost research feeding into this process.

In this presentation we highlight the progress made to date in the permafrost community to implement ICARPIII activities and pave the way to the events taking place at the Arctic Science Summit Week 2015.

## The influence of spatial variability of polar firn on microwave emission

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Precise measurements of snow structural parameters and stratigraphy are essential to understand and model the radiative properties of the snow cover. However, most snow measurements are limited in spatial resolution and by extensive measurement times, which particularly constrains their applicability in harsh polar environments.

For this reason, we developed a statistical model to derive three major snow structural parameters, density, correlation length and specific surface area solely from a portable, high-resolution penetrometer. We demonstrate the potential of the method by a 25 m long and 1.1 m deep transect through Antarctic firn at Kohnen Station, Antarctica, which reveals the stratigraphic features of the firn clearly.

Based on these data, we run the Microwave Emission Model of Layered Snowpacks (MEMLS) and analyze the influence of the spatial variability of the firn around Kohnen Station on the microwave emission of the snowpack. We discuss the potential and limitations of the method and highlight the need for spatially distributed, quantitative measurements for modeling the microwave emission from polar snow and firn.

## Review and new results on snow metamorphism in Eastern Antarctica

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Metamorphism is a ubiquitous and significant process occurring at the near surface of snow and firn. Relatively little is known about how snow metamorphism affects the physical and mechanical properties of snow in Antarctica, and observations are difficult by traditional means. One reason for the lack of knowledge is that depositional and metamorphic processes occur concurrently. Near-infrared photography, quantitative translucent profiles, high-resolution penetrometry, optical Specific Surface Area measuring instruments and micro-tomography are modern methods suitable for use in Antarctic snowpacks. These instruments gather detailed stratigraphic information at multiple scales. We applied these methods at three different sites in Antarctica: Allan Hills, Pointe Barcola and Kohnen Station. The characteristic stratigraphy and microstructures found at these locations will be presented and interpreted here. Based on our observations, we show that alternating temperature gradient metamorphism, which is the dominant type of metamorphism at the surface, has a strong effect on the re-mobilization of the hard snow surface during austral summer, and temperature gradient metamorphism is important during winter. Large erosional events, removing multiple years of deposition, can occur, and have a marked impact on stratigraphy.

## Rockglacier and stone-banked solifluction lobe movement in Hurd Peninsula (Livingston Island, Maritime Antarctic). First results

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Periglacial landforms and processes in the South Shetlands have been subject to extensive mapping and to several research papers describing their main characteristics and overall controlling factors, but an understanding on process rates is lacking. In the framework of PERMANTAR-3 project, we are monitoring the deformation of stone-banked solifluction lobes and of a rockglacier in Hurd Peninsula, Livingston Island. Most of the peninsula is occupied by Hurd Glacier. Ice-free areas dominated by periglacial processes margin the glacier, consisting both of mountain ridges up to 407 m asl (sector between Binn and McGregor Peaks) and plateaux with altitudes ranging from about 130 to 180 m asl (sector between Papagal – Bulgarian station and Salisbury Point). The bedrock is mostly composed of sandstones, shales and greywackes of the Myers Bluff formation.

Hurd rockglacier is located in the south part of Hurd Peninsula, in a glacial cirque with a ridge varying from 227 to 301 m asl that connects directly to False Bay through a series of raised-beach terraces. The valley shows steep rockwalls with extensive scree slopes and a small retreating valley glacier with a prominent frontal moraine, from where the rockglacier develops. The rockglacier body is ca 630 m long and 290 m wide and the surface shows frequent pressure ridges and furrows, especially in the lower sector. The rockglacier front is 15-20 m high and shows a slope of 45°.

The monitored stone banked solifluction lobes are located in different sites in the vicinity of the Bulgarian Station St Kliment Ohridski. They are composed by very angular gravels and boulders with a riser of 10 to 20 cm and a tread which is 1 to 3 m long.

In this poster we present the first data from surface deformation monitoring using stakes and D-GPS measurements conducted annually since 2011. Preliminary results show deformation values of 8 to 15 cm/year in Hurd rockglacier and of a few centimeters in stone-banked lobes. Since 2011 we are also conducting DInSAR analysis using TerraSAR-X imagery and despite problems related mostly to snow cover, we have obtained image pairs allowing to identify deformation similar to field observations. The deformation data is complemented by electrical resistivity data showing the presence of permafrost in rockglacier, while the stone-banked lobes are located in the discontinuous permafrost belt.

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## Acquisition and processing of ultra-high resolution images with UAVs for detailed and extensive surface mapping and change detection in Barton Peninsula

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The detailed mapping of ice-free areas in the Antarctic Peninsula region on a regular temporal basis is important to evaluate the dynamics of the landscape in a region with one of the strongest warming rates on Earth in the last half century. This task can be advantageously performed with the aid of remotely sensed data, as systematic surveys can be performed in a relatively swift manner. The acquisition of images with own platforms and sensors, that can be operated whenever the meteorological conditions allow, can thus overcome the difficulty of spaceborne systems to get clear and frequent images from these regions, where cloud covers are the common situation. Moreover, the possibility of having images with higher resolutions (spatial, spectral and temporal) than those provided by satellites is a relevant advance for mapping with the finest detail their periglacial and ecological features and thus giving a major contribution for monitoring the changes punctually observed in the field. Unmanned Aerial Vehicles (UAV) are therefore a solution to capture images. In this study we describe the activities we are developing in Barton Peninsula (King George Island, South Shetland) for acquiring ultra-high resolution images with two UAV systems: the first is a hexacopter that captures millimetric images and surveys particular sites of interest (several ha), the second is an airplane that acquires centimetric images and covers larger areas (several km<sup>2</sup>). We also present the kind and amount of data acquired by each system and the demanding processing chain that is needed to assemble the individual images acquired into a large one covering the entire site or region of interest (a mosaic) and the necessary subsequent geometric corrections using ancillary data obtained with field surveys with a differential GPS (ground-control points). The sites and regions presented show the diversity of the landscape and exhibit the predominant ice-free features of interest in Barton peninsula, namely lichens, mosses, snow, lakes, soils and rocks. The soils and rocks classes contain also abundant stone circles, a common type of patterned ground in this peninsula. The products obtained allow, for instance, to discriminate different types of vegetation or to compute the sizes of the elements that constitute stone circles and also to get a micro-topography of the regions of interest. The features perceived in these images allow mapping and monitor these regions with an unprecedented detail.

## Reconstruction of glacial dynamic in Union glacier, Ellsworth Mountains, using geomorphological and sedimentological record

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Cold-based glaciers are considered to be predominant in the interior of Antarctica, which were thought to have minimal or none influence on the landscape. Nonetheless, there is evidence for the cold-based glacier action from some glaciers. On the other hand, it is also reported the existence of extensive subglacial drainage in Antarctica, which means that these areas are at the pressure melting point.

This work presents features of erosion and deposition related to the subglacial bed conditions and thermal basal processes in Union glacier area, Ellsworth Mountains, West Antarctica (79°45'00"S; 82°30'00"W). Union Glacier is a windy area, with several blue ice areas on the leeward zones of the mountains. The mean ice thickness is about 1450m, covering a deep subglacial topography. With the exception of some valley glaciers, which ice margin terminates on the land, most of the modern glaciers drain into the main flow of Union glacier.

The area of study comprises Rossmann Cove, a Union glacier tributary with exposed mounded hills and ice-cored morainic ridges. Landforms and deposits were identified and mapped during the 2011/2012 field work, and by combined images from Advanced Spaceborne Thermal Emission Reflection Radiometer (ASTER), (2004/2010, spatial resolution of 15 m). Sediment granulometric analysis and clast shape description of surface characteristics were carried out in order to identify the facies of the analyzed deposits.

The evidence for subglacial activity is reconstructed from a range of geomorphological and sedimentological record, including exposed abrasion marks, parallel lineations, subglacial deposit, and glaciotectonic deformation. The later one is represented by giant lee sides of oversteepening bedrock promontories which follow the tributaries glaciers ice flow, with the stoss part relatively intact whereas the distal part is more impacted by fracturing and quarrying. Potholes were found on the weathered quartzite rock surface, which may be the product of subglacial meltwater erosion.

Sediment analysis of Rossmann Cove morainic ridge show a mixed grain size, ranging from sand and gravel to boulders. The roundness of the clasts grain-sized (2 - 8mm) is mostly subrounded, with medium sphericity. Several clasts are micro-striated, which may point reworked older wet-based subglacial tills. Conversely, the larger clasts (> 1.5cm) are mostly angular to subangular. The high RA values and the radius  $c/a$  lower than 0.4 of the most of them indicate a passive transport.

We infer that the past thick ice that covered the topography and converged through valleys into Union glacier could support frictional heating and basal processes. We also highlight the importance of the basal thermal regime and the transition from cold-to warm-based ice as a major factor in the glacier dynamic.

## Revealing aerobic carbon dioxide production in lake and wetland sediments in the Maritime Antarctica (Fildes Peninsula, King George Island)

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Low-flow inland waters as lakes and wetlands are preferential sites for inputs, mineralization and burial of carbon (C) in the watershed. Metabolic processes involved in the organic degradation of aquatic sediments are determined by temperature, and play an important role on the C cycling, releasing greenhouse gases that may potentially reach the atmosphere, as carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>). At the surface layers of aquatic sediments, the aerobic respiration based on CO<sub>2</sub> production and oxygen (O<sub>2</sub>) consumption dominates the organic mineralization. The Shetland Islands in the Maritime Antarctica, encompassing the King George Island, have experienced more rapid warming than any other part of the Southern Hemisphere. Consequently, the biological balance between C uptake and release in subpolar flooded areas on these islands could be highly sensitive to global warming.

Here, the aim was to assess aerobic CO<sub>2</sub> production rates using in situ sediment core incubations. The methods included sediment core incubations for aerobic respiration during 10-18 hours under relatively constant temperature (2-4 °C), and within a coolbox in the field soon after sediment sampling.

The results indicated a high significant variation of aerobic organic decomposition for sediments among studied aquatic ecosystems (Tukey-Kramer,  $p < 0.05$ ). Mean aerobic respiration rates varied from 2.0 to 54.8 mg O<sub>2</sub> m<sup>-2</sup> h<sup>-1</sup>, showing a coefficient of variation of almost 110%. Comparing different types of ecosystems, wetland sediments (n=4) showed aerobic respiration rates, in average, four-fold higher than those from lakes (n=5), respectively 24.3 and 5.9 mg O<sub>2</sub> m<sup>-2</sup> h<sup>-1</sup> (t-test,  $p < 0.05$ ). These mean values of aerobic organic degradation under warmer conditions in summer were lower but significant in relation to similar ecosystems at higher latitudes. Our findings reveal that very shallow waters could contribute for accumulation and degradation of organic matter in subpolar watersheds. The extensive wetland ecosystems could be, therefore, relevant components of the C cycle that still needs to be better known in deglaciated areas of Antarctica.

## Regional active layer warming along the western Antarctic peninsula

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Changes in active layer temperature and thickness can be good indicators of regional climate change. Factors influencing active layer temperatures include both changes in atmospheric conditions and geographic location. This study focuses on the effects of elevation and latitude on active layer temperatures along the Western Antarctic Peninsula.

Active layer elevational temperatures at the Argentine Station, Primavera Base, were monitored every three hours using iButton thermistors. These thermistors were installed at regular interval depths in ten boreholes, down to two meters below the surface. Monitoring occurred continuously from March 2012 to April 2014. Using regression analyses, a strong correlation between elevation drop and subsurface temperature increases at Primavera Base ( $R = 0.95$ ), which closely followed air temperature elevation gradients. There were also significant temperature differences caused by surficial material type. At all elevations the shallow boreholes were not deep enough to detect the maximum active layer depths.

To monitor and compare latitudinal active layer thickness differences, deep (15 m) boreholes were drilled at two locations along the central latitude of the Antarctic Peninsula (Primavera Base and Palmer Station). Similar to the shallow, elevational boreholes, thermistors were installed at regular interval depths in these boreholes. The active layer thicknesses at these locations were compared to recorded thicknesses farther to the north (Livingston Island) and farther to the south (Rothera Station). Unexpectedly, active layer thicknesses at both central locations were much deeper than anticipated at 8 and 14 m, respectively. Both locations had active layer thicknesses that were several meters deeper than locations to the north (2 m) and south (1.2 m). Additionally, a study at Palmer Station in 1982 found that permafrost was detectable within 0.5 m of the ground surface, much shallower than what was found in this study.

It is unknown why active layer thicknesses at these locations were so much deeper than at the more northerly sites, as there were no abnormally high air temperatures or solar radiation inputs during the study period. To elucidate the primary cause of this regional warming trend along the west-central Antarctic Peninsula continued data collection at the current monitoring sites, along with a more extensive network of active layer thickness and atmospheric monitoring sites along the Western Antarctic Peninsula, will be needed.

## Soils of the Schirmacher Oasis (Queen Maud Land): genesis and classification

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Schirmacher oasis is located in the central part of the QML (Coast of Princess Astrid) at a distance of 90 kilometers of Lazarev sea. The total length of oasis is 18 km and its width is from 0,6 to 3,5 km. Schirmacher oasis is one of the coldest flatland Antarctic oasis, because of its high latitude, trans- shelf location and its small size. The hypergenic and pedogenic transformations of loose deposits within moss-covered sites, algae-covered sites, patterned ground occupied by vegetation in different percentage and dry grounds within the Schirmacher Oasis were studied.

Large areas of moss covering from 45 to 95% of the surface were, as a rule, found close to snow patches that occurred on the hill slopes and within the upper reaches of the valleys. Soils under moss communities were the only soils with developed organogenic profile within the Oasis, despite that the summer temperatures under the moss were significantly lower than in the wet bare ground and the period of time suitable for pedogenesis was significantly shorter. There is an abundant growth of algae, predominantly blue-green algae (cyanobacteria), on wet and also periodically inundated substrates near large and small water courses and lakes. The algae communities are confined to the lowest topographic positions within the valleys and lake hollows. Soils under algae have been described by us on sands and sandy loams. Wet parts of valleys are almost entirely represented by patterned grounds which can be lifeless or covered by fragmentary vegetation attached as a rule to the edges of sorted polygons. Films of algae, lichens, and small turfs of mosses are found on them. Conditions for the growth of large moss communities occur rarely. If grounds are formed by sandy loams or loams, this can be caused also by frequent cryoturbations. The thickness of such soils ranges from 10 to 16 cm. There is no vegetation in dry parts of the Schirmacher Oasis except solitary and rare lichens, soil formation processes are indistinct here. Periodically they get some moisture with summer snowfalls and the occurrence of hypergenic processes in loose sediments becomes possible. These soils can be defined as «ahumic soils» (Tedrow, Ugolini 1966). Heterogeneity of their profiles is mainly the result of abiogenic processes. The presence of microorganisms gradually transforming the substrate is very probable and needs to be confirmed through laboratory research. According to the WRB system, the soils under mosses mainly belong to Turbic/Haplic Cryosols (Endoleptic); some of them should be classified as Turbic/Haplic Cryosols (Skeletal, Oxyaquic, Arenic). The soils of patterned grounds are Turbic Cryosols (Oxyaquic, Arenic, Eutric). The soils under algal communities near the lakes belong to Haplic Cryosols (Oxyaquic, Skeletic, Arenic, Eutric) or (Oxyaquic, Siltic, Eutric). The soils of lake shore subjected to ponding are Haplic Cryosols (Reductaquic, Siltic, Eutric).

## S09: ANTARCTIC CLIMATE AND METEOROLOGY

### Sensitivity Study of the antarctic surface mass balance to snow erosion by the wind

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A new version of the regional climate model MAR has been developed. New numerical schemes allow to set-up the model over Adélie Land, Antarctica, with a fine horizontal resolution (5 km) and an improved vertical resolution near the surface (lowest level is now situated 1 m above the surface). The domain of the model covers the steepest slopes of Adélie Land, on an area of 500 times 500 km<sup>2</sup>. Simulations last the 2 summer months (december 2010 and january 2011), allowing an optimal interaction between observers and modellers. The influence of model improvements on the wind speed, the horizontal blowing snow flux and the surface mass balance simulated by the model is discussed.

## Observations from the NILU-UV Antarctic network since 2000

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Total ozone and UV measurements have been performed with the NILU-UV radiometer at the station of Ushuaia (54°S), Marambio (64°S) and Belgrano II (77°S) since 2000. The network was established in 1999/2000 by the Spanish Agencia Estatal de Meteorología (AEMET) in collaboration with the Finnish Meteorological Institute (FMI), the Argentinian Dirección Nacional del Antártico - Instituto Antártico Argentino (DNA-IAA) and Centro Austral de Investigaciones Científicas (CADIC). The location of the network was chosen in order to monitor total ozone and UV radiation at different sides of the polar vortex: Belgrano II is mostly located inside the vortex, Marambio at various times inside, on the edge of, or outside the vortex, while Ushuaia is mostly outside the vortex.

The NILU-UV multifilter radiometer measures solar UV radiation at five channels, which central wavelengths are around 305, 312, 320, 340 and 380 nm, and bandwidths of around 10 nm at full width at half maximum. A sixth channel measures the photosynthetic active radiation (PAR) in the 400-700 nm wavelength region. By combining the readings of different channels, the total ozone, cloud transmission, UV-B, UV-A and erythemally weighted dose rates can be calculated. The near real time measurements are available at <http://www.polarvortex.aemet.es/>.

The quality assurance of the network is based on regular lamp measurements and a traveling reference instrument. The traveling reference instrument transfers the chosen irradiance scale from one station to another by solar comparisons. Each winter, the traveling reference is sent to the Arctic to be calibrated. During the calibration, solar comparisons are performed between reference spectroradiometers and the NILU-UV radiometer. When sent back to the Antarctic, the irradiance scale is transferred, which makes measurements of the Arctic and Antarctic comparable with each other.

In this study, the total ozone, UV-B -, UV-A - and erythemally weighted UV dose rate time series are studied. The influence of the Antarctic stratospheric ozone loss on surface UV radiation is quantified at the stations of Ushuaia and Marambio, where the years of severe ozone depletion are clearly seen.

## Greenhouse gas (CO<sub>2</sub>, CH<sub>4</sub>) measurements at Base Marambio, Antarctica

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The Southern Ocean is a significant net sink of carbon dioxide (CO<sub>2</sub>) from the atmosphere. Climate change alters atmospheric circulation around Antarctica that will affect CO<sub>2</sub> uptake and efflux from the sea. In the Antarctic seabed, there are methane (CH<sub>4</sub>) hydrate deposits, which may leak to the sea and partly to the atmosphere. To observe these phenomena, atmospheric greenhouse gas observations started in February 2013 at Base Marambio as a co-operation between Finnish and Argentinian scientists.

In January 2013, a laboratory in a sea-container was transported to Marambio (64.2433° S, 56.631° W, 198 m a.s.l.). In addition to the greenhouse gases we measured aerosol scattering and absorption (black carbon) and aerosol size distribution. Wind, global and ultraviolet radiation, air temperature, humidity and pressure were measured as well. Concentrations of CO<sub>2</sub> and CH<sub>4</sub> were measured continuously by Picarro G2301. To ensure compatibility of our calibration scale to the global greenhouse gas measurement networks, we used three calibration gases and one target gas traceable to the scale maintained by Central Calibration Laboratory (in NOAA) of the World Meteorological Organization.

Marambio is located on the tip of the Antarctic Peninsula. Prevailing winds were either from the south-southwest (continental air) or from the north-west (marine air). In summer, easterly winds from the Weddel sea occurred occasionally. Methane concentrations had only small variations embedded on the sinusoidal seasonal amplitude, which followed solar radiation cycle. The minimum was in March and maximum in September, the amplitude being 35 ppb. Concentrations were in the range observed in the flask samples by NOAA at the South Pole, Palmer Island and Ushuaia stations. Our continuous record showed that often methane concentrations were a few ppb higher when advection was from the ocean relative to the continent. Carbon dioxide concentrations were on the average very close to those at the NOAA flask sampling sites. In summer, concentration variations were higher and average concentrations were usually lower at Marambio than at South Pole indicating net oceanic uptake. We will present measurement system and results and try to estimate sink and source areas of these greenhouse gases.

## Ozonesonde observations at Marambio, Antarctic Peninsula

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Recent studies have demonstrated that surface climate has been affected by ozone depletion processes in the Southern Hemisphere and especially in the Antarctic region. Long term observations of Antarctic ozone development have been obtained at various locations in the Antarctic region. Here we focus on the ozonesonde measurements at Marambio, Antarctic Peninsula at 64° S, 56° W. The ozonesonde program at Marambio was established in late 1980s, soon after the discovery of the Antarctic ozone hole. Since 1990 we have obtained a nearly continuous data record of ozonesonde measurements over Marambio during all seasons, with an emphasis on springtime measurements. In this study we first focus on the homogeneity of the data record. The observations at Marambio have been made by electrochemical concentration cell ozonesondes since the beginning of the data record. However, sonde types and also operational practices have been updated, when newer technology has become available. Therefore a thorough data quality analysis has been needed to estimate measurement uncertainties over the long term period. Secondly, the homogenized data are used in a study of ozone profile trends and variability. A statistical model has been applied on the ozonesonde profile data. This model accounts for the changes in effective equivalent stratospheric chlorine and meteorological variability. In addition we have performed chemistry-transport model simulations to investigate long term changes in stratospheric ozone.

## Year-round measurements of aerosol particles in station Marambio

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Human impact on the increase of the greenhouse gas concentrations have resulted in dramatic changes especially in Antarctic peninsula. This has been demonstrated to be crucial for the fragile ecosystems of this region.

Atmospheric aerosol particles are an integral part of the climate, having effects on water-, carbon-, and nutrient cycles, the amount of solar radiation entering the surface and changing the amount of cloudiness and rain, as well as the properties of clouds.

To understand the interaction of aerosol particles with climate, several new measurements of particles were initiated in Antarctic peninsula, in Argentinean station Marambio in summer 2012/2013. These include in-situ particle size distribution in range 10 nm – 10 µm, aerosol scattering at three wavelengths and aerosol absorption, as well as weekly analysis of chemical composition of PM<sub>2.5</sub> and PM<sub>10</sub>. Measurements are continuous year-round, and here we present the results from the first full year of 2013.

Monthly average total aerosol number concentration showed a distinct cycle, with maximum (about 700 cm<sup>-3</sup>) in summer and minimum (about 100 cm<sup>-3</sup>) in winter. In contrast, no clear annual cycle could be observed in aerosol optical properties. Average black carbon concentration was about 10 ng m<sup>-3</sup> and average scattering coefficient (at 550 nm) about 3 Mm<sup>-1</sup>. Aerosol was highly scattering with single scattering albedo (at 637 nm) between 0.95 and 0.99, varying slightly between different months.

At the moment, we're analysing the variability of aerosol characteristics from specified source areas, using back-trajectories, and separating marine and continental aerosols. In addition, we're analysing the chemistry from the first year of filter measurements. These will be used to understand the reasons for the observed annual cycles of aerosol characteristics, of which the detailed results will be presented at the conference.

For our knowledge, this is the first long-time comprehensive aerosol particle characterization made at the region of Antarctic peninsula.

## Stratospheric mixing diagnosed from long-duration balloon flights

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The westerly winds that encircle the Antarctic stratosphere during winter and spring exert a strong influence on the exchange of material between the Antarctic stratosphere and southern mid-latitudes. Regions poleward and equatorward of the vortex edge are well mixed by processes including planetary wave breaking which induces large-scale stirring. The permeability of the vortex determines the gradient in a number of trace gases across the vortex edge. Many of these trace gases, such as ozone, are radiatively active gases whose morphology defines temperature gradients in the stratosphere. The spatial morphology of the stratospheric temperature field in turn determines the strength and position of stratospheric jets. The processes controlling the permeability of the Antarctic vortex, and how they are likely to respond to a changing climate, have not been well studied. Preliminary analyses of chemistry-climate model simulations of the permeability of the Antarctic vortex indicate that there is a very wide range of behaviour in the models.

To address deficiencies in model simulations of stratospheric transport barriers, our understanding of large-scale transport processes in the stratosphere needs to be advanced. However, improved understanding of small-scale turbulent diffusion is also required as this is not treated physically well in models. Previous field campaigns used long-duration stratospheric balloon flights to probe various attributes of the stratosphere. These campaigns typically used 10 to 15 balloons with tethered gondolas. While these campaigns added useful data to the body of scientific knowledge, what is required to make a significant break-through in understanding the processes driving stratospheric mixing (both transport and diffusion) is not a campaign using ten, or tens of, balloons, but rather a campaign using thousands or, since we're dreaming anyway, tens of thousands of balloons. Costs are clearly prohibitive, and yet that dream is about to come true in the form of Google [x] Project Loon which aims to provide worldwide internet access, primarily to remote locations, using long-duration balloons that fly in the stratosphere. This presentation will summarize how location data from the Loon balloons, which will start becoming available from May 2014 onwards, can be used to diagnose stratospheric transport and mixing. Early analyses of comparisons between measured (from Loon balloons) and modelled balloon trajectories will be presented. When and where balloon trajectories diverge from their expected paths, this reveals either where sub-grid-scale winds matter, where analysed large-scale winds are erroneous, or where regions of material stretching occur. This information will provide the scientific basis for a more in-depth understanding of the transport and diffusion processes that drive stratospheric mixing.

## Origin, behavior and fate of atmospheric amino acids in Antarctica

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Marine aerosols play a dominant role in the transfer of oceanic material to the atmosphere. The chemical composition and size distribution of marine aerosols are an important parameter to investigate the latter's impact on global climate change.

Amino acids constitute an important component of organic nitrogen aerosols, influencing organic nitrogen input to marine ecosystems. These compounds have the ability to activate and act as cloud condensation nuclei, with important effects on the radiation balance.

Antarctica represents an excellent natural laboratory to investigate the background in the aerosols due to distance from anthropogenic emissions.

In order to understand how amino acids are produced and which physical and chemical transformations occur during transport processes, aerosol samples were collected in four different Antarctic austral summer fields. Two consecutive sampling campaigns were carried out on the Antarctic plateau near the Italian-French base Concordia Station; another, at the Italian coastal base "Mario Zucchelli Station"; finally, shipboard aerosols were sampled on R/V *Italica* on the Southern Ocean near Antarctica.

During the austral summer Antarctic field 2010-11, aerosol samples were collected using a cascade impactor to obtain a size-particle distribution of amino acids in coastal aerosols. The mean concentration detected in this site was 11 pmol m<sup>-3</sup>, and arginine and glycine were the most abundant compounds. An important content of hydrophilic amino acids was detected, establishing that the local marine sources have produced amino acids in the fine particles.

In the two consecutive sampling fields (2011-12 and 2012-13) carried out on the Antarctic plateau, amino acids in the background aerosols were detected with average concentrations of 0.7 and 0.8 pmol m<sup>-3</sup>, respectively. To our knowledge, these are the lowest concentrations of amino acids reported in literature. Plateau aerosols have shown a higher concentration of amino acids in the coarse particles, caused by specific physical and chemical processes. Amino acids may be useful to determine the aerosol age.

Another sampling field was carried out on the R/V *Italica* during the austral summer 2012 in the Southern Ocean. A higher concentration of amino acids than in the samples collected in the coastal station was detected, due to the presence of biological material.

This is the first study to highlight the origin, transformation and fate of amino acids in Antarctic aerosols.

## Observing the atmospheric boundary layer with unmanned aerial vehicles

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The use of unmanned aerial vehicles (UAVs) is becoming increasingly common for many fields of Antarctic research. Since 2009 we have used small (< 1 kg) and modest (~15 kg) sized UAVs to make both local and distant observations of atmospheric boundary layer features. This presentation will discuss recent applications of UAVs to study the atmospheric boundary layer including key scientific findings from these UAV flights and lessons learned regarding the operation of UAVs in the Antarctic.

Local UAV flights have focused on the time evolution of boundary layer structure over the Ross Ice Shelf in the vicinity of McMurdo Station. Some key observations from these local studies include detailed vertical profiles of strongly stable to deep convective boundary layers and rapid deepening (~100 m over 10 min) of a well mixed boundary layer. Results from a 2-week campaign in January 2014 will also be presented. For this campaign observations from a 30 m meteorological tower will supplement UAV observations to 1.5 km AGL.

The larger UAVs have been used to make observations of the atmospheric and oceanic state over Terra Nova Bay during September 2009 and September 2012. These observations represent the first in-situ atmospheric observations over the Terra Nova Bay polynya during the late winter time period. A total of 30 flights and nearly 300 flight hours were completed during these two month-long field campaigns. The primary scientific focus of these flights was to document the downstream evolution of the cold, dry continental boundary layer air mass as it passed over the Terra Nova Bay polynya. Based on observations of the changing atmospheric state estimates of surface heat, moisture, and momentum fluxes were made from the UAV observations. The UAV observations also let us document the depth and horizontal extent of the strong off-continent flow and repeat flights over several days provided observations of the changing atmospheric and oceanic state during polynya opening and closing events.

## Characterization of aerosols in northern Antarctic Peninsula: Impact assessment on glacier retreat and its relationship with global warming

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The research showed in this abstract, aims to determine how aerosols emitted into the atmosphere as a result of natural and anthropogenic processes can be removed by wet and/or dried deposition phenomena. Deposition leads to the introduction of particles and/or gas in the snow, increasing its melting, accelerating the retreat of glaciers and changing the albedo, which finally impact on climate. The importance of aerosols on global climate change phenomenon is still far from fully understood, where many questions remain unanswered. One of them is the role of aerosols and atmospheric particles mainly composed of graphite cores, especial Black Carbon (BC), in the melting snow and glacier retreat. This unprecedented research, aims to improve understanding of this and other phenomena associated with the aerosols deposition in the snow of Antarctica and its impact on the greenhouse effect, which is vital to improve our understanding regarding the global climate change.

For first time, albedo, aerosol in gas and particle phase of PM<sub>2.5</sub>, BC, concentration of PM<sub>10</sub>, PM<sub>2.5</sub>, PM<sub>1.0</sub> and size distribution between 0.25-32  $\mu$ m in 30 different channels was measure in northern Antarctic Peninsula during one week in the Chilean Antarctic Station O'Higgins (BO, 63°19'15"S, 57°53'55"W) directly on the coast and in the Plateau Infantería, La Paloma Mountain (LPM, 63°21'20"S, 57°48'21"W, 409 m.a.s.l.), 10 km far from the Station.

In LPM a hybrid power system of wind and photovoltaic energy was installed to generate the energy for the instrument included 3 Polar Wind Turbine and a 6 m tower with 3 solar panel for the installation a complete meteorological station including a sonic snow level and albedometer sensors. The meteorological instrument has an automatic transmission system data using a YAGI Antenna with the GOES-EAST satellite. One of the purposes of this infrastructure is to transform this monitoring station at a future GAW station to participate in the international network of stations that measure radiation, gases and aerosols. This station will be generating an important data base that would be used to validate different satellite data, the chemical transport models that predict the trajectories and evolution of aerosols and gases from sources of anthropogenic or natural emissions in the Antarctic.

The first result about BC, concentration of PM and size distribution show an important difference between BO and LPM, showing a high concentration of PM and BC in the BO most probably due to the anthropogenic activities surrounding de Antarctic Station. In opposite the measure obtained in LPM showing a background level.

All the results measured until now, points out that the Plateau Infantería and La Paloma Mountain represents a well-suited place to obtain information about the aerosols transport and their climate impact. A more extended campaign will be carried out in the next years (2015-2016).

## Impact of ozone depletion on Antarctic surface climate

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Universite Pierre et Marie Curie

We look at the surface impacts of ozone depletion in two 20-year simulations with the LMDZ atmospheric general circulation model, with prescribed ozone climatologies representative of the 1960s and 2000s decades. The only significant impacts are in the summer (DJF) seasons; the model reproduces the poleward shift of the tropospheric jet and the usual associated changes. Over Antarctica, there is a surface cooling and drying, most pronounced over East Antarctica.

To distinguish direct impacts of ozone depletion from ones linked with the jet shift, we then reconstruct the expected impacts of the jet shift from its simulated variability at intra-seasonal timescales. Over the Southern Ocean, all of the temperature and precipitation changes are well explained by the jet shift. The drying over Antarctica is however not present at the intra-seasonal timescale. The detailed surface energy budget suggests that ozone depletion has a direct radiative cooling impact at the surface in addition to the one mediated by the jet shift, leading in particular to faster downslope surface winds and advection of drier air.

## The meteorology capabilities of the British Antarctic Survey in Antarctica

### Colwell S

British Antarctic Survey

The British Antarctic Survey operates 4 year round stations in Antarctica and below will be detailed what meteorological measurements are made at each of these stations.

#### **Rothera** 67°34'S 68°08'W

At Rothera we have a comprehensive suite of meteorological instruments, the main system for measuring the meteorological parameters is based around a Campbell Scientific CR1000 logger it has a pressure sensor, a PRT (Platinum Resistance Thermometer) for temperature and a HMP45 for humidity. There are two wind sensors, a Vaisala WS425 sonic anemometer is the primary source of the wind data but there is also an RM young aerovane as a backup. Solar radiation is measured using a Kipp and Zonen CNR1 and also sun duration. Data is logged every minute and software is run to allow a synoptic observation to be entered.

Radio-sondes are flown 4 times a week on Monday, Tuesdays, Thursday and Fridays using an MW31 ground station, RS92 radio-sondes and 350gram balloons.

A laser cloud-base recorder is also operated at Rothera and a real-time display is available that can be used to give information to aircraft.

Precipitation is measured using 4 different commercially available precipitation sensors.

Atmosphere aerosol is measured using a Prede POM-01 sun photometer that looks at the sun in different wavelengths. It measures the extent to which light from the Sun is scattered as it travels through the Earth's atmosphere, which allows the calculation of the size and density of the particles that are scattering the light.

Ozone and NO<sup>2</sup> are measured using a SAOZ (System d'Analyse par Observation Zenitale) instrument.

Satellite images are received using our ARIES (Antarctic Reception of Images for Environmental Science) system, this has a 2.4m dish and the captured images are used in real-time by the forecaster and are also archived.

#### **Halley** 75°35'S 26°34'W

Halley also has the same main meteorological station as Rothera with the addition of sonic rangars to measure snow accumulation.

Ozone is measured using a Dobson spectrophotometer and ozone and NO<sup>2</sup> are recorded using a SAOZ instrument.

There are daily radiosonde launches using a Vaisala MW31 ground station, RS92 radio-sondes and 350gram balloons

A cloud-base recorder is also operated at Halley and a real-time display is available that can be used to give information to aircraft, the data is also archived so it can then be for research.

Atmosphere aerosol is measured using a Prede POM-01 sun photometer.

#### **King Edward Point (South Georgia)** 54°17'S 36°30'W

Meteorological measurement are made at KEP using a Vaisala MILOS 520 which measures pressure, temperature, humidity, wind speed, wind direction and sunshine.

Precipitation is measured using a Biral LPS.

#### **Bird Island (South Georgia)** 54°00'S 38°03'W

Meteorological measurements are made at Bird Island using a Vaisala MILOS 520.

## Validation of the WRF model forecasting of the skin sea surface temperature in the Bransfield Strait region

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The present study aims to validate the forecast of the WRF (Weather Research and Forecasting) model of the skin sea surface temperature (S3T). Simulations of the model in high-resolution with different parameterization schemes of the WRF are confronted with *in situ* data measured onboard the Polar Ship Almirante Maximiano of the Brazilian Navy. Observational data at the 1 hour frequency were obtained in the Bransfield Strait between 5 and 23 February 2011. The outputs from the Global Forecasting System (GFS) were used as initial and boundary conditions data for the WRF simulations. The GFS assimilates remote sensing data for improving its performance and consequently that of regional numerical weather models in remote regions of the globe where meteorological observations are scarce and difficult to be taken. This study uses the microphysics WSM3 scheme proposed by Hong et al. (2004) and also the WSM5 scheme proposed by Hong et al. (2006).

For the simulations, three concentric nested grids have been used at the 9 km, 3 km and 1 km spatial resolution. The correlation of the S3T with real sea surface temperature (SST) data was 0.84 (RMSE of 1.87) for both microphysics schemes used here. The mean simulated S3T was 0.7 °C while the mean observed SST was 2.1 °C. The model underestimated the S3T by 1.5 °C. Dolon et al. (1999) showed that at conditions of wind weaker than 6 m.s<sup>-1</sup> the differences between the S3T and the SST commonly reach 1.5 °C. At night this difference is smaller, reaching the maximum of 0.5 °C. The mean (observed) wind speed over the studied period was 8.7 m.s<sup>-1</sup>. The differences between S3T and SST have an effect on the humidity evaporated from the ocean to the atmosphere and thus on the cumulus parametrization of the WRF. This leads to an underestimation of the latent and sensible heat fluxes. Zang and Mac Phaden (1995) showed that an 1 °C error causes a 10 W.m<sup>-2</sup> error in the long wave radiation (LWR) emitted by the sea surface. The results showed here suggest that the WRF underestimates the S3T and, as a consequence, there is a smaller amount of evaporated water and loss of LWR towards the atmosphere from the ocean's surface. This may cause an underestimation of the air temperature by the model (by longwave radiative loss) and consequently an error in the energy balance. This study is of special importance because the area surrounding the Antarctic Peninsula including the Bransfield Strait is warming more than the global average in the last decades (Barrand et al., 2013). S3T simulations by models are of great importance for understanding the local effects of these changes.

## Performance of the WRF model in fine-scale using several microphysics schemes for meteorological forecasting at the Deception Island, South Shetlands Archipelago

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This paper investigates the performance of the Weather Research and Forecasting (WRF) model using six Planetary Boundary Layer (PBL) schemes and two microphysics schemes (12 simulation schemes in total) at the Deception Island, South Shetlands Archipelago. Meteorological data at high latitudes, especially in Antarctica, are scarce and difficult to measure owing to the extreme weather conditions. Thereby it is difficult to characterize the active weather phenomenon in various (temporal and spatial) scales. Here we use observational data obtained by sensors installed on a micrometeorological tower to estimate the performance of the WRF with different parameterizations. The model can be a useful tool to describe the behavior of meteorological variables at several conditions (eg. before and after cold front passages, different conditions of sky cloudiness etc). All model experiments were run using three nested domains with 1 km horizontal resolution in the finest grid.

Results indicate that the 3-day simulations of the 12 schemes showed results qualitatively similar to each other. However there are quantitative differences between the different schemes. For the clear sky weather conditions the WRF model outputs of incident short wave (SW) and incident long wave (LW) are less sensitive to the choice of the parametrization scheme. This is a deficiency that may be attributed to the model difficulties in reproducing stratiform and high cloudiness. As a consequence, radiative emission by the clouds and the subsequent surface warming is also misrepresented. Then, the surface in the model remains colder than the reality. In general, the schemes used here presented better sensitivity (good performance) on middle cloudiness days. In contrast, the atmospheric pressure simulation was not strongly affected by the choice of schemes. On the contrary, the zonal and meridional components of the wind presented higher sensitivity in comparison to the different PBL schemes of air temperature and pressure. Given the scarceness of meteorological observations in our study region and vicinity, the global model data used as initial and boundary conditions to WRF does not accurately reproduce local perturbations of dynamical variables. Future studies of long-term climatic series may benefit from our results since seasonal and inter-annual variability patterns, which are not presently accounted, are fed by different weather situations. Those situations need to be properly simulated.

## Stratosphere-troposphere coupling in climate models

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This study aims to assess the ability of climate models to reproduce observed stratosphere-troposphere coupling. Coupling between the stratosphere and troposphere is examined using the Southern Annular Mode (SAM) index at multiple levels. This mode, associated with the shifting of atmospheric mass between the poles and mid-latitudes, is the principal mode of atmospheric extra-tropical variability in the Southern Hemisphere. The SAM has various effects on regional climate such as the strength of westerlies over the Southern Ocean and the latitude of the storm track. It has been shown that anomalous SAM events in the stratosphere are usually followed by an annular-mode anomaly of the same sign in the troposphere that can persist for around two months. Such results show that the stratosphere can play an important role in extended-range weather prediction.

It is therefore important for climate models to adequately reproduce the observed stratosphere-troposphere coupling in order to predict changes in regional climate due to variations in the stratosphere (such as the creation and recovery of the ozone hole). The models analyzed in this study include an atmosphere-ocean-chemistry coupled climate model with a well resolved stratosphere and comprehensive stratospheric chemistry (NIWA-UKCA) as well as models participating in the Coupled Model Intercomparison Project 5 (CMIP5) which handle changes in ozone with varying degrees of complexity. The accuracy of the stratosphere-troposphere coupling is assessed relative to various reanalyses and it is found that the NIWA-UKCA model provides a more accurate representation of the coupling strength than the CMIP5 ensemble.

Comparison of the different models as well as comparison of the NIWA-UKCA sensitivity simulations with and without changes in ozone depleting substance emissions, and with or without changes in greenhouse gases, allow us to investigate the influence of ozone and other greenhouse gases on changes in the coupling.

## Quasi-Lagrangian measurements of the nitric acid trihydrate nucleation rate in the late austral winter

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In 2010, the joint French-United States Concordiasi project released 19 long duration super-pressure balloons from McMurdo Station, Antarctica. Four of these balloons carried a gondola with particle counters and temperature sensors to measure polar stratospheric clouds. One gondola spent 5 days at stable temperatures between equilibrium temperatures for nitric acid trihydrate (NAT) and for supercooled ternary solution droplets. Sporadic particles with radii between 0.46  $\mu\text{m}$  and 4.5  $\mu\text{m}$  were measured in a small fraction of the measurements. At these times the corresponding size distributions and total particle volumes were consistent with NAT. Although the fraction of these observations was less than 3%, their frequency increased with time over the 5 days. From this frequency the NAT nucleation rate at 3°C below  $T_{\text{NAT}}$  was estimated to be  $\sim 2 \times 10^{-4} \text{ m}^{-3} \text{ s}^{-1}$  for these late winter austral NAT observations at a potential temperature of 410 – 415 K. This rate is about 4 times slower than estimates derived from models coupled with short period in situ measurements in early boreal winter. Interspersed with these measurements of polar stratospheric cloud particles consistent with NAT, were many more measurements of particles consistent with background stratospheric aerosol indicating that the polar stratospheric clouds sampled were highly discontinuous.

## Cloud-radiation interaction in Dronning Maud Land, East Antarctica, in ground-based measurements and regional climate models

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Clouds play a key role in the Antarctic ice sheet surface energy and mass budgets, controlling radiative fluxes and precipitation formation. We use ground-based remote sensing measurements along with near-surface meteorology and radiative flux data obtained at the Princess Elisabeth (PE) base in Dronning Maud Land (DML), East Antarctica (<http://ees.kuleuven.be/hydrant/>) to evaluate cloud properties and their effects on radiative fluxes in two regional climate models. Cloud properties are derived from 910 nm ceilometer backscatter profiles, an infrared pyrometer and 24GHz vertical profiling precipitation radar measurements. Although the ceilometer lacks polarization capability that would provide direct information on the cloud phase, the high backscatter coefficient of the liquid-containing layers together with the rapid extinction of the lidar signal enables detection of the liquid-containing clouds as geometrically thin but highly reflective layers. Hourly cloud occurrence frequency (COF) and cloud properties (base height and temperature, occurrence of precipitation) for all and liquid-containing clouds are estimated from the ground-based measurements and combined with hourly radiative fluxes measured by an automatic weather station.

Ground-based measurements are used to evaluate two regional climate model high-resolution simulations over DML - RACMO2 and MAR at 5.5 km and 5 km horizontal resolution, respectively. Preliminary analysis for February 2012 shows that both models underestimate surface incoming LW flux during clear-sky and most cloudy periods (with a mean bias of  $-18 \text{ W m}^{-2}$  for RACMO and  $-20 \text{ W m}^{-2}$  for MAR). Both models show larger biases during cloudy periods (PE COF > 50%) than during clear sky periods. They capture liquid appearance and associated strong increase in the cloud longwave (LW) forcing well during stormy and snowy periods. Higher LWP simulated by MAR during some of these periods leads to a better accordance with the measured LW flux compared to RACMO. However, both models fail to simulate liquid clouds associated with a transitional synoptic regime without snowfall in the beginning of the month, which leads to a large underestimation of incoming LW flux during this period. Model evaluation will be extended to a longer time period (2011-2013) with detailed analysis during specific cases focusing particularly on liquid-containing clouds and their properties.

## High latitude precipitation changes due to changes in ozone concentrations in the Southern Hemisphere

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Simulations from a coupled atmosphere-ocean chemistry-climate model are analyzed to investigate the impact of Southern Hemisphere ozone layer changes on precipitation in the southern hemisphere and specifically over Antarctica. Temperature over the Antarctic continent warms by 4 C over the considered period, compared to a 2 C warming over the southern mid-latitudes. Warming in Antarctica is approximately a factor of 3 smaller than in the Arctic. The rate of moisture increase is larger over the Southern Ocean compared to over the Antarctic continent.

The model has been run over the period of 1960 - 2100, following the RCP 6.0 scenario, as a contribution to the Chemistry-Climate Modelling Initiative (CCMI). In addition to the reference simulations, two sensitivity studies with individual climate drivers, e.g. increases in greenhouse gases and variations in ozone-depleting substances, removed have been performed. The simulations are aimed at improving understanding of the roles of these drivers in Southern-Hemisphere climate change.

## Twice-a-day precipitation in summer observed at Dome Fuji, Antarctica

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National Institute of Polar Research

This study demonstrates the typical daily cycle of precipitation observed at Dome Fuji station (77.5°S, 40°E) in summer for the period when it is not influenced directly by transient synoptic disturbances, based upon the observation in 1997/98 and 2003/04. This cycle is deeply associated with diurnal variation of vertical temperature profile in the boundary layer.

The more active precipitation occurs in midnight when surface-based temperature inversion is formed up to 100-150 m above the surface of the ice sheet. The deposition of moisture following to the drop of the temperature makes thick stratus clouds and ice fogs in boundary layer, which is observed as precipitation. The other precipitation occurs in daytime when the temperature inversion disappears from the boundary layer approximately up to the height of 300 m above the surface. This situation induces evaporation at the surface of the ice sheet and then, allows the moisture to be transported upward by thermal turbulences. The moisture may be deposited to ice crystals again under lower temperature condition aloft, which is observed as the secondary peak of precipitation in the daily cycle.

For both the precipitation, the moisture source is the ice sheet. This result will contribute to deepen the understanding of the process of moisture budget at the surface of the Antarctic interior.

## **An analysis of high resolution meteorological data from SNOWWEB near White Island**

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The surface climate on the Ross Ice Shelf and particularly the McMurdo Ice Sheet, bounded by Ross Island on the north and Minna Bluff on the south, is interesting for a number of reasons: complex topography surrounding the sheet, stable stratification of the air above it, its proximity to Scott Base and McMurdo Station, and our reliance on it for air operations (Pegasus Airfield, Willie's Airfield, and the sea-ice runway). To properly study the atmosphere in this region many measurements with a high spatial resolution are required, and to this end we deployed the SNOWWEB network of wirelessly-connected meteorological monitoring stations during the 2013/14 season from mid-November to late January. The deployment followed existing roads in the region, with stations placed along the South Pole Traverse to the north of White Island, as well as the road between White and Black Islands (to the west of White Island). Seventeen stations were deployed along these strings, with an average spacing of approximately 3 km providing good coverage for measuring the flow over and around White Island as well as between White and Black Islands. This study will present the results of our analysis of wind, temperature, and pressure data from the SNOWWEB stations, and compare that data with output from the Wisconsin Antarctic AWS network, the Antarctic Mesoscale Prediction System (AMPS), ERA-Interim, and MODIS. This analysis aims to examine the linkages between the micro-scale meteorology of the region and the overall synoptic situation and also identify the importance of this scale in this region.

## Enhanced formation of atmospheric iodine species in ice media and its impacts on Antarctica

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The active halogen species play significant roles in global environmental system. Halogen chemistry especially iodine compounds are related to the depletion of tropospheric and stratospheric ozone, perturbation of HOx/NOx cycle, generation of cloud condensation nuclei(CCN), and depletion of gaseous elemental mercury ( $\text{Hg}^0$ ) by oxidation to reactive gaseous mercury ( $\text{Hg}^{2+}$ ) in polar regions. The chemical processes of halogen compounds in water have been intensively studied, whereas those in frozen environments have been rarely investigated. In this work, we investigated iodide( $\text{I}^-$ ) oxidation to tri-iodide( $\text{I}_3^-$ ) in frozen solution in the presence and absence of irradiation. The oxidation of iodide to tri-iodide in water, which is very slow process, was significantly enhanced in frozen water even in the absence of irradiation. We explained that the accelerated oxidation of iodide in ice phase is owing to the freeze concentration of the existed iodides, protons, and oxygen molecules in ice grain boundaries upon freezing. The outdoor experiments conducted under natural conditions in King George Island, Antarctica(, 62°13'S 58°47'W, sea level) also confirmed that the tri-iodide formation by iodide oxidation is accelerated in natural ice media such as snow and glacier regardless of irradiation. The observed results imply that the generation of active iodine species such as tri-iodide might be accelerated in frozen environment and then released to the atmosphere when the ice media melt.

## Simulation of katabatic winds: comparison of terrestrial polar ice sheets and Mars

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Compared to other celestial bodies, Earth and Mars have some important features in common. This counts especially for their atmospheres. In terrestrial polar environments the katabatic wind is a well-studied phenomenon and beside being scientifically interesting, they can cause severe weather situations for people and instruments.

On Mission to Mars the EDL-phase (entry-descend-landing) is one of the critical steps to safely touch down a landing unit. A good estimation of the local and regional wind is important to plan and estimate the landing area. Additionally manned missions to the red planet are planned within the next decades and a local weather forecast will be necessary for safe operations.

During this work the Mars-model "MLAM" (based on HIRLAM) and data from ECMWF were analyzed and compared. In Antarctica the area of the Lambert Glacier and a transect from the South Pole to the Finnish station Aboa were examined. On Mars two similar types of landscape were chosen. The Chasma Boreale reflects some features of the Lambert Glacier and the transect from the Martian North Pole to the Phoenix Landing site is comparable to the transect in Antarctica.

The diurnal cycle on Mars is more perceptible than on Earth, though less solar radiation reaches the planet. The thinner atmosphere, lesser and thinner clouds and a missing ozone layer enhance the radiative influence. The results show many similarities, for instance wind speeds are on a similar magnitude in both compared areas. Both transects show the effect of the Coriolis force very well.

## **Operational Antarctic weather and sea ice forecast systems development in NMEFC**

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National Marine Environmental Forecasting Center

National Marine Environmental Forecasting Center (NMEFC) has been the only institute for providing polar environmental forecasting issue in China over 30 years. It's Polar Environmental Research and Forecasting Division has responsibility to provide technical support for Chinese Arctic and Antarctic Expedition.

Chinese R/V Xuelong was trapped in Commonwealth Bay, Antarctica after she helped to rescue the passengers in Russian vessel Akademik Shokalskiy in early January this year. NMEFC had provided emergency forecasting information to Xuelong and help her successfully breakout. The timely sea ice information and accurate weather forecasting were the key factors for her successful survive. The main reasons for her trapped were found by comprehensive analysis of the sea ice, meteorological and ocean conditions.

Firstly, the sea ice character there was very complicated because the trapped area, where first year ice was mixed with multi-year ice, was closed to continental shelf and surrounded by large icebergs. Secondly, continuous strong easterly wind caused by several cyclones made the sea ice move westward and accumulated.

## Solar cycle effect on polar ozone as derived from SBUV/SBUV 2 data

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We present estimates of the 11-year solar cycle effects on stratospheric ozone derived from the data of ozone measurements with SBUV/SBUV 2 instruments aboard Nimbus 7, NOAA 9, NOAA 11, NOAA 14, NOAA 16, NOAA 17, NOAA 18 and NOAA 19 satellites for 1978–2012 (<ftp://toms.gsfc.nasa.gov/pub/sbuvs/>). High-resolution spectral and cross-spectral methods as well as the method of multiple linear regression are used for the analysis. The regression model for ozone variations takes into account the annual cycle, the linear trend, the solar cycle and Pinatubo eruption effects and the effect of the quasi-biennial oscillation in the equatorial stratospheric wind. Local maxima of ozone sensitivity to the 11-year solar cycle are noted below the stratopause (45–50 km), in the middle stratosphere (30–35 km), and in the polar lower stratosphere. The sensitivity of the ozone response to the solar cycle for the whole analyzed period (1978–2012) is less than that for the period 1978–2003 which does not include the 24<sup>th</sup> solar cycle with anomalously small amplitude. The ozone response is seasonally dependent. Maximal amplitudes of the ozone response are characteristic for polar latitudes during winter-spring seasons. Ozone changes related to the solar cycle can reach 5% in the low and middle latitudes during the 1978–2012 period, while winter-spring ozone changes are up to 8–9% in the Arctic lower mesosphere and lower stratosphere and 12% in the Antarctic lower stratosphere. The solar cycle effect in the lower stratosphere ozone in the Antarctic is stronger than that in the Arctic. It can be associated with modulation of the intensity of circumpolar stratospheric vortex over the Antarctic by the solar cycle. The effect in mesospheric ozone over the Antarctic is less than over the Arctic. This difference can be related to the more significant effect of particle precipitation in the northern polar region compared to that in the Antarctic. The results obtained point at an important role of atmospheric circulation in the response to the 11-year solar cycle.

## Atmospheric NO<sub>2</sub> anomalies related to the Antarctic and Arctic ozone holes

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Winter-spring anomalies of the atmospheric NO<sub>2</sub> column content in the middle and polar latitudes of the Southern (SH) and Northern (NH) Hemispheres derived from ground-based measurements within the Network for the Detection of Atmospheric Composition Change (NDACC) are analyzed in relation to the ozone holes in 1990-2012 in the Antarctic and in 2011 in the Arctic.

Significant correlations of NO<sub>2</sub> variations with variations in total ozone and stratospheric temperature were found in winter-spring periods in the SH and in the winter-spring period of 2011 in the NH. The correlations for the NH in 2011 are stronger than those in years without ozone depletion in the Arctic stratosphere.

Correlations of NO<sub>2</sub> column variations with total ozone and stratospheric temperature variations in winter-spring periods derived from measurements at the SH stations depend on the phase of the quasi-biennial oscillation (QBO) of the equatorial wind velocity at 30-40 hPa. The correlations are stronger for the westerly phase of the QBO compared to those for the easterly phase. The 2011 Arctic ozone hole was observed during the westerly phase of QBO. The calculated correlation coefficients at the NH stations for the winter-spring period of 2011 associated with the Arctic ozone hole are close to the coefficients at the SH stations in winter-spring periods corresponding to the westerly QBO phase.

## Winter-time total ozone from arrival heights (77.82S, 166.65E), Antarctica: Comparing measurements with modelled results

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Ozone depletion has been observed over the Antarctic region every austral spring since the late 1970s. The development of each year's Antarctic ozone hole is controlled by the levels of ozone depleting substances and the particular meteorological conditions for that year.

During the winter in the Antarctic, which is the period leading up to the formation of the ozone hole, relatively few total ozone measurements are made. This is because the sun is below the horizon, so spectrometer measurements (which are usually made using sunlight) can only be made using moonlight. For this reason, there are no satellite measurements of total ozone over the Antarctic during winter. Since the moon is a weak light source, moonlight measurements can only be made on clear nights close to the full moon.

We present total ozone measurements made using moonlight with Dobson spectrophotometer #17, which has been in operation at Arrival Heights since 1988. We also present total ozone measurements which were made using moonlight, at nearby Scott Base from 1992 to 1994, with Brewer spectrometer #50. During the 1994 winter, the University of Wyoming ran an ozonesonde programme from nearby McMurdo station.

The sparsity of winter ozone measurements limits our understanding of the early stages of the ozone hole formation. It also means there are only a relatively small number of measurements available for model validation. Here we compare three independent datasets of winter ozone measurements: the Dobson and Brewer measurements, and the integrated total ozone from the ozonesondes. We also compare the winter-time ozone measurements with model results, for the Arrival Heights region, from the NIWA-UKCA global chemistry-climate model.

## **Analysis of blizzard cases in January 2013 observed at the King Sejong Station, Antarctic Peninsula**

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In 2013, strong wind was observed more frequently than before at the King Sejong Station located on King George Island, Antarctic Peninsula. We investigated strong blizzard case observed in January 2013 to understand underlying conditions and to tell if it is linked with changing climate in Antarctica. For that purpose, we ran Polar WRF V3.3.1 to simulate weather condition. Polar WRF has reasonably well reproduced the strong wind case. Besides, we found that a blocking system was existed east of south-America. Blocking system in southern hemisphere seems to affect the variation of Antarctic low pressure systems. We speculate that interannual variation of sea ice extent around the Antarctica would be one of important factors influencing pressure systems and blocking system. We will present our model results and linkage with blocking index.

## Multi-decadal time-series of stratospheric NO<sub>2</sub>, BrO and OCIO above Antarctica

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Ground-based differential absorption spectroscopy measurements of NO<sub>2</sub>, BrO and OCIO total column abundances are reported. The measurements were made at Scott Base and Arrival Heights, Antarctica, by the National Institute of Water and Atmospheric Research (NIWA), New Zealand. Here we present 30 years of NO<sub>2</sub> (1982-present) and 20 years of BrO and OCIO observations (1993-present). The observations reveal substantial trends associated with ozone-depleting substances, variability caused by volcanic eruptions, and have also helped identify the “tropospheric ozone hole” caused by bromine explosions above sea ice. We review achievements attributed to the measurement programme, and give an outlook into the relevance of the measurements in the next decades.

## **Spatial and temporal air-sea interaction characteristics variability in the Antarctic peninsula area**

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The spatial and temporal variability of the ocean and the atmosphere features were investigated in the Southern Polar area, including the Antarctic Peninsula region. The connections of large-scale atmospheric circulation variability with indexes South (SOI) and Antarctic (AAO) Oscillation, the air temperature and the area of ice cover were investigated in the Antarctic Peninsula region. Variability of the energy exchange between atmosphere and the ocean surface was studied on the base of experimental data received in the different areas of the Antarctic.

The modern archival contact data and satellite measurements, the data of meteorological measurements at the Antarctic polar stations, as well as a new experimental data obtained in the course of the Russian Antarctic Expeditions were used.

The results of the work is confirmed the relationship between the interannual variability of Antarctic ice boundary position and variability of SOI and AAO indexes and revealed their regional peculiarities in the Antarctic Peninsula region. The high connections between SOI, AAO and Antarctic ice cover were found at the west of the Antarctic Peninsula.

Significant interannual variation of the average characteristics of the energy exchange over the different underlying surfaces were established, that are associated with large-scale variability of weather conditions in the Southern Polar region. Aerodynamic coefficient and the parameter of the surface roughness, which affected the characteristics of energy exchange, is the subject to significant variability in time and space. To a large extent they depend on the state of the snow cover, the stratification of the ground air, the wind speed and its direction, in its turn, their variability is due to the interannual variability of global processes in the ocean-atmosphere system.

## **Study of surface energy balance at the Brazilian Antarctic Station in summer conditions using the WRF model**

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The knowledge of the radiation balance and the vertical turbulent fluxes of sensible, latent and soil heat flux on different surfaces is important for both diagnostic and prognostic climate change and environmental monitoring. The primary objective of this study is to investigate numerically the energy balance at the surface and thus the development of the planetary boundary layer during summer conditions in the region of the Brazilian Antarctic Station, on King George Island (62°05'S, 58°23'W).

The Weather Research and Forecasting Model (WRF) suitable to the Antarctic conditions was used in conjunction with the observational data obtained at the Brazilian station, by the ETA ("Estudo da TurbulênciaAntártica") Project. Observed data of net radiation and soil heat flux are available for comparison. The sensible heat and latent heat fluxes were estimated indirectly using low response sensors that provide vertical profiles of wind speed, air temperature and air specific humidity.

The ETA Project main objective is to obtain the surface energy balance with the surface turbulent fluxes estimated by the covariance method, during short-duration campaigns (direct measurement) and using different parameterization formulae, during long-duration campaign (indirect measurement).

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## Methane source variability constrained by Antarctic and global isotope measurements

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Atmospheric monitoring of stable carbon isotope ratios of methane ( $\delta^{13}\text{CH}_4$ ) provides insights into the source and sink variability of the global methane budget. Due to the absence of spatial  $\delta^{13}\text{CH}_4$  gradients in Antarctica we can use our  $\delta^{13}\text{CH}_4$  time series from Arrival Heights, Antarctica (Lat. 77.82 ° S, Long. 166.65 ° E), as well as from Baring Head, NZ (Lat. 41.42 ° S, Long. 174.87 ° E), to inter-calibrate analyses from three different laboratories and place global stations on a common scale. The combined globally averaged data set shows  $\delta^{13}\text{CH}_4$  trends over the last three decades. We investigate the underlying changes in isotopically distinct source types with a combined box-model and isotope mass balance approach. We find that a plateau in atmospheric methane concentrations in the early 2000s was caused by reduced emissions from fossil fuel production. The renewed concentration increase since 2007 C.E. occurred despite stable fossil methane emissions and is driven by biogenic sources such as wetlands or agricultural sources.

## **Thirty years of stratospheric trace gas measurements at Arrival Heights (77.82S, 166.65E), Antarctica**

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<sup>1</sup> NIWA, <sup>2</sup> Alexandra

We present an overview of thirty years (1982-2012) of stratospheric trace gas measurements made at Arrival Heights (AHTS) and Scott Base, Antarctica conducted by the National Institute of Water and Atmospheric Research (NIWA), New Zealand. A summary of activities over this period illustrates the development of the science, instrumentation and the laboratory infrastructure, along with current and planned future research activities.

The research has made a substantial contribution to our present understanding of Antarctic ozone depletion. Starting in 1982 with the installation of a prototype UV/Vis spectrometer to measure stratospheric nitrogen dioxide, the work now involves eight remote-sensing instruments located in a purpose-built atmospheric laboratory, measuring a range of ozone depleting and greenhouse gases. Cooperation with international colleagues has been a feature of the work. Arrival Heights is a founding site of the Network for the Detection of Atmospheric Composition Change (NDACC) – formally known as the NDSC (Network for the Detection of Stratospheric Change) - and is also a certified Global Atmosphere Watch (GAW) station.

We see the current measurement programme continuing to contribute to the NDACC and GAW networks whilst expanding the research direction towards tropospheric composition measurements. Taking advantage of AHTS geographical isolation from human activities, the expansion of research has already started with the use of AHTS ozone pre-cursor measurements in studies of industrial emissions, tropical biogenic emissions and biomass burning events.

## Impact of anthropogenic and natural emissions on trends and seasonal variations of tropospheric ozone precursors in Antarctica

Zeng G, **Smale D**, Robinson J, Morgenstern O

NIWA

Antarctica is the most pristine atmospheric environment on the globe and is far away from pollution sources. However, through long-range transport, these pollutants can be efficiently transported to Antarctica and therefore control the evolution of tropospheric constituents in this region. In the Southern Hemisphere, biomass burning and biogenic emissions are the two main sources that have significant impact on the amounts and seasonal variations of key ozone precursors, e.g. carbon monoxide and ethane. Moreover, emissions from fossil fuel usage, mainly in the Northern Hemisphere, can also be transported to the Southern Hemisphere through inter-hemispheric transport. Therefore observations of trends and variations of these species in Antarctica can be used to detect global changes in sources, transport, or chemistry of these species. NIWA has been making measurements of a wide range of trace gases using a Fourier Transform Spectrometer at Arrival Heights since the mid-1990s, including a number of key tropospheric ozone precursors. In this presentation, we analyse long-term measurements of these key trace gases at Arrival Heights, and assess impacts from both natural and anthropogenic emissions on the trends and seasonal variations of these species using a global chemistry-climate model. A set of sensitivity simulations will be used to attribute how atmospheric constituents around Antarctica can be affected by global emission changes.

## Identifying the polar vortex edge region using passive tracers

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The strong stratospheric vortex which forms above the Antarctic regions every winter causes polar air to become isolated from air at lower latitudes, which partially leads to very different chemical compositions. This contributes significantly to the formation of the ozone hole. The chemical composition within the vortex is further affected by descent of air from higher altitudes.

Recent studies have provided evidence that the vortex is divided into two dynamically distinct regions, a relatively well-mixed core region and a broad edge region, with transport between them being relatively rare. We use Aura-MLS measurements of carbon monoxide and nitrous oxide tracer concentrations to identify the location of this edge region using a method based on the probability distribution functions (PDFs) of the concentrations. This build on previous work in which the chemical distinction was derived based on the PDF and used to identify periods when the vortex exists.

Probability distribution functions of these tracers can be used to identify whether a given measurement was made within or outside the vortex. The distributions for carbon monoxide and nitrous oxide complement each other and using both tracers potentially allows the location of the vortex edge region to be determined with greater precision. Criteria based on these distributions have been used to determine the position and extent of the vortex edge region over August-October 2005 and 2009. Since this measure does not depend on wind velocity measurements it is likely that it can be extended to altitudes above 50km where reanalysis data generally becomes unreliable.

## A semi-empirical model of the stratosphere in the Antarctic climate system

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Chemistry climate models (CCMs) currently used to project changes in Antarctic ozone are extremely computationally demanding. CCM projections are uncertain due to lack of knowledge of future emissions of greenhouse gases (GHGs) and ozone depleting substances (ODSs), as well as parameterizations within the CCMs that have weakly constrained tuning parameters. While projections should be based on an ensemble of simulations, this is not currently possible due to the complexity of the CCMs. An inexpensive but realistic approach to simulate changes in Antarctic ozone, and its coupling to the climate system, is urgently needed as a complement to CCMs.

A simple climate model (SCM) can be used as a fast emulator of complex atmospheric-ocean climate models. If such an SCM includes a representation of Antarctic ozone, the evolution of the Antarctic ozone layer can be simulated for a wide range of GHG and ODS emission scenarios. In the current version of the MAGICC SCM stratospheric ozone changes depend only on equivalent effective stratospheric chlorine (EESC). In this work, MAGICC is being extended to include an interactive stratospheric ozone layer using a semi-empirical model of Antarctic ozone chemistry.

The new stratospheric component, referred to as SWIFT (semi-empirical weighted iterative fit technique) describes the time rate of change through the winter of key species in the polar stratosphere including HNO<sub>3</sub> (total), HNO<sub>3</sub> (gas phase), HCl, ClONO<sub>2</sub>, ClO<sub>x</sub> and ozone using a set of coupled first-order differential equations. SWIFT is driven by time series of the Fractional Area of the Polar vortex experiencing temperatures below 195K (FAP), and the Fractional Area of the vortex exposed to Sunlight (FAS). FAP is calculated from stratospheric temperature fields which are in turn obtained from a module called STePS (Stratospheric Temperature Pattern Scaling). A pattern scaling technique, using a least squares approach, has previously been applied to surface climate variables and the same technique is used in STePS to determine the functional dependence of stratospheric temperature on CO<sub>2</sub> and ozone. STePS begins with an *a priori* ozone field and runs iteratively together with SWIFT to produce physically consistent fields of ozone and temperature that are also consistent with instantaneous EESC and CO<sub>2</sub>. The revised ozone fields are then used to determine a global mean ozone radiative forcing. This is the first time climate pattern scaling has been used to generate stratospheric temperature fields. Pattern scaling is also applied to the total column ozone (TCO) required by STePS to determine the functional dependence of TCO on EESC and CO<sub>2</sub>.

This presentation will describe the new modules SWIFT and STePS and show the use of pattern scaling in stratospheric applications.

## Sensitivity test and validation of Polar WRF at the Antarctic Peninsula during an austral winter

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As most of the surface in polar regions is covered with snow and ice, surface characteristics such as albedo, surface temperature, and roughness are very different from those in low to mid-latitudes. Absorbed solar energy is very small so turbulent mixing is limited compared to lower latitudes. In geographical sense, Antarctica is covered with massive ice sheet and surrounded by cold ocean, which makes the Antarctica different from the Arctic. Thus, numerical models reflecting the features of Antarctica are necessary for accurate weather forecasting in the Antarctica.

In this study, we used a regional numerical model (Polar WRF V3.3.1) reflecting **characteristic** of polar regions to simulate weather over the Antarctic peninsula where the Korean King Sejong Station is located. The simulations were conducted for the period 20 June - 30 June 2011 (Austral winter) with initial and boundary conditions from the ERA-Interim reanalysis. Especially, simulations were conducted with different combinations of schemes in terms of radiation, microphysics, atmospheric boundary layer, and surface layer parameterizations. Then we evaluated the sensitivity of a physical parameterization in a numerical model in the Antarctic environment. Also, we evaluated the model results to several automatic weather observations on the Antarctic Peninsula.

Though short period modelling in winter, we found distinctive features between the schemes in atmosphere-surface interactions and boundary layer structures. These results will be helpful to understand and improve the accuracy of meso-scale numerical weather forecasting of the Antarctica.

## Atmospheric boundary layer over the ice-covered Weddell Sea during winter: vertical profiling using unmanned aerial systems (UAS)

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Measurements of vertical profiles of wind, temperature and humidity have been carried out by unmanned aerial systems (UAS) during RV *Polarstern* Antarctic winter expedition in June – August 2013. An unmanned aircraft SUMO (Small Unmanned Meteorological Observer) and a small quadcopter were applied, both equipped with several meteorological sensors. The data from these airborne instruments were supplemented by *Polarstern* radiosonde soundings and meteorological observations from a mast, deployed on the sea ice during ice-stations. Work at sea was restricted to the operation of the UAS's during ice stations because take-off and landing was not possible from *Polarstern*. Altogether we had 8 ice-stations with different length, but weather conditions were not always favourable for flying. The factors limiting operation on ice were strong wind (over 10m/s), poor visibility due to low foggy clouds and ice formation on the UAS's wings and propeller blades. SUMO was operated during 5 ice-stations. The typical flight pattern for SUMO consists of vertical profiles with a maximum altitude between 1.0km and 1.7km. When lower profiles were considered, two profiles were made during one flight. The quadcopter was operated during 3 ice-stations. It has a quite slow ascending and descending rate and was used in order to get more precise measurements of temperature and humidity from the lowest 100m layer of the atmosphere. In brief, 75 UAS flights were performed, turning out 100 single high-quality vertical profiles of temperature, humidity and wind. Synoptic situation and thus the vertical structure of atmospheric boundary layer were rather varying during ice-stations. Several episodes with strong surface based temperature inversions (inversion strength more than 10K) accompanied with essential decrease of relative humidity in vertical were observed. The inversion top remains typically at altitude between 200m and 400m. In some cases evident low-level jets were observed but due to technical limitations it was preferred to avoid situations with strong wind jets. Comparison of SUMO observations with *Polarstern* radiosonde profiles show fairly good match.

## Antarctic new particle formation from continental biogenic precursors

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Aerosols present the largest uncertainties in the future climate estimations. They can affect the climate by scattering and absorbing the sunlight as well as by acting as cloud condensing nuclei (CCN) and therefore affecting the cloudiness and cloud lifetime. The greatest uncertainties are related to the aerosol interactions with clouds. However, in order to act as CCN and affect the cloud properties, aerosols need to grow big enough. In Antarctica the air is very clean and thus the growth of aerosol particles is very slow. Until present, Antarctic continent has had no known sources of secondary aerosols. However, during the Finnish Antarctic Research Program FINNARP 2009 Antarctic expedition, we observed new particle formation (NPF) from continental biogenic precursors. The observed local and regional aerosol formation happened over areas with meltwater ponds and colonies of cyanobacteria *Nostoc commune*. We also observed how these secondary organic aerosols were acting as CCN only few hours after their formation. This observation is a major advance in the understanding of the aerosol formation mechanisms in Antarctica and has an increasing impact on aerosol-cloud interactions in the changing climate not only in Antarctica but also elsewhere in glaciated areas.

## In situ aerosol measurements at Dome C in 2007 - 2014

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Aerosol number size distributions and absorption coefficients have been measured at the Concordia station, Dome C, Antarctica (75°S, 123°E, 3200 m a.s.l.) since December 2007. Part of these measurements have been continuous since then, part of them only for shorter periods. In this presentation the data collected during the period December 2007 – May 2014 will be discussed.

Particle number size distributions in the size range 10 – 600 nm have been measured with a differential mobility particle sizer (DMPS) and in the size range 0.3 – 10 µm with a Grimm model 1.108 optical particle counter in 2007 – 2009 and with a TSI model 3330 Optical particle sizer since December 2013. In December 2010 – November 2011 an Air Ion Spectrometer (AIS) was used for measuring size distributions of charged particles in the size range of about 0.8 – 40 nm.

Light absorption by particles has been measured with a Radiance Research 3λ Particle Soot Absorption Photometer (PSAP) during the whole period. Absorption coefficients have been calculated from the raw signal and reference counts of the PSAP by taking long enough time differences between subsequent measurements of signal and reference. The PSAP data processing also needs scattering coefficients. Scattering coefficients were modeled from measured size distributions. In December 2013 also a new nephelometer, Ecotech Aurora 3000 was installed at the station so from then on there are also measured scattering coefficients available.

Seasonal cycles and the modal structure of particle number size distributions were presented by Järvinen et al. (ACP 13, 7473-7487, 2013). The majority of the particles were found in sizes below 100 nm of particle diameter. The concentrations were at their highest during the austral summer with the median number and volume concentrations of 260 cm<sup>-3</sup> and 0.086 µm<sup>3</sup> cm<sup>-3</sup>, respectively, and at their lowest during the austral winter with the respective concentrations of 15 cm<sup>-3</sup> and 0.009 µm<sup>3</sup> cm<sup>-3</sup>.

New particle formation (NPF) events were determined from the size distributions measured with the DMPS and the AIS. Several NPF events were similar to those observed at other continental locations. Exceptional features were winter NPF events that occurred during dark periods, as well as the events for which the growth could be followed during several consecutive days, and during which particles do not grow to sizes larger than approximately 10 nm, showing that the concentration of condensable gases is low.

## S10: SOLAR-TERRESTRIAL PHYSICS IN POLAR REGIONS

### Airglow and meteor radar observations over King George Island, Antarctica: previous results and current status

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Mesospheric gravity waves were observed at Ferraz Antarctic Station (62.1°S, 58.4°W) in two consecutive years (2010-2011), from March to October, by an airglow OH NIR all-sky imager. Mesospheric winds were simultaneously observed by a meteor radar installed at the same location in order to obtain the intrinsic wave parameters and for investigation of wave sources. The airglow imager was operated during 81 nights in 2010 and 123 nights in 2011. However, it was possible to identify and characterize wave events (due to the cloudy conditions) in 31 nights during 2010 and 46 nights in 2011. During these useful observed nights we identified 74 waves in 2010 and 149 events in 2011. Also, we could identify mesospheric fronts (bore candidates), specifically: one case in 2010 and three cases in 2011. In this work we reviewed the general wave characteristics, including the preferential propagation directions, observed and intrinsic wave parameters. Besides the observed mesospheric waves and their characteristics, we will show main features of winds and tides over the observation site at King George Island. Potential wave sources in the Antarctic Peninsula, including simultaneous small and medium scale waves, are subject of future investigation by using a reverse ray tracing technique. Due to a fire accident occurred at the Brazilian Antarctic station in February 24, 2012, the MLT observations have been stopped since then to the present. Future observations at Ferraz Station are planned for the winter of 2014 with the re-installation of an airglow all-sky imager and the rewiring of the meteor radar early in March 2014. So, new airglow data for this coming southern winter will be presented and discussed.

#### Acknowledgments

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## The southern polar cap index as an indicator of GIC activity

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During geomagnetic storms and substorms temporal variations in the horizontal components of the geomagnetic field induces an electric field that, in turn, may induce anomalous currents in grounded conductor networks (e.g. power distribution networks). These currents may cause damage to power transformers and may lead to system-wide blackouts in extreme cases. Accurate, timely forecasts of these events would enable power utilities to take mitigating action before significant damage to hardware occurs.

Substorms are an important driver of GIC in the midnight sector, mostly in high latitude regions. However, during intense events the auroral oval extends equatorward and middle latitude regions are also affected. Recently, Stauning (2013) suggested that the polar cap (PC) index may act as a precursor to substorm activity, and hence substorm-driven GIC. The PC index is based on geomagnetic field measurements taken at Thule/Qaanaaq, Greenland (77 degrees latitude) in the north and Vostok, Antarctica (at about 78 degrees south). The PC index serves as a proxy to the merging electric field in the solar wind and indicates deformation in the structure of the magnetosphere that may lead to substorm activity. This was demonstrated by Stauning (2013), using the northern PC index (PCN) and magnetic field observations from Sweden (about 50 degrees north).

We investigate the use of the southern PC index (PCS) as a precursor to GIC in a middle-latitude region. Although substorm activity is more severe at high latitudes, GIC driven by substorms have been observed in South Africa, even during moderate storms. The PCS index calculated at Vostok and geomagnetic field data from SANAE IV base in Antarctica (71 degrees south) are compared with a GIC proxy derived from magnetic field observations at Marion Island (46 degrees south) and Hermanus, South Africa (34 degrees south) to demonstrate the link between the PCS index, substorms and GIC at middle latitudes.

## Digital upgrade of SuperDARN radar at SANAE

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During the Austral Summer of 2013, the South African National Space Agency (SANA) became the second organization to install the T3 implementation of the all-digital HF Radar in the SuperDARN (Super Dual Auroral Radar Network). The new radar which replaced the previous radar at SANAE (71°40'37.67"S, 2°49'41.09"W) was based on the Australian design from La Trobe University. The new radar was fully built and tested at SANSA Space Science in Hermanus. It was funded through grants from the South African National Research Foundation and the South African National Antarctic Programme (SANAP). Due to the new radar being based on Field Programmable Gate Arrays (FPGAs), it provides a flexible platform that will allow researchers to run a diversity of experiments that fall outside the mandate of SuperDARN without having to invest in expensive and difficult to install infrastructure, whilst still satisfying its commitments to the SuperDARN network. One of the proposed new experiments is to receive the signals from a 14 MHz HF beacon on the first South African CubeSat (Tshepiso -Sat) launched on 21 November 2013.

The scientific goal of the SANAE HF radar programme is to increase understanding of aspects of the dynamics of the high latitude ionosphere and magnetosphere, magnetosphere-ionosphere coupling, the interaction of the magnetosphere with the solar wind and the energy transfer mechanisms between the solar wind, the magnetosphere, the ionosphere and the upper atmosphere, by addressing the following key questions in Space Science:

1. What is the nature of ultra-low frequency pulsations observed in the radar data, and how are they related to events in the solar wind?
2. What further information on such pulsations can be obtained using wavelet analysis?
3. What is the nature of the excitation mechanism of pulsations with large azimuthal wavelength?
4. What are the source and propagation mechanism of Pc5 band pulsations?
5. What are the mechanisms by which the interplanetary magnetic field controls convection in the high latitude ionosphere under different conditions?

The above key questions will be addressed through the use of data from the SANAE HF radar, and in collaborative programmes with other investigators.

The research aims to answer the key questions posed above, by, inter alia

1. analysing, using a variety of complex time series analysis tools, sample pulsation events observed in the radar data, together with solar wind data;
2. analysing convection patterns associated with different interplanetary magnetic field configurations; and
3. using the interferometer antenna system, undertaking atmospheric wave studies at SANAE, and combining these data with other SuperDARN data.

The paper will present some of the challenges in the implementation of the new digital radar, and some of the latest results obtained with the new radar.

## HF Beacon on South African CubeSat for characterization of SuperDARN radar antennas and interferometers

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ZACUBE-1 (Tshepiso-Sat) is a South African space weather CubeSat satellite mission carrying a 14.099 MHz High Frequency (HF) beacon transmitter designed to characterize the SuperDARN HF Radar antennas and support mid and high-latitude trans-ionospheric HF wave propagation experiments [1, 2]. ZACUBE-1 was launched on 21 November 2013 into a polar orbit at 640 km altitude (perigee: 596 km apogee: 681 km) with inclination 97.8°. It was developed by the Cape Peninsula University of Technology (CPUT), the South African National Space Agency (SANSa) and Stellenbosch University (SUN) with funding from the South African Department of Science and Technology (DST).

The ground-based component of the HF Beacon includes two interferometers to estimate the Direction of Arrival (DOA) of the HF beacon signals: A 16-element Twin Terminated Folded Dipole antenna array associated with the South African Super Dual Aurora Radar Network (SuperDARN) array at SANAE-IV, Antarctica (2.84°W, 71.67°S) and an L-shaped, seven-element direction finding (DF) cross-loop dipole array located at SANSa in Hermanus, South Africa (19.24°E, 34.42°S). The azimuth and elevation incidence angles of the received HF signal and its polarization will be calculated from the L-array in Hermanus using phase differences observed at the respective crossed-loop antennas.

Rigorous ionospheric ray tracing simulations using the International Reference Ionosphere (IRI) model and simulated satellite orbital geometries have shown that signals from the HF beacon will propagate through the mid and Antarctic high-latitude ionosphere under most ionospheric conditions [3]. However, depending on satellite geometry, sporadic visibility will be achieved from the low elevation SuperDARN beams at SANAE-IV. Using local GNSS receiver networks, the 3D electron density distribution in all the ionospheric layers will be derived using computerised ionospheric tomography.

This paper presents the analysis of the HF ray paths through the Antarctic ionosphere, the infrastructure for this mission, the current status of the experiment, the HF DF Ground station at SANSa Space Science in Hermanus and results obtained.

Any research groups within the ZACUBE-1 footprint are invited to make use of the HF beacon signal. Details of the mission and a visibility map are available at

<http://www.cput.ac.za/blogs/fsati/zacube-1/> and <http://webapps.sansa.org.za/zaspace>

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## Day-to-day variability of riometer absorption at Syowa: new results

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Day-to-day variability of riometer auroral absorption has been derived in the past from hourly values, determined at several Southern Hemisphere stations, located both near the centre of the auroral absorption zone and at higher and lower latitude fringes of the zone. Most of them relate to the so called "broad beam" riometers. For a given location and time-of-day, values are grouped so as to investigate solar and geomagnetic activity level effects. Cumulative amplitude-probability distributions for a given hour at a given location are found to be well represented by log-normal distributions for most locations, times-of-day and solar and geomagnetic activity levels, over the range of absorptions for which values are more accurate (typically 0.3 dB or above). Parameters of log-normal distributions are found to be related following a known simple expression, so as to permit full specification of any distribution by a single parameter.

In the last decades, however, auroral absorption values have been derived at a much higher time and space resolutions using the so called "IRIS" riometer systems. These use steerable antennas to point to many directions, typically scanning an ionospheric area some hundreds of square kilometres at about 100 km height centred overhead, in the course of a several seconds. Here the day-to-day variability of this type of observations at Syowa (69.0°S; 39.6°E) is reported using the same statistical methods as done before. Preliminary results show that there are significant differences. Some differences can be associated with the spatial structure of the ionospheric irregularities within the observing area. Others probably relate to different ways used to process the cosmic noise intensities to derive absorptions. An attempt is made to use these preliminary results to derive a homogenous time series of auroral absorption values spanning several decades.

## Optical and ionosonde determination of thermospheric neutral winds over the Antarctic Peninsula

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During a few days in 1997 thermospheric winds were measured with a Fabry-Perot Interferometer (FPI) at King Sejong station (62.22°S; 58.78°W), King George Island. All days correspond to intervals of low geomagnetic activity, low solar activity, and to different seasons. On the same days ionosonde observations were made at nearby Great Wall station (62.22°S; 58.97°W), also located at King George Island, and at further south Vernadsky station (65.25°S; 64.27°W), Argentine Islands. For each day and location the magnetic meridional component of the thermospheric neutral wind were derived using three different algorithms with ionosonde data input. Winds were also computed using the well-known HWM and VSH models. The geographic meridional FPI winds measured at the geographic south pointing location are compared with the magnetic meridional component of the wind derived from ionosonde data at Vernadsky station. The magnetic meridian FPI winds measured using all four cardinal pointing locations are compared with the magnetic meridional component of the wind derived from ionosonde data at Great Wall station. The shapes of the diurnal variations of the magnetic meridional component of ionosonde derived winds using the three different techniques are similar in most cases. So also are the winds calculated using the empirical models. However, the amplitudes of these variations and some individual values can differ by several tens of m/s depending on season. The same is generally observed for Vernadsky station. Results are consistent with those available for the Australia sector.

Recently, thermospheric winds were measured using a similar Fabry-Perot instrument at Palmer station (64.77°S; 64.05°W), very near to Vernadsky, for many more days but during 2011. These are compared with previous results for Great Wall and Vernadsky and similarities and differences discussed.

## Morphology of precipitated electrons in the austral auroral zone

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Here a morphology of precipitated electrons fluxes for the southern hemisphere auroral zone is presented. Observations made during a 13 year interval by polar orbiting satellites of the POES mission are used. The observations correspond to the SEM-2 onboard instrument. Directional differential-energy spectrum fluxes of electrons are determined assuming that a Maxwellian distribution approximation applies. Fluxes are grouped according to corrected geomagnetic latitude and longitude (height-adjusted version), magnetic local time and geomagnetic and auroral activity levels.

In an initial analysis fluxes are assumed to be distributed according to a Gaussian latitudinal variation. Parameters of the Gaussian latitudinal distribution (latitude of peak flux, peak flux and distribution width) are determined separately for given time-of-day intervals, longitude sectors and geomagnetic activity level. It is found that the latitude of peak flux and peak flux exhibit a small but clear longitude dependencies for some time-of-day intervals.

In a further analysis latitude distributions are more closely analyzed, leading to the determination of non-Gaussian distributions for some time-of-day intervals and longitudes sectors depending on geomagnetic and auroral activity levels. An attempt is made to assess whether these results may be consistent with particle precipitation been triggered relatively near the Earth and associated with a ring current that could have different latitude structures in the sun and away-from-the sun directions.

## The first Antarctic node of the LAGO (Latin American Giant Observatory) project

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The first antarctic node of LAGO (Latin American Giant Observatory), a dedicated network of water Cherenkov detectors (WCD), is projected to be installed at the Argentinian 'Marambio' base, located in the Antarctic Peninsula. This new node will be installed and operated in the context of a cooperation between the LAGO Collaboration and the Argentinian Antarctic Institute (IAA/DNA).

A WCD is a particle detector based on the Cherenkov effect. A simple tank is filled with purified water, and one or several photomultipliers are installed inside the detector looking the water volume. When a relativistic and charged particle crosses the water volume, Cherenkov radiation emission occurs. This Cherenkov light is then uniformized in the water volume by diffusion on the walls of the tank (usually covered by a highly diffusive material), and finally collected by the photomultiplier tubes.

When a cosmic ray reaches the Earth atmosphere, it produces a cascade of secondary particles. The charged component of this cascade can be directly detected by a WCD, while the photon contents of the shower can be detected by pair creation inside the water volume.

Due to the configuration of the geomagnetic field, different locations have different rigidities cut-off, so at a given location a primary charged particle can not reach ground level if its rigidity is lower than the local cutoff value. At present, the LAGO Collaboration is operating a network of WCDs across nine Latin American countries (Argentina, Bolivia, Colombia, Ecuador, Guatemala, Mexico, Peru, Venezuela, and recently Brazil). The LAGO network is recording the energy spectrum and the integrated flux of atmospheric particles at several sites with different altitudes and geomagnetic rigidity cutoffs.

The Antarctic continent has the unique advantage of combining low rigidity cut-offs values and infrastructure to support the operation of WCD, making this place as a privileged site for study the Sun-Earth coupling and Space Weather phenomena. The low rigidity cut-off at Marambio allows the observations of events that cannot be observed at any other site of the LAGO network. In particular, the upcoming years will be optimal for these studies, since the more intense solar events will appear in the next declining phase of the current solar cycle.

## Ground-based observations for auroral phenomena in Japanese Antarctic research program

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In the Japanese Antarctic Research Expedition (JARE), various ground-based observations for studying auroral phenomena are carried out at ground stations and unmanned network sites. At Syowa Station, various instruments are operated for doing a synthetic study, including all-sky imagers (panchromatic TV camera, color digital camera, monochromatic imagers (427.8, 557.7, 481.0, 486.0 nm)), Scanning Photometer (482.5, 483.5, 484.5, 485.5, 486.5, 487.5, 670.5, 844.6 nm), Imaging and broad beam riometers, VLF electromagnetic wave receiver, fluxgate and induction magnetometers, and two SuperDARN radars. Our special interests are in the study on conjugate phenomena between both hemispheres, especially between Syowa and Iceland conjugate stations. Auroral optical observations are carried out also at other stations as an international collaboration, at Dome Fuji with Australia, at South Pole with US, and at Zhongshan with China. Unmanned magnetometer network observations are also carried out in JARE in collaboration with UK and Belgium in the area including Syowa, Dome Fuji, and Princess Elisabeth Stations. With those ground-based network observations, we would like to study global evolution of auroral phenomena from auroral latitudes to cusp and polar cap regions and from nightside to dayside. In our presentation, some details of the ground-based observations for auroral phenomena in JARE will be introduced and some topics observed with such a widespread observation network will be shown, especially focusing on the Syowa-Iceland conjugate auroral activity and dayside auroral activity at South Pole.

## High-speed solar wind streams and nitric oxide production in the Antarctic middle atmosphere

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High-speed solar wind streams lead to widespread high-energy electron precipitation over the polar regions. Direct production of nitric oxide as these electrons ionize the atmosphere is a possible source of solar-disturbance signatures in polar ice-cores. A small VHF wind-profiler radar which has been operating in Queen Maud Land, Antarctica for the last 2 years, has detected evidence of these ionization events reaching down to 50 km altitude. Conjugate measurements of ionization profiles from the Arctic incoherent-scatter radar EISCAT, together with riometer (relative ionospheric opacity meter) measurements from both hemispheres, and modelling of D-region ion chemistry, allow us to quantify the amount of ionization (and by inference, the amount of nitric-oxide) produced. In the dark and isolated conditions of the Antarctic middle atmosphere in winter, nitric oxide has a long lifetime. Direct measurements of nitric-oxide profiles (by the SMR instrument on-board the Odin satellite) and their variation in response to solar-wind streams allow us to assess the relative contributions of direct production and downward transport from higher altitudes.

## Program of the Antarctic Syowa MST/IS (PANSY) radar: Updates of the first MST/IS radar in the Antarctic

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The PANSY radar is the first Mesosphere-Stratosphere-Troposphere/Incoherent Scatter (MST/IS) radar in the Antarctic, for profiling wind velocities and plasma parameters from the ground up to 500 km altitude. It is a monostatic coherent pulse Doppler radar operating at 47 MHz VHF, consisting of an active phased array of 1,045 Yagi antennas and the same number of transmitter/receiver (TR) modules obtaining a total peak output power of 500 kW, located at Syowa Station (69°00'S, 39°35'E). The first stage of the radar installation was carried out in early 2011, and since April 2012 the radar has been continuously operated with 228 antennas and modules. The full radar system operation will start in 2015.

The main scientific goals of the radar are to reveal the role of atmospheric gravity waves at high latitudes in the momentum budget of the global circulation in the troposphere and middle atmosphere, and to explore the dynamical aspects of unique polar phenomena such as polar mesospheric/stratospheric clouds. Strong and sporadic energy inputs from the magnetosphere by energetic particles and field-aligned currents can be quantitatively assessed by the broad height coverage of the radar from the lower troposphere to the upper ionosphere. Furthermore, katabatic winds as a branch of Antarctic tropospheric circulation and as an important source of gravity waves are also of special interest. In this paper we will present the scientific objectives of the project, technical descriptions, and the results of observations in the troposphere, stratosphere and mesosphere to date, including observations regarding severe snow storms, gravity waves, multiple tropopause, and polar mesosphere summer/winter echoes.

## **The middle and upper atmosphere observations using ground-based radio and optical instruments over Syowa Station (69S, 39E), the Antarctic**

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JARE (Japanese Antarctic Research Expedition) has been carrying out a six year prioritized project of the Antarctic research observations since 2010. One of the sub-project is entitled "the global environmental change revealed through the Antarctic middle and upper atmosphere." Ground-based radio and optical observations of profiling dynamical parameters such as temperature and wind, as well as minor constituents is the key component of observations in this project, together with a long term observations using existent various instruments in Syowa, the Antarctic (39E, 69S). The PANSY (Program of Antarctic Syowa MST/IS) radar, a Rayleigh/Raman/Resonance scatter radar, a millimeter-wave spectrometer are the new instruments which started observations during the project.

This paper will report recent studies and observations of this project at Syowa Station. The PANSY radar started research observation in April 2012 with the 1/4 of full-array antenna system. Observations of troposphere/lower stratosphere/ mesosphere are almost continuously executed except for the intermittent system adjustment periods. Our observations have indicated more frequent PMWEs (Polar Mesospheric Winter Echo) than other studies. The Rayleigh/Raman lidar have been observing gravity waves in the stratosphere/mesosphere by temperature perturbations, and recently the altitude range has been successfully extended down to upper troposphere by combining Raman scatter signals to the Rayleigh signals. A lidar for resonance scatter lidar observation to be added for extending the height coverage into the lower thermosphere is being developed and experimental observations in Tokyo at mid-latitude has been started. Millimeter spectrometer has been observing both ozone and NO, and revealing seasonal and short term variabilities related to the solar activities and atmospheric circulations. Sodium airglow imaging data at 90 km altitude since 2002 has extensively been analyzed for clarifying behavior of short-period gravity waves in the MLT region. We expect the full-power operation planned in near future will establish a very powerful radio/optical observation core site for the middle and upper atmosphere studies as well as troposphere, at Syowa Station.

## The impact of Energetic Electron Precipitation into the polar atmosphere: Coupling space-based process to the high latitude upper atmosphere and polar surface climate

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Energetic Electron Precipitation (EEP) into Earth's atmosphere is an energy coupling route which links transient changes in the solar wind to the chemical composition of the polar atmosphere. The energetic electrons originate from the inner magnetosphere, coming either from the Van Allen radiation belts or injected during magnetic reconnection processes in substorms. In both cases high fluxes of energetic and relativistic electrons precipitate into the polar atmosphere, due to the orientation of the geomagnetic field.

There is growing interest in EEP. Some of this comes from the renewed interest in radiation belt dynamics surrounding NASA's recently launched Van Allen Probes mission, which has stimulated new experimental and theoretical research and opened up new understanding into the fundamental physical processes. Beyond this, however, there is a new focus on the impact of the EEP on the polar atmosphere with increasing evidence of significant changes in upper atmospheric chemistry and coupling to polar surface climate.

Very recently relativistic electron precipitation has been shown to be a significant source of odd hydrogen and odd nitrogen in the polar atmosphere [Andersson et al., JGR, 10.1029/2011JD01724, 2012], which acts as a catalytic agent in the destruction of ozone. Due to the orientation and strength of the geomagnetic field, EEP preferentially occurs into the Antarctic atmosphere, particularly near the Weddell Sea. Satellite observed odd hydrogen observations contain a hot spot in this region, demonstrating this link [Andersson et al., ACP, 10.5194/acp-14-1095-2014, 2014]. Empirical evidence suggests these ozone changes modulate the southern annual modes, causing significant variability in polar surface air temperature on seasonal time scales [Seppälä et al., JGR, 10.1029/2008JA014029, 2009; Seppälä et al., JGR, 10.1002/jgrd.50236, 2013].

In this talk I will discuss how our growing understanding links changes in solar wind speed, geomagnetic storms, plasma wave intensity, energetic electron precipitation, upper atmospheric chemistry and polar surface climate variability. This research has involved fundamental space physics observations of particles and waves from space based and ground based instruments, along with satellite and ground based atmospheric chemistry measurements, as well as climate reanalysis datasets and GCM outputs. Ground based Antarctic observations include the Antarctic-Arctic Radiation-belt (Dynamic) Deposition - VLF Atmospheric Research Konsortium (AARDDVARK), riometers, magnetometers and radiometers.

## The South Pole, Antarctica, Solar Radio Telescope (SPASRT) system

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The study of the sun in the radio portion of the electromagnetic spectrum furthers our understanding of a myriad of solar processes that are concurrently observed in the X-ray, UV, and visible regions of the spectrum. For example, the study of solar radio bursts, which have been shown to cause serious disruptions of technologies at Earth, is essential for advancing our knowledge and understanding of solar flares and their relationship to coronal mass ejections and solar energetic particles, as well as the underlying particle acceleration mechanisms associated with these processes. In addition, radio coverage of the solar atmosphere could yield completely new insights into the variations of output solar energy, including Alfvén wave propagation through the solar atmosphere and into the solar wind, which can potentially modulate and disturb the solar wind and Earth's geospace environment. In this presentation we discuss the development, construction, and testing of the South Pole, Antarctica, Solar Radio Telescope (SPASRT) system that is planned for installation at South Pole. The system will allow for 24-hour continuous, long-term observations of the sun across the 1-18 GHz frequency band and allow for truly continuous solar observations. We show that this system will enable unique scientific investigations of the solar atmosphere.

## S11: GLOBAL NAVIGATION SATELLITE SYSTEM RESEARCH

### Scintillation case studies at high latitudes on January 2014

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Solar perturbations can increase the ionospheric electron density resulting in TEC (Total Electron Content) gradients. The GNSS signals passing through steep TEC gradients can experience scintillation observed by receivers on the ground. The impact is particularly important at high and low latitudes due to the sun-magnetosphere-ionosphere interplay. In January 2014 a series of solar events induced (resulted in) ionospheric scintillation of the GNSS signals received in the Arctic and in Antarctica. The focus of this paper are observations acquired by high-sampling frequency (rate) (50 Hz) GNSS receivers deployed at sub-auroral, auroral, cusp and polar latitudes in both the northern and southern hemispheres. The data obtained by specialized scintillation receivers are supplemented by geodetic quality receivers tracking the GPS signals at a rate of 1 Hz to provide a proxy phase scintillation index. A comprehensive study of the effects in the ionosphere caused by solar events that occurred between January 7<sup>th</sup> and 13<sup>th</sup> is presented. A giant sunspot erupted on January 7<sup>th</sup> producing a powerful X1-class solar flare at approximately 1832 UT and launching a CME that hit the Earth's magnetic field on 9<sup>th</sup> January (around 20:00 UT). On January 12<sup>th</sup> the Earth entered a fast stream in solar wind (solar wind velocity exceeded 800 km/s on January 13<sup>th</sup>). This study will address the objectives of the GRAPE (GNSS Research and Application for Polar Environment) SCAR Expert Group (<http://www.grape.scar.org/>).

## Characteristics of polar tropopause based on GNSS occultation observation

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The spatial and temporal variations of Antarctic tropopause are analyzed quantitatively with the COSMIC occultation data in 2011. The tropopause parameters, temperature and altitude, are extracted from the atmospheric temperature profiles, which are inversed by using occultation data. When the air temperature is less than 250K, the influence of wet air pressure can be ignored. Compared to ozonesonde and radiosonde, the occultation method has the same accuracy in tropopause parameters extraction. In the Antarctica, the lapse rate tropopause is more accurate than the coldest point tropopause, because there is no conventional tropopause in Antarctic winter, which results in wrong tropopause height for coldest point tropopause. The Antarctic tropopause shows one wave structure with contrary phase. The temperature ranges from 200K to 230K, high in summer and low in winter. The height ranges from 9km to 11km. Antarctic tropopause in winter and spring disappeared because of no convection induced by solar heating, and occurred inversion layer in summer and autumn. Antarctic tropopause temperature in winter and spring shows significant gradient feature. In latitude direction, the temperature is low near the pole and high around; in longitude direction, the temperature is lower in the West Antarctica, which relate to the distribution of the continent and ocean.

## Data management and TEC calibration of the INGV ionospheric GNSS measurements in polar regions

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In the frame of the projects “BIS - BIPOLAR IONOSPHERIC SCINTILLATION AND TEC MONITORING”, PNRA 2009/B.03 and ISACCO (Ionospheric Scintillations Arctic Campaign Coordinated Observations), a network of GNSS stations have been installed since 2003 in both polar regions. All the stations are equipped with a dual-frequency GNSS receiver in order to measure TEC and scintillations indexes to deeply understand complex phenomena that govern morphology and dynamics of the high latitude ionosphere. Currently 3 stations are deployed in the Svalbard Islands (Norway) and 4 stations are operating in Antarctica at Mario Zucchelli Station (74°41' S 164°07' E) and Concordia Base (74°30' S 123°00' E). The last station was installed at Concordia this year, during the XXIX Italian Antarctic campaign. All data from these stations are managed in near real time by the INGV “electronic Space Weather upper atmosphere” (eSWua) data system and are available at <http://www.eswua.ingv.it>. The eSWua system architecture is based on 3 high-performing servers that are installed at INGV in Rome (Italy) that can store database tables, process online user requests, and make different products available.

The GNSS TEC data are affected by well-known biases and errors (clock biases, phase ambiguity, multipath) that need to be cut off. This guarantees their proper use for scientific and application purposes. In this paper, after a brief presentation of the network and the related data management system, we present the TEC calibration procedure applied to the network data. The results include a comparison between TEC derived from GNSS calibrated data and EISCAT measurements over Longyearbyen (Svalbards islands) is also shown to demonstrate the importance of a proper calibration in integrating GNSS data with other data sources.

## Amplitude and Phase Scintillation proxies for ionospheric scintillation observed from southern high latitude stations

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Ionospheric scintillation along GPS ray paths can significantly degrade the accuracy of GPS navigation due to increased errors and loss of lock on the GPS satellites. In the Antarctic region, where GPS navigation is often of critical importance during travel in whiteouts and in regions with crevasces, the estimation of scintillation and its impact on navigation accuracy can be used to reduce the risk of losses due to navigation errors.

Amplitude (S4) and phase scintillation ( $\sigma\Phi$ ) indices are customarily obtained by specialized GPS Ionospheric Scintillation and TEC Monitors (GISTMs) from L1 signal recorded at the rate of 50 Hz.

To overcome the limited geographic coverage by GISTMs other GNSS data sampled at 1 Hz can be used to obtain scintillation proxy indices.

In this study the amplitude scintillation index proxy index S4p proposed by Du et al. (2000) and a phase scintillation proxy index delta phase rate, DPR (Ghoddousi-Fard et al., 2013) is obtained from 1-Hz data from GPS receivers at SANAE and other Antarctic bases. The 50-Hz and 1-Hz phase scintillation indices are correlated. The percentage occurrences of S4p>0.2 and S4 >0.2 and  $\sigma\Phi > 0.1$  rad and DPR > 2 mm/s, both mapped as a function of magnetic latitude and magnetic local time during moderate magnetic storms are presented to evaluate the usefulness of these proxies in Southern high latitude regions.

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Ghoddousi-Fard R., P. Prikryl, F. Lahaye, GPS phase difference variation statistics: A comparison between phase scintillation index and proxy indices, *Advances in Space Research*, 52, 1397–1405, 2013.

## Interhemispheric comparison of GPS phase scintillation and proxy index during the geomagnetic storms of 7-17 March 2012

Prikryl P<sup>1</sup>, Ghoddousi-Fard R<sup>2</sup>, Spogli L<sup>3</sup>, Alfonsi L<sup>3</sup>, Kinrade J<sup>4</sup>, Mitchell C<sup>4</sup>, Li G<sup>5</sup>, Ning B<sup>5</sup>, **Cilliers P**<sup>6</sup>, Sreeja V<sup>7</sup>, Aquino M<sup>7</sup>, Terkildsen M<sup>8</sup>, Jayachandran P<sup>9</sup>, Jiao Y<sup>10</sup>, Morton Y<sup>10</sup>, Ruohoniemi J<sup>11</sup>, Thomas E<sup>11</sup>, Coster A<sup>12</sup>, Danskin D<sup>1</sup>, Spanswick E<sup>13</sup>

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The interval of 7–17 March 2012 was selected at the Climate and Weather of the Sun-Earth System (CAWSES) II Workshop for group study of space weather effects during the ascending phase of Solar Cycle 24. An overview of the major solar, interplanetary and geomagnetic activity that resulted in a series of geomagnetic storms has been published (Tsurutani et al., 2014). Space weather impacts the operation of modern technology that relies on Global Navigation Satellite Systems (GNSS). Rapid fluctuations of amplitude and phase of radio waves passing through the ionosphere degrade GPS positional accuracy and cause cycle slips leading to loss of lock that affects performance of radio communication and navigation systems. The present paper focuses on interhemispheric comparison of the ionospheric response to the storms as observed by arrays of GNSS Ionospheric Scintillation and TEC Monitors (GISTMs), geodetic quality GPS receivers sampling at 1 Hz, HF radars, ionosondes, riometers, magnetometers and auroral imagers. The goal is to identify main ionospheric source regions and phenomena that result in GNSS signal scintillation.

Tsurutani, B. T., et al.: The interplanetary causes of geomagnetic activity during the 7–17 March 2012 interval: a CAWSES II overview, *J. Space Weather Space Clim.* 4 (2014) A02, DOI: 10.1051/swsc/2013056

## The ionosphere response at Antarctica and Sama region to the geomagnetic storm occurred on September 26, 2011

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Geomagnetic storms generate disturbances in the ionosphere due to the incidence of energetic particles, which effects are more pronounced at higher latitudes as well as inside the South America Magnetic Anomaly. For understanding the effects of the 26th September 2011 geomagnetic storm we present the ionosphere behavior obtained from GPS data scintillation and TEC at Comandante Ferraz Brazilian Antarctic Station (EACF, 62.1°S, 58.4°W) and at Itapetinga radio Observatory (23.2oS, 46.6oW). The analysis covers the period of 23-30 September and shows the ionosphere behavior at different latitudes in the American sector during the storm as detected by GPS experiments and by ionosonde experiment at EACF.

## Investigating polar ionospheric signals using GPS virtual arrays

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GPS total electron content (TEC) measurements are commonly used to study ionospheric disturbances in the near and far field. For co-seismic ionospheric disturbances (CIDs) the apparent velocity of the signal can be calculated from distance travel-time plots or interferometric stacking techniques. To date, signals related to solid earth-atmosphere coupling have been recorded as far as 3000 km from the source by using array-processing and an approximation to a spherical CID wave front. However, few studies have analyzed CIDs at greater distances where the spherical wave front approximation may not be appropriate due to complex propagation of the signal and superposition with other traveling ionospheric disturbances.

Using a modified version of the traditional frequency-wave number (F-K) filter applied to GPS ionospheric TEC measurements, we investigate Polar ionospheric signals observed during the 2010 Maule, the 2011 Tohoku-Oki and the 2013 South Orkney Islands earthquakes using the ANET component of the POLENET GPS network. Using this developed “virtual array” beamforming technique that treats the ionospheric piercing points as a sensor array, we obtained information about the azimuth and apparent velocity of the observed signals. This work describes preliminary results of the analysis of signals observed in the vicinity of McMurdo station and discusses their possible origin by analyzing their frequency, direction and apparent velocity.

## Long term GPS monitoring of Precipitable Water Vapour in Antarctic coastal areas and validation with Radio Sounding Measurements

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The columnar content of water vapor (WV) impacts the Earth's climate and its short- and long-term changes. The long-term monitoring of this important green-house gas should be ensured on a consistent and continuous basis to carry out reliable prediction with global climate and weather models and understand the climate evolutionary patterns. The detection and monitoring of WV in Antarctica is particularly challenging.

We processed the data of 5 permanent GPS coastal stations (Mawson, Davis, Casey, Mario Zucchelli and Mc Murdo) to derive the local WV content and its variations over a 12 year period. The GPS station selection was driven by the presence of radio sounding (RS) data locally performed using Barocap, Thermocap and Humicap-A sensors mounted on Vaisala radiosondes, for which we have used a well established correction procedure to minimize instrumental errors.

GPS- and RS-derived WV series are presented, compared and critically commented.

## Cloud computing infrastructure for Polar GNSS e-Science applications

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On the field on Polar studies and applications developed by the international scientific community, it is increasingly necessary to adopt computing infrastructure able to manage and process large set of data from polar regions. More often the issue is how to structure and deploy an IT infrastructure able to manage data coming from different teams in a multi-user environment. Moreover the computational architecture requires scalability and interoperability features.

Under the GRAPE initiative (GNSS Research and Application for Polar Environment), the DemoGRAPE project aims to provide on selected case studies an empirical assessment of the delay and of corruption induced by the ionosphere on satellite signals in polar regions. DemoGRAPE will demonstrate the usefulness of the proposed system to several application scopes as positioning and space weather as well as to support the investigation of polar cap dynamics, solid Earth and cryosphere evolution. The final scope is to develop a prototype for a service addressed to the scientific and technologic communities that relies on GNSS applications. The system is based on Cloud computing infrastructure. Innovative aspects in term of data and resources management for the ionospheric analysis will make an important step for creating flexible services to assist GNSS operations at the poles. The international contexts of the project constitute an opportunity to become pioneer in the frame of new potential services.

In the framework of GRAPE and DemoGRAPE initiatives, this paper reports the example of the GBSC (Ground Bases Scintillation Climatology) technique fully integrated on virtualized machine in an open source and cloud computing infrastructure. The paper introduce an innovative way to manage and share data in polar regions providing new scenarios in term of IT infrastructure and contributing to the aims of the Standing Committee on Antarctic Data Management.

## Inverse modeling using GNSS data and novel scintillation model to characterize high latitude irregularities over Antarctica

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We have developed a high fidelity "Satellite-beacon Ionospheric-scintillation Global Model of the upper Atmosphere" (SIGMA) which is a full 3D EM wave propagation model to simulate GPS scintillations globally. We demonstrate in this work that the results from this model can form a basic framework on the use of inverse method to understand the physics of high latitude irregularities using GPS scintillations. We are using SIGMA and an inverse method to understand the physics of the irregularities observed with GPS receivers from six different inter-hemispheric high latitude stations on 9 March 2012. The locations we analyzed the data from are: South Pole, McMurdo and Concordia in Antarctica and Resolute Bay, Tromso and Ny Alesund from the North. We also utilized ancillary observations from SuperDARN, ISRs, riometers etc. to obtain some of the input parameters of SIGMA. We implement a uniform-grid SIGMA simulation or a non-linear optimization of the model to obtain the model unknowns that give us the best fit with data. The input parameters of SIGMA thus derived represent the physical and propagation parameters related to the physics of the irregularity that produced those GNSS scintillations. Some of our findings from this investigation include that the spectral indices and outer scales for ionospheric heights of 350 km are higher than those at 120 km. The best fits we obtained from our inverse method mostly agree with the observations except for some cases, which might be because the spectral model we use is insufficient to describe irregularity physics. We need more auxiliary data in order to facilitate the possibility of accomplishing a unique solution to the inverse problem.

## **Poker Flat Research Range GNSS scintillation array: First results**

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In December 2013 four GNSS scintillation receivers were deployed to the Poker Flat Research Range (PFRR) at Fairbanks Alaska. These four receivers in addition to an existing scintillation receiver at PFRR, were augmented by two additional receivers in March 2014 for a total array of a seven scintillation receivers. The PFRR GNSS scintillation array (GSA) observations are supplemented by observations from the Poker Flat ISR (PFISR), ground all sky imaging (ASI) observations, neutral wind observations, SuperDARN, and other instrumentation from the PFRR. For this paper, we present initial results from the PFRR GSA observations including direct observations of spatial and temporal variability of the phase and amplitude scintillations across the array, estimates of bulk drift velocities, and, through inverse analysis, estimates of the physical parameters of the ionospheric irregularities that cause the scintillations. We also compare the scintillation and irregularity estimates to the background large scale physics from the other instrumentation available at PFRR in order to understand what large scale drivers are producing the observed irregularities.

## Surface velocity field from repeat GPS Measurements around Dome Argus, Antarctica

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The knowledge of surface topography and velocity field at an ice-core site are critical to the accurate interpretation of the ice-core records in a region such as Dome Argus, where a deep ice-core drilling project of China is carried out. We produced a map of precise surface digital elevation model around Dome Argus from measurements of Global Positioning System (GPS) in January 2013 from 49 sites. There are two peaks in Dome Argus, and we found the northern peak is ~7 cm higher than the southern peak. Combined with GPS measurements in 12 sites, surface velocity field around Dome Argus is calculated. The surface velocity speeds range from  $3.1 \pm 0.53$  to  $29.4 \pm 0.24$  cm yr<sup>-1</sup>, with a mean velocity magnitude  $11.1 \pm 0.49$  cm yr<sup>-1</sup>. The surface flow directions are nearly perpendicular to the surface elevation contours. The comparison between velocity field and surface topography shows that the surface velocity is determined by the surface topography. Furthermore, the GPS velocity field and InSAR results are compared. GPS has much smaller speed than InSAR. With the GPS results, the accuracy of velocity from InSAR is determined, with a standard deviation about 0.570 m yr<sup>-1</sup> of velocity speed and about 117.5 degree of velocity direction, respectively. This result is consistent with the declare accuracy of InSAR results.

## S12: ASTRONOMY AND ASTROPHYSICS FROM ANTARCTICA

### Characterising the auroral/airglow emission from Dome A, Antarctica

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The best ground-based sites for near-infrared astronomy are on the high plateau of Antarctica. The superiority of these sites is a consequence of their altitude, and the cold, dry atmosphere.

One property of the Antarctic atmosphere that is currently poorly known (from an astronomical site-testing point-of-view) is the effect of emission lines due to aurorae and airglow. These lines are particularly problematic in the near-infrared.

Most of what is known about the sky emission above the Antarctic plateau below 1.4 microns has come from broad-band photometry or very low resolution spectroscopy. Attention now needs to be focused on fully characterizing the sky emission, through measuring the absolute line-widths, wavelengths and intensities.

We are assembling an optical/near-infrared spectrograph to measure the sky emission between 0.7 and 1.4 microns. We plan to install the instrument at the Chinese Kunlun Station at Dome A over the summer of 2014/2015.

The spectrograph uses a 512-pixel InGaAs array detector coupled to a spectrograph with a choice of two gratings (R~600 and R~3000). The sky is coupled to the spectrograph using a single optical fiber with no additional optics.

In the high-resolution mode we will be able to resolve the auroral/airglow lines and measure their variability. The fiber input will be capable of pointing to different parts of the sky.

As with all instruments operating over winter at Dome A, this spectrograph system will be remotely controlled.

With these data, we can start to precisely calibrate the effect of the sky emission on near-infrared astronomy from Antarctica.

## Terahertz astronomy from Ridge A on the Antarctic plateau

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Since 2012 we have operated a terahertz astronomical observatory from Ridge A at 4035m altitude on the Antarctic plateau. The observatory has a 62cm telescope known as the High Elevation Antarctic Terahertz (HEAT) telescope and is supplied with power and communications from our observatory platform PLATO-R.

Ridge A has proven to be an unrivalled ground-based site for terahertz astronomy, due to the low levels of precipitable water vapor resulting from the extreme cold and high altitude of the site.

HEAT is constructing a map of our Galaxy in the emission-line features of atomic carbon at 492 and 809 GHz, carbon monoxide at 806 GHz, and ionized nitrogen at 1.46 THz. The maps will provide new insights into the structure and evolution of molecular clouds and the early stages of star formation.

During five days over the 2013/2014 summer we visited the Ridge A site to prepare the observatory for its third year of data taking. HEAT was swapped out with a new telescope with upgraded optics, a new optical table supported with carbon fiber tubes, and a new detector to reach to 1.46 THz. PLATO-R was refurbished with two new diesel engines, 1600 liters of Jet-A1 fuel, and upgrades of its electronic equipment.

The HEAT/PLATO-R observatory is providing unique data to the astronomical community that could otherwise only be obtained from long-duration balloon flights or spacecraft.

The observatory runs autonomously, with annual servicing missions from the US Amundsen-Scott South Pole Station. Reduced data are retrieved via Iridium satellite during the year, with the raw data being returned on disk drives following each servicing mission.

## The atmospheric emission at 2.4 microns from the Antarctic plateau

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Astronomers observing in the near-infrared are hampered by emission from the earth's atmosphere, which is often much brighter than the astronomical objects under study.

The atmospheric emission in the near-infrared in Antarctica is dominated by airglow below about 2.3 microns, and by thermal (blackbody) emission above about 2.5 microns. At 2.4 microns there is a window between the airglow and thermal emission, within which the sky can be a factor of 50 or so darker than that observed from the best temperate latitude observatories.

Measurements made from the US Amundsen-Scott South Pole Station in the late 1990's proved the existence of the 2.4 micron window, and quantified the sky emission at this wavelength.

There are good reasons to believe that the colder temperatures and higher altitudes at sites such as Dome A, Ridge A, Dome C, and Dome Fuji on the Antarctic plateau, will lead to even darker skies.

We are building an instrument to measure the sky emission at 2.4 microns from Dome A. The instrument is based on an earlier design (NISM—Near Infrared Sky Monitor), but with significant improvements in its noise performance in order to reach the low flux levels expected. The instrument uses an InSb diode detector, cooled to 77K with a Stirling cycle micro-cooler. Rather than employing the usual transimpedance amplifier, we are measuring the signal from the diode with a charge-integrating amplifier and an on-chip 20-bit ADC. The charge integration is synchronized with the Stirling cooler motor to minimize noise coupled electrically or mechanically.

As with previous instruments, the new instrument will measure the sky emission by chopping between regions on the sky at different elevations, and hence different "airmasses". The overall instrument design has reduced size, weight, and power consumption relative to previous instruments, and with few moving parts we expect high-reliability operation.

Knowledge of the sky brightness at 2.4 microns is important for planning the science cases for future large telescopes in Antarctica.

## THz imaging from Ridge A - the carbon inventory in the G328 molecular cloud

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We present spectral line images of [C I] 809 GHz, CO J=1-0 115 GHz and HI 1.4 GHz line emission, and calculate the corresponding C, CO and H column densities, for a sinuous, quiescent Giant Molecular Cloud about 5 kpc distant along the  $l=328^\circ$  sightline (hereafter G328) in our Galaxy. The [C I] data comes from the High Elevation Antarctic Terahertz (HEAT) telescope, a new facility at Ridge A on the summit of the Antarctic plateau where the precipitable water vapour falls to the lowest values found on the surface of the Earth. The CO and HI datasets come from the Mopra and Parkes/ATCA telescopes in Australia. Together, they provide wide-field panoramic imaging at good spatial and spectral resolution (2 arcminutes and 1 km/s) of the atomic and molecular gas of the interstellar medium.

We identify a filamentary molecular cloud,  $\sim 75 \times 5$  parsecs long with mass  $\sim 4 \times 10^4 M_\odot$  and a narrow velocity emission range of just 4 km/s. The morphology and kinematics of this filament are similar in CO, [C I] and HI, though in the latter appears as self-absorption. We calculate line fluxes and column densities for the three emitting species, which are broadly consistent with a PDR model for a GMC exposed to the average interstellar radiation field. The [C/CO] abundance ratio averaged through the filament is found to be approximately unity. The G328 filament is constrained to be cold ( $T_{\text{Dust}} < 20\text{K}$ ) by the lack of far-IR emission, to show no clear signs of star formation, and to only be mildly turbulent from the narrow line width. We suggest that it may represent a GMC shortly after formation, or perhaps still be in the process of formation.

## 2.4 $\mu\text{m}$ Kdark Observations from Antarctica

**Burton M**

University of New South Wales

Observing sensitivities for a telescope observing in the “ $K_{\text{dark}}$ ” window at 2.4 $\mu\text{m}$  from Antarctica – where the sky values can be upto two orders of magnitude lower than at temperate sites – are presented. Lessons learnt from the SPIREX project are discussed.

## ESCAPE: extreme solar coronagraphy for the Dome C Concordia station

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The coronal heating problem is still one of the most debated questions in solar physics. ESCAPE (the Extreme Solar Coronagraphy Antarctic Program Experiment) is designed to measure wave properties in corona and their possible contribution to the coronal heating and solar wind acceleration. It measures the polarization of coronal line emission, allowing to map the topology and dynamics of the magnetic field in corona. Furthermore, ESCAPE will be able of up to 3 months of continuous monitoring of the coronal activity, such as CMEs that are relevant for space weather studies. The Dome C high plateau is unique for coronagraphic observations: sky brightness is reduced, water vapour is low, seeing is excellent and continuity of observations on several weeks is possible. ESCAPE will perform 2-dimensional spectroscopy of the forbidden line of FeXIV at 530.285 nm, of FeXIII at 1074.7 nm and of the Sodium D3 line at 587 nm (precise line profile analysis will allow the diagnostic of the nature of waves by simultaneous measurements of velocities and intensities in the corona).

ESCAPE is approved by CNRS/INSU with a test this summer at Pic du Midi and a first campaign planned at Dome C/Concordia in 2015/2016. Most subsystems are available thanks to the ESA STARTIGER R&D program "Toward a New Generation of Formation Flying Coronagraph" performed in 2010 in support of the ASPIICS ESA/PROBA-3 formation flying coronagraph mission. A Three Mirrors Anastigmat telescope and a 4 stages Liquid Crystal Tunable-filter Polarimeter have been developed and allow us to propose an automated Coronal Green Line full-field Polarimeter for unique observations (waves nature and intensity to address coronal heating) and with the best possible performances on Earth. No other ground site would allow such coronagraphic performances (the sky brightness is a factor 2 to 4 better than in Hawaii) and with high spatial resolution (better than an arcsec).

ESCAPE will also help in validating the experimental approach of critical sub-systems of future space coronagraphy missions (e.g. the 587 nm filters of ASPIICS), bring ground simultaneous/complementary observations, and will open the way to future and more ambitious projects in Antarctica (e.g. AFSIIC) and in Space (e.g. HiRISE, NEOCE). ESCAPE is part of the SCAR/AAA research working group international effort.

## Thermalizing a telescope in Antarctica: The ASTEP experience

**Fossat E**, Guillot T, Agabi K, Abe L, Aristidi E, Rivet J, Mékarnia D, Daban J, Gouvret C, Faradji H, Crouzet N, Team A

Observatoire Cote d'Azur

The installation and operation of a telescope in Antarctica represent particular challenges, in particular the requirement to operate at extremely cold temperatures, to cope with rapid temperature fluctuations and to prevent frosting. Heating of electronic subsystems is a necessity, but solutions must be found to avoid the turbulence induced by temperature fluctuations on the optical paths.

ASTEP 400 is a 40 cm Newton telescope installed at the Concordia station, Dome C since 2010 for photometric observations of fields of stars and their exoplanets. While the telescope is designed to spread star light on several pixels to maximize photometric stability, we show that it is nonetheless sensitive to the extreme variations of the seeing at the ground level (between about 0.1 and 5 arcsec) and to temperature fluctuations between -80 and -30°C.

Day-time observations confirm a primary mirror seeing that depends on the difference between the temperature of the mirror and that of the surrounding air, with amplitude  $\sim 0.17$  arcsec/K. The entrance window to the heated camera box also contributes to some additional seeing as a function of the temperature difference between the exterior of the window and the outside air at a maximal rate  $\sim 0.11$  arcsec/K, but with a strong dependence on the declination of the telescope. The temperature fluctuations also cause variations of the focal plane of about  $\sim 17$  microns/K. These complications can be mitigated through a limited heating of the mirrors to prevent frost, a laminar flow of dry air over the mirrors and windows and an instrument model coupled to an automatic focusing.

The ASTEP experience shows that with these additions telescopes in a location such as Concordia can get all the benefits from the excellent weather, both in terms of duty cycle and stability.

## On the Dome C site photometric quality via A-STEP measurements

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Observatoire Cote d'Azur

A selection of non variable stars in the A-STEP time series of images has been exploited to estimate the photometric quality of the Dome C sky. A special care was taken to distinguish at the contribution of the transparency variations from that of the scintillation itself. They have different signatures in the Fourier spectrum. A comparison is then made with the mean quality of good mid latitude mountain photometric sites (Fossat, 1984). Despite some instrumental limitations in the A-STEP data set, it can be shown that, as expected, the Dome C quality is significantly superior to these mid latitude sites on the two parameters, transparency and scintillation.

## Chinese Antarctic telescope at Kunlun Station

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Chinese Antarctic Observatory has been listed as National large research infrastructure during twelfth five-year plan. Kunlun Dark Universe Survey Telescope, one of two major facility of Chinese Antarctic Observatory, is a 2.5 meter optic/infrared telescope and will be built at the Chinese Antarctic Kunlun Station. It is intended to take advantage of the exceptional seeing conditions, as well as the low temperature reducing background for infrared observations. As a pathfinder, AST3 project have been developed for three years. It is composed of three 680/500 mm Schmidt type telescope, the first one have been assembled at Dome A at 2012 and the second one is been testing at North part of China. This talk will introduce current situation of all of these telescopes.

## **ASTEP 400: Results of 3 years operation**

**Mékarnia D**, Goncalves I, Guillot T, Abe L, Agabi K, Schmider F, Daban J, Crouzet N, Gouvret C

Observatoire de la Côte d'Azur

ASTEP 400 is the main instrument of the ASTEP program. It was designed to withstand the harsh conditions in Antarctica achieving a photometric accuracy of a fraction of milli-magnitude. The observing strategy was tailored to both detect new transiting exoplanets and characterize known exoplanets by detecting (or attempting to) their secondary eclipses.

We review the performances of the ASTEP-400 instrument, and describe its operating conditions as well as the steps followed to perform high-precision time-series photometry. We present results obtained during the first three years (2010-2012) of operation of the instrument. More than 30 fields were observed and a hundred of thousands stars analyzed leading to a catalog of twenty planetary candidates and hundreds of variable stars.

We also observed, during about one month each the well known transiting exoplanets WASP-18b and WASP-19b. The observations of WASP-18b were tantalizing but did not yield a sufficient signal to noise for the secondary eclipse. For WASP-19b, we found evidence of a secondary eclipse of depth  $390 \pm 190$  ppm at phase 0.5 consistent with a circular orbit. This ASTEP 400 detection of a secondary eclipse is the first achieved in the visible from the ground and demonstrates that extremely stable and precise visible photometry and near-continuous observations are achievable from the Concordia station.

## Four years of photometry from Dome C with ASTEP South

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ASTEP South is the first phase of the ASTEP project that aims to determine the quality of Dome C for photometry in the visible and to discover extrasolar planets. ASTEP South consists of a front-illuminated 4k x 4k CCD camera, a 10 cm refractor, and a simple mount in a thermalized enclosure observing a 4x4 square degree field of view centered on the celestial South pole. ASTEP South has been observing nearly continuously for 5 winters, collecting about 30 TB of data. We built the lightcurves for 6000 stars for the first 4 years using an aperture photometry algorithm adapted to the particular shape and motion of the PSFs on the CCD. The thermalization was stable most of the time, but particular care was necessary to maintain the camera shutter warm enough and to correct for related calibration issues. The photometry is also affected by ground level seeing variations. These 4-winter lightcurves as well as the number of detected stars, FWHM, temperatures, and position of the South pole on the CCD provide a unique database to infer the quality of Dome C for photometry in the visible. With an excellent weather between 60 and 70% of the time, Dome C is competitive with the best astronomical sites. These 4-winter lightcurves are also analyzed to search for transiting planets and variable stars.

### Photometric observations of exoplanets at Concordia: From ASTEP to AST3

**Mékarnia D**<sup>1</sup>, Guillot T<sup>1</sup>, Abe L<sup>1</sup>, Wang L<sup>2</sup>, Tao C<sup>3</sup>, Rivet J<sup>1</sup>, Agabi K<sup>1</sup>, Schmider F<sup>1</sup>, Aristidi E<sup>1</sup>, Fossat E<sup>1</sup>, Daban J<sup>1</sup>, Gouvret C<sup>1</sup>, Crouzet N<sup>1</sup>

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The Concordia station in Antarctica is an excellent astronomical site both for its weather conditions and photometric stability. As shown by the first ground-based measurement at visible wavelengths of the secondary eclipse of an exoplanet (WASP-19b) by ASTEP and the hint of a phase curve (a measurement only possible from space so far), the continuous night confers a strong advantage to the site compared to mid-latitude surveys. Progresses in our ability to characterize these planets by photometry will require: (1) to increase the number of photons collected; (2) to limit systematic photometric noise; (3) to obtain measurements at several wavelengths.

We will show how both the extension of the ASTEP survey and the inclusion of up to two other larger telescopes through the installation of AST3 would meet these requirements. The number of collected photons per unit time would more than quadruple. Systematic noise could be reduced thanks to a continuous (rather than discrete) monitoring of the focal position, limitation of turbulence through the use of fans, and possible installation of the telescopes at a higher elevation. Finally, the possibility to obtain measurements in several wavelength bands would allow further possibilities. In particular, the possible extension to near-infrared observations would increase the sensitivity to the thermal emission of hot Jupiters and enable the observation of fainter M-dwarfs and their exoplanets.

## The Kunlun Infrared Sky Survey

### Mould J

Swinburne University

KISS is the first systematic exploration of the time varying Universe in the infrared. Location at Kunlun Station offers the supreme advantage of the whole sky available for study for the duration of the Antarctic winter every year. Our primary scientific targets are the physics of active galactic nuclei, supersupernovae (Gamma Ray Bursters), the terminal phases of red giants (Miras) and initial phases of protostars. KISS is complementary to ANU's SkyMapper in that it is infrared and complementary to NASA's 2MASS in that it is time sensitive.

Australian astronomers have demonstrated that the Antarctic plateau is the best site on Earth for infrared and submillimeter astronomical observations. By establishing Kunlun Station (Dome A), our Chinese colleagues have presented us all with the opportunity to exploit this scientifically .

For the past 5 years Australian and Chinese astronomers have been collaborating in astronomical imaging from Dome A (Kunlun Station), the highest point on the Antarctic plateau. The AST3 50 cm Schmidt telescopes were built at Purple Mountain Observatory (PMO) and the PLATO support unit was built and operated by UNSW. Over 20 publications have resulted from this work.

In August 2012 Astronomy Australia Limited (AAL) signed an MoU on Antarctic astronomy with the Division for Basic Research of the Chinese Academy of Sciences. Last year AAL and our Chinese colleagues agreed upon an implementation plan to progress the scientific opportunities offered by Chinese telescopes at Dome A and complementary observations using Australian telescopes.

A working group has been established and met at the Australian Astronomical Observatory in March 2013 and again in China in September 2013. Science leaders were also appointed and draft science plans were written. We aim to advance this collaboration to facility class scientific productivity by furnishing the third AST3 telescope with an infrared camera built at Swinburne University from a camera design by the Australian Astronomical Observatory. Installation of the camera will be by the Polar Research Institute of China and operation will be by UNSW and PMO. Scientific opportunities in the areas of each of the Working Groups are elaborated in this conference paper.

## IceCube: Overview and recent results

Seunarine S

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IceCube is a gigaton neutrino detector located at the South Pole. It consists of over 5000 photomultiplier tubes instrumenting a cubic kilometer of glacial ice. Construction of the detector was completed in 2010 but the partial detector provided data from 2006. IceTop, a cosmic ray air shower detector located on the surface above IceCube, complements the neutrino and cosmic ray physics probed by the in-ice detector. IceCube has reported results on neutrino physics that span an energy range sensitive to neutrino oscillations and dark matter to the recently reported evidence of very high-energy extraterrestrial neutrinos. We present an overview of IceCube and highlight recent results that have ushered in the era of neutrino astronomy.

## Test operation of the second Antarctic survey telescope

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The second Antarctic Survey Telescope (AST3-2) has been installed and tested thoroughly at Mohe, the northmost part of China, to take advantage of the low temperature in winter of 2013/2014. After the engineering tests are finished, the telescope entered real automatic survey mode to simulate operation at Dome A, Antarctica. The local temperature is -30C to -45C in average with moderate snowfalls. We report the performance of its Operation and Data system, real-time data pipeline, and scientific results from the test operation.

## The high Antarctic plateau astronomical data portal

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Since 2008, the various remote and robotic “Plateau Observatories” (PLATOs) have been recording site-testing and scientific observations from the high Antarctic plateau. These include PLATO and PLATO-A at Dome A; PLATO-F at Dome F; and more recently, PLATO-R at Ridge A. We present an online portal in which we make the data publicly available.

In some instances, this includes both raw and reduced versions of the data, as well as documented scripts to make processing and analysis simple for anyone not immediately familiar with the instruments. Reduction scripts are presented in the format of IPython Notebooks – providing formatted blocks of code along side documented commentary and figures.

Currently, the following observations are scheduled to be included:

### Dome A

- Nigel (optical/near-IR spectrometer)
- HRCAM (all-sky optical images)

### Dome-F

- HRCAM-2 (all-sky optical images)
- Egg of Vision (webcam)

### Ridge A

- HRCAM-3 (all-sky optical images)
- Uncle Bob (near-360 degree webcam panoramas)

## The HRCAM trio - auroral emissions and sky brightness from the high Antarctic plateau

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As plans for larger scale astronomical facilities on the Antarctic plateau continue to evolve, so too does the importance of accurate site characterisation and monitoring. The HRCAM (High Resolution CAMera) trio is an array of three Canon DSLR cameras situated at Dome A, Dome F, and Ridge A. Each camera is equipped with a 180 degree all-sky fisheye lens, and designed to continuously monitor auroral activity and sky brightness at each of the three sites.

Images are acquired roughly every 15 minutes and are stored on-site in the native Canon raw (CR2) format. For quantitative analysis, these photographs are converted into standard FITS files, preserving the 14-bit ADU values. Each FITS image is subsequently split into the three colour channels (RGB), where aperture photometry is automatically performed on over 1,000 stars per image to obtain an accurate photometric calibration.

We present a report of the three cameras' progress to date, and a preliminary look at image analysis techniques with sample quantitative results.

## **Prospects for a Planet Formation Imager on the high Antarctic plateau**

**Tuthill P**

The University of Sydney

The unique environment on the high Antarctic plateau, as well as the polar atmosphere above it, offer spectacular gains for many areas of Astrophysics. Optical Interferometry is among the most technologically demanding branches of modern instrumentation, and furthermore, is the one most strongly limited by the stability of the atmosphere at the observatory site. After a couple of decades in which no major new instrument project has been launched, the high resolution imaging community is becoming excited by a bold new initiative: the Planet Formation Imager (PFI). This audacious instrument is intended to directly reveal the physics operating on the remote stages of planetary birth. The potential gains in performance for PFI on the high antarctic plateau over a mid-latitude site will be explored.

## Time domain survey from Antarctica - from optical to near infrared

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Certain astronomical observations require continuous observations over extended period of several days to a few months. The Antarctic sites provide an excellent alternative to space for carrying out such observations. The Antarctica Survey Telescopes (AST3) consists of three 50cm telescopes and is in the process of being installed at Dome A, Antarctica. AST3 will perform science projects such as exoplanet transit survey and supernova survey. Its science goals overlap with ASTEP – an ongoing project at Dome C. A similar telescope working in the near infrared, especially in the K-band will allow detections of emission signatures of hot Jupiter and faint supernovae from nearby, bright star forming galaxies. The telescopes will be highly complimentary to other survey facilities in the Southern Hemisphere, such as SkyMapper and the SKA prototype ASKAP. A collaborative approach is required for such project to move to the next level.

## An analysis of weather data from KL-AWS at Dome A, during 2011

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We present an analysis of temperatures, wind speeds and direction data at different elevations above Dome A's surface taken by Kunlun Automated Weather Station, during 2011. We find the existence of strong temperature inversion above ground, e.g. the average temperatures at 2m and 14.5m are  $-54.2^{\circ}\text{C}$  and  $-46.3^{\circ}\text{C}$ , respectively. We also find that such a positive temperature gradient can last 25 hours or longer for 50% of the time. Meanwhile, the average wind speed is 1.51m/s at 4m and no preferable wind direction was found. We also find the temperature gradient is seldom larger than  $0.7^{\circ}\text{C/m}$  when the wind speed is higher than 2.5m/s.

Both strong temperature inversion and low wind speed can help result in shallow stable boundary layer and weak atmospheric turbulence, indicating Dome A could be an excellent site for astronomical observations. By comparing with measurements from SNODAR's data, we find a trend that when the temperature gradient becomes larger, the boundary layer becomes thinner.

## **S13: OCEAN ACIDIFICATION**

### **Estimating carbonate concentrations in the waters around Antarctica**

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A major gap in our ability to understand the present state of ocean acidification in New Zealand's EEZ and the Southern Ocean has been the limited number of observations of carbonate species in these regions. We use multiple linear regressions (MLR) to estimate alkalinity and DIC from the common hydrographic parameters; temperature, salinity, depth/pressure and oxygen. We find distinct regimes based on water masses, where the alkalinity and DIC have different relationships with the hydrographic parameters. The aim of this work is to use all the hydrographic data for the region to produce detailed maps of the carbonate parameters: pCO<sub>2</sub>, pH, [CO<sub>3</sub><sup>2-</sup>], aragonite saturation, calcite saturation, that take into account local currents, especially around complex topography.

This approach was initially applied to the Southern Ocean (south of 25°S) using observations from the GLODAP (1990s), CARINA and PACIFICA (2000s) global datasets. Then, we applied this approach to look more specifically at the region south of the Polar Front (approximated at 60°S), where the strong role of upwelling, productivity and sea ice is likely to lead to different relationships between hydrographic parameters and carbonate species.

**Response of Antarctic sea ice communities to future predicted ocean acidification and warming: results of in situ experimental manipulations**

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Sea-ice flora and fauna, and particularly sea ice algae, form a vital component of the Antarctic marine food web. Ocean acidification and warming are imminent threats in Antarctica and pose a complex set of challenges for these under-ice communities and the seafloor animals that rely on them for food. We investigate how the functioning and dynamics of intact coastal sea ice ecosystems might respond in a modified environment, through experiments conducted *in situ* at Cape Evans, Ross Sea, Antarctica in the early austral summer of 2013. We installed purpose built under-ice isolation chambers (each 140 litre volume) on the underside of first year sea ice, and used an above-ice manipulation system to alter the pCO<sub>2</sub> and temperature conditions of natural seawater. Using a fully replicated experimental design, and pCO<sub>2</sub> and temperature conditions predicted for the following decades, we assessed the separate and interactive effects of warming and acidification on sea ice communities. Effects on algal community composition and characteristics and sea-ice associated fauna, as well as primary productivity and nutrient utilisation will be presented, and our results discussed in light of potential implications to future coastal ecosystems.

## The effects of UV radiation and ocean acidification on oxidative damage in *Sterechinus neumayeri* embryos

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The response of marine organisms to multiple stressors caused by anthropogenic climate change is relatively understudied, and synergistic effects are largely unknown. Two biologically important stressors for animals in the Antarctic marine environment are; the effects of increased UVB (290-320nm) radiation caused by ozone depletion, and changes in the carbonate chemistry of seawater resulting in reduced seawater pH (ocean acidification).

The levels of oxidative damage through reactive oxygen species and the resulting upregulation of antioxidant enzymes is a good measure of how an organism's stress response is mitigating an environmental stressor, although this has not been directly quantified in response to ocean acidification. The effect of ocean acidification on oxidative damage within marine organisms has been noted largely through broad proteomic and genomic studies. The effects of UVB radiation on oxidative damage in larvae of the Antarctic sea urchin *Sterechinus neumayeri*, is better understood, with UV-exposure known to cause oxidative damage within sea urchin larvae.

The object of our study was to explore whether future ocean acidification causes oxidative stress during the early developmental stages of the Antarctic sea urchin, *Sterechinus neumayeri*. Does ocean acidification decrease the ability of larvae to deal with the additional stressor of UVR and are these responses of the polar organism consistent with the responses of temperate animals. We quantify the levels of oxidative damage and antioxidant enzyme production within larvae of *S. neumayeri* in response to near future levels of ocean acidification, and to investigate if larvae raised in future ocean acidification scenarios are able to cope with the synergistic effects of reduced sea water pH and UVR exposure.

Our results suggest that with *S. neumayeri* that oxidative damage and antioxidant enzyme activity increased in 7 day old blastula and this was matched by an increase in the number of abnormal larvae in pH 7.8 and 7.6 seawater, when compared to the control pH 8.1. This is also matched by a decrease in the cross sectional area of blastula. When larvae were exposed to UVR they show a 2-fold increase in the amount of lipidhydroperoxides produced and the number of protein carbonyls (both forms of oxidative damage). In response to this we saw an increase in the levels of antioxidant enzyme expression but this did not increase greatly in the blastula exposed to sea water pH 7.6 compared to pH 7.8. This suggests that synergistic effects with UV-R occur at low pHs where blastula appear to not be able to upregulate antioxidant enzyme activity in response to increased oxidative damage obtained through multiple stressors. These results suggest that *S. Neumayeri* larvae may be at risk with increasing ocean acidification and increasing UVB through stratospheric ozone loss or future sea ice loss.

## Impact estimation of Southern Ocean acidification on phytoplankton (diatoms and haptophytes)

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Ocean acidification experiment was carried out totally 4 times in the Austral summer of 2011-2012. This study was made as a part of the 53th Japanese Antarctic Research Expedition (JARE-53). Phytoplankton were collected by a clean pump method at 45°S (Stn C02) and 60°S (Stn C07) along the 110°E and 50°S (Stn D13) and 64°S (Stn D07) on 140°E. At each station, experiment was done for 1) without no enrichment, 2) with only Fe enrichment and 3) Fe enrichment with high CO<sub>2</sub> around 750 μatm of pCO<sub>2</sub> water to compare the non-acidified natural condition. Each experiment was done for three days.

About diatoms, the initial densities of *Fragilariopsis kerguelensis* and *Thalassiosira oestrupii* and *Chaetoceros* sp. were predominant in the study area. After the three days experiments, in comparing to the control, cell densities of major diatoms in the Fe enriched condition were increased 360% for *F. kerguelensis* and 280% for *T. oestrupii* at Stn C07 and 220% for *F. kerguelensis* and 172% for *Chaetoceros* sp. at Stn D07 as well as 290% for *F. kerguelensis* and 296% for *T. oestrupii* at Stn D13. On the other hand, cell density of diatoms in the Fe enriched with high CO<sub>2</sub> water in comparing to the Fe enriched bottle, *F. kerguelensis* and *T. oestrupii* decreased to 47% and 67%, respectively at Stn C07. In case of Stn D07, only *F. kerguelensis* increased to 126% whereas *Chaetoceros* sp. reduced to 81%. *F. kerguelensis* and *T. oestrupii* were declined to 63% and 43% at Stn D13.

In the haptophytes, *Phaeocystis antarctica*, *Emiliania huxleyi* Type B/C, and *Calcidicus leptopus* were abundant in the study area. Density rises were conspicuous at the Fe enriched incubation whereas marked declines were obtained in the Fe-enriched with high CO<sub>2</sub> bottle on *P. antarctica* and *E. huxleyi* dropping to -21.5% and -99.2% to the initial concentration, respectively with an exception of 4,109.9% increase in *C. leptopus* of the initial. On the other hand, concentrations of *P. antarctica* and *E. huxleyi* at the Fe enriched with high CO<sub>2</sub> bottle were not increase as much as 15.1% and 34.6% to the initial, respectively. This reveals that haptophytes particularly *E. huxleyi* are highly affected by the ocean acidification for their growth other than *C. leptopus*, which showed positive effect on its density representing 1.4 times higher density in the high CO<sub>2</sub> bottle at Stn. C02. Effects of the acidification on haptophytes may surely represent on the thinner cells than on the thicker cells. Concentrations of *P. antarctica* and *E. huxleyi* were almost same in the initial and the Fe enriched with high CO<sub>2</sub> bottles, as mentioned before. This also means that acidified water may disturb their production.

These results reveal that diatoms and haptophytes were affected by the ocean acidification under the Fe enrich conditions. However, negative biological effect of acidification was less obvious in the diatoms comparing to the small haptophytes such as coccolithopholds.

**Ocean acidification and sub-lethal metabolic stress responses in the Antarctic clam  
*Laternula elliptica***

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This poster presents results from recent experiments undertaken on the effects of ocean acidification and climate change in the Ross Sea on a prevalent geoduck species. *Laternula elliptica* is found throughout Antarctica at high regional densities and is a major source of water filtration and benthic-pelagic coupling for the Antarctic benthic ecosystem. It has a particularly narrow thermal envelope, being unable to perform critical functions at temperatures only a few degrees above ambient. This temperature limitation, added to its susceptibility as a calcifier under future ocean conditions, means that *L. elliptica* is at risk of metabolic and physiological stress. Even without suffering direct mortality, the species can experience sub-lethal stresses as a result of environmental conditions which depress physiological function. This repression may stimulate an increase in RNA, heat shock proteins (HSP), antioxidants, and oxygen consumption, as the organism works to compensate. These markers of physiological and metabolic depression were studied in adults under increased temperatures, reduced pH, and a combined 'greenhouse' treatment of low pH and high temperature, to determine: the overall sub-lethal stress response of *L. elliptica*; the level at which its metabolism is affected by future temperature and pH predictions; and whether it can acclimate over time. This research has implications for *L. elliptica* survival as its level of metabolic stress under future conditions predicted for the Ross Sea in 2100 indicates how other functions such as reproduction and gametogenesis may be limited by the reallocation of energy to maintaining respiration and other basal metabolic processes. Thus populations may be extant, but functionally limited due to metabolic repression and limited aerobic scope.

## Ice Acidification: Response of sea ice algae to changes in CO<sub>2</sub> concentration

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During sea ice formation internal gas concentrations in brine channels are heavily modified by changes to gas solubility at high salinity and low temperature, often resulting in supersaturation, degassing and a steep decline in pH. Brine channel and surface sea ice communities have only limited access to the outside and consequently their CO<sub>2</sub> (and nutrient) supply becomes severely restricted. Thus, unlike planktonic ecosystems where CO<sub>2</sub> is rarely in short supply, in sea ice brine systems the shortage is often acute and the addition CO<sub>2</sub> as a result of ocean acidification is likely to partially alleviate this stress. During sea ice formation there is an initial abiotic drop in pH associated with increasing ionic strength. However, in spring and summer this trend is usually overridden by the photosynthetic activity of often dense microalgal communities that cause the pH to rise as a result of the depletion of the dissolved CO<sub>2</sub>. Values of up to 8.9, for instance, have been reported from platelet ice and up to 9.9 in brine channels.

In 2011, 2012 and 2014 the effect of elevated CO<sub>2</sub> and reduced pH on brine algae was examined in McMurdo Sound. In each year the brine algae responded strongly to increased CO<sub>2</sub> by an increase in growth rate and an alleviation of stress (higher Fv/Fm). In 2012 and 2014 the effects caused by pH were differentiated from those caused by CO<sub>2</sub> by manipulating the DIC while keeping pH constant. Growth, maximum quantum yield and photosynthetic capacity were greater than the control in all treatments.

The response of brine algae in pack ice was also examined on the SIPEX2 voyage. This pack ice community, which was dominated by diatoms, showed a smaller response and high levels of CO<sub>2</sub> mostly caused a small decline in growth and photosynthetic parameters.

Sea ice algae showed an ability to cope over a wide range of pH/CO<sub>2</sub> conditions and it is unlikely they will be severely impacted by predicted changes in carbonate chemistry over the next century.

## Seasonal change in the flux of carbonate shelled zooplankton collected using mooring sediment traps in the Antarctic Ocean

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It is important to know the transport and loss processes of biogenic carbonate particles in the water column of the Southern Ocean, and very limited information on the spatio-temporal changes of carbonate shell bearing planktonic foraminifera and pteropods has been obtained, in particular during the winter season, because of the difficulties of samplings in ice floating or ice-covered seas. A sediment trap deployment was made to know the seasonal and vertical changes of downward flux of foraminifera and pteropods at 110°E, 60°S in the Antarctic Ocean (bottom depth of 4400 m) from 2 January to 14 December 2011. Sediment traps (Nichiyu SMD 13W-6000) were deployed at 780 m, 1750 m and 2820 m during the Shirase and the Umitaka-maru cruises. Collection cups were filled with a solution of 5 % (v:v) buffered formalin seawater. After recovery of the trap, large swimmer zooplankton (copepods, etc.) were removed by hand from entire sample. The sample was quantitatively split into several fractions for microscopic analyses. Foraminifera (>25 µm in size) and pteropods (>100 µm in size) were manually removed from the subsamples and they were identified and counted under dissecting microscope.

Three genera with 5 species (*Neogloboquadrina pachyderma*, *N. incompta*, *Globigerinita uvula*, *Gta. glutinata* and *Globigerina quinqueloba*) occurred throughout the year of 2011. The abundances (in terms of flux) of all species decreased in winter. The numerically dominant species were *N. pachyderma* in January, and *G. quinqueloba* in February. BAF (ball-like aggregates of foraminifera) were found at 2820m in April to May and July to August. The pteropods were dominated by *Limacina helicina antarctica*, *L. retroversa australis* (*Lra*) and unidentified small-sized *Limacina* sp (SSL). The highest flux of *Limacina helicina antarctica* and SSL, most of which were empty shells, were found in February to March. The fluxes of *Limacina helicina antarctica*, *L. retroversa australis* and SSL decreased with increasing depth. The flux of calcite shell-bearing foraminifera hardly decreased with depth, primarily because they were not lost due to dissolution during sinking, and the calcite saturation depth in the study area is known to be >3000m, while the aragonite shelled pteropods (*Limacina* sp.) decreased with depth in summer to fall, probably due to dissolution losses during sinking.

## Observed and estimated biomass of shelled pteropods in the Indian sector of the Antarctic Ocean during summer

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Carbonate shelled (thecosomatous) pteropods in the Antarctic waters have been known to be one of the sensitive organisms to environmental changes such as ocean acidification. To know the biomass contribution of shelled pteropods in Antarctic marine ecosystem, we tried to compare observed biomass and estimated biomass of dominant pteropods in the shallow water column around 60°S, 110°E in the Indian sector of the Antarctic Ocean.

Shelled pteropods was collected using an opening-closing net (Gamaguchi Net) in four depth ranges (0-50, 50-100, 100-200, 200-500m) at 5 stations south of 50°S along 110°E and 115°E during 30 December 2010 to 5 January 2011. Shelled pteropods were dominated by three species of *Limacina retroversa*, *L. helicina* and *Clio pyramidata*. The peak abundance of *L. retroversa* (214 ind.m<sup>-3</sup>) and *L. helicina* (20 ind. m<sup>-3</sup>) were found in shallow waters (<100m) between 58 to 60°S, and between 63-64°S, respectively. Less abundant *C. pyramidata* occurred below 50m. The abundance of small-sized *Limacina* (veligers & juveniles; 100 to 200µm in shell diameter) reached the maximum (1070 ind. m<sup>-3</sup>) in the upper 50m at 110°E, 63°S, which is comparable to the maximum abundance reported before in the Southern Ocean. According to the size compositions of *L. helicina*, two marked peaks in the abundance were found, and the smaller group (<400µm) and the larger (>4000µm) probably corresponded to young juveniles, and adults, respectively.

We made a simple ecosystem box model for waters around 60°S, 110°E. The ecosystem in this model primarily consists of large and small phytoplankton, microzooplankton, large and small copepods, large and small pteropods (adults and juveniles *Limacina* sp.), and carnivorous predators. The present model study showed that the estimated biomass of small-sized pteropods increased to about 15 mg POC m<sup>-3</sup> being a little more than dominant herbivorous copepods in summer (middle of January). The pteropod biomass (adults & juvenils) can potentially increase to the level of copepod biomass as directly observed in middle to late summer mentioned above. The present sensitivity analyses showed that the biomass of small-sized *Limacina* can vary with parameters of the grazing rate and the initial biomass in early summer. The high grazing rate can lead to overestimations of the estimated biomass.

The present study suggests that shelled pteropods mostly consisted of juveniles can increase to high biomass comparable to those of copepods under most favorable conditions such as foods in the SIZ in summer.

## Antarctic algae in the Anthropocene

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To understand human impact on the environment, thorough descriptions of community response to climate changes in their unique environments are necessary. Increased atmospheric CO<sub>2</sub> concentrations contribute to global warming and translate to an increased draw down of CO<sub>2</sub> into the oceans, which are the largest carbon sink on the planet, causing ocean acidification. In an era coined the Anthropocene projected climate changes include a decrease in oceanic pH from 8.1 to 7.7 by 2100 and average increase in ocean temperature 0.1 °C every decade. These changes are easily observed along the western Antarctic Peninsula. In this study, the physiological response of Antarctic marine algae was measured in four treatments; present day (pH 8.0, temperature 1.5 °C), near term pH (pH 7.6, temperature 1.5 °C), a near term temperature increase (pH 8.0, temperature 3.5 °C), and both near term pH decrease and temperature increase (pH 7.7, temperature 3.5 °C). Algae used in the experiment were prominent members of the subtidal Antarctic marine flora including the coralline alga *Clathromorphum obtectulum*, fleshy crustose alga *Hildenbrandia* sp., and two canopy forming species, *Desmarestia anceps* and *D. menziesii*. Mixed responses were observed across the four species, highlighting the complicated response of one trophic level in the benthic marine community.

**Impacts of ocean acidification on an Antarctic marine macroalgal-mesograzer community: insights from a laboratory mesocosm experiment**

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Anthropogenic atmospheric  $p\text{CO}_2$  concentrations are increasing at unprecedented rates and altering ocean carbonate chemistry resulting in declining seawater pH (ocean acidification). Estimates of the global mean seawater pH indicate that pH has already decreased by 0.1 units, and is predicted to continue to decrease by another 0.4 pH units by 2100. Large seasonal fluctuations in aragonite saturation associated with changes in seawater  $p\text{CO}_2$  have already been detected in coastal regions of Eastern Antarctica fostering predictions that aragonite undersaturation in Antarctica may occur within the next 25 years. To assess how ocean acidification may influence natural macroalgal-invertebrate assemblages we conducted a small mesocosm experiment employing a common Antarctic macroalga, *Desmarestia menziesii*, seeded with natural densities of a *D. menziesii*-associated amphipod species assemblages (the most common mesograzers). We exposed the assemblages to three levels of pH representing present-day (pH 8.0), near future – 2100 (pH 7.6) and distant future (pH 7.2) conditions. Each of the three seawater pH treatments consisted of six replicate mesocosms. Following a four-week exposure period, all amphipods were collected from each mesocosm and preserved in 70% ethanol for later identification and measures of density and species diversity. Results and their interpretation will be presented. Supported by NSF award ANT-1041022 (CDA, JBM, RAA).

## Ocean acidification and fertilization in the Antarctic sea urchin *Sterechinus neumayeri*: the importance of polyspermy

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Ocean acidification (OA), the reduction of seawater pH as a result of increasing levels of atmospheric CO<sub>2</sub>, is an important climate change stressor in the Southern Ocean and Antarctic. We examined the impact of OA on fertilization success in the Antarctic sea urchin *Sterechinus neumayeri* using pH treatment conditions reflective of the current and near future 'pH seascape' for this species: current (Control: pH 8.052, 384.1 μatm pCO<sub>2</sub>), a High CO<sub>2</sub> treatment approximating the 0.2-0.3 unit decrease in pH predicted for 2100 (High CO<sub>2</sub>: pH 7.830, 666.0 μatm pCO<sub>2</sub>), and an intermediate Medium CO<sub>2</sub> (pH 7.967, 473.4 μatm pCO<sub>2</sub>). Using a fertilization kinetics approach and mixed effects models we observed significant variation in the OA response between individual male/female pairs (N=7), and a significant population-level increase (70-100%) in t<sub>b</sub> (time for a complete block to polyspermy) at Medium and High CO<sub>2</sub>; a mechanism that potentially explains the higher levels of abnormal development seen in OA conditions. However, two pairs showed higher fertilization success with CO<sub>2</sub> treatment, and a non-significant effect. Future studies should focus on the mechanisms and levels of inter-individual variability in OA response, so that we can consider the potential for selection and adaptation of organisms to a future ocean.

## Phenotypic variation among Antarctic sea stars *Odontaster validus* may reveal capacity for adaptation to ocean acidification and warming

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The Antarctic ocean has been named a 'bellwether' for climate change effects in the ocean due to the higher rates of warming and acidification seen there than elsewhere (McNeill and Matear 2008). One major focus of the marine biological research community in recent years has been to quantify the reactions of Antarctic larvae to climate change (see Hofmann *et al.* 2010 for review). This research aims to show whether Antarctic echinoderm species, which are thought of as well-adapted to a stable cold environment, can possess the phenotypic flexibility to cope with ocean warming and acidification.

*Odontaster validus*, the Antarctic cushion star, has been named a 'keystone' species in shallow Antarctic benthic habitats due to its' ubiquitous distribution and important role in top-down regulation of community composition on the Antarctic shelf (McClintock *et al.* 1988). *O. validus* may be particularly vulnerable to the effects of ocean acidification (Gonzalez *et al.* 2013) and warming during its' pelagic larval development phase, which has been described as a 'bottleneck of mortality' (Byrne 2012) for many species. As larvae can 'carry over' negative developmental effects into their adult stages (Hettinger *et al.* 2013) it is important to understand how ontogeny, inheritance and environment interact to influence development and survival to recruitment age.

Using quantitative genetics, we aim to examine the capacity in *Odontaster validus* larvae for adaptation to warmer temperatures and reduced seawater pH.

Intra-population and intra-brood variation in parental gamete phenotypes are both known to act as selection pressures in dynamic or unpredicted environments (Crean *et al.* 2013). The presence of a range of tolerant phenotypes will indicate that this species can adapt and survive in an environment modelled on the IPCC 'business as usual' scenario (IPCC 2007).

The North Carolina II breeding design has been successfully used to demonstrate phenotypic diversity (or lack thereof) in larval sea urchins (e.g. Foo *et al.* 2012) but never in the related echinoderm class Asteroidea. The results of this experiment will represent one of the first reportings of genetic adaptation to multi-stressor climate change effects for a sea star species, and will contribute to our growing knowledge of how Antarctic larvae respond to the multiple selection pressures of increased CO<sub>2</sub> and temperature.

## Extracellular pH changes as a consequence of Ocean Acidification... 'The inside story'

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Ocean acidification will have significant effects on marine invertebrates, like sea urchins, however little is known about the effects external acidification and elevated  $\text{CO}_{2(\text{aq})}$  has on Extracellular pH (pHe), despite this being a key factor that will mediate their response. pHe is important for the maintenance of intracellular pH where a number of enzymes are pH sensitive so it is important to understand acid/base regulation and how larvae regulate this under different environmental conditions.

Due to the naturally lower calcium carbonate concentration, ocean acidification may have particularly significant effects in the Southern Ocean. While tropical areas, expected to remain saturated with respect to calcium and aragonite are likely to experience a decline in optimal aragonite concentrations by the year 2100. Therefore, the tropical sand dollar (*Arachnoidies placenta*), temperate sea urchin (*Evechinus chloroticus*) and the Antarctica sea urchin (*Sterechinus neumayeri*) were chosen for the present study to identify any latitudinal differences in pHe response to elevated  $\text{CO}_{2(\text{aq})}$ .

We used the fluorescent probe HPTS to investigate how elevated seawater  $\text{CO}_{2(\text{aq})}$  levels effects pHe of echinoderm larvae. Different stages of development were used (early cellular stage and pluteus) to determine how pHe changes during development. Larval regions were also distinguished (gut, arms, oesophagus) to look at how pHe differed throughout the larvae. Our study has revealed that pHe in the tropical *A. placenta* is very tolerant to changes in seawater pH, both in the early developmental stage and in the pluteus; meanwhile temperate and polar species are more susceptible. *S. neumayeri*, predicted to be the most sensitive, was able to cope with minor changes in pH (<0.3units) with its pHe only differing from ambient when raised under pH 7.2.

Extracellular pH differences between species indicate inter-specific responses that could reflect different metabolic activity potentially affecting the ability for a species to regulate extra and intracellular pH at different latitudes.

We propose that extracellular pH in echinoderms is lowered during hypercapnia due to the compensation of intracellular pH and species living in warmer waters have a greater capacity to regulate pHe under future ocean acidification scenarios, whereas cold water species, and some temperate species have a limited ability to compensate when exposed to conditions projected for 2300.

## Long term exposure of crabs to reduced salinity and pH: a temperate case study

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Under a future climate the shallow water benthos of Antarctica will experience undersaturation of carbonates and reduced salinity as a result of increasing anthropogenic CO<sub>2</sub> and ice melt. Crustaceans residing in these regions may struggle to maintain physiological homeostasis and biomineralisation of the exoskeleton under these conditions. Therefore survival of these organisms under future climate change scenarios is debatable with much of the literature to date predicting gross negative responses.

Current research requirements are those of long term exposures to multi-stressors to determine the capacity and sustainability of physiological adjustments to climate change. However no long term studies currently exist assessing the impacts of these stressors on Antarctic crustacean species. Although we do not present the responses of Antarctic crustaceans we instead address these research requirements in a case study using temperate decapods with differing physiological capacities to change: the invasive common shore crab, *Carcinus maenas*; and the subtidal, edible crab, *Cancer pagurus*. The latter will provide insight into the ability of benthic Antarctic crustaceans to respond to a future climate.

Crabs of both species were reared under IPCC forecasted carbonate saturation states and reduced salinity for up to a year and their physiological responses assessed. Such an approach can highlight the importance of widening exposure times in laboratory simulated experiments. Preliminary responses of *C. maenas* demonstrate long term survival to the combined effects of reduced salinity and pH, and surprisingly, reduced survival under independent stressors (e.g. salinity or reduced pH). This poster will present the growth and metabolic responses of these crabs as well as their compensatory capacities and immune status, contributing towards our understanding of possible crustacean responses in Antarctica.

## **S14: DYNAMICAL & CHEMICAL ATMOSPHERE SEA ICE-OCEAN COUPLING**

### **Simulated response of atmospheric circulation to recent SST trends**

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Some recent (since 1979) observed climatic changes near Antarctica are not reproduced by coupled models from the CMIP5 experiment: these include the sea-ice increase, or the rapid winter warming of West Antarctica and the Peninsula.

These observed changes have been linked to atmospheric circulation changes – especially around the Amundsen Sea, themselves possibly forced by tropical SSTs.

As a first check on this hypothesis, we here look at the atmospheric circulation trends simulated by models with imposed SSTs (AMIP experiment from CMIP5); which should be able to reproduce changes caused by natural SST variability. We then try to identify the key regions by running experiments where only regional SST anomalies are prescribed.

## The role of Southern Ocean SST and sea ice in Southern Hemisphere reanalysis trends prior to 1979

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Reanalysis data products such as the 20th Century Reanalysis Project (20CR) represent our best understanding of the weather and climate that existed for the last century. The 20CR project produced a 6 hourly reconstruction of atmospheric circulation for the entire 20th Century by assimilating only station records of mean sea level pressure. This approach helps to reduce the discontinuity that occurs in reanalysis products associated with the introduction of satellite data around 1979. From the 1950s to the 1980s the 20CR, along with all other reanalysis products, exhibits a moderately strong trend of increasing surface pressures in the Southern Hemisphere mid-latitudes and decreasing surface pressures over the South Pole. This is reflected in a positive trend in the Southern Annular Model (SAM) when derived from the reanalysis data. As has been demonstrated by many authors, station records available for this time period do not indicate that any significant or coherent trends in surface pressure actually occurred. Also coupled climate models are unable to reproduce such strong SAM trends during this period. We show here that the trend in the 20CR originates from model forcings in conflict with the assimilated observations. Two of the prominent model forcings, sea surface temperature and sea ice, were largely unobserved in the Southern Ocean prior to the advent of satellites. To investigate the role of sea ice in the pressure trends we present a statistical reconstruction of Antarctic sea ice extent, which is based only on atmospheric pressure measurements. This reconstruction does not demonstrate the stark decrease in sea ice extent from the 1950s to the 1980s seen in the HadISST sea ice reconstruction used by 20CR, and elsewhere. We demonstrate, via simulations of global atmospheric climate models, that the trends in mean sea level pressure and the SAM are approximately halved when the statistical sea ice reconstruction is used in place of the HadISST dataset. Furthermore we quantify the contribution to the SAM trend from the increased latitudinal temperature gradient imposed in the Southern Ocean by the HadISST sea surface temperature reconstruction.

## Temporal variability of the thermohaline properties and climate parameters in the Central Basin, Mar de La Flota (Bransfield Strait)

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The Mar de La Flota (Bransfield Strait) is the Antarctic region more affected by the climate change. The Central Basin (CB) reaches maximum depth of ~2000 m and it is isolated from the Western and the Eastern by a sill depth between 1000 to 1100 m. From historical data of NODC and GOAL (Brazil), the temporal variability of the thermohaline properties was studied in the CB.

During the period 1980-2004 the basin showed warming and dilution below 1100 m depth. These trends appear to be associated with the air temperature increase in the region observed during the last 30 years. The most significant salinity decrease ( $-0.002 \text{ psu}\cdot\text{year}^{-1}$ ) was observed below 1450 m depth. The new contributions of High Salinity Shelf Water reflecting the dilution of shelf waters, occupy shallower depths within the basin, until the subsequent mixing modified the water properties toward the bottom. In addition to warming and dilution which waters in the CB suffered along water column during 24 years, an intensification of the vertical gradients of potential temperature and salinity that occurred throughout the period supports this hypothesis.

To analyze the interannual variability observed between 1980 and 2004 were calculated the correlations between potential temperature and salinity anomalies; air temperature; sea-ice extent along 58 °W and SAM index. The temporal evolution of the anomalies shows oscillations with periods of 4 to 6 years. Significant positive correlations mainly between the sea ice and the air and water temperatures were found. The SAM index showed significant correlations with the salinity ( $r = -0.67$ ) in the bottom waters of the CB. These correlations suggest the influence of the Antarctic Circumpolar Wave and SAM index in the thermohaline properties of the deep water, although based on the available data, we cannot rule out other possible causes of variability.

## Hidrography during spring 2012 and summer 2013 in Potter Cove and Guardia Nacional Bay, South Shetland Archipelago

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The Potter Cove is located in the 25 de Mayo Island (King George Island), South Shetland Archipelago. It is surrounded on its eastern end by the Fourcade Glacier and its mouth opens to the Guardia Nacional Bay (Maxwell Bay). A shallow sill (< 35 m) separates the inner (50 m maximum depth) and outer (200 m depth) areas.

An Automatic Meteorological Station Campbell was installed between 21<sup>th</sup> December 2012 and 5<sup>th</sup> March 2013. The prevailing wind resulted from west (35.18%) and southwest (20.63%) and the air temperature recorded an increase of 1.52 °C. From early November 2012 to late February 2013, CTD (which included turbidity sensor) profiles up to 150 m depth were made both in the cove and the bay.

During November, the salinity in the Potter Cove was relatively homogeneous (between 34.06 psu and 34.16 psu) with the depth. At the early summer, stratified conditions in the water column were set. The surface sea temperature in the inner cove increased ~3 °C, and the salinity decreased 1.67 psu due to the greater contribution of the melting creeks and glacier melt. This also increased turbidity which reached 20 ntu in surface water. The surface waters in the inner cove were relatively warmer and fresher than in the outer area. From November to February at 150 m depth, the temperature increased from -1.07 to 0.5 °C and the salinity from 34.17 to 34.27 psu, in the outer cove. The depth of the isopycnal 27.4 kg/m<sup>3</sup> increased from surface in November to 75 m depth in February.

The cold temperatures and salinities higher than 34.2 psu, typical from the bottom water in the outer cove, were not observed in the inner cove. Upwelling (due to eastern winds) and downwelling (western winds) conditions have been observed in the eastern end of the cove. Three stations in the inner cove showed quick variations in the thermohaline parameters between high tide and low tide during a semidiurnal tide cycle. These variations were observed in the upper 20 m.

In Guardia Nacional Bay between December 16 and February 12, the temperature increased (1 to 1.5 °C) in the water column above 150 m depth. The salinity decreased in waters deeper than 50 m due to melting glacier and increased in deeper waters.

The observed variations in the Potter Cove waters were influenced by seasonal air warming, bathymetry and different conditions of wind and tide. The relation between the changes in water properties in the Potter Cove and Guardia Nacional Bay should be studied in future research.

## **Infrasound array observations in the Lützow-Holm Bay region, East Antarctica - Dynamic interaction between atmosphere and ocean in Southern Ocean -**

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Characteristic features of infrasound waves observed at Antarctica reveal the physical interaction involving surface environmental variations in the continent and surrounding Southern Oceans. A single infrasound sensor has been continuously recorded since 2008 at Syowa Station (SYO; 39E, 69S), the Lützow-Holm Bay (LHB), East Antarctica. The continuously recording data clearly represent a contamination of the background oceanic signals (microbaroms) during whole seasons. In austral summer in 2013, several field stations by infrasound sensors are established along the coast of the LHB. Two infrasound arrays with different diameter size are installed at both SYO (by 100 m spacing triangle) and S16 area on continental ice sheet (by 1000 m spacing triangle). Besides these arrays, two isolated single stations are deployed at two outcrops in LHB. These newly established arrays clearly detected the propagating directions and frequency contents of the microbaroms from Southern Ocean. Microbaroms measurements are a useful tool for characterizing ocean wave climate, complementing other oceanographic and geophysical data in the Antarctic. Moreover, several kind of remarkable infrasound signals are demonstrated, such as regional earthquakes, together with a detection of the airburst shock waves generated from meteorite injection at the Russian Republic on 15 February 2013. Detail and continuous measurements of the infrasound waves in Antarctica could be a new proxy for monitoring a regional environmental change as well as temporal climate variations in high southern latitude.

## Patterns of change above the Southern Ocean and Antarctica

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Trends in surface atmospheric variables, namely temperature, wind speed and direction, total column water vapour, cloud cover, and precipitation, display subtle patterns that are likely linked to climate change and the major modes of climate variability. In particular, over the Southern Ocean and Antarctica patterns of variation are strongly impacted by the Southern Annular Mode (SAM) and the relationships between changes in different variables can also be explained with respect to physical changes linked to the SAM. This study aims to examine variations in a range of variables and the relationships between these changes in WindSat satellite observations, reanalyses and model output. In particular, we aim to identify whether the patterns of relationships that might be expected a priori based on our underlying knowledge are reproduced by the climate model. We also aim to identify the relative impacts of greenhouse gas and stratospheric ozone depletion forcings, particularly those linked to polar processes, on these relationships.

We will examine the patterns over the Southern Ocean for a range of atmospheric variables in WindSat satellite and reanalyses data (ERA-interim and MERRA) and derive the underlying relationships between these trends and variability within these measures. We will then complete a similar analysis on the output from a 20th century run of an atmosphere-ocean-chemistry coupled climate model to examine the ability of this model to simulate the observed SAM responses and importantly their interdependencies. We will then compare the trends and their relationships in the Southern Hemisphere extra-tropics for runs which include and neglect ozone forcings. We hope that this will allow us to identify the relative importance of various forcings on the patterns observed and their relationships, providing a more holistic analysis than previously considered.

## Decadal trends in the Antarctic sea ice extent ultimately controlled by ice-ocean feedback

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The large natural variability of the Antarctic sea ice is a key characteristic of the system that might be responsible for the small positive trend in sea ice extent observed since 1979. In order to gain insight in the processes responsible for this variability, we have analyzed in a control simulation performed with a coupled climate model a positive ice-ocean feedback that amplifies sea ice variations. When sea ice concentration increases in a region, in particular close to the ice edge, the mixed layer depth tends to decrease. This can be caused by a net inflow of ice, and thus of freshwater, that stabilizes the water column. A second stabilizing mechanism at interannual time scales is associated with the downward salt transport due to the seasonal cycle of ice formation: brine is released in winter and mixed over a deep layer while the freshwater flux caused by ice melting is included in a shallow layer, resulting in a net vertical transport of salt. Because of this stronger stratification due to the presence of sea ice, more heat is stored at depth in the ocean and the vertical oceanic heat flux is reduced, which contributes to maintain a higher ice extent. This positive feedback is not associated with a particular spatial pattern. Consequently, the spatial distribution of the trend in ice concentration is largely imposed by the wind changes that can provide the initial perturbation. A positive freshwater flux could alternatively be the initial trigger but the amplitude of the final response of the sea ice extent is finally set up by the amplification related to ice-ocean feedback. Initial conditions have also an influence as the chance to have a large increase in ice extent is higher if starting from a state characterized by a low value.

## The role of sea ice DIC and TA boundary conditions on the cycling of carbon in a global blue-white-green ocean modeling system

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The direct role of sea ice in the carbon cycle of Polar Oceans is not represented in current Global Earth System Models. In many instances, how the model sea ice stores or transfers biogeochemical tracers is specified arbitrarily: the incorporation of tracers in sea ice is not considered and sea ice is assumed to prevent ocean-atmosphere gas exchanges. We focus on one of those aspects and investigate the role of sea ice and the role of CaCO<sub>3</sub> precipitation on carbon cycling in the Polar Oceans. To accomplish this goal, we implemented the incorporation of tracers (here dissolved inorganic carbon, DIC and total alkalinity, TA) in sea ice in a state-of-the-art ocean-ice coupled model (NEMO) that includes an ocean biogeochemistry/food web model (PISCES). We ran a control (CTRL) simulation of NEMO in a 2° configuration (ORCA2) for 500 years and two 500 years experiments using different hypotheses on the incorporation of DIC and TA in sea ice. In the first experiment (PHYS), we considered the incorporation of DIC and TA in sea ice in the same proportion as sea ice salinity (i.e. ~6/34 of the DIC and TA oceanic concentrations). In the second experiment (IKAITE), we considered the incorporation of DIC in sea ice to 6/34 of its oceanic concentration and the incorporation of TA equal to 12/34 of its oceanic concentration. This latter experiment represents an upper limit of the impact of CaCO<sub>3</sub> precipitation occurring in sea ice, leading to a sea ice TA/DIC ratio of ~2.

The PHYS experiment shows that the incorporation of tracers in sea ice significantly modifies CO<sub>2</sub> fluxes in both the Arctic (by  $-1 \cdot 10^{-3}$  Pg C yr<sup>-1</sup>) and the Southern (by  $-4 \cdot 10^{-3}$  Pg C yr<sup>-1</sup>) Oceans. This incorporation also has the potential to modify the export of DIC to the deep layers of the Global Ocean. Compared to the sole incorporation of tracers in sea ice (PHYS), the IKAITE experiment shows that the precipitation of CaCO<sub>3</sub> in sea ice also significantly modifies CO<sub>2</sub> fluxes in both Polar Oceans (by  $4 \cdot 10^{-3}$  Pg C yr<sup>-1</sup> in the Arctic Ocean and by  $-5.5 \cdot 10^{-3}$  Pg C yr<sup>-1</sup> in the Southern Ocean) and, potentially, the export of DIC to the deep Global Ocean. Finally, the response of the model to the incorporation of tracers in sea ice is dominated by the role of ice growth regions in the Arctic Ocean and by the role of ice melt regions in the Southern Ocean. This study represents both a potential improvement to the representation of the biogeochemical cycle of carbon by Global Earth System Models and a contribution to a better understanding of the role of CaCO<sub>3</sub> precipitation/dissolution in sea ice at a global scale.

## Atmosphere-ocean coupling and Sea Ice in the NIWA-UKCA chemistry-climate model

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Antarctica has experienced some of the largest rates of both surface warming and cooling found anywhere on the planet. Unlike the Arctic, where sea ice has been declining, sea ice extent in the Southern Ocean has been increasing in recent decades despite some regional decreases. Stratospheric ozone depletion has generally been implicated in aspects of climate change in the Southern Hemisphere. Often such inferences are based on climate model simulations that exclude ozone chemistry. Trends in Antarctic sea ice are generally not reproduced in contemporary climate model simulations; consequently, at present, the causes of sea ice trends in the Southern Ocean are poorly understood.

Here we present results using simulations by the NIWA-UKCA global atmosphere-ocean chemistry-climate model; these simulations will contribute to the Chemistry-Climate Modelling Initiative (CCMI). We use an ensemble of simulations following the “REF-C2” specification with all anthropogenic forcings operating, as well as sensitivity simulations in which ozone depletion, or alternatively increases in greenhouse gases (GHGs), have been suppressed. We characterize the ocean part of the model in general terms, regarding the sizes of gyres in the Southern Ocean. In the ensemble-average of the REF-C2 simulations and in the simulation with suppressed GHG increases, total sea ice extent declines markedly until around 1980 but increases or remains unchanged for a period thereafter. By contrast, the simulation with suppressed ozone depletion does not exhibit this turn-around. After ~2020, in the REF-C2 simulations the model projects decreasing sea ice extent. We compare with ice-core derived proxies for sea-ice extent. There are important differences in the geographic patterns of sea ice trends among the REF-C2 ensemble members. This suggests the presence of regional decadal-scale climate variations which may help explain the lack of agreement on patterns of sea ice change characterizing recent climate model simulations.

## The importance of resolving sea ice in modeling recent abyssal ocean warming

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The recently observed warming of Antarctic Bottom Water (AABW) represents an important component of accumulated sea level rise and hints at shifting ocean dynamics in response to surface climate changes (Purkey and Johnson, 2011). Yet, abyssal ocean warming is not a robust result in model simulations of greenhouse warming scenarios. Instead, the primary mechanism of Southern Ocean heat uptake in models is the warming, northward transport, and mid-latitude subduction of surface waters. The inability to accurately simulate abyssal warming may present an important

modeling bias, as deep ocean warming tempers the rate of surface warming and alters the expression of local feedbacks.

We present results showing that the simulation of abyssal ocean heat uptake is highly sensitive to model resolution, especially the resolution of sea ice formation. We specifically present the differences in abyssal Southern Ocean heat uptake in the Community Climate System Model 3.5 (CCSM 3.5) run at two resolutions in the ocean and sea ice components, after being forced with a 1% increase in CO<sub>2</sub> per year until doubling. Our fine resolution simulation was run at 0.1 degrees, at which sea ice formation is more faithfully captured, and eddies are resolved, while our coarse simulation was run at 1 degree, which is the standard resolution of most IPCC models and relies on eddy parameterization. The fine resolution simulation produces more AABW in the control climate, which sinks to a more realistic depth. We attribute this to the improved simulation of sea ice formation regions granted by increasing the model resolution, and find it to be key to the abyssal warming in response to greenhouse warming. Two processes contribute to abyssal warming in our fine resolution model: the advection of heat to the abyss by the residual circulation, and the redistribution of heat due to the reduction in AABW formation. Both of these processes are resolutiondependent and more active at fine resolution, such that below 4000 meters, the fine resolution simulation accumulates two orders of magnitude more heat than its coarse resolution counterpart, and at a rate comparable to observations.

We develop a framework to explore the impact this variable spatial pattern of deep ocean heat uptake has on the rate of transient climate change. In this way, we can assess the relative efficacy of heat uptake by different water masses, each with a different mean timescale of sequestration from the surface ocean. We can then assess the importance of correctly simulating patterns of deep ocean heat uptake and the surface processes that drive these patterns.

## Investigation of ACCESS climate models response to recent ozone perturbations over Antarctica and the Southern Ocean

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We have used the ACCESS 1.0 and ACCESS 1.3 models to do two sets of 3 historical ensemble simulations designed to investigate the impact of the perturbation in ozone since 1960. The first is the standard CMIP5 historical simulation including all greenhouse gases, aerosols, volcanic and solar forcing and ozone perturbations. In the second set in the set of these experiments the ozone distribution was held at the 1960 values, but the remaining fields followed the historical change, so by comparing these runs with the all forcing historical runs we can discern the effect of the ozone changes used in the CMIP5 simulations.

Preliminary model results show the two ACCESS versions show some differences in response to ozone change, both at the surface and in the upper levels, which need further investigation. Both ACCESS model versions, however, suggest that recent ozone change has had the effect of reducing surface pressure and temperature in summer over most of Antarctica relative to changes brought about by other external forcing terms. The presentation will also discuss the teleconnections of ENSO to the high latitude and whether this has been influenced by the ozone signal.

## Antarctic sea ice and southern hemisphere extratropical cyclone interactions

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It is known that the development of extratropical and polar cyclones is strongly affected by sea ice due to the enhanced baroclinicity at the interface between ice covered areas and open water. Likewise, the cyclones passage influences the sea ice drift, and thus its cover, through the divergence and convergence of high wind speed. In this context, this study is aimed at understanding the southern hemisphere cyclones response and its equilibrium mechanisms by imposing a maximum Antarctic sea ice state in climate simulations with a coupled climate model with current climate conditions.

Two sets of experiments are carried out, only differing in its sea ice model . The first uses a multi-layer (*fully*) sea ice model and another a slab sea ice model (*slab*) aiming to isolate the impact of the sea ice dynamics. Dynamic interaction is only represented in the *fully* experiments since the slab model does not have internal forces to deform the sea ice. Starting from the same atmospheric and oceanic initial conditions the GFDL-CM2 coupled climate model was integrated in a 30-member ensemble for 10 years for both sensitivity experiments (*max* and *ctl*). The numerical experiments were designed to understand the role of extratropical cyclones on the climate balance after an Antarctic sea ice perturbation through teleconnections.

The results show that the extreme Antarctic sea ice enhances the north-south meridional temperature gradient leading to an intensification of westerlies. Baroclinic activity is also intensified, over the sea ice edge during the spring and winter following the latitudinal sea ice expansion, with higher values in the Pacific Sector. The storms number and intensity were increased over higher latitudes. The exchange mechanism between sea ice and atmosphere for Southern Hemisphere is driven by baroclinic instability originated by air temperature contrasts over the sea ice-ocean interface.

The increase of cyclonic activity at mid-latitudes in spring and winter and more southerly in summer and autumn is driven by the increased meridional temperature gradients and consequent strengthening of the westerlies.

## Impact of the Southern Ocean to the atmospheric CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O

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Since 2010 the first Korean ice-breaking research vessel Araon has carried out a variety of research activities in the polar oceans. Including are long-lived trace gases, CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O, measured underway both at sea below and in the air above the sea surface to estimate the sink or source strengths of the oceans at high latitude. The ocean plays a wide range of role in the budget of these gases in the atmosphere: as a sink for CO<sub>2</sub> and a source for CH<sub>4</sub> and N<sub>2</sub>O. High latitude of the Southern Ocean is particularly important in view of the atmospheric budget of these gases as the change in the cryosphere can impact the ecological and physical settings that govern the content and flux of these dissolved gases in seawater. We have visited the Pacific sector of the Southern Ocean, the Amundsen Sea, and the Ross Sea during the austral summer in 2010 to 2014 onboard Araon. In addition, we had opportunity to survey the Pacific sector of the Southern Ocean in 2009 onboard R/V Polarstern. In the open ocean, CO<sub>2</sub> in the seawater was mostly undersaturated, CH<sub>4</sub> was slightly undersaturated, and N<sub>2</sub>O was supersaturated with respect to the overlying marine boundary layer. These features were not always observed in the sea-ice region; CO<sub>2</sub> in the seawater was slightly supersaturated in early austral summer in the Amundsen Sea. Another interesting feature is that CH<sub>4</sub> in the surface waters in the sea-ice zone and the polynya were undersaturated with respect to the overlying air. Based on these 4-year observations during austral summer season, high latitude of the southern ocean contributes as a sink for atmospheric CO<sub>2</sub> whilst as a source for N<sub>2</sub>O. In the case of CH<sub>4</sub>, the open ocean was slightly undersaturated overall, which differs from the role of the ocean in the global scale.

## **Preliminary results from the first in situ measurements of the ocean-atmosphere interaction and land-atmosphere CO<sub>2</sub> fluxes in Deception Island**

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National Institute for Space Research - INPE

The innovative use of a Brazilian meteo-oceanographic buoy anchored inside Port Foster Bay, Deception Island during November 2012 provided novel data about the ocean-atmosphere coupling for the first time in this area. At that time, radiosonde and XBT (Expandable Bathy-Thermograph) launchings inside and outside Deception Island were also performed by a crew onboard the Brazilian Polar Ship Almirante Maximiano. During March 2013, a micro-meteorological tower was installed at the vicinity of the Spanish Station Gabriel de Castilla. As an active volcano, Deception Island is known for its intense geothermal activity. This activity is expected to modulate much of the land-atmosphere and ocean-atmosphere heat fluxes. Using a weeks long data from the meteo-oceanographic buoy, the sensible and latent heat fluxes were estimated from parametrization schemes. Latent heat fluxes were often positive (from the ocean to the atmosphere) in the order of 50-100 W.m<sup>-2</sup> while sensible fluxes were almost null and sometimes negative. Both fluxes were mainly modulated by a combination of the diurnal (ocean's skin temperature and air temperature) cycle and by the large scale atmospheric systems crossing the area. A weeks long time series of meteorological and CO<sub>2</sub> fluxes data obtained in land in Deception Island corroborate the idea that the diurnal cycle is very important in the study region. The radiosonde profiling in the area clearly demonstrates that, in addition to the diurnal modulation, the stability of the marine atmospheric boundary layer (MABL) is forced by distinct sea surface temperature patterns of Port Foster's waters in comparison to the Bransfield Strait ones. The preliminary results shown here are a contribution to the description of the temporal variability of the ocean's and atmosphere's physical variables like the air and sea water temperature, winds, atmospheric pressure, precipitation, relative humidity, and radiative fluxes. The in situ measurements are compared to estimates from the Weather and Forecast Model contributing to enhance the performance of the model in the study area.

## Temporal and spatial dynamics of the climate-active gas dimethyl sulfide (DMS) and related compounds in Antarctic sea-ice ecosystems

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In polar regions, major climate-gas exchange events occur during the period of sea-ice melt and associated growth of phytoplankton. An important compound that is released is dimethylsulfide (DMS), a potentially climate-cooling gas. The non-volatile compound dimethylsulfoniopropionate (DMSP) is the precursor of DMS and is solely produced by algae. Another important sulfur compound is dimethyl sulfoxide (DMSO), the (photo-)oxidation, and non-volatile, product of DMS. DMSP, DMSO and DMS are all produced in sea ice at concentrations that are three orders of magnitude higher than in surface waters. This is a consequence of the extreme conditions in sea ice: low temperatures and high salinities. A general rule for open ocean systems is that only a few percent of the originally produced DMSP is emitted to the atmosphere as DMS, since the majority of DMSP is converted by bacteria or photo-oxidized to DMSO. What happens in sea ice is of interest given the extremely high concentrations and close connection with the atmosphere. Both the temporal variation of concentrations and conversion processes as the spatial heterogeneity of the S-compounds is of importance in order to realistically model sea-ice associated biogeochemical processes and their potential impact on climate.

Here we present an overview of sulfur compounds and ancillary parameters followed during a temporal study on an ice floe in the Weddell-Sea with RV Polarstern (ANTXXII-2: ISPOL) and a spatial study through first- and multi-year sea ice of the Western Weddell Sea (ANTXXIII-7: WWOS). The spatial and temporal heterogeneity of both the concentrations and conversion pathways of S-compounds were investigated with the use of stable isotope additions. The data provide a showcase for the importance of sea ice as a source for DMS(O/P) in the marginal ice zone.

## S15: ANTARCTICA'S GATEWAYS TO LOWER LATITUDES

### Biogenic weathering as related to energy input into soil in maritime Antarctica

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Weathering is of utmost importance for the support of life on earth, as it turns bedrock into soil and delivers nutrients to organisms. *Vice versa*, life itself is heavily engaged in mineral weathering by investment of photosynthates into weathering processes. We aim at investigating the processes and thresholds in biogenic weathering as a function of photoautotrophic community succession from microalgae/cyanobacteria to lichen-dominated stages towards the appearance of higher plants along soil development gradients built by global-change induced glacier retreat in maritime Antarctica. Our hypothesis is that biogenic weathering rates are driven by the interplay of photosynthetic efficiency and C-transport velocity & specificity towards mineral surfaces, resulting in higher weathering potential with developmental stage in evolution of the involved symbioses. For this, along succession- and soil development gradients weathering agents, organic carbon allocation to the soil, mineral *in-situ* composition and biogenic weathering on surfaces of introduced and defined, rock forming minerals were assessed and related to phototrophic community structure. First results suggest in-soil biogenic weathering dominated by mosses, and not as expected by *Deschampsia antarctica*, most likely due to the absence of mycorrhiza at our study sites.

## Understanding Inter-hemispheric polar linkages suggested by the Arctic Lake El'gygytgyn paleoclimate record of the past 3.6 Myrs

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The new record from Lake El'gygytgyn (Lake E), NE Arctic Russia, notably the largest, deepest, oldest unglaciated basin in the Arctic borderlands provides the first complete record of Pliocene and Pleistocene climate change from the terrestrial high latitudes [1, 2]. Lake El'gygytgyn evidence shows 3.6-3.4 Ma ago summer temperatures were ~8°C warmer than today when pCO<sub>2</sub> was ~400 ppm and ANDRILL records suggest Antarctic ice sheets, especially WAIS were smaller than today. Multiproxy evidence from Lake E suggests extreme warmth and polar amplification during the middle Pliocene with low amplitude changes between cold and warm Milankovitch cycles consistent with the LR stack and limited changes in global sea level. Sudden stepped cooling events during the Pliocene-Pleistocene transition recorded at Lake E are consistent with a number of marine proxies from the North Pacific and North Atlantic suggesting that polar amplification was recorded across the northern hemisphere in both marine and Arctic terrestrial environments. Summers warmer than present Arctic persisted with a few exceptions until ~2.2 Ma, after the onset of Northern Hemispheric glaciation and a more persistent WAIS. The warmth recorded at Lake El'gygytgyn raises new questions about the size and geometry of initial ice over North America and elsewhere in the Arctic (especially during M2) as well as challenges the notion of perennial sea ice before 2.5 Ma. Our multiproxy evidence is consistent with global sea-level records and other proxies indicating that Arctic cooling was really insufficient to support large-scale ice sheets in the NH until the early Pleistocene. Pleistocene super interglacials recognized in the Lake E suggest that periods of Antarctic warmth may have preceded periods of exceptional "Pliocene-like" warmth in the Arctic borderlands. This hypothesis begs further testing. [1] Brigham-Grette *et al.* (2013) *Science* **340**, 1421-1427.[2] Melles *et al.* (2012) *Science* **337**, 315-320.

## A Radiolarian-based paleoclimate history of Core Y9 (Northeast of Campbell Plateau, New Zealand) for the last 160 kyr

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Sea-surface temperatures (SSTs) based on radiolarian assemblage changes are estimated for the last 160 kyr, from a sediment core (Y9) recovered from Pukaki Saddle, northeast of Campbell Plateau.

Site Y9 lies beneath Subantarctic Surface Water (SAW) immediately to the north of the Subantarctic Front (SAF), which in this region is bathymetrically constrained by the edges of Campbell Plateau and defines the northern boundary of the Antarctic Circumpolar Current (ACC).

Radiolarian assemblages are characterised by an exceptionally high abundance of the antarctic to subantarctic species *Antarctissa* spp. (up to 68 %), especially during glacial intervals. SST estimates are derived using Factor Analysis and the Modern Analog Technique (MAT). Both methods capture the glacial-interglacial (G-I) pattern.

The SST reconstructions show the changing relative influence of distinct water masses during the past G-I cycle, with major temperature variations of the order of 7 - 9 °C at glacial Terminations.

Glacials (marine isotope stages (MIS) 6 and 2) are associated with particularly cool SSTs that are indicative of a more vigorous SAF/ACC and the associated enhancement of the inflow through Pukaki Saddle and/or frequent development of cold-core eddies at the SAF.

By contrast, the influence of warmer waters and relaxation of the ACC during interglacials can be inferred from temperatures slightly warmer (e.g., mid-Holocene) and/or comparable to present day (e.g., MIS 5e). During these intervals, relatively warmer temperatures most likely indicate a higher warm-core eddy activity due to a strengthened Subtropical Front and/or a weakened inflow of cool water through Pukaki Saddle and/or an increased stratification in the Campbell Plateau region.

Furthermore, the SST record is characterised by an abrupt warming at ca. 10 kyr (i.e., Termination I), together with the occurrence of a reversal at Termination I, and a warming event at the end of MIS 4 coinciding with the A4 event in the Byrd ice core.

These characteristics, together with the pronounced G-I cycle shown by the SST estimates, suggest that Site Y9 is influenced by major oceanographic changes in the SW Pacific and responds to thermal changes at high southern latitudes.

## Millennial-scale sea ice expansion in the Indian sector of the Southern Ocean during the last glacial

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The Southern Ocean has played an important role in the evolution of the global climate system. Area of sea ice shows a large seasonal variation in the Southern Ocean. Sea ice coverage on sea surface strongly affects the climate of the Southern Hemisphere through its impacts on the energy and gas budget, on the atmospheric circulation, on the hydrological cycle, and on the biological productivity. In this study, we have conducted fundamental analyses of ice-rafted debris (IRD) and diatom assemblage to reveal a rapid change of sea ice distribution in the glacial Southern Ocean. Piston cores COR-1bPC and DCR-1PC were collected from the Conrad Rise and Del Cano Rise, Indian sector of the Southern Ocean. Sediments are composed of diatom ooze. Age models of both cores were established by <sup>14</sup>C dating and oxygen isotope stratigraphy of planktic and benthic foraminifera. Records of IRD concentration suggest millennial-scale pulses of IRD delivery during the last glacial period. The depositions of rock-fragment IRD excluding volcanic glass and pumice were associated with increasing of sea-ice diatoms, suggesting that the millennial-scale events of cooling and sea-ice expansion were occurred in the glacial South Indian Ocean. Similar episodic IRD depositions were identified in the South Atlantic during the last glacial period (Kanfoush et al., 2000). Tephra-rich grains in the South Atlantic IRD events (SA-IRD events) were mainly derived from South Sandwich Island volcanic arc, and concluded that sea-ice was the dominant ice rafting transport of such IRD grains (Nielsen et al., 2007). Provenance study of IRD grains suggest that the source of IRD in the South Indian Ocean was also volcanic arc in the South Atlantic, based on chemical compositions of rock-fragment IRD grains. Thus prominent IRD layers in the glacial South Indian Ocean correlate the SA-IRD event, suggesting episodes of sea ice expansion and cooling in the Atlantic and Indian sectors of the Southern Ocean.

## Modern foraminifera assemblages in the Amundsen Sea Embayment

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The West Antarctic Ice Sheet (WAIS) is considered the most unstable part of the Antarctic Ice Sheet. As the WAIS is mostly grounded below sea level, its stability is of great concern. A collapse of large parts of the WAIS would result in a significant global sea-level rise. At present, the WAIS shows dramatic ice loss in its Amundsen Sea sector, especially in Pine Island Bay. Pine Island Glacier (PIG) is characterised by fast flow, major thinning and rapid grounding-line retreat. Its mass loss over recent decades is generally attributed to melting caused by the inflow of warm Circumpolar Deep Water (CDW). Future melting of PIG may result in a sea level tipping point, because it could trigger widespread collapse of the WAIS, especially when considering ongoing climate change.

Our research project aims to establish proxies (integration of foraminifera, sediment properties and oceanographic data) for modern environmental conditions by analysing seafloor surface sediments along a transect from the glacier proximal settings to the middle-outer shelf in the eastern Amundsen Sea Embayment. These proxies will then be applied on sediment records spanning the Holocene back to the Last Glacial Maximum for reconstructing spatial and temporal variations of CDW upwelling and ice-ocean interactions during the past c. 23,000 years.

We will present preliminary results from the analyses of ten short marine sediment cores (multi and box cores) collected during expeditions JR179 (2008) and ANT-XXVI/3 (2010) along a transect from inner Pine Island Bay to the middle-outer shelf part of the Abbot Palaeo-Ice Stream Trough at water depths ranging from 458 m (middle shelf) to 1444 m (inner shelf). The sediment cores are currently investigated for distribution patterns of planktonic and benthic foraminifera and grain-size distribution at 1 cm resolution. Core tops (0-10 cm) were stained with Rose Bengal for living benthic foraminifera investigations. The chronology of the cores will be based on <sup>210</sup>Pb and calibrated <sup>14</sup>C dates. First results reveal the presence of living benthic foraminifera in surface sediments of all investigated cores suggesting that modern seabed surfaces were recovered. Moreover, a core retrieved from a water depth of 793 m in the Abbot Palaeo-Ice Stream Trough shows particularly high abundances of planktonic foraminifera *Neogloboquadrina pachyderma*.

## Extent of the West Antarctic Ice Sheet on the eastern Amundsen Sea shelf during the last glacial period

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High-resolution swath bathymetry data collected during several research cruises over the past two decades reveal a palaeo-ice stream trough (Abbot Glacial Trough) crossing the middle and outer shelf of the easternmost Amundsen Sea Embayment, east of the main Pine Island Trough. Regions of both fast palaeo-ice flow (within the central trough) and slow palaeo-ice flow (on adjacent seafloor highs referred to as inter-ice stream ridges) bear glacial landforms indicative of phases of grounding-line stabilization of the ice sheet. We associate a grounding-zone wedge situated within the outer Abbot Glacial Trough with a grounding-zone wedge in outer Pine Island Trough and suggest a synchronous grounding-line halt in both troughs. New sediment echosounder and sediment core data collected from outer Abbot Glacial Trough, between the seaward limit of the grounding-zone wedge and the shelf edge, reveal an up to 6 m-thick well stratified drape that is composed of unconsolidated glaciomarine sediments occasionally bearing calcareous microfossils. In order to decipher whether this unusually thick sediment drape might indicate sub-ice shelf and/or seasonal-open marine deposition throughout or since the Last Glacial Maximum, we used a multi-proxy approach to characterize its lithofacies and applied radiocarbon dating of calcareous microfossils. Here we present our initial results and discuss since when the outer shelf in the eastern Amundsen Sea has been free of grounded-ice. Such information will 1) improve ice sheet models that aim to reconstruct the flow and extent of the West Antarctic Ice Sheet during the Last Glacial Maximum, 2) help to quantify the ice volume of the West Antarctic Ice Sheet during this time, and 3) prove or reject the possibility that Antarctic benthic biota endured glacial periods in outer shelf refugia.

## New minimum age of the postglacial transgression in Potter Cove, 25 de Mayo (King George) Island

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Since Sugden and John's (1973) research on the glacier fluctuations in the South Shetland Islands, it is generally accepted that the first Holocene marine transgression that reached the inner fiords of this archipelago occurred at least by 9540 +/- 235 cal yrs BP. This age is very important, since it provides the minimum on land obtained age of the end of the last glacial period and start of the Holocene in this Antarctic sector.

Watcham et al. (2011) reconstructed a relative sea level curve for the South Shetland Islands with a sea level rise of 15 m above mean sea level (amsl) for Fildes Peninsula by 9000 cal yrs BP and a drop after 7000 cal yrs BP because the rate of glacial unloading and isostatic rebound exceeded the rate of eustatic sea level rise.

According to our new ages obtained from Potter Peninsula, the Holocene postglacial marine transgression of the southern Potter Cove section initiated before 7650 cal yrs BP, reaching about 12 m amsl, and was locally interrupted by a glacier advance after about 7285 yrs BP.

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Watcham, E. P., Bentley, M. J., Hodgson, D. A., Roberts, S. J., Fretwell, P. T., Lloyd, J. M., Larter, R. D., Whitehouse, P. L., Leng, M. J., Monien, P. and Moreton, S. G., 2011. A new Holocene relative sea level curve for the South Shetland Islands, Antarctica. *Quaternary Science Reviews* 30, 3152–3170.

## Reduced Drake Passage throughflow during the last glacial and millennial-scale variability

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The Antarctic Circumpolar Current (ACC) plays an essential role in the thermohaline circulation and global climate. Today, a large volume of ACC water passes through the Drake Passage, the major geographic constrain for the circumpolar flow. Here we present the first millennial-scale proxy records of Holocene and last glacial variations of the Drake Passage throughflow. Our study reports geochemical, paleomagnetic, and grain-size data from a sediment core retrieved from the upper continental slope off southernmost Chile. The site is located beneath the strong Cape Horn Current that transports northern ACC water towards the Drake Passage. Our data reveal large amplitude changes in current intensity proxy records suggesting pronounced variations in surface and sub-surface flow. We interpret these changes in terms of strongly reduced contributions of northern ACC water to the Drake Passage throughflow during the glacial in general and particularly during millennial-scale cold phases as known from e.g. Antarctic ice-cores. At the same time, advection of northern ACC water into the Humboldt current system was likely enhanced. These results support climate models showing largely reduced volume transport through the Drake Passage during the last glacial maximum and an increasing throughflow during the last deglaciation that affected the strengthening of the Atlantic Meridional Overturning Circulation.

## Eocene opening of Drake Passage: geophysical and dredge rock evidences

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A model of oceanic development by ridge jumping for the opening of the Drake Passage is proposed from an extensive data set collected in the Ona Basin, the westernmost ocean basin located in the southern Scotia Sea. The basin is bounded by the Shackleton Fracture Zone to the west, the Terror Rise to the east and the South Scotia Ridge to the south. The basin is connected northwards into the western Scotia Sea. Dredge rock samples show evidence of the occurrence of slivers of continental crust in the oceanic domain, which represent relict fragments of the original continental bridge between South America and the Antarctic Peninsula. The rocks include greywackes, quartzites, peraluminous micaschists, metaluminous gneisses and granulites, gabbros, metaluminous diorites, granodiorites and granites, and peraluminous rhyolites.

The Ona Basin was mainly developed by back-arc oceanic spreading during the initial stages of development of the Scotia Arc. Fragments of the Andean continental crust were caught into the tectonic arc and drifted eastwards due to the oceanic spreading, constituting continental banks such as the Terror Rise. Other continental fragments, in contrast, were isolated within an intra-oceanic setting during the process of continental fragmentation and development of the Cenozoic arc-back-arc oceanic crust, and form the sampled topographic highs within the Ona Basin. The minor OIB-type vacuolar olivine basalts seem to have been formed in a more extensional tectonic regime, later than the arc-back-arc regime.

Based on the magnetic anomalies of the ocean floor and the seismic stratigraphy of the deposits, a middle Eocene age is postulated for the initiation of oceanic spreading in the eastern Ona Basin, while spreading in the western Ona Basin occurred during the early Oligocene, where oceanic spreading is associated with the jumping of the ridges. We propose shallow gateways between the Pacific and Atlantic oceans during the middle and late Eocene, which initiated the thermal isolation of Antarctica.

## Enhanced Antarctic deep water export in the warm Pliocene: Isotopic evidence from the Atlantic basin

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The mid-Pliocene is the most recent interval in Earth's history to sustain global temperatures within the range of warming predicted for the 21st century. To understand this analog interval, the USGS PRISM Project has developed a reconstruction of global conditions from 3.264 to 3.025 Ma which identifies a large North Atlantic warm SST anomaly accompanied by increased evaporation. While some coupled model simulations predict transient decreases in North Atlantic Deep Water (NADW) production in the 21st century, warm anomalies in the PRISM reconstruction are also detected in the deep Atlantic ocean as far as 46°S, suggesting that enhanced meridional overturning circulation may have been responsible for more southerly penetration of NADW under this warm climate regime. The PRISM interval is further characterized by a transient increase in Southern Ocean  $\delta^{13}\text{C}$ , which narrows the Atlantic  $\delta^{13}\text{C}$  gradient. This low intrabasinal D13C has been attributed to either 1) delivery of northern component water to the Southern Ocean via enhanced North Atlantic overturning circulation or 2) an increase in the preformed  $\delta^{13}\text{C}$  of southern component water due to enhanced Southern Ocean productivity.

Here, we present a new synthesis of deep Atlantic circulation during the PRISM interval, employing the neodymium isotopic composition ( $\epsilon_{\text{Nd}}$ ) of fossil fish teeth as a proxy for water mass source and interpreting the  $\delta^{13}\text{C}$  of benthic foraminifera in the context of meridional overturning efficiency and primary production in the region of export. This reconstruction utilizes both new and previously published data from 11 DSDP and ODP sites in the North Atlantic and along depth transects from equatorial Ceara Rise, southern mid-latitude Walvis Ridge, and South Atlantic Meteor Rise/Agulhas Ridge. New records are presented in the context of modern water column  $\epsilon_{\text{Nd}}$  profiles; published data from ferromanganese crusts are used to constrain Pliocene Antarctic and North Atlantic deep waters end members. Our  $\epsilon_{\text{Nd}}$  reconstruction demonstrates that, although northern-sourced water extends into the South Atlantic today, these sites were bathed exclusively in southern-sourced water during the warm Pliocene. This conclusion has implications for the Pliocene carbon cycle and will be useful for both initialization and evaluation of future model simulations.

## Holocene climate change on South Georgia from terrestrial records

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South Georgia's location within the Polar Frontal Zone and the Southern Westerlies wind belt between Antarctica and the mid-latitudes makes it a key location for studying the main drivers of past and present-day climate variability in the Southern Ocean. We compared multi-proxy data from lake and peat cores at two key sites on either side of the mountainous orographic barrier on South Georgia. The climate of Annenkov Island, on the southern side of South Georgia, is not affected by the orographic effect that influences the climate of Prince Olav Harbour on the northern coast of the archipelago. Theoretically, therefore, past climate change on Annenkov Island should be more directly coupled to the influence of the Southern Westerlies. Standard physical data alongside fossil diatom, pigment, and high resolution  $\mu$ -XRF core scanning and magnetic susceptibility (MS) analyses from lakes in both locations showed that lake ecosystem development was relatively slow after deglaciation of low altitude and outer fjord areas, which was completed during the Early Holocene warm period. Low nutrient/productivity environments persisted until c. 4200-3500 cal. yr. B.P., coinciding with the Mid Holocene warmth on South Georgia. Initially higher, and then highly variable in-lake biological production from c. 3500 years onwards indicates that small glaciers and/or persistent ice-cover and frozen ground were restricted to higher altitudes in both catchments. On Annenkov Island, the Late Holocene record of Fan Lake is characterized by a multi-decadal cycle of minerogenic-rich sediment eroded from the catchment, clearly identifiable as well-developed peaks in Ti- and Sr  $\mu$ -XRF and MS records. The overall diatom compositions remained dominated by a single planktonic species (*Cyclotella stelligera*) throughout the Late Holocene, but were interrupted by several phases of larger-scale catchment disturbance identified by *Fragilaria capucina* peaks in diatom data and persistently elevated Ti, Sr in  $\mu$ -XRF data. Coincident with this, reduced in-lake productivity was broadly synchronous with known phases of Mid-Late Holocene glacier readvance on South Georgia. By identifying proxies that reflect catchment and in-lake processes which are directly coupled to climate on both sides of the South Georgia orographic barrier, we determined how changes in the Southern Westerlies circulation influenced Holocene climate in the South Georgia sector of the sub-Antarctic.

## High-resolution records of Southern Hemisphere mid-latitude change over the last 2,000 years: A perspective from a New Zealand varve sequence

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Inter-annual climate variability around New Zealand and the SW Pacific is primarily driven by the position and intensity of Southern Hemisphere westerly winds (SWW), which are sensitive to changes in El Niño Southern Oscillation (ENSO) and the Southern Annular Mode (SAM). These climate phenomena have a significant influence on New Zealand rainfall, with SAM accounting for over 60% of the observed variability in summer precipitation. High-resolution paleoclimate records from Antarctica and the Southern mid-latitudes are required to better understand the regional influence of these synoptic systems beyond the instrumental record. Requisite paleoclimate data are available from Antarctic ice cores but very few highly-resolved climate reconstructions exist in mid-latitudes of the Southern Hemisphere. The identification of annually laminated sediments in Lake Ohau, Mackenzie Basin, New Zealand (44.234°S, 169.854°E) offers a unique opportunity to investigate changes in regional hydrology and climate, and by extension also explore connections to large-scale climate patterns. Importantly, Lake Ohau is situated east and in the lee of the Southern Alps, rendering the region characteristically dry and sensitive to small fluctuations in precipitation and temperature.

We present an assessment of climate-varve relationships based layer classification and ITRAX micro-XRF elemental data. Initial correlation with records of lake inflow (1924-2012), and local precipitation and temperature (1926-2012) suggest the lake system is highly sensitive to changes in summer precipitation, a variable strongly correlated with the SAM. We also explore initial results using back-trajectory analysis and sedimentology, which demonstrates strong relationships between sediment characteristics (grain size and accumulation) and storm origin and trajectory. This work is the foundation for the reconstruction of a longer ~17,000 year sedimentary sequence to be collected from Lake Ohau in 2015. Ultimately, this annually resolved late-Holocene climate record from the Southern Hemisphere mid-latitudes will be critical for testing our understanding of the behavior of large-scale climate patterns and the influence of Antarctica and the Southern Ocean on New Zealand.

## **A new high-resolution record of South Island hydrology from Lake Ohau sediments, South Island, New Zealand**

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Lake Ohau (44°10'S, 169°49'E) contains a ~100+ metre-thick laminated sedimentary sequence that we believe contains a 17,000 year long record of precipitation that varies primarily in accordance with changes in southern hemisphere westerly wind flow over the southern alps. On millennial and shorter timescales these changes appear to reflect the relative influence of the Southern Annular Mode (SAM) and El Niño Southern Oscillation (ENSO). A study of modern lake sediment processes, including short cores, sediment traps, temperature and turbidity data, river inflow and meteorological data demonstrates that Lake Ohau sediments reflect seasonal changes in lake sedimentation representing lake inflow and more broadly South Island precipitation. Short sediment cores (<6 m) from the lake contain mm- to cm-scale sedimentary couplets defined by colour and grain size changes. These cores have been dated by <sup>137</sup>Cs, <sup>210</sup>Pb and <sup>14</sup>C methods and show a sedimentation rate of ~5mm/yr and thus cover the last ~1200 years. Specifically, the pattern of downcore colour reflectance variability expressed in the sediments is very similar to climate model simulations of the SAM for the past 1200 years, suggesting that Lake Ohau record has the potential to preserve both synoptic and hemispheric scale climate change.

The planned recovery of the ~17,000 year sedimentary sequence in 2015 will provide an unprecedented opportunity to reconstruct South Island hydrology from the LGM to present at decadal to annual timescales. This includes using established (e.g. sedimentology, paleomagnetism, C/N ratios, pollen, diatoms, chronostratigraphy, etc.) and novel techniques (e.g. lipid biomarkers) to reconstruct regional climate. The regional proxy data will be compared to transient GCM, and down-scaled RCM for the region to identify model /proxy data synergies and develop hydrological response models over the past 17,000. The Lake Ohau core offers a new mid-latitude record that can be compared with climate data derived from ice core and marine sediment records from Antarctica and the Southern Ocean to strengthen our understanding of the role of SAM as a cause of precipitation changes in New Zealand and the southwest Pacific and to identify cross-latitude (ENSO) climate connections and drivers.

## Iceberg Alley - Antarctic gateway to lower latitudes

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Currently, the lack of highly resolved Southern Ocean marine paleoclimate archives limits our understanding of the dominant feedbacks between the Antarctic ice sheets, Southern Hemisphere oceanic and atmospheric circulation, and global sea level. Two high-resolution deep-sea sites from the Scotia Sea are located in the center of Iceberg Alley and reveal a chronologically well-constrained coupling of dust proxies to Antarctic ice cores during the last glacial cycle (Weber et al., 2012).

The majority of Antarctic icebergs routes through this unique gateway to lower latitudes today. The sites capture a spatially integrated signal of Antarctic Ice-Sheet (AIS) mass loss during deglaciation, indicating eight events of very rapid AIS collapse (within a decade!) for the time 19 – 9 ka. Transient deglacial modeling suggests millennial-scale fluctuations that involve major atmospheric and oceanic reorganization with overall trends of southward-shifting Southern Hemisphere westerly winds, sea-ice reduction, enhanced marine productivity, increase in CO<sub>2</sub>, oceanic and atmospheric warming, and increased Antarctic ice mass loss (Weber et al., in review).

Within IODP proposal 847 (Weber et al., 2013) we intend to study the Plio-Pleistocene changes in ocean and atmospheric circulation as well as Antarctic ice-sheet dynamics in Iceberg Alley. This includes AIS ice mass loss through climate terminations, provenance studies to determine sources of AIS mass loss, the interhemispheric phasing of ice-sheet and climate events, and the relation of AIS dynamics and global sea level through the ice ages.

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## Dating past landscape events on South Georgia Island

### White D

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Reconstruction of past landscape changes, particularly in glacial environments, requires techniques for mapping the age of sediments and landforms preserved in the terrestrial environment. Cosmogenic exposure age dating is presently the 'gold standard' in many cases, but is time consuming and expensive, so difficult to apply on a landscape scale. Further, results are only known long after returning from a field campaign, and repeat sampling to follow up unexpected results is especially problematic in logistically difficult sub-Antarctic regions.

A range of field based relative dating techniques have been used to fill this void, such as lichenometry, soil development and landscape relaxation. However, many of these techniques are difficult to apply systematically across a range of geomorphic environments and timescales in the sub-Antarctic. For example, the rate of soil development is strongly influenced by nutrient and habitat gradients that vary strongly with elevation and/or slope, and lichen sizes do not appear to increase beyond the last few hundred years in many sites.

New data using Schmidt hammer rebounds suggest it has the potential to be a robust and widely applicable relative dating tool in sub-Antarctic environments. Results from South Georgia Island indicate that for stable landscapes, it is broadly applicable across a range of altitudes and geomorphic environments. Further, initial results from the application of this technique on outer Lewin Peninsula, South Georgia Island, suggest that the 600 m high peaks on were covered by ice around the time of the last global glacial maximum, c. 20-30 ka BP. If validated by absolute dating techniques, this would imply substantively greater ice coverage than presently assumed at this time.

## Late Holocene post glacial rebound on South Georgia Island

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Uplifted coastal landforms are an important resource in sub-Antarctic environments, exerting a strong control on habitat availability for human settlement, and also for many plant, animal and lacustrine species. Former sea levels also provide key evidence for former ice sheet volume changes.

South Georgia Island has a rich record of uplifted coastal landforms. However, obtaining good ages for the high energy beaches that exist across much of the island is challenging. These beaches generally lack well-preserved organic material that was unambiguously deposited at the time of beach formation.

In this study, we improved the former sea level record by testing an alternative technique, utilising Infra-Red Stimulated Luminescence (IRSL) dating of beach dunes to constrain former sea level change in West Cumberland Bay. Here, a series of 10-20 dune ridges have formed coeval with, and are preserved directly on top of former beaches, providing close minimum chronologies for former sea levels.

Our results indicate that the technique can provide reliable chronologies for the dune sediments. The record indicates a relative sea level fall of 3.5-5 m since 3-4 thousand years ago. Much of this change appears to have occurred soon after this time, with relative sea levels stable for most of the past thousand years.

## S16: SIGNIFICANT EVENTS IN THE GEOLOGICAL EVOLUTION OF ANTARCTICA

### Giant pseudo-toothed birds (Pelagornithidae) from the Eocene of Antarctica

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The finding of the oldest Antarctic pelagornithid in Ypresian levels (early Eocene), a humerus without the proximal end (MLP 12-I-20-4), motivates the revision of the Antarctic record of the group. It comes from the fossiliferous locality IAA 1/95, Cucullaea I Allomember of La Meseta Formation (Seymour Island, Antarctic Peninsula). This unit is exposed along the slopes of the plateau of Seymour (Marambio) Island. La Meseta Formation is approximately 560 meters thick and fills a 7 km wide valley cut down into older sedimentary rocks constituting the island; its current location is the product of regional uplift and tilting of the Paleocene and Marambio Group.

Pelagornithids, commonly known as pseudo-toothed birds, are a peculiar group of volant seabirds characterized by numerous osseoustooth-like processes in the beak, and extremely light and thin bones with a highly specialized structure adapted for pelagic soaring. They were cosmopolitan birds whose fossil record dates back to the late Paleocene to the latest Pliocene. Antarctic fossil record of pelagornithids is entirely constituted by isolated bones. Although systematic approach is poor, we can group them in two morphotypes according to their size and robustness.

Both morphotypes recognized for Antarctic pelagornithids exhibit a combination of primitive and derived characters (typical of *Dasornis* and *Pelagornis* respectively), condition already described for other middle and late Eocene specimens.

Morphotype 1 includes the early-middle Eocene humerus MLP 12-I-20-4 and a probably a humeral shaft (USNM 494035) from coeval strata of East Antarctica. They correspond to large forms equivalent in size to *Dasornis emuinus* (4.5 m wing-span). Antarctic materials included in morphotype 2 are younger in age (late Eocene, Submeseta Formation, Seymour Island) and correspond to the most giant forms known.

Giant sizes (*i.e.*, more than 5 m wing-span) would have been originated in the middle Eocene. Smaller pelagornithids (*i.e.*, albatross sized and smaller taxa) would be extinct by the late Eocene maybe due to an ecological competition for food or breeding sites with other birds. The presence of the oldest Procellariiformes in Cucullaea II Allomember (Ypresian-Lutetian), and the extremely diversified penguin fauna could be the cause.

The highly specialized forms, such as the *Pelagornis* species, would be probably originated in more recent times, but unfortunately, fossil record of Oligocene pseudo-toothed birds is actually scarce.

## Timing of metamorphism of inland nunataks in central Dronning Maud Land: implication for amalgamation of different metamorphic terranes in East Africa Antarctica Orogen

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Sensitive high-resolution ion microprobe (SHRIMP) U–Pb zircon age dating was applied to several types of high-grade metamorphic rocks in central Dronning Maud Land, East Antarctica, to clarify the timing of tectono-thermal events during the amalgamation of East and West Gondwana. The zircon ages of ca. 522–525 Ma and 598–599 Ma were obtained in Filchnerfjella and Hochlinfjellet, respectively, and the CL images of zircons analyzed are consistent with those formed during a high-temperature metamorphism. These two sets of ages are interpreted to represent the periods that immediately followed the peak metamorphism. The dating results reveal an age gap of 80 Myr between the two areas, indicating different collisional events. Compared with the previous results of U-Pb zircon age dating, metamorphic basement in CDML can be divided into several domains from Gjelsvikfjella to Wohlthatmassiv. Our preliminary terrane division revealed that there are five domains: (1) Grenville-age metamorphism (ca. 1090 Ma) with igneous protolith crystallized at 1120–1100 Ma, (2) 530–520 Ma metamorphism with igneous protolith at 1150–1000 Ma, (3) 600 Ma metamorphism with detritus zircon of various ages (930, 780, 730Ma), (4) 570–550 Ma metamorphism with igneous protolith (1080–1070 Ma), and (5) 650 Ma metamorphism with detritus zircon formed between 1150 and 800 Ma. The obtained age results imply that various different allochthonous metamorphic terranes were assembled in the huge collisional zone of the EAAO during the period from 650 to 500 Ma. Further studies tied to geochemical and metamorphic characterization of each domain are required to confirm proposed divisions.

## The opening and closing of marsupial dispersal gateways into and out of Antarctica

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The first record of marsupials in South America comes from the Adamantina Fm. of Brazil and is considered to be Late Campanian in age, which coincides with hadrosaurs dispersing into South America (Argentina) during the Campanian to Maastrichtian, indicating a land connection between North and South America. An isthmus connecting Patagonia and the Antarctic Peninsula is hypothesized to have been present, as a similar plant biota between the two continents exists by the Late Campanian. Hadrosaurs were found in the mid-Maastrichtian (~68 Ma) of Antarctica (Vega Island) demonstrating that they continued their southward dispersal into Antarctica. Marsupials are assumed to have accompanied the hadrosaurs into Antarctica at the same time. The earliest record for marsupials in Australia is from the Early Eocene of Queensland. Estimates for the arrival of marsupials in Australia also comes from DNA based interordinal divergence times for living australidelphian marsupials, a clade whose divergences began in the Early Paleocene and is suggested to be a solely Australian event.

New data postulate an earlier opening of the Drake Passage between Antarctica and South America than previous dates at the end of the Eocene (~33 Ma). An 8-fold increase in separation rate between the two continents would have led to crustal thinning and opening a shallow gateway (proto-Drake Passage) during the Early Eocene (~50 Ma). Recent results of ocean-atmosphere-ice modeling suggest that the Drake Passage had a shallow opening causing a decline in sea surface temperatures in the Southern Ocean, also commencing at ~50 Ma. Data from phylogenetic analyses of South American and Antarctic ungulates, litopterns and astrapotheres, and the divergence dates based on the first appearance of Antarctic and South American species indicate an even earlier separation of Patagonia and the Antarctica. The sister taxa to the Antarctic ungulates from the Acanilados allomember of the La Meseta Fm. (~54 Ma) are from the Itaboraian of Brazil (~55 Ma), this would put the divergence times and continental isolation between these taxa at approximately 56 Ma.

Data from marine microfossil and organic geochemical records spanning the early to mid-Eocene transition from the Wilkes Land Margin, East Antarctica, plus dinoflagellate biogeography data and sea surface temperature paleothermometry reveal that the earliest through flow of a westbound Antarctic Circumpolar Current began ~50 Ma through a southern opening of the Tasmanian gateway. Species of South American ungulates, litopterns and astrapotheres, are in Antarctica by 54 Ma, but never disperse to Australia while marsupials are present in Australia 54 to 55 Ma. This may indicate that marsupials arrived in Australia at an earlier time period and the gateway for placental ungulates and more derived marsupials, such as those from the La Meseta fauna, was closed by at least 54 Ma.

## **Tectonics of the northern Victoria Land along the paleo-Pacific margin of Gondwana: structural evidence from the Millen Schist Belt (Antarctica)**

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Northern Victoria Land (Antarctica) belonged to the active proto-Pacific margin of Gondwana, which was the site of convergence during the Paleozoic.

This work provides new insights into the structural architecture of northern Victoria Land, focusing on the boundary area between the Bowers and Robertson Bay terranes, i.e. in the Millen Schist belt. The area is characterized by the occurrence of the Millen Schist (MS) belt, that is a high strain equivalent of the adjoining terranes, presently delimited by the Leap Year and the Handler faults. Our study reveals that these two faults overprint a pre-existing transitional deformational boundary and are associated with a significant syntectonic circulation of fluids and mineralization that could be linked to the one responsible for the gold mineralization, described in the Bowers Mts (northern Victoria Land).

The Millen Schist belt consists of two lithotectonic packages, juxtaposed along the Crosscut-Aorangi duplex thrust system (CAT), with a top-to-NE sense of tectonic transport. This thrust system overprints the ductile structures of the Millen Schist belt, that are interpreted as due to the Ross-Delamerian Orogeny. Moreover, the CAT is overprinted by the Leap Year and the Handler fault system and this testifies to an ongoing transpressional regime.

As there is increasing evidence of a post-Ross contractional event in northern Victoria Land, we suggest that the structural architecture of the Bowers-Robertson Bay terrane boundary results from a long-lasting SW-NE contractional regime, during the Ross-Delamerian Orogeny and still active afterwards. This points to an extension of the Australian Lachlan Orogeny in Antarctica. The similarity of the structural architecture, the gold mineralization, the rock type and the age supports the correlation of the Bowers and the Robertson Bay terranes with the Stawell Zone of the Lachlan Fold Belt. In our new tectonic scenario the Lanterman Fault (northern Victoria Land) could have played the same role as the Moyston Fault (southeastern Australia) and the Leap Year and Handler faults correlate with the "intra-zone faults" of the Stawell Zone (e.g. the Ararat-Stawell Fault Zone).

## The Ferrar Large Igneous Province: Gondwana break-up and modern Antarctica

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The supercontinent of Gondwana, which had existed for more than 400 m.y., started to break apart in the Early Jurassic. The initial split separated West Gondwana (Africa-South America) from East Gondwana (Antarctic-Australia-India). This event, a major step in the development of present-day Antarctica, is recorded by voluminous magmatic rocks of the Ferrar Large Igneous Province, which stretch from the Weddell Sea region to SE Australasia, and by the Karoo Province in southern Africa. The Ferrar Province, comprised of extrusive lavas and pyroclastic rocks, and intrusive sills, dikes and a layered mafic intrusion, is unusual for its apparent linear distribution and distinct geochemical signature. The Ferrar is characterized by trace element abundances and patterns, and initial isotope ratios (Sr, Nd, and Pb) that indicate crustal involvement in the genesis and evolution of these mantle-derived magmas. Further, two chemical types are recognized: one includes a range of compositions (MgO contents range between 9 and 3.5%), whereas the other has a very distinct, restricted and evolved composition (MgO = 2.3%). The latter is found throughout the Transantarctic Mountains and has been interpreted to demonstrate long-distance transport from a single source in the proto-Weddell Sea region. Establishing a precise age has been challenging because of the lack of minerals that can be reliably dated, but recent work analyzing the mineral zircon has demonstrated a short duration of emplacement for Ferrar sills and lavas (less than 0.5 m.y.) at 182-183 Ma. These age constraints are important for understanding the relationships to Karoo magmatism, the transport of magmas and rates of emplacement, and possible environmental effects of large-scale magmatism. Within uncertainties on dates, there is no clear spatial trend in the timing of emplacement, nor in the order of emplacement of the intrusive versus the extrusive rocks in any given region. However, the age constraints indicate rapid emplacement of magma over a distance of about 3,500 km. The emission of volcanic gases from extrusive rocks and the volatilization of subjacent coals by intrusion of magmas, both over the short duration of emplacement, could have caused a significant atmospheric perturbation. This should have been coincident with similar impacts from Karoo magmatism in southern Africa. Current geochronology suggests Ferrar/Karoo magmatism began within uncertainty of the Toarcian Oceanic Anoxic Event (TOAE) (ca. 182-180 Ma), permitting a connection between the Ferrar/Karoo emplacement and global changes in biodiversity and seawater chemistry recorded during the TOAE. Ferrar magmatism was the first step in large-scale tectonic events that led to the fragmentation and rearrangement of the long-standing active margin of Gondwana, and set the scene for the present-day collage of crustal blocks that make up West Antarctica.

## New information on diversity patterns of Eocene Antarctic sharks, skates and rays (Chondrichthyes, Elasmobranchii)

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Seymour Island (NE Antarctic Peninsula) is one of the most productive localities for Palaeogene fossil vertebrates in the Southern Hemisphere. Most vertebrate remains come from the Eocene La Meseta and Submeseta Formations (Telm 1–7) with isolated remains of elasmobranchs being the most abundant records. The high number of elasmobranch taxa (24 genera in 15 families) and extreme abundance of specimens makes this fauna a prime object for diversity analyses.

The distribution of elasmobranchs is very uneven throughout the La Meseta and Submeseta Fms. according to all available data. Elasmobranch diversity generally was low in Telm 1, which characterizes the start of the sedimentary sequence of the La Meseta Fm. The depositional environment was as low-energetic and/or protected lagoon or estuary during warm, wet, and seasonal climatic conditions until the middle Eocene. The highest diversity of chondrichthyan fishes occurs in Telms 4 - 5 when climatic conditions changed to strongly seasonal and cool-temperate. The composition of this assemblage represents a cool-water fauna with *Palaeohypotodus rutoti*. It is considered a Palaeocene relict form. The most common taxon throughout the Antarctic Eocene, however, is *Striatolamia macrota*.

Chondrichthyans seemingly disappeared at the end of Telm 6 and no remains have been found in Telm 7 up to now although bony fish and tetrapod remains are very abundant in the Submeseta Formation. New but rare chondrichthyan material recovered from middle to late Eocene strata (Telms 6–7) confirms a significant decrease of elasmobranchian diversity shortly before the onset of Antarctic ice-shield formation.

The low diversity of elasmobranchs in the Submeseta Fm correlates well with the observed trend of a general decrease in taxonomic diversity of chondrichthyans throughout the upper part of the La Meseta Fm. This correlates with habitat loss on the upper shelf and gradual cooling of the Southern Ocean due to shelf ice development. At the end of the Eocene, most elasmobranchs disappeared from Antarctic waters resulting in the extremely impoverished modern elasmobranch fauna of the modern Southern Ocean, which includes only few skates. Sharks, conversely, only invade the Southern Ocean occasionally.

## The Cape Wallace Beds and its geological implications, South Shetland Islands, West Antarctica

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Heterochronous sedimentary successions were notably deposited since the late Paleozoic and early Mesozoic in Antarctic Peninsula (AP). Similar rocks outcrop in the west of the South Shetland Islands (SSI), particularly in Livingston Island (Lil) and Low Island (LoI). The study and the direct comparison of some of these units such as the Trinity Peninsula Group (TPG) in AP, with similar rocks of the SSI like the Anchorage Formation and the Miers Bluff Formation (MBF) both situated in Livingston Island and the Jurassic sedimentary-volcanic succession of the Cape Wallace Beds (CWB) in Low Island provides relevant implications for the knowledge of the Upper Jurassic geology of the region. The comparison of U-Pb detrital zircon age pattern of the CWB with the MBF and the TPG indicates that the CWB presents a slighter younger Upper Permian peak event not recorded in the Permian sources of the TPG, MBF units, and also a significant Triassic through Jurassic sedimentary reworking probably due to an important geographical barrier between the Jurassic plutons in AP and the sedimentary pathways.

Two sedimentary successions were compared on the base of the geological mapping and U-Pb zircon geochronological data: the CWB in LoI (cf. Bastias & Hervé, 2013) and the Byers Group in Lil (c.f. Hathway & Lomas, 1998). Both basal succession members were deposited under Upper Jurassic deep-water environments, then submarine sedimentation was probably accompanied by mafic to intermediate volcanism indicated by the volcanic member of the CWB in LoI and the Start Hill Formation in Lil. Volcanism was probably disrupted by the emplacement of Lower Cretaceous calc-alkaline granodiorites and the onset of a tectonic change in the regional framework of the Larsen Basin evolution. These lithostratigraphic similarities suggest a possible lateral correlation of turbidite deposits within a major basin located along the west flank of AP that indicates that the turbidite complexes along the active continental margin west of the northern AP continued during the Triassic and part of the Jurassic at least in the Low Island latitudes.

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## Implications for Jurassic magma emplacement and Gondwana breakup of strike slip faulting between East and West Antarctica imaged by aerogeophysical data

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British Antarctic Survey

Fragmentation of the Gondwana supercontinent began in the Jurassic and was the most significant reconfiguration of the continents of the southern hemisphere in the last 500 Ma. Jurassic continental rifting began adjacent to South Africa in the Weddell Sea region of Antarctica. This region is therefore critical for understanding the process that initiated supercontinent breakup, including the role of mantle plumes, magmatism, and major plate and microplate re-configurations. However, due to the remote location and blanketing ice sheets, the magmatic and tectonic evolution of the Weddell Sea sector of Antarctica has remained poorly understood and controversial. Our recent aeromagnetic and airborne gravity investigations reveal the inland extent of the Weddell Sea Rift system beneath the West Antarctic Ice Sheet, and indicate the presence of a major left-lateral strike slip fault system, separating the Ellsworth Whitmore block from East Antarctica (Jordan et al., 2013 Tectonophysics).

In this study we use 3D inversion of magnetic data to investigate the geometry and emplacement mechanism of Jurassic granites both along the boundary and within the Ellsworth-Whitmore block. Our models demonstrate a high degree of structural control on Jurassic granite emplacement along the newly identified left-lateral Pagano Shear Zone that flanks the Ellsworth-Whitmore block. Other granitoids emplaced further west within the Ellsworth-Whitmore block itself do not appear to have the same structural control, suggesting that this possible microplate or block was relatively more rigid. Extensive and likely more rigid Precambrian basement of Grenvillian-age is clearly delineated from aeromagnetic signatures at the northern edge of the Ellsworth-Whitmore block, lending support to this interpretation. Most intriguing, it that the high amplitude anomalies over the northern margin of the Ellsworth-Whitmore block are remarkably similar to those previously mapped over the Shackleton Range in East Antarctica. In the Shackleton Range, the association between Grenvillian-age basement and aeromagnetic anomalies is less well-constrained but nevertheless possible. Here we test in Gplates our new geodynamic model that involves the Ellsworth Whitmore block being originally closer to the Shackleton Range region in East Antarctica and then translated to West Antarctica in Jurassic times via ca 300 km of crustal extension in the Weddell Sea rift. We compare and contrast our new model with the currently more widely accepted geodynamic model that predicts significantly more complex movements of the Ellsworth-Whitmore microplate, including 180 degree rotation, and ~1500 km of strike-slip displacement from the Natal Embayment adjacent to South Africa to its current position in West Antarctica.

## Early Cambrian magmatic arc flanked by an inverted Cambrian sedimentary basin in the Wilson Terrane of East Antarctica

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The Ross Orogen, in East Antarctica, is linked to Cambro-Ordovician subduction and terrane accretion processes along the paleo-Pacific active margin of Gondwana. Geological investigations within the partially exposed basement rocks of Northern Victoria Land (NVL) have revealed several major terrane bounding and intra-terrane faults that were active during the Ross Orogen. However, considerable uncertainty remains regarding the deeper crustal architecture and tectonic evolution of the innermost Wilson Terrane (WT), the closest recognised tectonic domain to the East Antarctic Craton. Here we compile and analyse enhanced aeromagnetic and gravity anomaly images from NVL to the Wilkes Subglacial Basin (WSB) to provide new geophysical constraints on the crustal architecture and the tectonic and magmatic evolution of the WT.

Aeromagnetic imaging delineates a major fault system flanking the eastern margin of the Wilkes Subglacial Basin, which connects to the previously interpreted Prince Albert Fault System to the south. Contrary to previous interpretations, however, this fault system is distinct and lies west of the Exiles Thrust fault system. Magnetic modelling indicates that much larger and thicker batholiths were emplaced along this fault system, compared to the thinner sheet-like granitoid bodies emplaced along the late-Ross Exiles Thrust fault system. Zircon U–Pb dating over small exposures of gabbro-diorites within the Prince Albert Mountains to the south lead us to propose that this part of the magmatic arc was emplaced in a dominantly transtensional setting along a major pre-existing fault or suture zone during an earlier phase of subduction (>520 Ma or older), compared to the intrusions exposed further to the east. Long-wavelength magnetic lows and residual Bouguer gravity highs over the central Wilson Terrane further to the east are interpreted with the aid of two-dimensional modelling as reflecting several-km thick inverted sedimentary basins of inferred early Cambrian age. Tectonic inversion likely occurred along major thrust faults, formed in a dominantly transpressional late stage of the Ross Orogen. Overall, our interpretations provide new geophysical evidence in support of a long-lived and composite WT that experienced magmatic arc migration and basin inversion in response to changes in the geometry and dynamics of the subduction system, much like several modern subduction systems.

## New perspectives into crustal architecture and tectonic evolution of the Antarctic continent derived from a decade of extensive aerogeophysical research

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A decade of extensive aerogeophysical research is significantly advancing our knowledge of crustal architecture and tectonic evolution in Antarctica. High-resolution aerogeophysical imaging discloses for example the Jurassic Jutulstraumen rift and reveals a Grenvillian-age igneous province and magmatic arc along its flanks, in addition to Pan-African age pull-apart basins. Further in the interior, a mosaic of Precambrian provinces is delineated from aeromagnetic and satellite magnetic data and new models of crustal thickness and lithospheric strength (Ferraccioli et al., 2011, *Nature*). A major suture can now be recognised between the Archean Ruker Province and the inferred Mesoproterozoic(?) Gamburtsev Province. Suturing may have occurred during Rodinia assembly, although reactivation during Gondwana assembly remains a distinct possibility, that needs further testing with the aid of new geophysical observations linking the Gamburtsev Province to the Denman Glacier. This inherited mosaic of Precambrian provinces and suture zones clearly exerted key influences on the much later East Antarctic Rift System that is now thought to extend for 3,500 km from India to the Recovery Subglacial Highlands. Continental rifting in Permian times may have been followed by intraplate Cretaceous strike-slip faulting and extension, potentially providing key tectonic triggers for Gamburtsev Subglacial Mountains uplift (Ferraccioli et al., 2011, *Nature*).

New aeromagnetic and gravity compilations are now providing tantalising new glimpses into the Wilkes Subglacial Basin region. An over 1,900 km long fault system flanks a composite Archean-Proterozoic Mawson continent and is interpreted as a major Paleoproterozoic suture zone that likely controlled the location of the later Neoproterozoic rifted margin of East Antarctica (Ferraccioli et al., 2014, in prep. *Nature*).

New aeromagnetic compilations are also helping disclose more recent Phanerozoic provinces along the paleo-Pacific active margin of Gondwana. Our knowledge of magmatic and tectonic patterns of the Cretaceous to Cenozoic West Antarctic Rift System is also steadily increasing with the aid of new aeromagnetic and gravity perspectives (e.g. Bingham et al., 2012 *Nature*). Finally, new constraints on the inland extent of the Weddell Sea Rift and its boundary with East Antarctica are emerging from recent aerogeophysical observations (Jordan et al., 2013 *Tectonophysics*).

## Vegetation and climate change across the Cretaceous-Paleogene Boundary (66Ma), Antarctic Peninsula

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The Cretaceous-Paleogene (KPg) boundary, which marks a global mass extinction, is preserved within an expanded sequence of shallow marine sediments, ~70-40Ma in age, in the James Ross Basin, now exposed on Seymour Island, Antarctic Peninsula. A detailed picture of vegetation and climate change has been reconstructed from latest Cretaceous – early Paleogene pollen and spores in the sediments, originally derived from the vegetated volcanic arc to the west of the basin.

On the volcanic arc the coastal lowlands and riverine valleys were covered with warm – cool temperate rainforests with large podocarp conifers (including Huon pine *Lagarostrobos*), southern beech (*Nothofagus*) with mistletoe, and tree ferns, growing alongside shrubby proteas and other angiosperms such as lilies and clematis. Large-leaved *Gunnera* grew along river banks, with sphagnum moss, lycopods and liverworts on the damp forest floor. These plants suggest that the mean annual temperature was ~10-15°C. Forests of araucarian conifers (monkey puzzle) grew in upland areas, giving way to open ericaceous heath and low-growing shrubs (e.g *Microcachrys*) above the tree line where mean annual temperatures in these subalpine conditions may have been ~5-8°C.

The palynological record shows that the climate changed from cool-cold climates during the Maastrichtian with intermittent phases of higher humidity. The climate warmed significantly for ~2 million years at the end of the Cretaceous, prior to the KPg transition, but cooled again in the earliest Paleogene. This climate trend is seen in both the marine and terrestrial palynological data and in geochemical records. A new pictorial reconstruction of the Antarctic Peninsula environments will be presented.

## Benthic foraminiferal assemblage from Late Miocene of the Prince Charles Mountains, East Antarctica

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An abundant benthic foraminiferal assemblage was associated with pectenoid shell collected from glaciomarine sediments of the Fisher Bench Formation in the Prince Charles Mts. The shell was <sup>87</sup>Sr/<sup>86</sup>Sr dated at 10.2 Ma indicating its early Late Miocene age (Jadwiszczak et al. 2013). The assemblage of approximately 600 individuals in total, collected from less than 1 cc of sediment, is strongly dominated by only two genera *Rosalina* and *Nonion*, that are accompanied by a few individuals of *Fursenkoina* and *Lagena*. The taxonomic composition and population structure suggests shallow-marine environment of this assemblage. The foraminifera are associated with juvenile pectenoids, fragmented echinoids, ostracods, gastropod, and a fish tooth.

## The structural geology of Straumnsnutane area, western Dronning Maud Land, Antarctica - implications for the amalgamation of Gondwana

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The Straumnsnutane Formation basaltic andesites underlying the Straumnsnutane area of western Dronning Maud Land show a complex structural history. Early planar and linear fabrics and thrust faulting with associated quartz veining, typically forming multi-generational rotated en-echelon arrays suggest top to the NW tectonic transport directions under brittle-ductile greenschist facies conditions. Right dihedral paleoanalysis of later shallow-dipping slickensided fault planes indicate top to the SE tectonic transport consistent with SE vergent overturned folds reported by Watters *et al.*, (1991) in NE Straumnsnutane. The later deformation also occurred under greenschist facies conditions as indicated by extensive epidote deposition on the slickenside surfaces.

Comparison of the tectonic history with that of the adjacent Maud Belt metamorphic terranes to the east suggests that the early deformation is correlatable with top to the NW Mesoproterozoic structures in the Maud Belt. In contrast, the later deformation is correlatable with top to the SE D3 structures (Grantham, 1993) of Neoproterozoic to Cambrian age in the Maud Belt.

The latter deformation implies that the cratonic cover rocks of the Ritscherflya Supergroup were probably submerged in the footwall of the meganappe structure interpreted as part of the process of the amalgamation of Gondwana, involving collision between N and S Gondwana in the Kuunga Orogeny, between ~550-600Ma ago. The tectonic evolution is consistent with geochronological data reported by Marschall *et al.*, (2013) who suggest a depositional age of ~1125 for the Ritscherflya Supergroup volcano-sedimentary rocks. A discordant subset of zircons indicate metamorphism and alteration at between 600-480Ma consistent with burial under greenschist facies conditions. No evidence of strike-slip deformation similar to that described by Perritt and Watkeys (2003) was recorded in Straumnsnutane.

## Tectonic control on the Ordovician Sandstones and Permo-Carboniferous Dwyka Glaciation of Gondwana

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Recent descriptions of detrital zircon age-data from various Dwyka Group localities in South Africa (Cradock and Thomas, 2011) suggest ice transport from wider areas than previously thought with ages of between 600Ma and 900Ma and 2600-2700Ma in samples from the Cape, KwaZulu-Natal being consistent with derivation from Mozambique and Zimbabwe. Polar wander paths suggest that between ~410Ma and ~330Ma the pole was located over southern Africa in Gondwana (Torsvik and van der Voo, 2002).

The East African and Kuunga Orogenies involved in the amalgamation of Gondwana, which involved collision between E and W and N. and S. Gondwana respectively between ~700Ma and ~480Ma (Grantham et al., 2008) would probably have formed partially eroded highland areas between ~490 and ~330Ma. These areas would have been traversed by or would have drifted across the polar regions, probably resulting in an extensive polar ice cap, probably similar in extent to that covering Antarctica today. In addition data from various sources suggest detrital zircons in Ordovician-Silurian sandstone deposits in southern Africa and Antarctica suggest derivation sources consistent with Mesoproterozoic to Neoproterozoic basement in Mozambique and Antarctica.

This combine tectonic-paleoclimatic erosion-deposition setting would have resulted in the extensive sandstone deposits of the Cape Group and correlatives, interlayered with diamictites in the Cape Group and younger Dwyka Group tillites. Paleo-ice transport directions from southern Africa, Antarctica, India and the Falkland Islands, plotted on a map of reconstructed Gondwana show widely divergent ice transport directions, most of which imply transport away from the locus of orogenic belts of ages ~700-490Ma. These data provide much support that mountainous areas formed during the Kuunga and East African Orogenies resulting in widely divergent ice transport directions and also sourced material with widely varying ages, over extensive areas of southern Africa and adjacent continental blocks in Gondwana.

## The Early Miocene Cape Melville Formation fossil assemblage and the evolution of modern Antarctic marine communities

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The fossil community from the Early Miocene Cape Melville Formation (King George Island, Antarctica) does not show the archaic retrograde nature of modern Antarctic marine communities, despite evidence, such as the presence of dropstones, diamictites and striated rocks, that it was deposited in a glacial environment. Unlike modern Antarctic settings, and the upper units of the Eocene La Meseta Formation on Seymour Island, Antarctica, which are 10 million years older, the Cape Melville Formation community is not dominated by sessile suspension feeding ophiuroids, crinoids or brachiopods. Instead, it is dominated by infaunal bivalves, with a significant component of decapods, similar to present day South American settings. It is possible that the archaic retrograde structure of the modern community did not fully evolve until relatively recently, maybe due to factors such as further cooling and isolation of the continent leading to glaciations, which resulted in a loss of shallow shelf habitats.

## New sauropodomorphs from the Early Jurassic of Antarctica

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Since the discovery of an Early Jurassic dinosaur fauna in the Hanson Formation during the 1990-91 austral summer, there have been two additional paleontological expeditions to the Mt. Kirkpatrick site during the 2003-04 and 2010-11 seasons. During the last season excavations at the original large quarry that yielded a fairly complete skeleton of the theropod *Cryolophosaurus ellioti* and postcranial elements of the sauropodomorph *Glacialisaurus hammeri* were completed. In addition two additional sites nearby were discovered and excavated. Specimens from the 2010-11 season included additional elements of *Cryolophosaurus* and *Glacialisaurus* plus two new sauropodomorphs. Both of these sauropodomorphs represent new genera and species.

One of the specimens is a nearly complete skeleton with the skull of a juvenile sauropodomorph with an estimated body length of no more than one meter. In addition to its small size the lack of neurocentral fusion, highly vascularized fibrolamellar bone and absence of distinct lines of arrested growth all indicate that this specimen is a juvenile. Autapomorphies of this specimen include the presence of enlarged foramina within the maxilla narial fossa, a pronounced proximal femoral sulcus and a robust anteromedial fibular flange. Several other characters, such as a transversely wide ventral ramus of the postorbital, elongate chevrons and a bulbous, hemispherical femoral head suggest a close relationship of this animal to *Ignavusaurus* from the Early Jurassic upper Elliot Formation of South Africa rather than *Glacialisaurus*.

The second new sauropodomorph is represented by a left ilium, a portion of the proximal end of the left ischium including the obturator process, the distal end of the left pubis, a nearly complete right pubis and the last two posterior dorsal vertebrae articulating with the first sacral vertebrae. Autapomorphies of this specimen include a proportionally elongate preacetabular process with a ventral curvature and the shape of the dorsosacral rib attachment. Synaptomorphies of this Antarctic taxon with other sauropods suggest a close relationship to *Leonearasaurus* from the Early Jurassic Las Leoneras Formation of Brazil.

In conclusion, the three Antarctic sauropodomorphs all represent taxa that are not found in other parts of Gondwana, however, they do not form a clade within the sauropodomorphs, since they are not closely related to one another but to taxa from Africa and South America. Thus this fauna is cosmopolitan, with components that evolved in clades from other parts of Gondwana and independently migrated south.

## Sedimentology, ichnology, and palynology of Permo-Triassic strata at Lamping Peak, Central Transantarctic Mountains, Antarctica: Paleopolar lakes, braided rivers, and associated forests of greenhouse Antarctica

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Permian through Triassic (P-T) strata at Lamping Peak (LP) in the Central Transantarctic Mountains (CTM) of Antarctica preserve a previously unrecognized P-T boundary crossing succession containing a diverse paleopolar greenhouse continental ecosystem. At LP, paleopolar (75–80° S) Panthalassan margin foreland basin deposits of the Upper Permian Buckley Formation are overlain by those of the Fremouw Formation, thought to be Triassic.

Deposits include sandy braided rivers encased in organic-rich floodplains containing abundant shallow lakes and lake-marginal forests. More than 80 trees from over 40 horizons were identified in weakly developed, commonly gleyed lake-marginal or river marginal paleosols that may also contain abundant logs, some with morphologies suggesting fire damage. Permian trace fossils found in lakes, rivers, and paleosols include *Kouphichnium*, *Undichna*, *Planolites*, *Palaeophycus*, *Cochlichnus*, anabranching < 1-mm-diameter burrow networks, and shallow rhizoliths.

Overlying Lower Triassic strata include sandy braided river deposits with little preserved floodplain. Floodplains are relatively inorganic and evidence for *in situ* forests are absent in the earliest Triassic; however, rhizoliths on braid bars and in floodplain muds are common. Triassic trace fossils, found primarily on river barforms, in abandoned channels, and on proximal floodplains include *Fuersichnus*, *Kouphichnium*, *Planolites*, *Palaeophycus*, *Aulichnites*, *Cochlichnus*, *Cylindrichum*, *Diplichnites*, *Macanopsis*, rhizoliths, rhizohaloes, rhizotubules, and vertebrate tracks.

One sample of organic-rich sediment collected < 2 m below the contact with the Fremouw Formation at LP produced identifiable microfossils. Most organic microfossils found in P-T deposits in the CTM are thermally altered, some beyond recognition. This thermal maturation is linked to tholeiitic dolerite intrusions and comagmatic basalts of the Jurassic Ferrar Group found in close proximity to P-T deposits. Of the assemblage at LP that sufficiently survived the thermal maturation to be recognized at genus level, 50% are taeniate pollen grains, 20% are nontaeniate bisaccate pollen grains, 26 % are spores (mostly ornamented trilete) and 4% are indeterminate. Although thermally damaged, identifiable palynomorphs are similar to those collected just below the P-T boundary at Graphite Peak by Rosie Askin in 1995, and confirm that the sample is of late Permian age.

Combined sedimentology and ichnology at LP indicate an overall decrease in accommodation and a lowering of the water table across the P-T boundary, while the palynology indicates that the late Permian floral assemblage was characterized by a high abundance of glossopterids and other pteridosperms, along with a low diversity pteridophyte component.

## Trace fossils as proxies for continental life and physicochemical factors that record a hydroclimate shift across the Permian-Triassic boundary, Beardmore Glacier region, Central Transantarctic Mountains, Antarctica

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Changes in trace fossil composition, occurrence, and sedimentary facies through Permian-Triassic boundary (PTB) crossing successions of the Upper Permian Buckley (BF) and Lower Triassic Fremouw Formation (FF) at Lamping Peak, Coalsack Bluff, Wahl Glacier, and Graphite Peak record a hydroclimatic shift in ichnodiversity from high to low soil moisture, lowering of the water table, and improving drainage.

The upper BF contains interbedded braided river, paludal, lacustrine, and organic-rich floodplain deposits emplaced at paleopolar latitudes under a humid, cool temperate climate. The lower FF contains alternating braided river and relatively inorganic floodplain deposits emplaced under a warmer and seasonally drier climate. Traces in the BF were found mostly in paludal and lacustrine deposits, with few found in fluvial deposits and none in coal. The small-diameter vertical and horizontal burrows found in fluvial deposits represent shallow burrowing in aquatic and semiaquatic settings. Burrow networks, trails, and resting traces in paludal and lacustrine deposits are mostly horizontal, representing shallow tiering in aquatic settings. Paludal deposits typically contain tree stumps and logs with a variety of preservational forms with common evidence of burning or charring. In contrast, traces in the FF record better-drained conditions, lower soil moisture, and lower water tables. Overbank deposits contain small- (~2-5 cm), large- (~10-15 cm), and mega-diameter (~50 cm) vertebrate burrows that penetrate to 15-100 cm below the paleosurface. Simple to complex, shallow (< 5 cm) to deep (~20-50 cm) branching rhizoliths are present in various forms that reflect high to low soil moisture conditions. This association represents vegetated floodplains with therapsid burrows. Burrows, trails, and trackways on channel barforms and in abandoned channels record fluctuating flow in freshwater rivers. Some barforms have high concentrations of small-diameter (0.5-1 cm) vertical (10-30 cm) burrows suggesting lower water levels and diminished flow, while slack-water deposits and abandoned channels contain annelid, horseshoe crab, millipede, and probable centipede trails.

Overall, many of the aquatic trace fossils cross the PTB without loss in diversity; however, trace fossils are more penetrative in Triassic deposits. Trace fossils reflect activity in warm summer months, similar to present-day life cycles of terrestrial and aquatic organisms common to central-northern Alaska.

## Antiquity of the Transantarctic Mountains

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Recent thermochronologic data collected along the Byrd Glacier Outlet of the Transantarctic Mountains (TAM) reveals a prolonged and punctuated denudational history. Apatite fission track cooling ages from over 30 samples range from Late Jurassic (~148 Ma) to Oligocene (~32 Ma). The ages vary systematically along the length of the outlet, with oldest ages located towards East Antarctica, and ages younging towards West Antarctica.

Samples collected along two vertical transects, each with over 1000 m of vertical relief, separated by ~30 km, all have apatite fission track cooling ages of ~80 Ma. The >1 km of relief with nearly identical cooling ages indicates rapid denudation associated with significant topography. The spatial extent of this rapid cooling indicates that this topography was of regional importance.

These results are difficult to reconcile with the commonly held view that the Transantarctic Mountains formed as a rift-flank uplift during the Eocene. The presence of pre-Eocene cooling ages, the spatially systematic distribution of cooling ages, and the widespread 80 Ma rapid denudation "event" confirm the presence of significant topography well before the Eocene. These results could be explained by the Mesozoic development of a regional highland associated with subduction along the West Antarctic margin; perhaps similar to the Altiplano, and the hypothesized Nevado-Plano.

## Cooling history of the Lützow-Holm Complex deduced from diffusion zoning of garnet from Skallen

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The Lützow-Holm Complex, East Antarctica, has experienced an clockwise pressure-temperature path (e.g., Motoyoshi et al. 1985). The path includes early isothermal decompression followed by isobaric cooling within about 20 million years (Fraser et al. 2000). The estimated cooling rate during this period is extremely large as 30 °C/Myr in average. The implied rapid cooling has been supported by several lines of evidence such as incomplete reaction microstructures (e.g., Hiroi et al. 1986), crystal size distribution of garnet indicative of absence of ripening (Goto, Ikeda 2008), and occurrence of quenched glass (Hiroi et al. 2014). Regardless of such a rapid cooling, some constituent minerals have modified the chemical composition at peak metamorphism to some extent. Garnet commonly has chemically homogeneous interior with a zoned margin where Mn increases outward, which can be explained as diffusion zoning formed during cooling.

This study proposed a preliminary formulation to estimate duration time for formation of the diffusion zoning, and applied it to the garnet in pelitic gneisses from Skallen, Lützow-Holm Complex. The garnet shows two stages of zoning formation, which represents a relatively slow and rapid cooling at early and later stages, respectively. The present results are qualitatively consistent with the cooling history deduced by geochronology.

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**The Mackellar Inland Sea: Ichnology of a stressed, river-dominated, deltaic shallow marine environment, Lower Permian Mackellar Formation, Central Transantarctic Mountains, Antarctica**

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The Lower Permian Mackellar Formation (MF) in the Central Transantarctic Mountains (CTAM) was deposited at 80–85° S paleolatitude. Previous interpretations proposed that the MF was deposited into either a large glacial lake or inland glaciolacustrine sea. We identified 25 different trace fossils from strata in the Beardmore Glacier region (BGR) at Turnabout Ridge (TR) and Buckley Island (BI) with morphologies characteristic of marine organisms. Based on combined ichnologic and sedimentologic observations we interpret that facies of the MF were deposited into a fully marine to brackish-marine inland sea.

The 25 MF ichnogenera found at the TR and BI sites include: *Arenicolites*, *Bergaueria*, *Chondrites*, *Circulichnus*, *Cochlichnus*, *Conichnus*, *Cruziana*, *Diplichnites*, *Diplocraterion*, *Gordia*, *Haplotichnus*, *Kouphichnium*, *Lockeia*, *Palaeophycus*, *Phycodes*, *Planolites*, *Protovirgularia*, *Rusophycus*, *Sagittichnus*, *Scolicia*, *Skolithos*, *Taenidium*, *Teichichnus*, *Treptichnus*, and *Undichna*. The highest diversity of traces occurs in the BI sandstones, typically within mudstone and siltstone interbeds.

The MF in the BGA comprises meter-thick heterolithic interbeds of sandstone-siltstone and mudstone, coarsening-upward successions of wave-to-current-ripple cross-laminated siltstone and sandstone, and compensationally- stacked, erosionally- based lenticular sandstones capped by mudstone-siltstone interbeds. Facies, sand-body geometries, and stacking patterns are consistent with submarine fan-channel complexes (lower MF) and the subaqueous portion of deltas including prodelta and delta-front deposits (upper MF). Ichnocoenoses include: *Phycodes–Planolites–Teichichnus*, *Arenicolites–Planolites*, and *Cruziana–Rusophycus*. These ichnocoenoses are characteristic of epi- and endobenthic worms and arthropods, with the vast majority of the traces being diminutive in size (i.e., diameter). Trace fossils also exhibit shallow (< 2 cm) tiering depth. This clear reduction in morphology from “normal” to “diminutive” and the shallow tiering depth are characteristic of benthic organisms in a stressed environment, such as a nearshore brackish-water setting. Our results suggest that the MF represents a stressed marine deltaic environment (the Mackellar Inland Sea) with short-lived communities composed of small-bodied organisms influenced (stressed) by high sedimentation rates and freshwater input. We propose that meltwater freshets reduced salinities near these paleopolar deltas.

## Significance of extensive 1000-900 Ma old rocks in eastern Dronning Maud Land: an extension of the Rayner Complex?

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The Rayner Complex represents a ca. 1000-900 Ma orogenic belt fringing the Napier Craton. To the W, it appears to be overprinted by the ca. 550 Ma Lützow Holm-Prydz Bay mobile belt. In the Sør Rondane Mts., eastern Dronning Maud Land, the SW Terrane has rocks of very similar age than the Rayner Complex. New data confirm the view that the SW Terrane is a juvenile oceanic arc terrane, with the main phase of subduction-related magmatic activity at ca. 990 Ma. Younger magmatism (920-960 Ma) was influenced by passive upwelling and adiabatic melting of depleted mantle and indicates that subduction had halted by that time. Early Neoproterozoic crust formation ages are absent from central and western Dronning Maud Land. Therefore, a connection of the Sør Rondane with Sri Lanka-India during Rodinian times is more likely than with the Kalahari Craton. This could also indicate that the Lützow Holm-Prydz Bay mobile belt as part of the Kuunga Orogen might represent a rather minor mobile belt. Early Neoproterozoic crust forming ages can possibly be traced from Sør Rondane to the Schirmacher Hills, beyond which Early Neoproterozoic ages are absent. In central DML, the major Forster Magnetic Anomaly separates rocks with Grenville-age protolith ages of ca. 1130-1000 Ma to the W, from rocks with Rayner-type protolith ages to the East. The Forster Magnetic Anomaly is therefore interpreted as a suture. New field-work during two recent international expeditions, *Geodynamic Evolution of East Antarctica* (GEA) I + II, and first geoscientific results reveal a complex tectonic architecture between Sør Rondane and central DML. East of the Forster anomaly, the magnetic anomaly pattern changes significantly and typical Maud type crust is not present any longer. GEA II targeted a range of nunataks between Sør Rondane and central DML that had never been visited previously (from Blåklettane and Bergekongen in the E to Urna and Sørsteinen in the W). These nunataks are dominated by medium- to high-grade metasedimentary and metavolcanic rocks of possibly Neoproterozoic age, including abundant marble and graphite schists. We expect a lot of new data from this region in the very near future.

## Mapping of subglacial tectonic provinces of East Antarctica

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Simplistic models of tectonic structure of the southern continent were proposed by the pioneers of Antarctic earth science investigations in the early 20th century but they remained largely speculative until the IGY 1957-1958. Subsequent signing of the Antarctic Treaty facilitated rapid advance of Antarctic earth science studies. However, it was not before the end of the past century when implementation of modern geological and geophysical technologies enabled more credible compilations that encompassed not only the Antarctic continent but also the surrounding seas to 60° S.

The East Antarctic bedrock consists mainly of the Precambrian crystalline complexes and the Paleozoic-Early Mesozoic platform units. Crystalline Shield is locally complicated by Neoproterozoic aulacogenes and Late Paleozoic to Mesozoic rifts. Shield assemblages reliably recognized in coastal outcrops indicate the predominant occurrence of Archean cratonic nuclei and Mesoproterozoic mobile belts. The platform cover strata are exposed in East Antarctica mainly along its boundary with West Antarctica. Tectonic structure of ice-covered regions is interpreted mostly using magnetic and bedrock topography data, but other geophysical and geological information (satellite, airborne and over-ice gravity; seismology; active seismics; erratics; detrital zircons dates; etc.) is also important.

Archean cratons are geologically documented in western Dronning Maud Land, Enderby Land, Princess Elizabeth Land and in the southern Prince Charles Mts. Their distribution under the ice is marked by a specific magnetic pattern including low-amplitude mosaic and/or high-amplitude long-wavelength anomalies. The most extensive ancient craton being 1000 km across is believed to extend from the southern Prince Charles Mts. to the Gamburtsev Mts. Mesoproterozoic mobile belts are distinguished by elongated high-amplitude magnetic anomalies and are mapped along the coastal area as the zone of 250–600 km wide. The Gamburtsev Mts. area is also interpreted to be a part of Mesoproterozoic mobile belt.

Precambrian aulacogens and Paleozoic to Mesozoic rifts are more difficult to recognize with confidence from geophysical data, except the largest Lambert-Amery rift which is well expressed in potential fields and bedrock topography. Many other linear bedrock depressions are believed to result from ice erosion which probably amplified precursor structural features (faults, sutures etc.). Extensive platform cover is assumed to occur mainly in vast subglacial lowlands of East Antarctic interior.

## Terrestrial paleoassemblages from Magallanes Region, southern Chile, reinforce the hypotheses of an Antarctic-South American landbridge during the latest Cretaceous

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The Las Chinas-Cerro Guido Complex is located north of the Magallanes Region, southern Chile, and has been visited by scientific expeditions since 1898, but their paleobiogeographic importance was just uncovered. The Magallanes Region, during the Late Cretaceous, was part of a progradational system from deep marine to deltaic deposition environments. The paleoflora was dominated by *Sterculia*, without *Nothofagus*, and the fauna restricted to curculionid insects. As a result of a recent multidisciplinary work, including detailed stratigraphy, satellital analysis, palynology, invertebrate and vertebrate paleozoology, palaeobotany and petrology, the existence of a river delta, controlled by tides and three stages of plant assemblages was established. The upper level contained *Nothofagus* leaf imprints, underlying partially-articulated hadrosaurs and other undetermined vertebrate remains. The presence of *Nothofagus*, key genus of the sub Antarctic forests of Chile and Argentina, can be interpreted as strong evidence of Antarctic-Patagonian land bridges during the latest Cretaceous (Maastrichtian), presence that could be correlated to an overall decline in sea level and a brief cooling event following the Cretaceous greenhouse period. Indeed, this *Nothofagus* record is the oldest in America (67,8 mya), and the dinosaurs findings are the southernmost worldwide excluding Antarctica. We are grateful to the crew of "Estancia Cerro Guido" and the Chilean Antarctic Institute for their logistic support for our field campaigns to this area. Financial support by FONDECYT 11080223 (2009-2011) and the German BMBF (CHL 10A/09) are gratefully acknowledged.

## The thermal history of the Ross Sea's East Antarctic margin as revealed by detrital minerals in glacial till

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Zircons, hornblende and biotite were extracted from nine glacial till samples from heads of major outlet glaciers in the Transantarctic Mountains, one sample at the mouth of Scott Glacier, and beneath three West Antarctic ice streams. Detrital zircon (DZ) U-Pb ages and detrital <sup>40</sup>Ar/<sup>39</sup>Ar hornblende and biotite ages from both East- and West Antarctic- derived sediments in the Ross Embayment samples are strongly dominated by Ross/Pan African orogeny ages (450-625 Ma), with <sup>40</sup>Ar/<sup>39</sup>Ar ages being slightly younger than U-Pb zircon ages. As the Ross/Pan-African U-Pb DZ population is ubiquitous in these Antarctic tills and many Beacon Supergroup sandstones, 83 grains were analyzed for ZHe to subdivide this population in an effort to test whether East and West Antarctic sources could be distinguished by their cooling history. Although East and West Antarctic Ross/Pan African sources are not distinguished by the approach, we found that two ZHe age populations are evident in East Antarctic tills, with 64% of grains 115-200 Ma and 35% between 200-650 Ma. The older population is interpreted to be the expression of slow cooling since the Ross/Pan-African orogeny (potentially including cooling of the Granite Harbour Intrusives and/or exhumation of the older basement rocks to form the Kukri Peneplain). Grains in East Antarctic tills with a ZHe age of 115-200 Ma likely reflect regional heating associated the Ferrar dolerite intrusions, subsidence within the rift basin, and/or a generally higher geothermal gradient.

The 115-200 Ma ZHe population may also be characteristic of the Beacon Supergroup as most of the tills that contain ZHe of this age are adjacent to nunataks mapped as Beacon Supergroup, and the moraines contain an abundance of Beacon pebbles. To test this, we measured the ZHe ages of 9 zircons from 3 Beacon Supergroup sandstone clasts collected from moraines across the Transantarctic Mountains, as well as 32 zircons from the Fremouw, upper and lower Buckley Formations at Shackleton Glacier. These samples all yield Ross/Pan African U-Pb ages and ZHe between 110-180 Ma, thus confirming the Beacon Supergroup is likely the source of this characteristic pair of U-Pb and ZHe ages.

## **A tomographic transect across West Antarctica: Evidence for recent extension in the Bentley Subglacial Trench and a mantle hotspot beneath Marie Byrd Land**

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The upper mantle seismic structure beneath central West Antarctica has to-date only been investigated by continental-scale tomographic models. As a partial remedy, we present both P and S wave relative velocity models that resolves detailed structure along a dense seismic transect that extended from the Whitmore Mountains, across the West Antarctic Rift System (WARS), to the Marie Byrd Land (MBL) coast and was a major component of the POLENET/A-NET experiment. These regional models are constructed using relative travel time residuals from teleseismic P and S phases that have been corrected for travel time effects due to crustal and ice sheet structure using the receiver function models of Chaput et al. [2013].

Both P and S wave velocity models reveal a strongly heterogeneous upper mantle ( $\delta V_p = \pm 2.0\%$ ;  $\delta V_s = \pm 4.0\%$ ) that correlates well with the bedrock morphology and proposed West Antarctic crustal blocks. Beneath the Whitmore Mountains seismic velocities are faster than the mean of the model and are interpreted as thicker, colder lithosphere relative to the rest of the study region. Slower velocities are observed beneath MBL and coincide with a region of elevated topography that is not isostatically supported by the crust [Chaput et al., 2013]. The highest amplitude of this anomaly occurs at 200-300 km depth and is centered beneath Mt. Sidley in the Executive Committee Range, a linear volcanic chain with a active magmatic complex [Lough et al., 2013]. This region of slow velocities is observed extending to the transition zone and possibly deeper, however due to the poor vertical resolution of the models it is difficult to determine whether the anomaly is an upper mantle hotspot or a mantle plume. Regardless, this feature is consistent with warm, low viscosity mantle that provides topographic support and has previously relaxed since the last glacial maximum.

The shallow ( $\leq 100$  km depth) velocity pattern across the WARS is similar in both models with the slowest velocities in this tectonic domain occurring beneath the Bentley Subglacial Trench (BST) and is interpreted as a slightly elevated geotherm. The BST is also a region of locally thinned crust that likely reflects a region of localized Cenozoic extension and given our results may represent the most recent phase of extension, possibly in the Neogene [Garnot et al., 2013].

**Benthic foraminifera community from the Polonez Cove Fm. (Oligocene) of King George Island, West Antarctica**

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Benthic foraminifera from the Polonez Cove Fm. on King George Island are the only Oligocene assemblage reported from the Antarctic Peninsula sector of West Antarctica. The single, although collected at several sites, assemblage is dominated by robust calcareous species (*Cibicides temperata* s.l., *Globocassidulina* cf. *G. subglobosa*, *Discorbis* sp., *Melonis* sp., *Lobatula lobatula*, *Gyroidina zealandica*) and represents a shallow-water environment of fan-delta system. It has no modern Antarctic analogue, supporting different climates during Oligocene. The assemblage shares a group of the most morphologically conservative Antarctic foraminifera with other Cenozoic shallow-water sites in West Antarctica, suggesting their presence in that area at least since early Eocene. Because of that strong taxonomic imprint of the shallow-water environment resulting in a lack of well constrained stratigraphically species, it was impossible to correlate the assemblage from the Polonez Cove Fm. with any particular interval of the Ross Sea foraminiferal record.

## **A Geochemistry of the Straumsnutane lavas (Jutulstraumen Group) in western Dronning Maud Land, Antarctica and the Espungabera lavas (Mkondo Group) in central Mozambique: Evidence for comagmatic and continental emplacement**

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The Straumsnutane lavas overlie the sedimentary platform sequence of the Ahlmannryggen Group in western Dronning Maud, Antarctica while the Espungabera lavas overlie that of the Umkondo group in Mozambique. The volcanic units are thought to be in the same stratigraphic position in both localities, and are believed to form part of a ~1100 Ma Umkondo Igneous Province in southern Africa. This study presents a comprehensive geochemical survey of these lavas, and will contribute to a better understanding of the ~1100 Ma Umkondo Igneous Province in southern Africa and Antarctica.

Published geochemical data of the Straumsnutane lavas were compared with the data obtained from Espungabera lavas. Radiogenic isotope data for these lavas were also obtained. Both these lavas are very fine grained, moderately weathered and slightly to moderately amygdaloidal. These lavas are dominantly basaltic andesites, basalts, minor basaltic trachyandesites and trachyandesites. The petrographic studies indicate that the Straumsnutane lavas are dominated by clinopyroxenes, Fe-Ti Oxides and plagioclase which show some degree of saussurization from moderate to severe. Metamorphic mineral assemblages indicate greenschist facies conditions for the Straumsnutane lavas which are similar to that of the Espungabera lavas. Very close trace element ratios values of Nb/U and La/Yb for both the lavas suggest a cogenetic origin. The REE data for Straumsnutane and Espungabera lavas have comparable LREE and HREE distributions and slopes, with both being characterised by weak negative Eu anomalies. Also similar between Straumsnutane and Espungabera lavas is negative Nb anomaly and enrichment in large ion lithophile elements (LILEs). The  $^{87}\text{Sr}/^{86}\text{Sr}$  isotopic data calculated at 1100Ma and negative  $\epsilon\text{Nd}$  values (-2.83 to -3.49) for the Espungabera lavas suggest contamination by continental crust during their genesis. The  $^{87}\text{Sr}/^{86}\text{Sr}$  vs  $^{143}\text{Nd}/^{144}\text{Nd}$  isotopic modelling calculated at 1105Ma shows that both lavas may have been formed from mixing of a MORB-like source and with about 5% of older crust.

The similarities seen in major, trace elements and rare earth element geochemistry indicate that the Espungabera and the low Ti Straumsnutane lavas have the same magmatic origin and emplacement in a continental environment.  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $^{143}\text{Nd}/^{144}\text{Nd}$  isotope analyses conclude that the lavas suggest contamination by continental crust during their genesis.

## Differential thinning of the mantle lithosphere underneath East African Orogen- inferred from post orogenic magmatism

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EAO located in the eastern part of Africa marks the suture between east and west Gondwana (Stern, 1994). The suturing is proposed in form of a continent-continent collision. Wherever exposed, granulite grade rocks of ~640Ma have been shown to demarcate the suture on ground (Ravikant et al., 2004, 2007; Baba et al., 2006). Reports of such Neoproterozoic granulites from CDML in the strike extension of EAO enables identification of this suture from east Antarctica (Pant et al. 2013).

Undeformed magmatic rocks are nearly always associated with orogenic belts (Turner et al., 1992). Often these are represented as bimodal magmatic suites. These magmatic rocks are distinct from deformed (orogenic) magmatic rocks in being more primitive and appear to have been derived from a less evolved source.

We report post orogenic magmatic rocks, mainly A-type granites, from east Antarctica and northern Africa, the two ends of the reconstructed EAO. Granites from sector of Ethiopia are mainly of two types namely amphibole granite and mica granite. Andalusite growth in the marginal low-grade schist marks the contact effect. Well preserved textures indicate two-stage magmatism. Electron microprobe geochronology of monazite constrains these two stages at  $541 \pm 34$  Ma and  $482 \pm 34$  Ma. The fayalite bearing A-type granite from CDML in east Antarctica in proximity to the inferred extension of EAO dates ~576 Ma.

A compilation of the age data of post orogenic granites along EAO indicates that there is no secular variation of timing of magmatism along the length of orogen. It is proposed that post orogenic differential thinning of lithosphere beneath EAO can explain this magmatism.

References Available on request

## New eutherian mammal from the Eocene of La Meseta Formation, Seymour Island, Antarctica

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The Antarctic fossil record of terrestrial mammals is restricted to Eocene times. It is represented by several lineages derived of those present in the Cretaceous and Paleogene of South America. This record includes Gondwanatheria, a wide diversity of “opossum-like” metatherians and placental mammals represented by native ungulates (*i.e.* Astrapotheriidae, Sparnotheriodontidae). The presence of Xenarthrans and Insectivora or Dryolestida, needs further confirmation.

We report an eutherian left m2? fragment represented by the talonid (MLP 12-I-20-4), recovered from La Meseta Formation at the IAA 1/90 locality in Seymour Island. This small talonid (6.25 x 6.01 mm) shows a strong hypolophid?, with a large hypoconid filling the distolabial side, and a small hypoconulid, placed as the more distolingual cusp. The talonid basin is deep. An unworn bunoid and small entoconid is located mesial to the hypoconulid and related to it by a faint postcrisid. The entoconid and the hypoconid are placed almost in the same transverse line. A small cusp? mesial to the entoconid seems to be close the talonid valley lingually. In the labial side, a narrow and slender cristid obliqua projects almost mesially. There is a small ‘pocket’ or rim present in the base of mesiolabial side and the ectoflexid is absent. The base of the labial side of the talonid shows a wrinkled surface not seen in the sharper lingual side. MLP 12-I-20-4 more resembles the morphology of some Sparnotheriodontidae for the position and development of the entoconid, than any other placental mammal. Even though, it differs from them, particularly of the Antarctic *Notiolofos*, for the labial pocket, the close talonid basin, absence of cingulids and ectoflexid, and different inclination of wear between the cristid obliqua and the hypolophid?.

While the occurrence of non-therian mammals could be explained by vicariance or dispersal events, therian mammals fit well with a dispersion model related to the land bridge formed by the Weddellian Isthmus. This bridge connected West Antarctica and southern South America, probably up to the early late Paleocene. The great importance of this material lies in the increase of the diversity in the mammalian fossil record in the Antarctic continent. Further studies and new materials could corroborate if MLP 12-I-20-4 is related to known South American lineages or represent a new group that could be part of an Antarctic endemism.

## The first non-therian dryolestoid from Antarctica

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The Early Eocene strata (*Cucullaea* I Allomember) of La Meseta Formation of Seymour Island, Antarctic Peninsula contain a diverse mammalian assemblage including gondwanatherians, marsupials, pilosans, litopterns and astrapotheres. This composition reflects a strong paleogeographical link between Paleogene faunas of Patagonia and West Antarctica. A small isolated tooth, MLP 91-II-4-3, found at IAA 1/90, with zalambdodont morphology was originally interpreted as a possible bat or “insectivore”, although after subsequent comparisons with therians it was assigned to Mammalia incertae sedis, with possible placental affinities. It was interpreted as a M3 with zalambdocone, mesiostyle (parastyle), stylocone, distostyle (metastyle), and pre- and post-cingulum. Zalambdodont morphology is convergent in several mammalian groups and the evaluation of an isolated tooth could generate conflictive hypotheses. An alternative interpretation for the primary homology of MLP 91-II-4-3 is the base of the present contribution. Based on it, MLP 91-II-4-3 is considered as a right lower molar of a new taxon of non-therian Dryolestoidea, perhaps related to, or member of the clade Meridolestida. The crown is dominated by three cusps and a distolingual talonid cusp. The protoconid is flanked mesially by the paracristid and distally by the metacristid, which reach the paraconid and metaconid, respectively. Both crests form an acute angle and there is no distinctive notch at mid-way. The labial wall of the protoconid is convex while the lingual face is slightly concave. The paraconid is worn out, and lower than the other cusps. The flexid is notorious and forms a “v” shaped notch between paraconid and metaconid. The metaconid and protoconid are similar in height. The metaconid connects by means of a crest the talonid. The talonid has a hook-like disto-lingual projection with a large cusp. Its relationships with the distal cingulum are obscured due to preservation. The mesial cingulum starts as a faint line below the paraconid and gets wider ventrolabially. Due to preservation it is unknown if the cingulum continues on the labial slope of the protoconid. Information on root morphology is sparse. There is a portion of root preserved below the paraconid-protoconid, which seems to be transversely wide. This crown morphology resembles the meridolestidan *Barberenia* from the Late Cretaceous of Patagonia. Meridolestidan dryolestoids are a conspicuous component of the Late Cretaceous mammalian association of Patagonia. The group survived the Cretaceous/Paleogene boundary and one taxon (*Necrolestes*) persisted until the early Miocene of Patagonia. If the taxonomic interpretation we present here is correct, MLP 91-II-4-3 constitutes the second Mesozoic lineage surviving in the Eocene of Antarctica and certainly represents a new component of the taxonomically diverse mammalian assemblage of La Meseta Formation.

**The first record of the chimaeroid genus *Edaphodon* (Chondrichthyes, Holocephali) from Antarctica (Snow Hill Formation, Late Cretaceous, James Ross Island)**

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Holocephali (rat fishes, elephant fishes and relatives) is a relatively poorly diversified marine chondrichthyan clade that ranges from the Paleozoic to the Recent. It radiated during the Cretaceous but its diversity diminished during the Cenozoic. The most distinctive character of the group is its bradyodont dentition. The dentition of chimaeroid fishes consists of two pairs of tooth plates in the upper jaw and one pair in the lower jaw. Chimaeroid tooth plates show hypermineralized tissue concentrated in areas called tritons, which never spread over the entire occlusal surface like in other holocephalian fishes. Associated holocephalian dentitions are uncommon. The specimen reported here is three-dimensionally preserved and consists of an almost complete dentition represented by five big sized tooth plates. The material was collected in the late Campanian Herbert Sound Member of the Snow Hill Island Formation in the James Ross Island, Antarctica. According to the size of the tooth plates, this specimen is one of the largest chimaeroid fish known. Also, this finding represents the oldest and the most complete dentition of a holocephalian fish from the Southern Hemisphere and the first record of the genus *Edaphodon* from the continent. Moreover and according to a character combination the specimen could be a new species.

## Reaction to form corona around garnet from Ongul Island in the Lützow-Holm Complex

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Corona structures provide us important information on P-T path of the rocks and mass transfer in the crust. This study described a corona structure around garnet in ultramafic gneisses from Ongul Island in the Lützow-Holm Complex, and estimated a reaction to form the corona based on the microstructure and chemical composition of constituent minerals.

The Lützow-Holm Complex increases metamorphic grade from amphibolites facies to granulite facies (Hiroi et al., 2006). The granulite facies metamorphic rocks are widely distributed throughout East Ongul Island, where garnet gneiss and hornblende gneiss occur regionally (Ishikawa et al., 1994). The ultramafic gneisses dealt with this study occur as thin layers in the garnet gneiss.

The ultramafic gneisses consist of hornblende-rich and plagioclase-rich domains. Both domains are composed of hornblende, plagioclase, brown biotite and orthopyroxene. Garnet also occurs in Hbl-rich domain and associates the corona consistig mainly of green biotite and plagioclase.

Garnet rim shows higher Fe and lower Mg than the interior.  $X_{an}$  of plagioclase increases in the order of Pl-rich domain, Hbl-rich domain and corona.  $X_{an}$  of one grain increases from core to rim. Ti and Al contents of biotite decrease in the order of Pl-rich domain, Hbl-rich domain and corona. The rim is depleted in Al than the core. Hornblende in Hbl-rich domain shows higher Al and Mg/(Fe+Mg) than Pl-rich domain. The rim is enriched in Al than the core. Orthopyroxene is almost homogeneous.

The compositional difference between core and rim of each mineral in the matrix can be regarded as growth zoning. We used the rim composition in each domain to estimate the corona-forming reaction. The reaction using the compositions of Hbl-rich domain was given as  
 $Grt + 1.10Bt + 3.25Pl + 0.76K + 0.81H_2O = 1.91Bt + 3.62Pl$ .

This suggests that K is supplied fluid during corona formation.

The feature of the corona restricted around garnet suggests that diffusion of component from garnet controlled the rate of the reaction.

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## Geological inheritance of West Antarctica - Echoes of past subduction and ongoing consequences

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Formed along the active margin of Gondwanaland in Paleozoic – Mesozoic time, the lithosphere of West Antarctica traces its origins to the Paleozoic accretionary margin of Gondwanaland. U-Pb, Hf and O isotope data from zircon, together with structural and petrological investigations in the Ford Ranges of Marie Byrd Land (MBL), illuminate the terrane history, transformation and stabilization of immature sediments derived from Ross-Delamerian orogeny into continental crust, and development of the broad West Antarctic rift province. In respect to terranes, distinctive zircon characteristics reveal the presence of domains having affinities outside MBL, that possibly constitute terranes or tectonic slivers. For continental crust evolution, the isotope data amplify our understanding of the two major magmatic events in MBL, both related to subduction. The former, from 375 to 345 million years ago, contributed to a widening and stabilization of new continental crust, followed by a long period of stability. An abrupt end came in Cretaceous time, high temperature metamorphism (115-105 Ma), alkali granite plutonism (105-101 Ma), and detachment faulting (102-98 Ma) occurred during transpression to transtension across Marie Byrd Land. Contemporaneous events in New Zealand make clear that New Zealand formed part of the affected region. Hf and O isotopes in zircon indicate crustal reworking and input from a more radiogenic, mantle-like source, most probably within a buoyant and hydrated mantle wedge beneath the leading edge of Gondwana. Ongoing mafic magmatism in Marie Byrd Land may reflect the continuing importance of hydrous mantle beneath West Antarctica. Geological faults and conduits for magmatism, established during the formation of the broad Antarctic rift system and rejuvenated in the present time, are consequential features within the geological setting for the West Antarctic ice sheet.

## Exploration of Gamburtsev Subglacial Mountains: Sampling and analysis plan

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The Gamburtsev Subglacial Mountains (GSM), located in the central part of East Antarctica, has highly dissected Alpine topography reaching maximum elevations of 3000 m and are completely covered by over 600 m of ice and snow. Even the intensive research of the GSM was carried out within AGAP project, only limited constraints on the topography, geology, and lithospheric structure are still available, and the origin of the GSM has been a matter of considerable speculation, in particular whether they are a hotspot or remnants of ancient orogenic events. The next step of the GSM exploration focuses on the direct observation of ice sheet bed by drilling. To penetrate into subglacial bedrock in the GSM region it is proposed to use cable-suspended drilling technology, in which an armored cable with a winch is used instead of a pipe-string to provide power to the down-hole motor system and to retrieve the down-hole unit. It is assumed to choose the drill site with the ice thickness at most of 1000 m and to pierce into the mountain slope to a depth of few meters. Proposed borehole construction includes five following steps: (1) dry core drilling of upper permeable snow-firn layer with bottom-air reverse circulation; (2) reaming; (3) casing installation; (4) fluid core drilling of glacial ice with bottom-fluid reverse circulation; (5) bedrock core drilling. All drilling equipment will be installed inside a movable sledge-mounted warm-keeping and wind-protecting drilling shelter that is transported to the chosen site with crawler-tractor. The new approaches of subglacial bedrock drilling technology are connected with utilization of environmental friendly, low-toxic drilling fluids: they have suitable density-viscosity properties, and can be consider as a viable alternative for drilling in glacial ice and subglacial bedrock. According to approved schedule, the first field tests are planned to carry out just outside Zhongshan Station near Antarctic coast in season 2015-2016. Next season 2016-2017 the movable drilling shelter is planned to be transported to the chosen drilling site in the GSM region, and drilling to the bedrock would be finished during two seasons. Besides the standard mineralogical, crystallographic, petrographic analysis, radioactive isotope methods (<sup>40</sup>K, <sup>230</sup>Th, <sup>234</sup>U, <sup>238</sup>U) and magneto-stratigraphy are planned to use for dating of rock samples. The borehole magnetometer will be deployed to measure the direction of the magnetic field, and borehole thermometer – to determine geothermal flux.

## Change of modal abundance of minerals of arrested charnockite from Sri Lanka

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Arrested charnockite occurs commonly in East Gondwana (Sri Lanka, south India and Antarctica). The formation of the arrested charnockite has been ascribed to infiltration of fluid and/or partial melting of the country rocks. The lines of evidence to support them include fluid inclusion (e.g. Hansen et al., 1987), field occurrence (e.g. Hiroi et al., 1990), isotope and trace-element variation (e.g. Burton and O'Nions, 1990) and thermodynamic consideration (e.g. Endo et al., 2012). These works have treated charnockite and gneiss as a single rock-type. This study describes modal abundance of minerals within each rock as a function of distance from the boundary of two rock-types in Sri Lanka, and explained temporal change of charnockite formation.

Charnockite and surrounding gneiss have layer structure composed of melanocratic and leucocratic parts. Each part continues across the boundary. The melanocratic parts consist mainly of hornblende and biotite. Orthopyroxene is added in charnockite. In the gneiss, modal abundance of hornblende and biotite has no systematic trend. In contrast, hornblende and biotite decrease in the charnockite drastically and gradually, respectively, while orthopyroxene increases gradually. The leucocratic parts are composed mainly of quartz, plagioclase and alkali feldspar. Biotite is present in the gneiss and decreases gradually toward charnockite, whereas it is absent in the charnockite.

It is emphasized that biotite was decomposed even in the outside of the charnockite in the leucocratic part. The element released from biotite in the leucocratic part migrated to melanocratic part to produce orthopyroxene. This migration may be driven by the former presence of orthopyroxene in melanocratic part due to breakdown of hornblende.

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## S17: SOUTHERN OCEAN PALAEOCEANOGRAPHY AND PALEOCLIMATIC MODELLING

### Is there a link between early Eocene opening of the Tasmanian Gateway and the onset of Eocene cooling?

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The early Eocene is an interval in the earth's climatic history with extremely warm Southern high latitudes. This warmth culminates in the early Eocene Climatic Optimum, 52-50 million years ago. Following this optimum, Antarctic and the Southern Ocean begin to cool, ultimately to temperatures that support the development of a large continental ice sheet on Antarctica. Initially it was hypothesized that the opening of critical Southern Ocean Gateways, Drake Passage and the Tasmanian Gateway controlled the Eocene climatic evolution. Of these gateways, at least the Tasmanian Gateway was mostly closed in the early Eocene, which prevented an isolating circumpolar ocean circulation. In turn it was hypothesized that the absence of such a circumpolar connection created the opportunity of a much stronger poleward oceanic heat transport which leads to warmer polar regions and the deep convection of warm water explains the warmer intermediate water temperatures seen in deep-sea oxygen isotope records. Opposition to this hypothesis came from numerical models opposing the idea that closed Southern Ocean gateways would result in increased poleward heat transport, and the timing of opening of the Southern Ocean Gateways did not coincide with the onset of Antarctic glaciation, and thus could not have been the primary force factor. Instead, the increase in proxy data for Cenozoic greenhouse gases (notably CO<sub>2</sub>) showed coherent patterns with the intermediate-water temperature evolution of the Eocene, and numerical ice sheet models could reproduce the buildup of an Antarctic ice sheet by only decreasing atmospheric CO<sub>2</sub>. This laid the foundation of the hypothesis that the decline of atmospheric CO<sub>2</sub> during the Eocene was the primary force for the Eocene climatic evolution. However, the greenhouse-gas hypothesis cannot explain why polar regions cool during the middle Eocene while tropical regions seem to show stable warm temperatures over the same time interval. With only atmospheric CO<sub>2</sub> as forcing, the cooling should have been much more uniform over the earth. As an additional factor, we here investigate the role of an as yet unnoticed early phase of opening of the Tasmanian Gateway, and its potential role in contributing to the greenhouse gas decline to fully explain the regional patterns of climate change during the middle Eocene. We have found evidence for the early opening through investigation of dinocyst biogeographic patterns from sediment cores from across the gateway. These biogeographic patterns were subsequently reproduced for different gateway scenarios using passive tracer experiments in an ocean circulation model. Also, we could correlate the onset of opening of the Tasmanian Gateway to the onset of cooling terminating the EECO with use of organic biomarker- and terrestrial palynomorph-derived paleotemperature estimates. We investigate the causality of cooling and opening of the Gateway through comparative model simulations with different Gateway scenarios. This combined model-data approach yields a robust insight into the possible climatic consequences of the early opening of the Tasmanian Gateway, and the implications to the Eocene climatic evolution of Antarctica.

## Episodic cooling and glacial initiation during the Late Eocene 'Pre-Icehouse' interval

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The history of global cooling and the state of polar glaciation leading up to the onset of Icehouse conditions at the Eocene-Oligocene Transition (EOT; 34 million years ago; Ma) are a matter of great uncertainty and debate. Deep-sea foraminiferal oxygen isotope ( $\delta^{18}\text{O}$ ) records represent a combined signal of temperature and ice-volume variation and provide valuable insight into climatic evolution during the Paleogene. In this study, we compile planktonic and benthic foraminiferal stable isotope records from multiple Southern Ocean sites spanning the late Middle-to-Late Eocene time interval (~43 to 34 Ma), including datasets from Ocean Drilling Program (ODP) Sites 689, 690, 738, 744, and 748 located in the Atlantic and Indian sectors of the Southern Ocean. The resulting composite record is of sufficient resolution to make general inferences concerning both long-term and short-term temperature variability in the Southern Ocean, and can be used to identify potential intervals of pre-Oligocene glaciation. The Middle Eocene Climatic Optimum (MECO) at ~40 Ma stands out as the most prominent warming reversal in the long-term cooling trend through the Middle-to-Late Eocene interval of the study interval—indicating that the MECO was the final major transient warming event of the Eocene. Post-MECO cooling was rapid and initiated a long-term cooling trend that culminated in the early Late Eocene at ~37 Ma (within magnetochron C17n.1n). The highest benthic foraminiferal  $\delta^{18}\text{O}$  values of the Eocene characterize this transient event, which we interpret as the most likely period of glacial activity prior to the EOT. Cooling combined with the transient development of small-to-medium size ice sheets during this event is supported by new detrital neodymium isotope data from ODP Site 738. This event was subsequently followed by several warming and cooling cycles that preceded major cooling and large-scale ice-sheet expansion at the EOT. In the broad perspective, the MECO represents a major turning point in Eocene climatic evolution, and unprecedented cooling in the post-MECO interval was associated with the development of a new Eocene climatic regime between ~38 and 34 Ma. This "Pre-Icehouse" interval, which was likely associated with multiple episodes of small-scale glaciation of Antarctica, set the stage for full-scale Icehouse development by early Oligocene time.

## The spatial extent and dynamics of the Antarctic cold reversal

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The Antarctic Cold Reversal (ACR) is a major millennial-scale cooling event during the last glacial termination. Here, we present a synthesis of Southern Hemisphere palaeoclimate records from ice core, ocean and terrestrial archives for the purpose of mapping its spatial extent. The observed pattern is compared to that simulated by a recent coupled atmosphere-ocean transient GCM run (the DGL-Overshoot-C experiment). Results from the comparison are used to test hypotheses for the proximal forcing of the ACR and to identify and explain regional differences in the dynamics of the Southern Hemisphere climate response.

We assess the Southern Hemisphere records using an objective statistical test. The test is based on the structure and timing of the ACR signal observed in a composite of five Antarctic ice cores. Our results show that ACR signals are expressed most strongly in the South Atlantic and at latitudes close to and south of the subtropical front. ACR signals are weak or absent in the remainder of the Southern Hemisphere, including the sub-tropics to tropics of South America, Oceania and Africa; instead, a number of records from these regions show warming trends that share significant covariance with Greenland ice core records of abrupt Greenland Interstadial -1 (Bølling-Allerød) warming. More complex signals are observed at the interface of the cooling and warming regions.

The modelled spatial extent of the ACR is in good agreement with observations. Observed cooling in the South Atlantic and Southern Ocean is consistent with a positive anomaly in northward ocean heat transport. At the same time, the observed warming at lower latitudes of the Southern Hemisphere is consistent with enhanced southward atmospheric heat transport and a strengthened Hadley circulation. Together, the results show that the atmosphere fluxes heat southwards in order to counteract the energy imbalance set up by the anomalous northward flux in the ocean. Deviations from this general picture may be explained in part by movement of ocean fronts, changes in climate modes (including a negative shift in the Southern Annular Mode and a La-Niña-like pattern in the Pacific) and the non-linear and/or threshold responses to climate changes that are expected in some proxies.

## Past and future wind changes over the Southern Ocean

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In this study, we use the new simulations from the CMIP5-PMIP3 exercise to look at changes in the winds over the Southern Ocean during the last glacial maximum (LGM), and compare them with the ones predicted for the warmer future climate.

We find that wind changes at the LGM are not a cold counterpart of the future ones: while the models simulate a systematic poleward jet shift with increasing CO<sub>2</sub>, the past changes are small and of inconsistent sign. This behavior can be attributed to the higher Antarctic ice cap during the LGM, which cools the atmosphere at high latitudes and increases the equator-pole temperature gradient near the surface, thereby compensating the effect of decreased CO<sub>2</sub>.

Both past and future behaviors of the jet in the different models can be well reconstructed using two indices of the temperature changes in the Tropics and at high latitudes.

## Impact on surface ocean dynamics during MIS 31 (ca. 1Ma) in subantarctic Atlantic and Indian sectors: the calcareous nannoplankton signal

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The micropaleontological analysis of sediments from ODP Site 1094, recovered in the subantarctic sector of the Atlantic ocean, allows us to interpret that a prominent southward displacement of the PF occurred during the mid-Pleistocene. According to our age-model, based in geomagnetic and biostratigraphic calibrated events, this period is dated at around 1 Ma, and corresponds to a marked eccentricity and high amplitude in the insolation signal during the interval of Marine Isotope Stage (MIS) 31. Five intervals are identified, based on the absolute coccolithophore abundance and different nannofossil assemblage composition, which allow us to reconstruct the position of the PF and SAF in this region. Intervals V and I (oldest and youngest, respectively) characterizes episodes with low abundance of coccolithophores and with a dominance of siliceous plankton, related to the position of the site in the PPZ. Interval IV contains the maximum abundance in coccolithophores, with an assemblage characteristic of the SAZ, close or related to the SAF. From this interval some coccolithophore taxa suggest a reduction in salinity, perhaps in response to a pulse in the melting of WAIS. Interval III reflects a northward shift of the PF, reaching the PFZ. Interval II is considered in this context as another southward pulse, but less important than during Interval IV, with a characteristic PFZ assemblage and influence of the SAF, but with reduction in the species related with the frontal system and/or melting processes.

IODP Site U1359 was recovered in Wilkes Land margin. Siliceous organisms are the main component of the micropaleontological assemblage. However, for the interval corresponding to MIS 31, several peaks in the carbonate composition was interpreted as pulses in the nannoplankton production in the region.

In this study we correlate at medium resolution episodes of high concentration/production of carbonate during the climate optimum defined ca. 1 Ma and their relationship with variation in the ocean frontal system, as well as events interpreted as pulses of melting in the Atlantic sector.

## The nearly 100 years hydrodynamic environment change in North Weddell Sea, Antarctic

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Over the past century, the global change characterized by global warming has affected Antarctic and the Southern Ocean. As one of the major generated place of the Antarctic Bottom Water (AABW), the Weddell Sea is a very important margin sea in Antarctic, its hydrodynamic environment change and its response has important significance to the global change. Therefore, the short sediment core sample of D5-6 was taken in the north of Weddell Sea, south to the South Orkney Islands and east to the Antarctic Peninsula. With <sup>210</sup>Pb dating, the hydrodynamic environment changes were analysed and discussed using the grain size parameter of D5-6 core sample. The results show that the hydrodynamic force of Northern Weddell Sea has significant change in nearly hundred years from 1922 to 2011. The 1972 is the cut-off point of transformation. In 1922-1972, the Northern Weddell Sea was in a high-energy, high-speed and turbulent hydrodynamic environment, and a large amount of ice raft debris was carried and deposited, which well corresponding to the relatively low stage temperature of the earth. In 1972-2011, the Northern Weddell Sea remained relatively calm and low energy hydrodynamic condition, which well corresponding to the relatively high temperature stage of the world keeping heating up. In 1955-1972, it is a rapid transition from the high-energy and turbulent state to the low-energy water dynamic of the Northern Weddell Sea. In the course of them, there were twice hydrodynamic environment weakened event happened during 1930-1936 and 1936-1952, which followed the subsequent global warming of 1937-1946 and 1952-1954. And two increased events of the Ice Raft Debris content also were found in 1937-1940 and 1948-1952, which have very good corresponding relationship with the sunspots burst frequently year. It is very interesting to learn that since 1955 the global warming stages no longer corresponds to the Valley years of solar activity, the global cooling stages also no longer corresponds to the solar maximum. The reason need make an intensive study on. So in a nutshell, the hydrodynamic environment changes in the Northern Weddell Sea is a perhaps feedback effect on the global climate and environment change.

## Paleoceanographic and paleoclimatic implications of epiphytic benthic diatoms rafted to Southern Ocean Miocene deep-sea sites on buoyant macroalgae

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Marine epiphytic diatoms in Miocene sediments from legacy cores collected in the 1970s at DSDP Site 269 offer new insight into Southern Ocean history. Their stratigraphic occurrence is episodic, suggesting variable paleoenvironmental controls on their delivery to this site. These shallow water diatoms were most likely rafted to this deep-sea site attached to buoyant macroalgae. Large epiphytic diatoms *Arachnoidiscus*, *Isthmia*, *Rhabdonema*, *Gephyra*, *Trigonium*, and smaller *Achnanthes*, *Cocconeis*, *Grammatophora*, and *Rhabdonema*, reflect a rich benthic diatom flora that maintained its position in the photic zone attached their seaweed hosts. High diatom growth rates provided biomass to a community of other organisms associated with these floating biotic 'oases'. Amphipods and other herbivores likely grazed the benthic diatoms and produced fecal pellets that were delivered to the sea-floor. Their discontinuous occurrence amongst the background of planktonic diatoms, suggests variable paleoenvironmental controls on the presence of the macroalgae and their release into the Southern Ocean. At the present time, arguments can be made for cold-induced or warm-induced scenarios to explain their cyclic occurrence. Similar benthic diatoms occur in IODP Exp. 318 cores, which are more continuous and better dated, and carry a host of modern proxy data to help identify what the benthic diatom record may represent in terms of sea-surface temperatures, extent and invagination of interior basin coastline, and discrete cooling events that may have caused lift-off of macroalgae in large quantities. Holdfasts of buoyant macroalgae are known to lift and transport large lithic fragments, and serve as the host for diverse communities of benthic invertebrates. The wide distribution of shallow benthic marine invertebrate taxa on widely separate subantarctic islands has been suggested by this dispersal mechanism. We are investigating benthic diatom co-occurrence with lithologies in the IRD-size fraction sediments to assess biological-rafted-debris (BRD) contribution of lithic materials to deep sea-sites. These data provide complexity, and potential, in provenance studies of deep-sea sediments. Too little is currently known about the microalgae and macroalgae associations of living material, though advances in this field would refine paleontological- and stratigraphical-based interpretations if benthic diatom species to macroalgal host relationships were better known.

## Reconciling proxies and fossils with Southern Ocean circulation models for the Paleogene

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Recent advances have resulted in a multiproxy-based terrestrial climate and marine temperature history for the Paleogene of the SW Pacific and Southern Ocean. Reconciling proxy-based climate reconstructions with models remains difficult but discrepancies may be explained by biases in the proxies and zonal heterogeneity as a consequence of variation in paleogeography and ocean circulation.

Marine microfossils provide a means to test proxy- and model-based climate reconstructions. They are well represented in numerous Paleogene sediment cores that span much of the global ocean and have key species with restricted geographic ranges. The results of analysis of paleobiogeographic data for three groups of marine plankton (radiolarians, planktic foraminifera and calcareous nannofossils) will be presented and discussed. Preliminary results indicate that microfossil-based meridional gradients during times of global warmth show a better fit with modeled sea surface temperatures (SST) than with the very low gradients indicated by geochemical proxies for SST. This suggests that extreme polar amplification indicated by geochemical proxies may be an artifact of summer bias at high latitudes or that existing calibrations fail to fully represent high-latitude conditions.

## Changes in sea surface temperatures and terrestrial input in the Southwest Pacific as recorded by molecular proxies

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The Australian-New Zealand region of the Southern Ocean is a highly dynamic area influenced by subtropical and subantarctic fronts and associated ocean current systems, thus a sensitive recorder of climate change. Here, we will present a record of terrestrial and marine climate variability over the last glacial-interglacial cycle in the Pacific Southern Ocean offshore Southeast New Zealand (Core PS75/99 retrieved from the Bounty Plateau). Sea surface temperature (SST) estimates were obtained using three independent organic proxies (TEX<sub>86</sub><sup>L</sup> based on C<sub>86</sub> glycerol tetraethers (GDGT), U<sub>37</sub><sup>K</sup> based on alkenones, and LDI based on long-chain diols). The organic proxy records show similar trends, however, with differences in absolute temperatures. Alkenone-based SSTs compare well with modern mean annual temperatures of about 8°C in that area while GDGTs reflect more spring/summer temperatures of 10-11°C. The SST records document glacial cooling of about 4-5°C implying a northward shift of major front systems and a stronger influence of polar water masses during the last glacial. Warmest SSTs are observed in the early Holocene, followed by a decline of about 1°C to modern SSTs in the mid to late Holocene. Terrigenous proxies, which are measures of continental vegetation and climate conditions, are based on long-chain n-alkanes (leaf waxes of land plants) and branched GDGTs (membrane lipids of soil bacteria). The spatial distribution of both terrigenous compounds in surface sediments in the South Pacific indicates transport in the organic fraction of aeolian dust to at least 115°W, although likely representing different carbon pools and sources. Dust deposition during the last glacial was 2-3 times higher compared to the Holocene in the pelagic South Pacific which may be related to stronger aridity in the potential source region in Australia/New Zealand. Enhanced winds may have facilitated dust uptake and export to the Pacific Southern Ocean. However, we expect that terrigenous sediment input to the Bounty plateau located relatively close to New Zealand is controlled by both aeolian and fluvial sediment input. Ongoing stable carbon and hydrogen isotope analysis of higher plant n-alkanes will give additional information on vegetation type and precipitation in the source regions.

## Ocean and atmosphere changes in the Pacific Southern Ocean across the last glacial-interglacial cycles

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The polar South Pacific comprises the largest Southern Ocean (SO) sector and therefore influences atmosphere-ocean processes on a global scale. Despite this global importance, relatively little is known about its Quaternary paleoceanography as few sediment records had been previously recovered from this remote ocean. Here, we present results from a new set of sediment cores collected in the mid- and high-latitude South Pacific during expeditions with RV Polarstern and RV Sonne over the past few years.

A major achievement is the generation of the first comprehensive data sets of glacial/interglacial dust supply cycles in the South Pacific indicating 3-fold higher dust deposition during glacial periods than during interglacials for the last million years. The first-order changes in Subantarctic biological productivity largely follow increased dust supply during glacials. Taken together our new sediment records document a substantial glacial dust supply from Australian and New Zealand sources to the Pacific SO eastward to at least 125°W. Such enhancement of dust supply is consistent with stronger aridity in Australia and a glacial dust source in New Zealand. Although the most likely dust source for the Pacific SO is Australia/New Zealand, the glacial/interglacial pattern and timing of lithogenic sediment deposition is similar to dust records from Antarctica and the South Atlantic dominated by Patagonian sources. These similarities imply large-scale common climate forcings such as latitudinal shifts of the southern westerlies and regionally enhanced glaciogenic dust mobilization in New Zealand and Patagonia.

Furthermore, our new sediment records allow for the first time to constrain in detail sea surface temperature (SST), sea-ice extent and seasonality, and biological productivity regimes since the last glacial on a wide spatial coverage in much of the Pacific SO. The new time series of the climate development since the last glacial document complex basin-basin contrasts in SST and sea ice extent variability in the Atlantic and Pacific sectors superimposing the effects of the Atlantic bipolar seesaw. Most unexpected is the finding of a distinct Pacific west/east gradient in SST and sea ice occurrence during glacial periods, with a strongly expanded perennial sea ice field north of the Ross Sea.

Taken together our data add an important and yet missing set of information to construct global scale scenarios of climate and ocean driving processes at different end members of climate states. Such data are critical to explain the physical and biological mechanisms controlling the variability in atmospheric CO<sub>2</sub> concentrations.

## Late Holocene paleoclimatic record of sediment from the Weddell Sea off the northern Antarctic Peninsula: preliminary results

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A 4.7-m-long sediment core JV10 covering about 4000 years was collected from the Weddell Sea located near the Joinville Island (63° 15'S, 55° 45'W), the northern tip of the Antarctic Peninsula. The study area is influenced by both Weddell Sea Transitional Water and Upper Circumpolar Deep Water, so it can be a good site to study ocean circulation of Southern Ocean. Six AMS radiocarbon ages were determined by carbonate shells at the CAIS (Center for Applied Isotope Studies) at the University of Georgia. No age inversions were observed, implying a lack of reworking during deposition. Sedimentological, geochemical, and micropaleontological parameters were analyzed to reconstruct paleoenvironmental changes. The core was visually described and sliced for X-radiographs, and analyzed to determine magnetic susceptibility (MS) and the content of total organic carbon (TOC) and calcium carbonate (CaCO<sub>3</sub>) content. Grain size is analyzed at 4 cm interval and diatom assemblage composition and abundance are analyzed at about 2 cm interval. Long chain alkyl 1,13- and 1,15-diols, specific lipids of diatoms of the genus *Proboscia*, are analyzed to test as a new proxy of sea surface temperature (SST). Chemosynthetic Bivalve shell *Calyptogena* sp. which is associated with the cold seep occurred at six horizons from ca. 4000 to 2500 yr BP. We postulate that the environment of study area was relatively stable during this period. It is consistent with the result of the James Ross Island close to the study area. After 2500 yr BP, MS, TOC, diatom abundance changed by about 500-year periodicity. This trend is being examined in terms of the Antarctic sea ice variability.

## Late Quaternary palaeoproductivity history of from the Indian sector of Southern Ocean using biogenic proxy records

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High resolution multiple proxy parameters ( $\text{CaCO}_3$ , opal, organic carbon and  $\text{Ba}_{(\text{excess})}$ ) studied in sediment cores SK200/22a and SK200/27 from the Subantarctic front (SAF) and Polar front (APF) regime of the Indian sector of Southern Ocean to reconstruct the palaeoproductivity variation and palaeoenvironmental changes during the last 95,000 years. The records indicate that in general, decreased carbonate productivity and increased opal productivity existed at the APF compared to the SAF region throughout the late Quaternary. The records suggest that substantial increase in productivity during MIS 2 - MIS 5 at both cores and increased opal productivity at Holocene at APF regime. The low bioproductivity during the LGM at the APF region deduced from the opal records, due to the intensified sea ice cover and limited consumption of upwelled biogenic silica. Biological productivity increased gradually after 18 ka BP, corresponding to the rising sea surface temperature, suggesting that the change in sea ice distribution influenced the bioproductivity at APF and SAF regimes in the Southern Ocean. In addition, enhanced aeolian dust input during the glacials had minor role on bioproductivity at core sites. At both core locations,  $\text{Ba}_{(\text{excess})}$  records are showing good correlation with opal records in both the core sites and correlates with millennial-scale variations in  $\text{CaCO}_3$  at SK200/22a, indicating that Ba is closely associated with both opal and carbonate productivity. Carbonate, opal and  $\text{Ba}_{(\text{excess})}$  records from these core suggest that the opal records are more reliable as proxy records of palaeoproductivity. Increased productivity, nutrient cycling and enhanced terrigenous influx were synchronously linked in the Indian sector of the Southern Ocean and the shifting of the ACC fronts and the shifting of CDW/AABW during the glacial periods may be the reason for the increased productivity at the core sites.

## Nd and Sr isotopic evidences for the provenance and transport mechanism of terrigenous sediment in the Indian sector of Southern Ocean

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Neodymium (Nd) and Strontium (Sr) isotope records of the terrigenous sediment fraction in two AMS <sup>14</sup>C-dated sediment cores from the Indian sector of Southern Ocean reveal fluctuations in the provenance and transport pathways during the late Quaternary. The <sup>87</sup>Sr/<sup>86</sup>Sr and <sup>143</sup>Nd/<sup>144</sup>Nd in the Subantarctic core (SK200/22a) ranges from 0.705 – 0.707 and 0.51245 – 0.51266, respectively. The εNd records of the SK200/22a (Subantarctic) and SK 200/27 cores varied between 0.4 – -3.7 and -0.2 – -5.3, respectively. The records revealed that the εNd values and Nd concentrations increased during the MIS 2 at both core sites and the lowest values were present during the interglacials (MIS 1, and MIS 5).

The Nd and Sr isotopic characteristics of the core sites are in agreement with the records from South Atlantic, Patagonia dust as well as some of the islands from the Indian sector of the Southern Ocean. The high εNd (0.4 – -5.3) and low <sup>87</sup>Sr/<sup>86</sup>Sr values (0.705 – 0.707), indicate that the most likely sources of sediment to the Southern Indian Ocean are the basaltic materials from the nearby volcanogenic islands and SW Indian Ridge with a minor contribution from southern South America. More juvenile rock component in the northern core SK200/22a compared to the core SK200/27 indicate an increased volcanogenic sediment input at the former site. Since wind driven erosion and bottom water processes greatly influences the supply and transport of the detrital materials at the core sites, stronger ACC due to increased glacial winds must have transported increased amounts of sedimentary material from nearby islands, making the εNd values comparatively high during glacial intervals.

## Southern Ocean records across the last deglaciation and their timing

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The last deglaciation is marked by rapid climatic events linked to large reorganizations of the deep ocean circulation. To decipher whether changes in the Southern Ocean have been leading changes in oceanic circulation or responding to North Atlantic circulation changes, and to define the role of the Southern Ocean in the evolution of atmospheric CO<sub>2</sub> concentrations, it is necessary to reconstruct the evolution of its stratification and its zonal behavior during the last deglaciation from well dated records. While deep sea coral data provide accurately the timing of deep water radiocarbon changes, sediment cores provide high resolution records of water mass changes, but the timing of these changes are difficult to assess accurately. Establishing a precise chronology for marine sediment records in high latitudes requires the determination of radiocarbon surface water age changes. We thus aim at tying marine to terrestrial records, using tephra deposited in marine and terrestrial region in the different sector of the Southern Ocean when it is possible. This work is in progress within a French-Swedish project. We will present results at different depth from South West Pacific sector of the Southern Ocean and preliminary results from the Indian sector. A precise chronology in the Indian sector requires to first establish the tephrochronology of Kerguelen Islands.

We compare these new records with previously published records of the Atlantic and Pacific sectors. It indicates that upwelling events drive radiocarbon changes in waters above 2000 m depth and atmospheric CO<sub>2</sub> increase and it seems that upwelling changes occurred simultaneously in the Atlantic and Pacific sectors. Oceanic circulation changes are not synchronous at deeper depth between 2500 and 4000 m depth.

## Glacial-interglacial variability of Antarctic sea-ice extent and frontal systems: implications for diatom abundance and size

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Antarctic sea-ice extent varied considerably during the glacial-interglacial periods, which is also known to have driven glacial-interglacial variations of atmospheric CO<sub>2</sub>. Similarly, enhanced Southern Ocean biological productivity during glacial periods is also believed to have contributed in glacial drawdown of atmospheric CO<sub>2</sub>. Here we present the glacial-interglacial changes in Antarctic sea-ice extent, Southern Ocean frontal systems, diatom productivity and size variation during the past ~ 95 ka BP. The present study is based on diatom assemblage from the Polar Frontal Zone of Indian Ocean sector of Southern Ocean. From the records of sea-ice diatoms, open ocean diatoms and ice rafted debris (IRD) it is evident that Antarctic winter sea-ice limit and Polar Front shifted up to the present Polar Frontal Zone during the marine isotopic stage (MIS) 2 and MIS 4. Whereas, there was a southward shift in Polar Front relative to its present position as recorded by the permanent open ocean zone diatom group during MIS 5. During the last deglacial period and MIS 5, a southward shift in Subtropical Front is evident from the records of sub-Antarctic Zone diatom group. Also an indication of coupling response between northern and southern hemisphere climate is apparent from the occurrence of IRD events during the Dansgaard-Oeschger cycles. Additionally, diatom absolute abundance and diatom valve size were reconstructed to investigate their responses towards migrating sea-ice extent and frontal boundaries. It was seen that during glacial periods diatom productivity was higher and diatoms had larger valve sizes as opposed to interglacial periods. This is believed to be due to the nutrient and iron replete conditions provided by the northward migration of Polar Front and 'opal belt' along with enhanced aeolian dust/iron flux during glacial periods.

**Southern Ocean endemism evident in Late Eocene radiolarian assemblages, DSDP Site 277, Campbell Plateau (New Zealand)**

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This project investigates the effect of extreme global warming on fossil radiolarian distribution in the Eocene (54-34 Ma ago), and aims to further advance the tools for Paleogene climate reconstruction and identifying the oceanographic changes that occurred prior to, and during, the build up of the first Antarctic Ice Sheets. The advantage of radiolarians is their greater overall diversity and abundance in high latitudes compared to calcareous plankton. Initial research is focussed on changes in radiolarian assemblages through the Middle Eocene Climatic Optimum (MECO) and post-MECO cooling interval (42-32 Ma) because this is an interval in which radiolarians are well represented in Southwest Pacific sediments, and documents the end of the Eocene greenhouse climate state.

The study is based on sediment cores from the high-latitude southwest Pacific (DSDP Site 277, Campbell Plateau) and Lord Howe Rise (DSDP Leg 21) and sedimentary sections onshore New Zealand (Marlborough). Radiolarian census studies of these records are used to reconstruct the southern extent of tropical water masses during the MECO. Interpretation of variation and trends in radiolarian assemblages entails a thorough review of Eocene radiolarian taxonomy and distribution with reference to key sites in lower latitudes and the Northern Hemisphere, such as the equatorial eastern Pacific (IODP Leg 320), the West Atlantic (ODP Leg 207, Demerara Rise), and the North Atlantic (IODP Leg 342).

Initial results for DSDP Site 277 show that the Middle Eocene radiolarian assemblages lack warm-water species and so the site was not influenced by subtropical currents during this time. However, we have not confirmed the presence of the MECO at this site. Radiolarian turnover accelerated in the early Late Eocene and peaked in the latest Eocene. Turnover was linked to the progressive expansion of Antarctic taxa, indicating that Southern Ocean cooling began prior to the E/O boundary.

## Deglacial changes in the Southern Ocean carbon pool – Implications from marine $\Delta^{14}\text{C}$ and $[\text{CO}_3^{2-}]$ records

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Throughout the transition from the last Glacial to the current Interglacial, rising atmospheric  $\text{CO}_2$  levels were accompanied by declining atmospheric  $\delta^{14}\text{C}$  values. A likely mechanism, influencing both components is the deglacial release of  $\text{CO}_2$ , stored for millennia in the deep Ocean, to the atmosphere. Due to its long residence time within the oceans interior this  $\text{CO}_2$  rich water mass was considerably depleted in radiocarbon. Although a large number of studies address this topic, the extent, location and pathways of the glacial carbon pool are still subjects of an ongoing debate. As deep water masses are upwelled and new intermediate waters are formed around Antarctica, the Southern Ocean is a potential area for the deglacial release of stored  $\text{CO}_2$ . Here we present radiocarbon and carbonate ion data from a transect of sediment cores off New Zealand that covers the major water masses in this area, from the AAIW down to the AABW. During the Glacial, our data locate a significantly  $^{14}\text{C}$  depleted pool in a water depth between 2000 and 4500 m. The combination of  $\delta^{14}\text{C}$  and  $[\text{CO}_3^{2-}]$  records provides new insights into the process of oceanic-atmospheric  $\text{CO}_2$  exchange in the Southern Ocean. In addition, our results yield new implications for contradicting  $\delta^{14}\text{C}$  records from the Southern Ocean and lower latitudes.

## Investigation of the grain size, shape, and texture of the Perseverance Drift, Antarctic Peninsula: transport history and Holocene variability

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Ice pulled back from shelf offshore the northern Antarctic Peninsula following the Last Glacial Maximum. Since then, sedimentary drift deposits have been forming, receiving sediment from a variety of sources. The Perseverance Drift is a 100m thick sedimentary drift deposit at the northwestern tip of the Antarctic Peninsula; the drift deposit is composed of laminated, olive-colored diatomaceous mud and ooze, carbonate shells, and many horizons of ikaite crystals. This study, which is under the umbrella of the LARISSA project, is using a 24m jumbo piston core collected in 2012 and is focused on using grain size, shape, and texture of sediments in the Perseverance Drift deposit as tools to determine sediment transport history and variations in the relative roles of current transport, iceberg-rafted debris, and aeolian transport bring sediment to the site. Grain size varies with distance from source and mechanism of transport. A Malvern Mastersizer LPSA was used for downcore grain size analysis every 5cm. In each interval, clay content ranges from 8-19%, silt content ranges from 50-85%, and sand content ranges from 0-36%. The high percentage of sand is interpreted as a result of the winnowing of fine-grained sediments by ocean currents leaving behind a sandy lag, the release of ice-rafted debris during the melting of icebergs, and the drift deposit's proximity to exposed sediment along the surrounding islands allowing for aeolian transport of coarse material. Aeolian deposits contribute to the drift via the seasonal melting of sea ice and are a source of iron that triggers large phytoplankton blooms. Transport mechanism has a great influence on grain shape: as glacial influence decreases, grain roughness decreases and as glacial influence increases, grain roughness increases. A Cilas LPSA was used to measure grain shape statistics of 52 intervals of high and low sand abundance. The majority of the grains from the drift deposit have low to medium sphericity values, indicating glacial transport; however, there are some smooth grains with high sphericity values, which indicate transport by either ocean currents or aeolian transport from surrounding sediment exposures. Plots of sphericity versus circularity allow determination of the respective transport history for each interval. Large mineral grains from the intervals of high and low sand content were chosen to study under the scanning electron microscope to examine the role of glacial transport by comparing the relative abundance of grain microtextures, such as deep troughs and fracture faces. The grains exhibit a high to medium abundance of these microtextures. By studying the differences in grain size, shape, and texture relative fluctuations in the different sediment sources and transport mechanism can be determined. We hypothesize that the intervals of higher abundance of aeolian transport may correlate to intervals of ikaite abundance.

## Carbonate deposition on Southern Tasman Rise, Southern Ocean during the last 2 Ma and its responses to the circulation system and orbital cycles

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Southern Ocean CaCO<sub>3</sub> deposition not only records the processes of the biological pump modulating atmospheric CO<sub>2</sub>, but also the changes in surface ocean frontal system and deep ocean circulation of the Southern Ocean. The fluctuations in CaCO<sub>3</sub> content and its mass accumulation rate (MAR) during the past 2 Ma at ODP Site 1170 from the Southern Ocean Tasman Rise indicate low values during glacial and high during interglacial times. Three CaCO<sub>3</sub>% regimes are roughly bounded by MIS 34/35 (1.15 Ma) and MIS 14/15 (0.55 Ma), and the MAR-CaCO<sub>3</sub> represents five phases fluctuation. Cross-spectrum and wavelet analysis between CaCO<sub>3</sub> and orbital parameters (ETP), and benthic δ<sup>18</sup>O record show a clear Mid-Pleistocene Transition (MPT) pattern of the main cyclicity transition from 40 kyr to 100 kyr during the 1.15-0.55 Ma. The variations in CaCO<sub>3</sub> deposition are closely related to the displacement in Southern Westerlies and Antarctic Circumpolar Current (ACC) frontal system during the MPT climate instability. Migration of Southern Westerlies and ACC frontal system during the MPT resulted in the dilution effect of siliceous deposition and terrigenous input to the CaCO<sub>3</sub> deposition. The MAR-CaCO<sub>3</sub> variability is linked to the changes in deepwater circulation and its carbon chemistry. Enhanced deep water ventilation during the 1.6-0.85 Ma favored the CaCO<sub>3</sub> preservation and the increased MAR-CaCO<sub>3</sub>, whereas the Circumpolar Deep Water depleted in CO<sub>3</sub><sup>2-</sup> enhanced during the 0.85-0.55 Ma, leading to the shoaled lysocline, thus enhanced CaCO<sub>3</sub> dissolution, and decreased MAR-CaCO<sub>3</sub>.

## Diatom export fluxes to the ocean interior in the Australian Sector of the Antarctic Zone

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The diversity and abundance of modern diatom assemblages in the Southern Ocean are intimately related to specific ecological parameters of the water masses where they live and hence their frustules can be used as biotic proxies for palaeoenvironmental reconstructions. However, in order to validate the fossil assemblage it is necessary to study the whole sedimentation process, from initial surface production to eventual preservation in the sediments.

As part of the ACE CRC SAZ Project, biogenic particle and diatom valve fluxes were recorded over a one-year period (2001-02) at 2000 and 3700 m depth at the Antarctic Zone of the Australian Sector of the Southern Ocean. Total particle and diatom fluxes were highly seasonal at both depth levels, with maxima registered in January, coinciding with the austral summer phytoplankton bloom and very low values during the winter months. A time lag of two months between peak production in the surface waters and onset of particle export was observed. Biogenic opal dominated sedimentation, followed by carbonate and organic carbon. The seasonal trend of diatom fluxes was mainly driven by changes in the flux of the open ocean and heavily silicified diatom species *F. kerguelensis*. The occurrence of the sea-ice affiliated diatoms *F. cylindrus* and *F. curta* in the trap samples could correspond to the sedimentation of a diatom bloom advected from an area upstream the ACC under the influence of sea ice. Highest fluxes of the deep-dwelling species *Thalassiotrix antarctica* registered at the end of the summer bloom were linked to a drop of the light levels during the summer-autumn transition. High correlation between the seasonal variability of particle fluxes registered by the upper and lower traps and similar diatom assemblage composition suggest fast and relatively undisturbed downward transport of particles between 2000 and 3700m.

## Centennial-scale climate variability of the Holocene Scotia Sea (Atlantic Southern Ocean)

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Holocene climate variability in the high latitude Southern Ocean is little studied due to the lack of high resolution records. Centennial-scale climate variability has been revealed by diatom based high resolution records from the Scotia Sea. Our study shows that, other than the northern Scotia Sea which displays similar climate development to the open Southern Ocean, the central and southern Scotia Sea remained stable during the Holocene with frequently visiting winter sea ice, even at the early Holocene Southern Ocean climate optimum. This may be attributed to the melting of Antarctic Peninsula ice sheet which induced persistent cold conditions in the south. Upwelled nutrients sustained the diatom productivity during the early Holocene due to the enhanced upwelling at that time. The Holocene megascopic ash layer in the Scotia Sea is dated at 8.1 ka, which provides an additional age marker for further studies in this area.

## Late Quaternary paleoceanography of the southern Drake Passage, West Antarctica: the preliminary results from sedimentology and geochemistry

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Two sediment cores (GC06-DP04 and GC06-DP05) were collected in the southern Drake Passage to reconstruct paleoceanographic changes and to illustrate sedimentation processes during Late Quaternary. The chronology of these cores is based on AMS-14C dates and the relative paleomagnetic correlations. The age models for both cores indicate that GC06-DP04 spans the last 80 kyr BP, while GC06-DP05 encompasses the last 50 kyr BP. Calculated sedimentation rates are in the range of about 1 cm/kyr. In terms of X-radiograph images and visual observation, manganese nodules and manganese-coated IRD (iceberg-rafted debris) are founded in the surface and the core, indicative of low sedimentation rate (<1 cm/kyr) which matches well with the calculated sedimentation rates. Together with sedimentological, XRF and isotopic data, the record provides paleoceanographic information back to the mid Pleistocene. Variability in sediment flux and elements seem to have been related to changes in oceanic water masses in the Southern Ocean.

## **S18: ENVIRONMENTAL CONTAMINATION OF ANTARCTICA**

### **Distribution of fecal coliforms in Antarctic seawater surrounding the permanent stations in King George Island (South Shetland Islands)**

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In Antarctic stations during the summer season the human population increases significantly in a short time, this can cause stress in the wastewater treatment system and changes in coast seawater quality due to increased production of wastewater. Sewage microorganisms have the potential to infect and cause disease or become part of the gut flora of local sea mammal and bird populations as well as fish and marine invertebrates. Consequently, it is important to minimize the release of human-derived fecal microorganisms. The current standard for detection of fecal pollution in surface waters is the determination of fecal coliform bacteria density. Fecal coliforms are used as indicators of enteric pathogenic organisms in aquatic environments

In order to evaluate the effect of wastewater discharges in the vicinity of the Antarctic stations, the spatial distribution of fecal coliforms was determined in the seawater near seven permanent stations located in King George Island, South Shetland Islands. Each of these Antarctic stations has different sewage treatment system. Five stations discharge their treated wastewater directly into the sea (Frei, Carlini, Great Wall, King Sejong and Escudero with Chilean Navy Station), one of the stations, Bellinhausen, discharges its treated wastewater to a small river flowing into sea and finally, the Artigas station stores its wastewater for transport out of the Antarctic continent.

In this study, seawater samples were collected from sites evenly distributed around the sewage outfalls of the stations. Control samples were collected from pristine sites. The samples were collected during January of 2014. Fecal coliforms enumeration was determined by membrane filtration using Chromocul Coliform Agar-ES medium.

High densities of fecal coliforms (maximum 29400 CFU/100 ml) were found in seawater surrounding the sewage outfalls. However, the bacterial counts decreased rapidly with increasing distance from the outfall. In all samples collected further than 150 m from the outfall, the bacterial indicators were absent. Fecal coliforms were not detected at the pristine sites or sites with presence of Antarctic wildlife.

The distribution of fecal coliforms in seawater exhibits a clear pattern associated with wastewater discharged. The levels found indicated that human activities could change the water quality of the Antarctica environment in specific sites.

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## Sources, speciation and transport of Hg, As, Pb, Cd and Cu in Deception Island, Antarctica

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Deception Island, an active Volcano in the South Shetland Islands with a large flooded caldera named Port Foster, is one of the most frequently visited sites in Antarctica.

In order to track the sources of natural and anthropogenic inputs of trace elements (Hg, As, Pb, Cd and Cu) into that ecosystem, samples were collected from several environmental compartments (water, ice, snow and sediments) in different locations of the island, as well as in saline waters of Port Foster using diffuse gradients in thin film (DGT) devices, from 1 to 20th December 2011.

Concentration values for Cd were consistently high in saline waters but not in land, pointing to the existence of a natural and diffuse source possibly related with underwater hydrothermal activity. On the other hand it was found that Cu and Pb values should be related with important punctual sources.

Interestingly, higher concentration values of As were found in samples collected in or near spring water courses and its transport may be related with processes of lixiviation in underground waters. The results suggested that volcanic activity is the most important Hg source. Mercury levels in water and sediments sampled at two fumaroles were up to 10,000 times higher than in the other sampling sites. Dissolved methylmercury (MeHg) is below the detection limit in those samples, probably due to the very high temperature found in fumaroles (above 80 °C). On the other hand MeHg accounted for, on average, 23% of total dissolved Hg in the saline waters of Foster bay, which suggests exceptional conditions for Hg methylation. Combined with the high residence time of the water in Foster bay, the results point to the existence of a MeHg pool available for aquatic living organisms.

The high Si/Al ratio, low carbon content, and a non-significant anthropogenic heavy metal input may explain the surprisingly homogeneous heavy metal content found in sediment samples.

## Trace element concentrations in environmental samples from Fildes Peninsula (King George Island, South Shetland Islands, Antarctic Peninsula): A potential problem?

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Compared to the Arctic, much less is known about sources, biogeochemistry and fate of contaminants in Antarctica. The frozen continent is considered pristine; however human presence in Antarctica has resulted in a sharp increase in anthropogenic pressure, leading to pollution problems, predominantly near scientific stations. The South Shetland Islands may be particularly vulnerable to human impacts as they contain one of the highest concentrations of research stations on the continent. Consequently, appropriate environmental monitoring is essential to inform the actions of Treaty Parties and national programme managers active in this region.

In the austral summer season of 2012/2013 and 2013/2014 two field campaigns were performed on Fildes Peninsula. Sediment/soils, water, ice/snow and vegetation were sampled at several sites in the Bays of Fildes, Great Wall, Elephant and Collins and analyzed for particulate and dissolved As, Cd, Cu, Hg (including MeHg), Pb and Zn. Some other interpretative parameters were also determined (e.g. organic carbon). In the laboratory trace element chemical and biological availability tests were also performed.

Results from the 2012/2013 campaign, showed Hg (and MeHg) concentrations to be low; however, high levels of up to 2000 ppm of Pb, 15 ppm of Cd and/or 418 ppm of Cu were determined in soils samples from two locations on Fildes Peninsula. In water samples from the same area, a maximum concentration of 0.58 ppb of Pb was found, which is considerably higher than other reported values for Antarctic waters. For all trace elements analyzed, concentrations in the lichen *Usnea antarctica* reflected the concentrations on the corresponding soils, indicating efficient uptake.

These results point to the importance of a recent field campaign, that took place February in 2014, the results of which will be presented at this meeting.

Our work, in agreement with the evidence of earlier researchers, suggests a potential contamination problem in Fildes bay. It is hoped that environmental managers operating in the area will note these data and take appropriate action.

## PBDES in Antarctic soils

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Antarctica is usually considered a pristine ecosystem, nevertheless it is influenced by persistent organic pollution, mainly due to a cold-trapping process driven by long-range atmospheric transport (LRAT). Local sources such as research stations also contribute to contamination. Polybrominated diphenyl ethers (PBDEs) are toxic flame-retardant pollutants that have been recognized to affect the Antarctic environment, deriving from both kinds of sources. Moreover, fire hazards constitute a major concern inside Antarctic research stations, because of the dry weather conditions. The abundance of PBDEs-containing materials, such as insulating polyurethane foams, flame-retarded plastics and electronics, constitutes a potential source of contamination for the surrounding environment.

In this work, we focus on the determination of PBDEs in soils sampled during the 27<sup>th</sup> Italian Antarctic Expedition (austral summer 2011–2012) in seasonal ice-free areas around the Mario Zucchelli Station (MZS) in Antarctica. Six samples were collected in the immediate proximity of the base, including downstream the passing-through drainage of melting snow. Another soil was sampled close to the refuelling point of the landing strip for Twin Otter (2 km from the base) and three samples were collected in two “clean” reference sites (Faraglione Camp, Gondwana 3 - 10 km from the base).

PBDEs were extracted from about 10±0.01 g of dry sediment by means of a Pressurized Liquid Extractor (PLE™, FMS) and purified onto a disposable neutral silica column with an automated system (PowerPrep™, FMS). Analyses were performed by High Resolution Gas Chromatography-Low Resolution Mass Spectrometry (HRGC-LRMS). Quantification was performed using internal standards and isotope dilution techniques. Results were corrected using procedural blanks.

Total PBDEs concentrations range from 0.5 to 33 ng g<sup>-1</sup>, with the highest levels found near the station, where decabrominated BDE-209 dominates (0.1-32 ng g<sup>-1</sup>). The presence of this heavy compound indicates a local source, indeed it was not detected in the reference samples, in agreement with its low volatility. According to literature, the other major compounds are BDE-47 and BDE-99, more prone to LRAT.

Human activities at the MZS constitute a source of PBDEs to the environment, but are likely to affect only a local area.

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## Survey of Mt. Erebus fumarolic ice caves for human contamination

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Fumarolic ice caves in the summit area of the Mt. Erebus volcano have attracted much attention from the scientific community, visitors to Erebus summit and from the popular media. Scientists have examined the caves to study volcano outgassing and the unique extremophilic microbial communities that are associated with Fumaroles and Dark Oligotrophic Volcanic Ecosystems (DOVE's) in the summit area of the Mt. Erebus volcano. In particular with the beginning of microbial research, it has also become obvious that some caves are contaminated from previous human entries. The nature of the identified contamination suggests that some of it is related to the use of these caves as a shelter and a comfortable place for eating and smoking. Other contamination suggests the presence of (eukaryotic) microbes that are uniquely associated with humans. Additional contamination may be due to the introduction of organic carbon compounds that are alien to these oligotrophic environments. These concerns, in addition to the extreme value of these caves as research objects motivate our effort to begin a conversation that aims at protection of the integrity of these caves and establishing a code of conduct that maximizes the value of these caves to all scientists wanting to study them.

We have found that Warren Cave has many species of fungi associated with human contamination and have expanded our survey to include ten additional caves. Previous work has identified a number of fungal species associated with skin and hair. The purpose of this survey is to help inform the Antarctic Environmental protection committee devise a management plan for the caves by determining which caves have human introduced contamination.

## Investigation of the depositional characteristics and sources of perchlorate in Antarctic snow

Cox T

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Perchlorate is used as an oxidizer in solid rocket fuel, munitions, fireworks and other applications. It can be dispersed into the environment through both the manufacturing process and applications. Environmental perchlorate may also come from natural sources via a probable atmospheric production mechanism that has not been fully characterized. Polar snow and ice cores can be used as an investigative tool to assess the environmental concentrations of perchlorate.

Previous works regarding perchlorate in the environment have evaluated the depositional history of perchlorate in the Northern Hemisphere via non-polar ice cores in North America and ice core samples from central Greenland. Limited effort has been focused on the evaluation of perchlorate in the polar region of the Southern Hemisphere. The goal of this project is to achieve just that via the following objectives: (1) determine the levels of perchlorate in Antarctica, (2) investigate the depositional characteristics of perchlorate, (3) identify correlations of perchlorate with other ions, (4) investigate the potential source(s) and source contributions of perchlorate (eg, oceanic, atmospheric, continental, etc). Ion chromatography tandem mass spectrometry (IC-MS/MS) method was used for perchlorate measurements. We have measured perchlorate concentrations at the sub-parts-per-trillion level in well-dated Antarctic snow samples. These high-resolution, sub-annual perchlorate measurements will be compared with the major ion fluctuations to investigate possible correlations. This data will aid in investigating the possible production pathways and sources of perchlorate in the Southern Hemisphere.

## Persistent organic pollutants (POPs) at Ross Sea (Antarctica) and through Circumpolar Deep Water

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The Antarctic region is ideal place for environmental studies of the marine ecosystem both near the coastal line and off-shore, due to the almost total absence of local pollution sources. In fact, pollutants reach Antarctica almost exclusively by long range transport processes involving both the atmosphere and the hydrosphere. The Circumpolar Deep Water (CDW), the largest circulation feature of the Southern Ocean, is mainly responsible for the rather limited exchange processes between the Antarctic seas and the outer oceans, thus it may be a possible source of persistent organic pollutants (POPs).

The most significant findings on the presence of POPs in the marine ecosystem at Ross Sea and on CDW circulation will be discussed. Seawater samples were collected in many sampling sites located in a large area of the Ross Sea and during the travel to and from Antarctica during the XXVIIth Italian expedition. Two classes of POPs are considered, namely polychlorobiphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs).

Some data was also obtained on the mixing process between two important water masses present in the area of the Ross Sea under investigation: the Modified Circumpolar Deep Water (MCDW) and the High Salinity Shelf Water (HSSW). The MCDW, relatively warmer, comes from the external oceanic circulation in the Pacific sector of the Southern Ocean, whereas the HSSW, relatively colder, is generated inside the Ross Sea basin. Both move towards Cape Adere where they mix. The intrusion of MCDW in the colder HSSW is clearly evident: the very sharp change in the temperature at about 170m depth from -1.5 °C (typical of the HSSW) to +0.2 °C (typical of the MCDW) is in very good agreement with a sudden change in the PCB concentration by a factor of two. The same behaviour was also observed for the total content of PAHs.

This is the first experimental evidence of the pollutant input in the Ross Sea basin from the external oceanic circulation, which happens in a period of the season when the ecosystem is particularly sensitive since the biological activity is at its peak.

## Vertical distribution of Polychlorinated Biphenyls (PCBs) in sediment cores from Admiralty Bay, King George Island, Antarctica

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Polychlorinated biphenyls (PCBs) were globally used in products such as electrical transformers and capacitors, lubricants and hydraulic fluids. PCBs are highly persistent in the environment, lipophilic and bioaccumulative, being ubiquitous contaminants in the marine environment. Their presence has been detected in the Antarctic continent since the decade of 1970.

Sediment cores (length  $\leq 20.5$  cm) were taken at nine different locations in Admiralty Bay: Martel Inlet: (a) Ferraz Station; (b) Botany Point; (c) Ulmann Point; (d) Stenhouse Point. Mackellar Inlet: (e) Refuge II; (f) Crepin Point. Ezcurra Inlet: (g) Arctowski Station; (h) Barrel Point; (i) Thomas Point. The samples were collected by scuba divers or box corer.

Concentrations of total PCBs ( $\Sigma 51$  congeners) in the sediment samples ranged from <DL (below detection limit) to  $36.21 \text{ ng g}^{-1}$ . The predominant congeners were PCB 52 > PCB 101 > PCB 95 > PCB 70 > PCB 110 > PCB105, which agrees with previous data on congener composition in this area.

Sediment core (a) presented the highest concentrations, with mean concentration of  $8.72 \pm 5.32$ . The PCB peak ( $36.21 \text{ ng g}^{-1}$ ) was detected in the layer corresponding to the year 1985, right after the installation of the Brazilian Station in 1984.

The PCB levels in sediment core (b), (d), (f), (g), (h) and (i) were basically constant, with mean concentrations of  $2.67 \pm 0.25$ ,  $1.43 \pm 0.54$ ,  $1.51 \pm 0.50$ ,  $1.68 \pm 0.75$ ,  $1.06 \pm 0.65$  and  $1.51 \pm 0.58 \text{ ng g}^{-1}$ , respectively. The cores (g) and (i) are located relatively close to each other, and their higher values ( $3.98$  and  $2.69 \text{ ng g}^{-1}$ , respectively) were detected at the same estimated year, in 1987. The mean concentrations in the sediment cores (c) and (e) were  $4.38 \pm 1.90$  and  $3.46 \pm 2.01 \text{ ng g}^{-1}$ , respectively. The highest levels in the cores (e) and (f) ( $3.46$  and  $1.51 \text{ ng g}^{-1}$ , respectively) was detected in relatively recent sediments, corresponding to the year of 2004.

Long-range transport of PCBs is well documented in scientific literature, and the presence of low-chlorinated congeners (up to 5 chlorine atoms) usually indicates that the PCB contamination originates from distant sources. These congeners registered the largest PCB contribution in the sediment cores analysed, with a mean contribution of 85% of total PCBs. Despite this fact, the presence of some high-chlorinated congeners (PCB 138, PCB 149, PCB 153) in some sediment cores also suggests possible local sources of PCBs, during the period of construction of old Brazilian station.

## Summer variation of Antarctic coastal zooplankton of Admiralty Bay, King George Island, Antarctica

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Zooplankton is a component of the plankton constituted by a diversified group of organisms that live in the water column of the oceans. Zooplankton community structure have been used as an indicator of environmental variability in the Antarctic ocean and are useful in monitoring program to evaluate natural and anthropic activities. Since 2009 a Brazilian multidisciplinary monitoring program, INCT-APA – Thematic Module 3, whose objective is to evaluate the impact of anthropic activities on Antarctic marine environment is being conducted in Admiralty Bay. The assessment of zooplankton communities near research stations could be an important tool in the environmental monitoring of the Bay. With the purpose to contribute to the monitoring program this study focuses on zooplankton community analysis to provide data to support environmental management processes and instruments. Biological samples and environmental data were obtained in four shallow areas (stations 1, 3, 4 and 5) located in front of research stations and a reference area at Botany Point (station 2). Hill diversity index among stations was calculated. One-way analysis of variance was used to determine the statistical difference in the density and diversity of taxa among stations. Principal Component Analysis on a correlation matrix, was performed of the plankton abundance data combined with a suite of environmental variables likely to influence zooplankton abundance at the sampling locations. A total of 15,882 organisms were sorted from 55 samples resulting in a total density of 303 organisms/100m<sup>3</sup>. Nineteen taxa were identified. Copepoda were the most common and abundant group of holoplanktonic organism and larvae of echinoderms followed by polychaetes were the dominant group of meroplankton. The results of Principal Component Analysis emphasized the importance of phosphate and dissolved oxygen for holoplankton, as nitrite and water temperature for the meroplankton during the sampling period. Distinct differences in species diversity were observed between the group of stations 5, 4, 3, 1 and the reference station 2. Hill (N1) diversity index indicated higher values for station 5 > 4 > 3 > 1 and lower value for reference station 2. The dynamics of the water circulation and the wind regime of the bay associated to the presence of the research stations and the discharge of nutrients from the ornithogenic soils in the west coast of the region probably favored the increase of primary production and in consequence of the zooplankton.

## Environmental contamination by persistent organic pollutants (POPs) in Admiralty Bay - Antarctic Specially Managed Area (ASMA 1)

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Persistent organic pollutants (POPs) comprise different synthetic chemicals, such as chlorinated pesticides (OCPs) and polychlorinated biphenyls (PCBs). These compounds represent a group of persistent and toxic pollutants that are globally distributed via the atmosphere and transferred to remote and polar regions.

Admiralty Bay is located on King George Island, and was designated by the XX Antarctic Treaty Consultative Meeting (ATCM) in 1996, as the first Antarctic Specially Managed Area (ASMA-1), due to its outstanding environmental, historical, aesthetic and scientific values.

A range of data on levels of POPs was compiled, especially on chlorinated pesticides and polychlorinated biphenyls from Admiralty Bay in the last three decades (1978-2007) to evaluate the bioaccumulation and temporal trend of environmental contamination by POPs.

The predominant pollutants were: PCBs>DDTs>HCB>HCHs. New contaminants, such as polybrominated diphenyl ethers (PBDEs), have also been detected in the Admiralty Bay, but at low background levels. Tissue concentrations of pesticides in marine birds and mammals remain low compared with levels in similar species from regions with relatively high environmental pollution, and migrant species may show higher concentrations than predominantly endemic species.

DDEs/DDTs ratios > 0.8 for several Antarctic organisms suggest contamination by old DDT. However, cold condensation implies that polar regions will be a sink for most volatile pollutants, and that these compounds may then be present at higher environmental levels than at lower latitudes. On this basis, animals occupying a specific trophic niche in a polar ecosystem may have higher POPs loading than the corresponding species in a temperate or tropical ecosystem. Furthermore, Antarctic Peninsula has increased 6°C in the last 30 years, increasing the volume and frequency of glacial retreat and melt water contributing thereby to the release of POPs in the Antarctic environment.

Temporal trends for POPs in Admiralty Bay show a marked decline for DDTs and HCHs from the 1990s to the 2000s whereas PCBs are constant over time, despite the decrease in environmental levels.

These results contribute to elucidate the degree of contamination that Admiralty Bay – Antarctic specially managed area (ASMA-1) is exposed to POPs and emphasize the need to enforce the Protocol on Environmental protection to the Antarctic Treaty.

## Assessment of sewage input and baseline concentrations of faecal sterols into different inlets of Admiralty Bay, King George Island, Antarctica

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The Antarctic region is considered one of the best preserved environments in the world, particularly sensitive to anthropogenic changes and highly susceptible to human impact due its remote location and weather conditions. Local sources of contamination in the Antarctic area include scientific activities, fuel usage, garbage incineration and sewage. In this study, we report baseline values of faecal sterols in Admiralty Bay, Antarctica.

Four sediment cores were collected during the 2006/2007 austral summer at the Ezcurra (THP and BAR), Mackellar (REF) and Martel (BTP) inlets, located in Admiralty Bay, King George Island.

Faecal sterols (coprostanol and epicoprostanol) are organic markers that have been used to detect sewage inputs in Antarctica, as an alternative to faecal microorganisms due to their specific source, resistance to degradation processes and chemical stability under specific temperature and salinity conditions. In addition, faecal sterols can be associated with the faeces of marine mammals (e.g., whales and seals).

The determination of baseline values of these organic markers in different Antarctic regions is important to provide information about natural sources of faecal sterols and to assess anthropogenic impacts, particularly for studies near established scientific stations.

Concentrations of faecal sterols (coprostanol + epicoprostanol) were  $<0.16 \mu\text{g g}^{-1}$ , suggesting no sewage contamination and probable biogenic contributions for these compounds. Despite the proximity of these sites to human activities, the concentrations of coprostanol in all samples analysed were below the established limit and suggested no/low sewage input in these regions.

Baseline values, calculated using the mean concentration of faecal sterols in core layers for THP, BAR, REF and BTP, were  $0.04 \pm 0.02$ ,  $0.03 \pm 0.01$ ,  $0.07 \pm 0.01$  and  $0.04 \pm 0.02 \mu\text{g g}^{-1}$ , respectively.

These results established as natural contributions of faecal sterols, suggesting that these markers can be useful indicators of human-derived faecal input and contributing to monitoring programs of anthropogenic impacts. Full text: <http://dx.doi.org/10.1016/j.marpolbul.2013.10.034>

## Possible role of selenium against the toxicity of cadmium in Antarctic skuas

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Skuas are seabirds at the top of Antarctic food chain and therefore susceptible to the accumulation of contaminants, including the heavy metals. Cadmium (Cd) is a highly toxic metal, neurotoxic and it is naturally found in high levels at Antarctic webs. Selenium (Se) is an essential element for most of vertebrates. It is well known that Se acts protecting the organism against the toxicity of heavy metals. In recent years the use of non-destructive methods to determine levels of contaminants in birds are becoming more common and feather analysis is considered to be one of the most effective. When feathers are growing metals bind the feathers proteins and get trapped into the tissue, so the levels of metals in the feathers become stable. This study aimed to investigate if Cd levels can influence Se levels in Antarctic Skuas (*Catharacta maccormicki* and *C. lonnbergi*). Samples of breast feathers were collected from 17 South-polar-skuas (*C. maccormicki*) and 12 Brown-skuas (*C. lonnbergi*) in 2010/2011 and 2011/2012 (Antarctic summers), in Keller Peninsula and Hennequin Point (King George Island, Antarctic Peninsula). Feathers were washed to eliminate external contamination. The samples were solubilized and analyzed in an Atomic Absorption Spectrometer (ETAAS). The results were standardized with the mass of the samples and the levels of Cd and Se are expressed in  $\mu\text{g}\cdot\text{g}^{-1} \pm$  standard deviation. The concentration of Cd found for *C. lonnbergi* ( $30.3 \pm 15.6$ ) were significantly higher than for *C. maccormicki* ( $18.8 \pm 12.4$ ; *Mann-Whitney Test*-  $U= 2.29$ ;  $p<0.05$ ). The levels of Se did not differ significantly for both species (*C. maccormicki*:  $2988.5 \pm 1068.9$ ; *C. lonnbergi*:  $2487.9 \pm 935.7$ ). There was a positive and significant correlation between the molar concentration of Cd and Se only for *C. maccormicki* ( $r^2 = 0.31$ ;  $p<0.05$ ). These results indicate that the levels of Se follow the levels of Cd in *C. maccormicki*, indicating that Se seems to have an important role in the process of detoxification and elimination of Cd to this specie. For *C. lonnbergi* there was not any relation between concentrations of Cd and Se. Although this two species are very similar, they may have unknown physiological differences. Thus, these physiologic aspects should be better investigated and other factors like gender, age, diet and nutritional status need to be taken into account to evaluate the real role of Se and Cd in both species.

## Bioremediation of Casey Station, Antarctica using biopiles: A microbial community investigation

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Hydrocarbon contamination in terrestrial Antarctica is widespread and poses a major threat to the sensitive ecosystem. Successful remediation of contaminants requires not only site-specific methods but also the development of distinct end-point targets. In order to understand the impact of hydrocarbon contaminants on the ecosystem and the effects during the bioremediation process it is important to gain insight into the affects of remediation on the inherent microbial communities. The focus of this study was Casey Station, Eastern Antarctica: a region that is highly contaminated with petroleum hydrocarbons (TPH). The site is currently undergoing bioremediation through the construction of biopiles and to our knowledge this is the first construction of biopiles in Antarctica. Our aim was to assess the effectiveness of the bioremediation process by investigating the bacterial communities and associated gene functions present in the contaminated soils within the biopiles, prior to and during the bioremediation process. A comprehensive analysis of environmental variables, including the distribution of TPH showed an average 67% decrease in TPH concentrations within the biopiles over the course of the 2-year study. Within the area surrounding Casey Station, TPH was found to be the main driving force contributing to bacterial community structure, while ammonium was the main influence within the active biopile communities. Microbial community fingerprinting and 454 tag pyrosequencing targeting the 16S rRNA gene were also examined combined with quantitative PCR targeting functional genes. Significant shifts in both the bacterial community and functional gene abundance were revealed that complemented the observed reductions in the levels of TPH. These results confirmed that bacterial communities were indeed active throughout the bioremediation process. More importantly, for the first time, we have successfully demonstrated bioremediation through the construction of biopiles as a viable strategy for petroleum hydrocarbon remediation in Antarctica.

## Environmental gradients determine soil microbial diversity and sensitivity to petroleum hydrocarbon toxicity in Antarctica

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Petroleum hydrocarbon contamination is extensive throughout the Polar Regions and particularly prevalent around areas of concentrated anthropogenic activity. Whilst toxicity information is limited there is evidence to suggest that petroleum hydrocarbon contamination is more damaging near the poles than in temperate regions due to the low temperatures, low nutrient availability and extended exposure to the contaminants. As the dominant biota present in Antarctic soils, microbial populations are ideal candidates to target for the development of appropriate ecotoxicology assays. Bacteria in particular are valuable indicators of ecosystem health due to their pivotal role in biogeochemical cycles, nutrient cycling and ecosystem sustainability. In this investigation, soil samples were collected from five locations within Eastern Antarctica and sub-Antarctic Macquarie Island. Bulk soils were collected and spiked with Special Antarctic Blend diesel fuel across a concentration gradient. The environmental variables of soils were measured including pH, conductivity, grain size, percentage mud, percentage sand, total Carbon, Nitrogen and Phosphorus content, and the concentration of ions including Calcium, Sodium, Potassium and Magnesium. Total genomic DNA was extracted from the soil samples in triplicate and after initial community fingerprinting analysis, representative DNA extracts were sequenced targeting the bacterial and fungal portions of the community with the use of high throughput tag pyrosequencing using the Roche 454 FLX Titanium platform. Soil fertility, including total nitrogen and the organic carbon content was found to be the most important edaphic control on microbial richness and evenness, whereas pH was the key controller of composition and phylogenetic diversity. The diversity, species richness, species evenness and similarity indices declined with increasing diesel fuel concentrations. Yet, the greatest response of the diesel fuel was to alter relative abundances of key lineages rather than remove entire species. This response was consistent across all soils but varied in the severity of the response between locations. Key processors within the nitrogen cycle were also inhibited but the severity of the response was site-specific, highlighting the need for site-specific remediation targets to be established.

## **Out to sea: Antarctic research station effluents as a source of organic micropollutants in coastal waters**

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Antarctica is considered to be one of the last untouched wilderness areas on earth and as such is the focus of intense scientific investigation. The growing influx of science staff in the spring/summer season has increased focus on reducing the environmental impacts of scientific research activities in Antarctica. Many of the research stations are located in coastal areas into which they discharge sewage. Only 63% of the permanent bases and 31% of the summer stations have any kind of sewage treatment. Research parties undertaking extended periods of fieldwork are allowed under certain circumstances to dispose of raw sewage via tidal cracks in the sea ice. Sewage discharges are a significant source of organic micropollutants entering aquatic environments. Personal care products including soaps, sunscreens and toothpaste are a key source of organic micropollutants entering sewage treatment plants. Environmental monitoring for the presence of organic micropollutants in Erebus Bay was undertaken over two field seasons to determine if micropollutants from personal care products were present in treated sewage effluents and were being released into Antarctic coastal waters. Wastewater samples from two Antarctic research stations, McMurdo Station (USA) and Scott Base (New Zealand) and seawater samples from the surrounding coastline were analysed for a suite of organic micropollutants. Marine biota collected from Erebus Bay including fish, clams and sea urchins were also screened for selected contaminants. Organic micropollutants were detected in the treated effluents as well as at all of the sea water sampling locations including the reference site located up current of the research stations. The compounds detected in seawater and sewage effluents included paraben preservatives, triclosan, octylphenol, bisphenol A, UV-filters, and the hormone estrone. Target analytes were detected in both wastewater and seawater at concentrations similar to those reported in temperate environments with higher population densities. Paraben preservatives, octylphenol and steroid hormones were detected in the marine organisms. The environmental fate of the detected compounds will be discussed in terms of Antarctica's unique environmental conditions. The implications for monitoring and management of sewage effluents from Antarctic research bases will also be discussed.

## Increased sensitivity to contaminants and risk to subantarctic marine invertebrates under predicted climate change scenarios

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Stressors associated with climate change, and contaminants resulting from the activities of humans, are affecting organisms and ecosystems worldwide. Until recently, the impacts of these stressors on marine ecosystems have largely been examined in isolation. High latitudinal species may be more susceptible to contamination and climate change than equivalent species in temperate and tropical areas. Detoxification of contaminants by polar species is likely to be slower due to slow metabolisms in colder climates. Organisms in polar regions also have characteristically small temperature tolerances through adaptation to relatively stable and low oceanic temperatures. Therefore, any increase in ocean temperature associated with climate change is likely to be particularly detrimental to marine ecosystems in these areas. Despite this, very little is known of how climate change stressors and contamination will affect Antarctic and subantarctic species, nor how these stressors will interact with each other in marine ecosystems worldwide.

Despite being relatively untouched, the subantarctic has endured many decades of human habitation leading to the accumulation of wastes and contamination in some areas. In addition, climate change in subantarctic marine environments is evident. On Australia's subantarctic Macquarie Island, temperature and rainfall are increasing. Not only will this create thermal and osmotic stresses, increased rainfall will potentially increase mobilisation of contaminants from the land into the intertidal zone. Near-shore marine assemblages are particularly at risk, due to both fuel spills associated with shipping, which often occur close to land, and to run-off of contaminants from terrestrial systems.

The effects of multiple stressors were investigated on intertidal marine invertebrates from a range of taxonomic groups collected from subantarctic Macquarie Island. Copper was chosen as a representative contaminant as it is highly toxic to biota and is common at contaminated sites in polar environments. Replicate tests were run on each species to enable determination of point estimates such as median lethal concentrations (LC50s). Once sensitivity to copper alone was determined, multi-stressor tests were conducted by exposing test organisms to a range of copper concentrations, and to several salinities and temperatures relevant to predicted climate change scenarios. Interactions between stressors were determined by comparing LC50s for each stressor combination, and by ANOVA. Sensitivity to copper was found to be amplified by increased temperature and reduced salinity. Concurrent with other regions of the world, this indicates that the interactive effect of contamination and climate change stressors will have major impacts on subantarctic marine invertebrates and ecosystems.

## Semi-quantitative detection of $^{239}\text{Pu}$ in the Antarctic plateau snow

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Plutonium is a useful time marker for dating ice cores and snow pits because it in the environment mainly originates from atmospheric nuclear weapons tests carried out since the 1950s. To determine  $^{239}\text{Pu}$  in snow pit samples, collected every 5 cm down to 4 m, covering ~50 years (1957-2007), at Dome Fuji in East Antarctica, we used an inductively coupled plasma-sector field mass spectrometer (ICP-SFMS) coupled to a high-efficiency sample introduction system. The main advantages of ICP-SFMS technique are rapidity of analysis and simple sample preparation method for  $^{239}\text{Pu}$  at femtogram levels in small-volume samples from snow/ice. However, this technique is prone to spectral interferences. The existence of high content of uranium in sample could lead to significant interferences with  $^{239}\text{Pu}$  owing to uranium hydride ( $^{238}\text{UH}^+$ ) formation. In this study, we found that the interference effect of  $^{238}\text{UH}^+$  was negligible when the  $^{238}\text{U}$  concentrations lower than  $10 \text{ pg g}^{-1}$ . In the snow pit samples, the  $^{238}\text{U}$  concentrations were lower than  $0.5 \text{ pg g}^{-1}$ . Accordingly,  $^{239}\text{Pu}$  signals were detected without  $^{238}\text{UH}^+$  interference. For the calculation of  $^{239}\text{Pu}$  concentration, semi-quantitative method was used. It is based on assumption that the ionization energy for Pu and U are very close and therefore they should have a similar behavior when ionized in the plasma. Consequently, the  $^{239}\text{Pu}$  records related to nuclear weapons tests were reconstructed at femtogram levels in the Antarctic snow pit sample by the application of a semi-quantitative method. It is demonstrated that ICP-SFMS technique represents a useful for the analysis of  $^{239}\text{Pu}$  in the Antarctic samples.

## Distribution of persistent organic pollutants in surface snow from the east Antarctica

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A series of evaporation and deposition, a long-range atmospheric transport, and a cold-condensation process is important processes to widespread distribution of Persistent Organic Pollutants (POPs) in remote polar regions. The atmospheric POPs from the source regions could be deposited into the surface snow in Antarctica. However, the data of the snow concentration of POPs are limited than other environmental matrixes. In the present work, we report the concentrations of hexachlorocyclohexanes (HCHs) and hexachlorobenzene (HCB) in the surface snow samples obtained from the East Antarctica between 2011 and 2013. The concentrations of HCHs and HCB in the East Antarctic snow were low compared to those in remote regions of the northern hemisphere. Our previous snow concentrations of POPs from Dome Fuji and Dome A were compared to those of the present studies. Our results indicate that the surface snow in East Antarctica contains low levels of POPs, which could affect Antarctic ecosystem.

## **Biogeochemical cycling of black carbon; a proxy for human impact in the McMurdo Dry Valleys, Antarctica**

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This study focuses on quantifying human impact in the McMurdo Dry Valleys through studying black carbon in the dissolved phase in water. Robust efforts and policies exist to minimize human impact in Antarctica, the most remote and pristine continent. Previous studies have been conducted to quantify various tracers of human impact from McMurdo Station, however, no known studies have looked at Black Carbon, soot particles, or products of in-complete combustion of fossil fuels, in the dissolved phase in the lakes of the Dry Valleys. One might expect the lakes to be completely void of black carbon; however, preliminary samples from Lake Fryxell and Lake Hoare show that some BC is present in the lakes, at approximately 4-6 mg/L, one-third of the concentration of temperate lakes. Potential local sources include field camps, relatively heavy helicopter traffic, especially compared to other regions of the Antarctic, as well as generator use. During the height of the austral summer, the edges of these perennially frozen lakes thaw, enabling wind deposition of debris and particles including black carbon, onto the surface of the water. Long range transport is also potential, though previous studies have shown that few particles have the ability to make it through the strong polar vortex, additionally the southern hemisphere has much less industrial production than the north. Therefore, our assumption is that most of the BC we find in the lakes, could be traced to human impact.

## **The footprint of human impacts in cold climates: Lessons learned at McMurdo Station, Antarctica**

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The largest of the three scientific bases operated by the United States Antarctic Program (USAP), McMurdo Station has experienced localized environmental impacts over its fifty-plus year history. Starting in 1999 and continuing until present, a long-term environmental monitoring program has examined the impact of science and operations on the station's local terrestrial and marine environments. This program was developed from an assessment of system attributes amenable to monitoring, an understanding of the nature of historical and ongoing environmental impacts and a consideration of the spatial scales over which impacts would be expected.

Synthesizing more than ten years of environmental monitoring measurements has revealed the spatial patterns of impact in both terrestrial and marine environments. This time series now enables investigation of changes in contamination concentrations at McMurdo Station over time. With the exception of a small number of marine sites, no statistically significant temporal trends in the contamination levels over the 2003-2011 period are apparent. This is true both for the station as a whole and for individual areas where inadvertent releases of petroleum hydrocarbons, the most common contaminant, are most likely to occur.

Based on the monitoring program decade of observations, we reexamine how well the program's initial assumptions aligned with our observations. We also discuss how past monitoring can inform changes to future monitoring at McMurdo Station to make it more effective and cost efficient and enable it to continue to provide the scientific basis for future assessments of human impacts.

The monitoring program began at McMurdo Station is now being translated geographically to sites including the McMurdo Dry Valleys and Palmer Station. We discuss how the lessons learned at McMurdo Station have informed the design of monitoring activities at these sites; as well as being valuable to programs at other international Antarctic research stations with similar physical settings and mix of human activities to McMurdo Station.

## Trace and minor elements in cryoconites and supraglacial streams, Canada Glacier, Antarctica

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Antarctica is one of the most geochemically pristine environments on our planet. The analysis of current snow and ancient glacier ice over the past two decades has demonstrated that Antarctic precipitation contains some of the lowest trace element concentrations observed globally. Here we present data from cryoconites and supraglacial stream waters on the Canada Glacier, Taylor Valley, Antarctica (~78°S). Cryoconites are ice-lidded melt features caused by the introduction of dust onto the glacier surface. Cryoconites may occur in isolation, or be hydrologically connected with supraglacial streams draining off the glacier surface. Supraglacial streams on the western and eastern portion of the Canada Glacier have median dissolved (<0.4 μm) concentrations of Fe, Mn, As, Cu, and V of 102 nM, 21 nM, 1.8 nM, and 9.6 nM and 43 nM, 79 nM, 0.6 nM, and 1.6 nM, respectively. All dissolved Cd concentrations and the vast majority of Pb values are below our analytical detection (i.e. 0.4 and 0.06 nM). Geochemical distinctions between western and eastern supraglacial streams result from eolian deposition and likely the timing of release of cryoconite solute and sediment into supraglacial streams. The dissolved concentrations of all these elements are much lower in nearby proglacial streams draining the Canada Glacier. A comparison of all the available data indicates that the major source of metals to this aquatic system is from dissolution of dust and other eolian debris within the cryoconites, but dissolved metals are “lost” from solution as water moves through the supra and proglacial hydrologic system.

## Correlation between hydrocarbon degradation profile and distribution of bacterial populations isolated from 'Machu Picchu' Scientific Base surroundings in Admiralty Bay, King George Island in Antarctica

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We studied 11 locations (stations) around the Peruvian 'Machu Picchu' Base, from which different type of samples were obtained: thaw water (D), surface seawater (S) and soil sediments (F). Temperature, pH, heterotrophs count and coliforms count of each station was determined (APHA, standard method). Temperature ranged from 0.5 to 1.6°C (average temperature=1.3°C, SD=0.3°C) and pH ranged from 5.2 to 8.1 (average ph=7.7, SD=0.7). Our analysis showed the presence of coliforms but absence of fecal coliforms.

A total of 380 bacterial strains were isolated. We tested their cryotolerance for 7 days at 4°C, 18°C and 25°C. Hydrocarbonoclastic activity was tested in mineral medium (Mills *et al*, 1978) supplemented with crude oil at 4°C for 7 days. Degradation profile was evaluated for each strain in Mills' mineral medium supplemented with 84-octane gasoline, paraffin and vacuum residuum. Emulsifying activity was examined according to Goldman *et al* (1982).

Only 211 strains were psychrophilic bacteria: 3.32% (7) were strictly psychrophilic bacteria; 94.78% (200) were facultative psychrophilic bacteria, and 1.9% (4) were psychrotrophic bacteria. From all the strains, 20% (43) showed hydrocarbonoclastic activity; 9% (19) degraded vacuum residuum; 7.6% (16) degraded 84-octane gasoline and 8.5% (18) degraded paraffin. In addition, 5.13% showed more than 1 EAU (Emulsifying Activity Unit); 25.64% showed from 0.5 to 0.66 EAU, and 69.23% exhibited from 0.1 to 0.46 EAU.

8 strains that shown degradation capacity of all petroleum fractions and oil emulsifying activity were identified with API 20NE and API 20E kit: *Aeromonas hydrophila* strains 9A2, 63B, 79AF1 and 95F; *Burkholderia cepacia* strains 9A1 and 79AF2; *Pseudomonas luteola* strain 85AF and *Enterobacter cloacae* strain 116B.

We evaluated the correlation of 14 variables previously tested by Principal Components Analysis (PCA). This analysis showed a significant correlation (48.65%) among 13 variables therefore we could cluster populations in 3 groups with similar characteristics. In the first group we found strains with the higher hydrocarbonoclastic activity from E11-S, E9-S and E6-S stations, which correspond to surface seawater of the bay entrance that has continuous contact with the ballast water from vessels. The next group includes E1-S and E4-S stations, which correspond to thaw seawater from innermost coastal areas of the bay, and D2 station, which correspond to thaw water from nearest glacier to Machu Picchu Base; where we observed low quantity, low diversity and absence of strains with hydrocarbonoclastic activity. The last group clusters the higher number of stations; furthermore strains with low-to medium-hydrocarbonoclastic activity were evidenced, regardless of sea depth and sediment.

In conclusion, our analysis shows the influence of anthropogenic activity on microbial ecosystems of the Admiralty bay.

## Antarctic pinnipeds as bioindicators of mercury in the Southern Ocean: a case study using the stable isotopes of carbon and nitrogen

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Among the different metals subject to environmental interest mercury (Hg) occurs naturally in high concentrations and is a global contaminant and toxicant of major concern for both wildlife and humans. Given its ability to undergo bioaccumulation and biomagnification along the food web, top-predators as marine mammals tend to exhibit high mercury concentrations in their tissues via placental or lactational transfer and through their diet. Antarctic pinnipeds are top-predators in a short food web at the Southern Ocean considered good indicators of spatial and temporal trends in Hg bioavailability in the Antarctic. Our study evaluated lanugo samples from Southern Elephant Seals (n=35, SES) and Antarctic Fur Seals (n=11, AFS) for Hg, stable isotope composition ( $\delta^{13}\text{C}$  &  $\delta^{15}\text{N}$ ) and trophic position in relation to sex and body weight (BW). Samples were obtained from randomly selected pups from breeding colonies at Stinker Pt., Elephant Is. in the austral summer of 2007/08. Mean mercury concentration normalized for body weight ( $\text{Hg}_w$ ) suggests no significant differences between sexes for both species although heavy SES pups exhibited lower Hg than lighter pups. There was no such relationship between BW and Hg for AFSs.  $\delta^{15}\text{N}$  values and trophic position of AFS and SES pups did not differ but their Hg and  $\delta^{13}\text{C}$  values were significantly different. Our results suggest that differences in Hg and  $\delta^{13}\text{C}$  for both species and the values for other pinnipeds reflect not only contrasting feeding habits and antropogenic mercury inputs (Arctic vs. Antarctic environments) but also lipid metabolism and female foraging strategies and locations.

## Impacts of human activity on Antarctic Soils: a review

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Antarctic soils are vulnerable to disturbance due to their physical properties and naturally slow recovery rates due to low temperatures and, in some regions, low moisture contents. Early whalers and visitors of the "heroic era" left structures and equipment behind, thus establishing the first legacies of environmental impacts. Since the International Geophysical Year of 1957/58 there has been a sustained increase in human activity. The Protocol on Environmental Protection to the Antarctic Treaty was signed in 1991 and designates Antarctica as "a natural reserve devoted to peace and science", mandating the protection of Antarctic wilderness and aesthetic values.

Human impacts on the terrestrial environment include; physical disturbance, spillage of foreign substances, and introduction of foreign organisms. Physical disturbances range from land disturbance during construction activities through to individual footprints in previously pristine areas. Accidental fuel and wastewater spills have occurred and human waste was sometimes disposed of by discharge onto land. There is now evidence that alien vascular plants and other taxa can successfully colonise Antarctic soil ecosystems and there is increasing concern about potential for human activities to impact on soil microbial populations.

Where physical disturbance includes removal of the protective "active layer" the underlying permafrost will melt with resulting land surface subsidence and, in drier regions, accumulation of salt at the soil surface. The effects of large scale surface recontouring can remain visible in the landscape for well over 50 years. Where surfaces are active or where liquid water is available seasonally, smaller scale impacts are obliterated within a few seasons.

Hydrocarbon spills have been shown to persist in the environment, with fuel perching on top of ice-cemented permafrost, for decades. Hydrocarbon degrading microbes are present but, within the Ross Sea region, their effectiveness is limited by moisture and nutrient (N and P) availability.

Little is known about the response of Antarctic soil microbial communities to human disturbance or on what timescale responses can be detected. Current knowledge of the drivers of bacterial ecology suggests that a disturbance of sufficient intensity to affect soil EC, pH, or moisture content is likely to cause a shift in bacterial community structure.

Many of the most intense impacts on the Antarctic soil environment are legacies of past practice, and are concentrated in areas near bases. Visible disturbance collectively impacts only a small proportion of terrestrial environment. With increasing environmental awareness, the standard of prevention of human impacts undertaken by many of the Antarctic programmes, is now more stringent than environmental management standards in most, if not all, other regions of the planet.

## Long-term environmental monitoring of sediment contamination, macrobenthic communities and epibenthic fauna at McMurdo Station, Antarctica

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Monitoring of human impacts has been conducted by our team in the near-shore marine environment adjacent to McMurdo Station, Antarctica for 14 years. The monitoring program collects marine sediment from two transects in historically contaminated (disturbed) areas which are compared to control (undisturbed) transects. Each transect consists of three stations, at 12, 24 and 36 meters. Diver-collected cores of sediment are analyzed for chemical contaminants, toxicity and macrobenthic community structure. Epifaunal megafauna (invertebrate and fish) species were also collected for determining whole-body contaminant concentrations (bioaccumulation). Chemical contamination has remained largely the same at the contaminated stations since 2000, when monitoring was initiated, although Total Organic Carbon has decreased at several stations and contamination has decreased in the deep station of a disturbed transect (Winter Quarters Bay). Contaminated stations are high in PCBs, DDT, petroleum hydrocarbons and heavy metals relative to the control stations. The toxicity test results have been compromised due to interference with naturally occurring sponge spicules at the reference transect. The macrofaunal community structure is distinctly different between the two contaminated transects and the control transect. Macrofauna community structure has changed directionally over time; however the changes do not correlate with contaminant history and thus appear to primarily be the result of natural variability at the study sites. Epifauna tissue contamination is elevated relative to control sites in most taxa groups, most notably by PCBs. PCB concentrations in many taxa are elevated above the US Food and Drug Administration advisory level for organisms consumed by humans. Lead and PAH concentrations are elevated in the clam *Laternula elliptica* in disturbed sites.

**Proteomic responses induced by Lead in the Antarctic limpet *Nacella concinna* (Gastropoda: Patellidae)**

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Anthropogenic heavy metals have implications on polar coastal marine ecosystems. Changes in intertidal environment, as the increasing in Lead (Pb) water concentration, could have effects on physiological processes in numerous taxa. It includes the Antarctic limpet *Nacella concinna*. We chose the Antarctic limpet for our investigations for several reasons, including the isolation and ecological importance of the polar marine ecosystems, the availability of the species on the field, its south oceans populations distribution particularly sensitive to impacts, and the relative ease of collection and maintenance of its for laboratory experimentation. We wanted to investigate the proteomic changes associated with time under different concentrations. *N. concinna* (> 30 mm) were exposed to two Lead different concentrations (0.12 and 0.25  $\mu\text{gL}^{-1}$ ) over 12, 24, 48 and 196 hours. We extracted proteins from gill tissues and separated these with 2D gel electrophoresis. To identify protein expression patterns, we analyzed with Delta 2D gels (Decodon). Performed 2-way ANOVA to compare different metal concentrations and exposure times ( $p < 0.02$ ). Were analyzed three hundred nineteen spots. Roughly, 40% of the spots observed and analyzed changed in abundance in response to different concentrations and times under Lead exposition. Proteins identified with tandem mass spectrometry in gill tissue include proteins involved in the cytoskeletal, energy production and metabolism, inorganic ion transport, intracellular signaling, post translations modification, protein turnover and chaperones.

## Dissemination of antibiotic resistance determinants via sewage discharge at Davis Station, Antarctica

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Discharge of untreated or macerated sewage into Antarctic marine waters may present a significant risk to ecosystems via introduction of non-native microbial species. Despite these risks, untreated sewage disposal continues in Antarctic and sub-Antarctic environments. As part of an environmental impact assessment of the Davis Station sewage outfall, we investigated carriage of antibiotic resistance determinants in *Escherichia coli* from marine water and sediments, marine invertebrates (*Laturnula* and *Abatus*), birds and mammals within 10 km of the Davis sewage outfall. Genetic elements (class 1 integrons) associated with antibiotic resistance in Gram-negative bacteria were detected in 12% (54 of 471) of *E. coli* isolates. *E. coli* carrying these integrons were primarily isolated from the near shore marine water column and the filter feeding mollusc *Laturnula* within 1.5 km of the outfall. Class 1 integrons were not detected in *E. coli* isolated from seal (*Mirounga leonina*, *Leptonychotes weddellii*) or penguin (*Pygoscelis adeliae*) feces. However, isolation of *E. coli* from these vertebrates' feces was generally low. Sewage is facilitating the introduction of microbes and associated resistance genes into the Antarctic environment. The impact of this "gene pollution" on the diversity and evolution of native Antarctic microbial communities is unknown. Further, potential risks are compounded by the unknowns associated with response and adaption of microbial communities to environmental change.

## Record of volcanism in a West Antarctica ice firn

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Volcanic aerosols from major eruptions are transported through the stratosphere and deposited across the world, including polar areas. Ice and/or firn cores retrieved from these areas offer a unique record of volcanic events. The firn core IC-6 (35.06 m long) was collected in the West Antarctic Sheet (at 81°03'10"S, 79°50'09"W, 750 m above sea level) in the 2004/05 Austral summer. We subsampled this core using a continuous melting system at the Climate Change Institute (CCI, University of Maine, Orono, Maine, USA) under Class 100 room conditions. Using an Inductively Coupled Plasma Sector Field Mass Spectrometry (ICP-MS) (Element 2, CCI, Maine, USA), we determined the concentration of trace elements (arsenic, barium, cadmium, bismuth, cobalt, chromium, manganese and lead) in 1378 samples. For ionic species (Cl<sup>-</sup>, Na<sup>+</sup> and SO<sub>4</sub><sup>2-</sup>), we analyzed the samples by ion chromatography (IC) (Dionex, CCI, Maine, USA). The chronology of the firn core was deduced from nonsea-salt SO<sub>4</sub><sup>2-</sup> peaks and by the seasonal variations of Cl<sup>-</sup> and Na<sup>+</sup>. The estimated age is approximately 68 years from 1934 to 2002. Mean concentrations of As (1.88 pg/g), Ba (5.77 pg/g), Bi (0.34 pg/g), Cd (0.28 pg/g), Co (1.00 pg/g), Cr (3.92 pg/g), Mn (15.44 pg/g) and Pb (5.03 pg/g) are low and similar to the ones found in previous studies. The contributions from primary natural sources of trace elements in each sample were evaluated using the following indicators: nss- SO<sub>4</sub><sup>2-</sup> for volcanic emissions, Mn for rock and soil, and sea-salt Na from sea-salt spray. Volcanic emissions from both quiescent degassing and explosive eruptions have contributed significantly in the concentrations of trace elements studied, ranging from 20% (lead) to up to 70% (cadmium and bismuth). The eruptions of the volcanoes Pinatubo in Philippines (1991), Cerro Hudson in Chile (1991), El Chichón in Mexico (1982) and Ngauruhoe in New Zealand (1972-1974) appear clearly recorded as large peaks in the EF profiles (Enrichment Factor).

## Long term environmental monitoring program McMurdo Station Antarctica: Soils

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The Antarctic Treaty including its Annexes and US Statutes establish the framework for monitoring activities of scientific research stations. The monitoring program at McMurdo Station is based on years of international and US planning activities and is consistent with international obligations. Human impacts to the local environment at McMurdo Station have been monitored and systematically documented using multiple years of sampling to detect change while continually improving the sampling design. Observations were initially collected during a three-year pilot project established the preliminary design. These were augmented with ten years of additional sampling. As part of this monitoring effort, hundreds of terrestrial soil samples were collected annually and analyzed for total petroleum hydrocarbons (TPH) and selected trace metals.

The largest potential source of contamination is from petroleum products transported to and used at McMurdo Station. Over 80% of the TPH concentrations from the random sampling program from 2003 to 2012 were below the background concentrations of 30 ppm (ug/g). The few relatively high TPH samples have concentrations below levels expected to elicit biological responses.

Trace metal contamination at terrestrial sites is primarily limited to areas where metallic materials have been used, stored or discarded. The spatial patterns of metals measured at McMurdo Station are similar to those for TPH. Lead is the most ubiquitous trace metal in soils; however, over 90% of the lead concentrations from the random sampling program from 2003 to 2012 are below 10 ppm. In general, trace metals are present at background levels with few exceptions and far below any levels of concern.

Based on historical data and our continued monitoring, TPH and trace element contamination is localized around input sources (e.g. fuel storage facilities, refueling stations, vehicle storage areas, heavy shop areas and historical dumps) and does not show signs of an increasing "footprint" over time.

## As, Mo and U enrichment in pristine Antarctic meltwaters

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Ponds and lakes between 77°S (Wright/Victoria Valleys) and 80°S (Darwin Glacier) in Victoria Land, Antarctica, show a range of chemical compositions, from dilute freshwaters to the highly saline brines formed as a consequence of evaporation and freeze concentration. If trace elements were to behave as conservatively as sodium or chloride during brine formation, their concentrations would become elevated and potentially toxic to aquatic organisms. However, ponds undergo periods of anoxia and H<sub>2</sub>S genesis over winter; conditions which can become permanent in the base of some stratified lakes. Consequently, significant enrichment of thiophilic trace elements such as Fe, Cu, Pb and Zn is rarely observed.

Until recently, Mn was the only trace element that was known to consistently experience enrichment to the same degree observed for conservative major ions in saline brines. However, in this study significant As, Mo and U enrichment has been observed during pond freezing, to levels which would be of environmental concern in more temperate systems. Arsenic concentrations of up to 1.17 mg/L have been found, with ponds at Bratina Island (78°S) typically showing the most elevated As concentrations. Mo and U concentrations as high as 1.62 mg/L and 0.99 mg/L respectively, have been found in inland terrestrial saline ponds of the Dry Valleys; with the nature of the geological terrain a likely contributing factor to the higher concentrations. In permanently stratified, ice-covered Lake Wilson (80°S), As, Mo and U are all elevated in the more saline water column below 45m depth. However, the As concentration profile across the oxic to anoxic transition at 60-90m depth, is quite different from that of Mo and U, highlighting key differences in their geochemical behavior.

While As, Mo and U concentrations are all clearly elevated by the processes of pond evaporation and freeze concentration, enrichment is still moderated by the precipitation of mineral phases in some environments. Dissolved Mo removal was observed during the final stages of freeze concentration in autumn at Bratina Island, for example, and both Mo and U are being removed from the bottom waters of Lake Wilson. Evidence of dissolved As removal was only apparent in the lake water profile environment, in the oxic to anoxic transition zone. Geochemical modelling with PHREEQC has been used to identify potential removal mechanisms for these three oxyanions.

## Mercury accumulation in Gentoo penguins *Pygoscelis papua*: spatial, temporal, and sexual intraspecific variations

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Contamination caused by anthropogenic activities has increased over the last decades and is affecting even remote areas such as Antarctica. Mercury is one of these global contaminants and its high toxicity and capacity to biomagnify through food webs is a matter of concern. As Gentoo penguins (*Pygoscelis papua*) breed all around Antarctica and forage nearby their colonies, they are expected to be a good biomonitor of the mercury concentrations in the region. Their feathers can indicate the amount of mercury accumulated annually, as moult occurs every year. In this study we evaluated the mercury concentrations in Gentoo penguin feathers, of known sex and size, at Bird Island, South Georgia. There were no significant differences in mercury levels between 2009 and 2010 (mean:  $0.97 \pm 0.67 \text{ mg kg}^{-1}$ ; mean:  $1.13 \pm 0.62 \text{ mg kg}^{-1}$ , respectively). There was an increase of mercury levels with increasing weight and proportion of fish on penguins' diet. Sex had no influence on mercury levels independently of these variables. No temporal (decadal) variations in levels of mercury in Gentoo penguin feathers were observed in the area, but spatial (latitudinal) differences are clear in the Antarctic region when comparing the results of previous studies. As expected these differences were related to the location of the Antarctic Polar Front, with lower values recorded south of the front and closer to the Antarctic continent.

## Mercury contamination in wandering albatrosses: influence of age, sex and breeding status

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Mercury is a pollutant of concern, which bio-amplifies through the food chains and accumulates in numerous top predators such as albatrosses. Mercury concentration in tissues of the wandering albatrosses (*Diomedea exulans*) are greater than in any other vertebrate, including closely related species, and the reasons for this remain unclear. In order to explore the alternative explanations for this pattern, we measured total mercury concentrations in feathers, plasma and blood cells of wandering albatrosses of known age, sex and breeding status sampled at Bird Island, South Georgia. Mercury concentrations were low in feathers and blood components of chicks, and higher in the feathers of young pre-breeders (aged 4-6 years) than in feathers or blood of older pre-breeders (aged 9-15 years) and breeding adults (aged 11-33 years). There was no effect of sex on mercury concentrations in the feathers of pre-breeders or breeding adults, whereas mercury levels were significantly higher in blood cells of breeding females than males. Differences in mercury levels between the sexes seem therefore to largely reflect differences in trophic ecology during the breeding rather than the nonbreeding period. The high feather mercury concentrations of young pre-breeders compared with older birds suggests either a switch in diet or distribution (and hence exposure to mercury in prey) or, much more likely, an increase in moult frequency as birds approach maturity, such that the body mercury pool becomes reduced by its excretion into feathers. The significant effect of sex on mercury levels in blood suggests that excretion of mercury into the egg is not sufficient to lower the body pool of mercury in breeding females to below that of males. Wandering albatrosses are classified as Vulnerable in the IUCN Red List because of population declines since the 1960s (such as at South Georgia) or 1970s resulting from unsustainable levels of mortality in longline fisheries. Mercury toxic effects, which may include neurological and physiological impairments, can lead to population declines in marine birds, especially when combined with other environmental perturbations like climate change, which is known to affect mercury distribution in polar ecosystems. Since mercury emissions are predicted to increase in the future, probably resulting in higher mercury accumulation in Antarctic top predators, monitoring of the mercury contamination in these threatened seabirds is advisable.

## S19: ANTECO: DIVERSITY AND DISTRIBUTION OF LIFE IN ANTARCTICA

### Spatial distribution of *Pseudo-nitzschia* (Bacillariophyceae) species in shelf and oceanic waters of the South Western Atlantic

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Some diatom species belonging to the genus *Pseudo-nitzschia* are potential producers of domoic acid, a neurotoxin which causes amnesic shellfish poisoning (ASP). Despite the harmful effect that these species may have on marine food webs and human health, no previous studies have addressed their abundance and distribution covering a large spatial scale in the oceanic waters of South Western Atlantic. The present study is based on the analysis of 116 samples collected from 34°S to 76°S during different surveys conducted in the outer Argentine shelf, the Brazil-Malvinas Confluence, Drake Passage, Antarctic Peninsula, and Weddell Sea during austral spring and/or summer. Diatom densities were estimated by cell counting under an inverted microscope, while species identification was carried out after the oxidation of organic material, drying on cover glasses and mounting in a refractive medium.

The genus *Pseudo-nitzschia* showed a mean concentration of 186 cells l<sup>-1</sup> and occurred in 96% of the stations. A total of 14 species of *Pseudo-nitzschia* were recorded, four of which reached concentrations up to 10<sup>4</sup> cells l<sup>-1</sup> (*P. lineola*, *P. turgiduloides*, *P. prolongatoides* y *P. subcurvata*). The former three were particularly abundant in ice-free waters of the SE Weddell Sea, while the latter peaked around the tip of Antarctic Peninsula. Seven other species identified (*P. multiseriis*, *P. australis*, *P. pungens*, *P. turgidula*, *P. fraudulenta*, *P. delicatissima* complex, and *P. cf. calliantha*) are commonly regarded as potential producers of domoic acid. An ecological characterization (excluding the Weddell Sea) based on *Pseudo-nitzschia* species abundance and environmental variables (nitrates, phosphates, silicates, temperature, and depth) was carried out through a Canonical Redundancy Analysis. Among other results, we found that: a) the Brazil-Malvinas Confluence can be differentiated by the presence of *P. multiseriis* (major load), *P. fraudulenta*, *P. subfraudulenta*, and *P. cf. calliantha*; b) subantarctic oceanic waters and the Drake Passage host a high load of *P. lineola*, *P. heimii*, *P. turgiduloides*, and *P. turgidula*; c) the Argentine shelf and slope, and the waters surrounding the Antarctic Peninsula are characterized by the dominance of *P. lineola* and *P. turgiduloides*, with lesser concentrations of *P. subcurvata* and *P. pungens*.

## Anti-predatory chemical defenses of selected Antarctic benthic organisms

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Antarctic benthic communities are mainly structured by biotic interactions, such as predation. Echinoderms, and particularly sea stars, are the main predators in these communities; therefore, during evolution, sessile and sluggish organisms developed a wide array of anti-predatory mechanisms to avoid them. Among those, chemical defenses, by using natural products, have been scarcely studied in these areas. We choose the abundant, eurybathic, and generalist sea star *Odontaster validus* as a sympatric predator to perform repellence bioassays following previous methodology from our group. We attempt to assess repellency within 11 marine phyla including algae (Achrophyta and Rodophyta), sessile invertebrates (Porifera, Cnidaria, Bryozoa, Chordata, and Hemichordata), and mobile invertebrates (Mollusca, Echinodermata, Nemertea, and Annelida). Samples were collected mainly at shelf depths (aprox. 200–400 m) in the Eastern Weddell Sea and Bouvet Island, and at shallow-water depths (0–50 m) at the South Shetland Islands. When possible, animals were dissected to further study the allocation of deterrent compounds. With some species, we compared repellency among different localities to assess if there was variation in defensive compounds. Among the 65 species tested in our survey, 72% were studied here for the first time in repellency bioassays. Our results reflect the conspicuous chemical defenses of the Antarctic benthic fauna in nearly all phyla studied, representing a 45% of the species examined. We tested ether (lipophilic) and butanol (hydrophilic) extracts. Our results showed that the main repellence activity was present in the lipophilic extracts, thus suggesting a non-polar nature of the natural products. Some species display intraspecific variation in their production of secondary metabolites. Whether this fact may be due to trade-offs between internal physiological processes or to external interactions within the ecosystem, requires further investigation.

## **Biological diversity and chemical diversity in Antarctica: from new species to new natural products**

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Antarctica is a still unexplored area in many senses, among which biological diversity and even more, chemical diversity. Over the last years our research group has been studying marine benthic ecosystems in different Antarctic areas. These works have produced many interesting discoveries regarding both new species to science as well as new natural products. We have been trying to unravel the complex interactions network existing between marine benthic organisms in these cold and hardly accessible ecosystems. We present here a review of our recent results considering the biology and ecology of these organisms and the chemistry laying behind their interactions. As a summary, these ecosystems are as complex as any other similar environment in the planet, and many questions remain to be answered yet.

## Feeding repellent defenses in Antarctic benthic organisms against opportunistic amphipod predators of the species *Cheirimedon femoratus*

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Predation is a selective force structuring Antarctic benthic communities. The lack of a continuous nutrient supply in Southern latitudes drives organisms to adopt opportunistic habits, and here consumers tend to scavenge and forage on almost any potential prey available. Among the highly influencing predators we may find sea stars, nemertine worms, and also amphipods. Instead vertebrate feeders, like fish, are much less frequent in contraposition to other geographic areas.

Certain amphipods congregate in highly dense populations on living substrata, mostly sponges and seaweeds, which they use as habitat and potential food. Sessile macroorganisms provide small crustaceans with three-dimensional chemical and physical retreat from prospective predators, and direct or indirect nutrient supplies by feeding currents, adhered biota, or hosts' tissues themselves. Consequently, this dual use amphipods make of host organisms, may derive in an intense ecological pressure, and in an extended production of chemical defenses. Actually, often the sedentary lifestyle of benthic amphipods, in continuous contact with their host-and-potential-prey biosubstrata, represents a stronger force in promoting protective mechanisms than that of larger mobile predators (e.g. echinoderms, nemertines or fish) that encounter their prey less frequently.

We assessed the presence of chemical defenses in selected species of Antarctic invertebrates and algae against the relevant circumantarctic and eurybathic amphipod *Cheirimedon femoratus*. Several samples were further dissected to allocate possible defenses in specific anatomical parts. A total of 142 crude extracts, including diethyl ether (apolar/lipophilic) and butanol (polar/hydrophilic) partitions, obtained from sponges, cnidarians, ascidians, bryozoans, molluscs, echinoderms, and other minorly represented groups, such as several macroalgae were tested in feeding preference assays. The organic extracts were included at their natural occurring concentrations in alginate based food pearls, which were then presented to the experimental amphipod predators along with a simultaneous choice of control extract-free pearls. Feeding deterrent activities within the extracts were measured as the significant rejection of treatment (extract-containing) respect to paired control feeding-pearls.

In general, there was a high incidence of chemical defenses, with 71.1% of the extracts resulting active in feeding deterrence. Some molluscs and echinoderms seemed to store defensive metabolites in particular body-regions. Moreover, ether partitions tended to yield repellent activities more often than butanol fractions (64 ether extracts elicited repellency *versus* 37 active butanol fractions), suggesting that lipophilic deterrents are more commonly used among benthic Antarctic potential prey to efficiently fight against intense predation.

## Population structure and behavior of the elusive blue whale

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Our inability to directly observe animals in complex environments has limited our understanding of elusive species. The blue whale, although the largest animal that has ever lived, has elusive behavior. Their pelagic habitat, wide dispersal and low population densities make field observations difficult. The sub-species the pygmy blue whale, listed as data deficient, occurs in the southeast Indian Ocean, yet little is known about their occurrence in the southwest Pacific Ocean.

Pygmy blue whales (*Balaenoptera musculus brevicauda*) produce regionally-specific calls-dialects- including the Madagascan, Sri Lankan, Australian, New Zealand and Solomon type calls. We recorded year-round passive acoustic data at five sites, three in the southeast Indian Ocean and two in the southwest Pacific Ocean (2009 to 2012) and used automated methods to detect occurrence of different call types.

Over a four year period two types of pygmy blue whale calls (Australia and New Zealand) were detected, where the 'Australian' dialect dominates the southeast Indian Ocean the 'New Zealand' dialect dominates the southwest Pacific Ocean. Distribution patterns divide at the Bass Strait (southeast Australia) which appears to be a separation boundary. Differences in spatial and temporal occurrence patterns between the ocean basins suggest the whales use these areas differently.

Here acoustics plays a vital role in providing not only evidence of a previously unknown population, but also insight into differences in population structure and migration patterns across the ocean basins. We propose that these "acoustic populations" should be considered when assessing conservation needs of blue whales in the Indian and Pacific Oceans.

## The link between surface productivity and deep-sea benthos biology at the Southern Polar Front

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The ANDEEP-SYSTCO (ANtartic benthic DEEP-sea biodiversity: colonization history and recent community patterns - SYSTEM COupling) project was initialized in the Atlantic sector of the Southern Ocean. It aims to study responses of the abyssal benthos to different primary productivity situations.

In austral summer 2012, during the expedition ANT-XXVIII/3 onboard RV Polarstern, several abyssal stations along an east-west transect along the Southern Polar Frontal Zone (SPFZ, ~52°S) were sampled. The stations were situated within different primary production regimes (in areas where phytoplankton blooms persisted for some time vs. areas without enhanced primary productivity). In order to test whether the benthic fauna shows a response to these differing situations, abyssal organisms were sampled alongside with the investigation of several environmental parameters (e.g. long term satellite derived surface phytoplankton data, in situ real time phytoplankton biomass and productivity measurements, sediment oxygen consumption, sediment chl-a concentrations).

The results of the studies conducted in the framework of ANDEEP-SYSTCO show distinct patterns for all investigated benthic size classes (microbes, foraminiferans, meio-, macro- and megafauna). For example, no indications for pelago-benthic coupling could be detected when comparing two areas with high- vs. an area with low-chlorophyll conditions in the eastern part of the SPFZ. On the contrary, strong indications for such coupling processes were observed at an area with high surface primary productivity situated northwest of South Georgia. Evidence for this is in particular derived from benthic abundance and biomass data, sediment conditions as well as from fatty acid measurements.

Thus, ANDEEP-SYSTCO succeeded in gaining new and basic information on coupling processes between surface production and the abyssal seafloor for all benthic size classes.

## Visual analysis of benthic megafaunal community structure along the western Antarctic shelf

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A high level of endemism and diversity of benthic invertebrates is found on the Antarctic continental shelf and is generally attributed to its isolation. The physical oceanographic barrier of the Antarctic Polar Front, which is enhanced by the Antarctic Circumpolar Current, normally prevents immigration/emigration of benthic organisms. This isolation is increasingly being minimized by anthropogenic disturbances. Global climate change is responsible for increasing temperatures, decreasing pH and changes in sea-ice distribution. Increasing human activity in the region in the forms of tourism, resource exploitation and scientific research have the potential to significantly alter benthic megafaunal communities through introduction of pollutants, invasive species, and physical disturbances from trawling and resource exploration. Identification of the long-term consequences of such disturbance is hindered by the lack of appropriate surveys. To help establish a baseline portrait of the benthic community along the western Antarctic shelf we used seafloor photographic surveys conducted aboard the RVIB N. B. Palmer in 2013 (cruise NBP12-10) at 16 stations at depths of 335–1111m to evaluate and compare benthic megafaunal abundance, community structure, and species diversity.

## Update in root fungal associations of Antarctic vascular plants

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In the extreme environment of Antarctica, the two native plants, *Deschampsia antarctica* and *Colobanthus quitensis*, have been reported as lacking some of the common root fungal associations found elsewhere, i.e. beneficial mycorrhizal fungi. The aim of this study was to survey both roots and soil from the rhizosphere of *D. antarctica* and *C. quitensis* and the alien species, *Poa annua*, in order to identify the current root fungal associations and their soil propagules. For this, roots have been collected in a north-south transect along the maritime Antarctic from three major areas, the South Shetland Islands, Paradise Bay and Marguerite Bay, and from habitats differing in water supply. Roots were stored in 70% ethanol and then stained with 0.01% trypan blue in the laboratory, and slides with thirty 1 cm fragments were mounted with lactoglycerol for microscopic observation. The soil propagules were retrieved by wet sieving and decanting and later centrifugation with a sucrose gradient. In roots, the most common fungi were the dark septate endophytes, with melanized hyphae and sclerotium-like structures found in both native plants. There were no signs of arbuscular mycorrhizal fungi in none of the species. The second most common fungi, especially from wetter sites, were chytrids with *Olpidium*-like structures, which practically have not been studied in Antarctica and are currently being identified by molecular analyses by our group. *Poa annua* was virtually free of root colonization by any fungus. In soil, ascomycetous microsclerotia were common, with increasing number in wetter and moss covered habitats. No glomerospores were found in soil. The functional role of the found fungal groups is discussed regarding the actual warming scenario of Antarctica.

## Grass-moss communities and soil properties along herbaceous tundra transect on the west coast of the Antarctic Peninsula

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Native Antarctic tundra communities are distributed along the west coast of the Antarctic Peninsula (WAP), including several offshore Islands and Archipelagos. Recently, it has been shown, that the Antarctic hairgrass *Deschampsia antarctica* is frequently associated to moss carpet communities. In order to detect a potential common pattern and differences in soil characteristics between grass-moss (GM) and grass only communities (GC), we monitored a total of 18 sites on 8 islands through a transect from the Shetland island to Margarite Bay in the WAP comparing composition of plant communities as well as chemical and physical factors of soil beneath them. At every site, we took soil samples and measured *in situ* plant cover (%). Vascular plant (grass) cover changes significantly along the transect, with a maximum value of 67% on Lagotellerie Is. and a minimum <1% in two sites on King George Is. In general, vascular plant cover was significantly higher at sites where mosses dominate (31% and 23% with and without moss carpet), but different patterns were observed: whereas in Admiralty Bay and on Fildes Peninsula, grass cover increases at sites with mosses compared with bare ground, it was higher without mosses on Byers Peninsula, and on Lagotellerie Is. On the other hand, values of soil macronutrients (NPK) are different between the different islands as well as comparing soil beneath GC and GM communities along the WAP. Nitrogen and phosphorous variations were the strongest: N content was highest on Galindez Islands (10 %), but in general, values were fluctuated between 0.1-1.0% along the transect; highest P values were found on Gallindez Is., Anchorage Is. and Biscoe Point, (397 - 2000 mg/Kg), lowest values at Collins Harbour (6 mg/Kg). K values were variable, in the range of 0.1 to 2.9 mg/Kg and pH varied between 4.5 and 7.1 along the different sites on the WAP. Significant were the changes in N, P, Mg, Ca, C, C/N ratio in soils beneath G vs. GM.

Our data suggest that high grass cover is not related with the presence of mosses along the Antarctic Peninsula. Nutrient content in different soils is generally high, probably due to input by birds as has been reported. The results indicate that under the actual climate change scenario, soil nutrients are not a limiting factor for growth and expansion of vascular plant communities along the Antarctic Peninsula.

**Phylogenetic relationship of *Antarcticothamnion polysporum* (Wrangeliaceae, Ceramiales, Rhodophyta) based on morphological and molecular data**

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*Antarcticothamnion polysporum* Moe et Silva was described from South Shetland Islands and Antarctic Peninsula, Antarctica in 1979. It differs from previously described Ceramiacean species in some vegetative structures and reproductive structures borne on modified indeterminate branch systems. Moe and Silva (1979) therefore, proposed a new species and genus in its own tribe, Antarcticothamnieae, which shares important features, however, with the Callithamnieae, Compsothamnieae, and Ptiloteae. We recently collected a dozen individuals of the species from 20-30 m depth on rocks in King George Island of South Shetland Islands. Each two sequences of nuclear SSU rDNA and plastid *rbcL* gene from two individuals of the species and other ten species in the Wrangeliaceae were newly determined in this study. Phylogenetic relationships among over 50 species of the Wrangeliaceae were determined based on SSU and *rbcL* sequences. *Antarcticothamnion polysporum* strongly allied into the Compsothamnieae and the tribe Antarcticothamnieae is not supported in the SSU tree. The taxonomic issues and phylogenetic relationships of *A. polysporum* among the related species in the Wrangeliaceae will be discussed based on procarp and post-fertilization evolution of the female reproductive structures.

## Diversity hotspots on a microscale - Biological soil crusts in continental Antarctica

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Biological soil crusts (BSC) are associations of lichens, mosses, algae, cyanobacteria, microfungi and bacteria in different proportion forming a thin veneer within the top few centimeters of soil surfaces. They occur in all biomes but, particularly in arid and semi-arid regions, even in the most extreme climates. They carry out crucial ecosystem functions, such as soil stabilization, influencing water and nutrient cycles, and contribute to the formation of microniches for heterotrophic life. Such roles are key ecological roles, especially in continental Antarctica where no higher plants provide these services to the ecosystem. We provide a detailed description including species lists of BSC from Garwood Valley, Dry Valleys region (78°S) and Diamond Hill (80°S) in the Darwin Mountains region. The coverage was low at 3.3% and 0.8% of the soil surface, respectively. At Garwood Valley the BSC were dominated by green algal lichens, cyanobacteria, several species of green algae and the moss *Hennediella heimii*. BSC at Diamond Hill appear to be unique in not having any species of cyanobacteria. Major parts of the BSC are embedded in the soil, and their thickness correlates with ecosystem inputs, like higher chlorophyll contents and higher soil organic carbon, which are together with the nitrogen input key ecological roles of biological soil crusts in this species poor cold desert zone.

## Metagenomic characterization of Antarctic soil viral communities

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The metaviromes of two distinct Antarctic hyperarid desert soil communities have been characterized. Hypolithic communities, cyanobacteria-dominated assemblages situated on the ventral surfaces of quartz pebbles embedded in the desert pavement, showed higher virus diversity than surface soils, which correlated with previous bacterial community studies. Prokaryotic viruses (i.e. phages) represented the largest viral component (particularly *Mycobacterium* phages) in both habitats, with an identical hierarchical sequence abundance of tailed phage families (*Siphoviridae* > *Myoviridae* > *Podoviridae*). No Archaeal phages were found. Unexpectedly, cyanophages were poorly represented in both metaviromes and were phylogenetically distant from currently characterized cyanophages. Putative phage genomes were assembled and showed a high level of unaffiliated genes, mostly from hypolithic viruses. Moreover, unusual gene arrangements were observed, in which eukaryotic and prokaryotic virus-derived genes were found within identical genome segments. *Phycodnaviridae* and *Mimiviridae* viruses were the second most abundant taxa and more numerous within open soil. Novel virophage-like sequences (within the Sputnik clade) were identified, representing the first report of such virus populations and their satellite viruses in Antarctic soil habitats.

## Insights into the soil biodiversity of the Southern Prince Charles Mountains in the context of the abiotic environment

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While the continental interior of Antarctica is apparently devoid of ground dwelling life, its soils are home to various microscopic organisms such as bacteria, unicellular eukaryotes, fungi, cryptogamic plant communities and small invertebrates. Climatic changes, human presence and invasive species are already altering coastal communities. On the contrary, potentially unaltered communities in remote areas remain unexplored due to the logistical difficulties as well as methodological constraints of large scale biodiversity studies.

The most urgent requirement to better understand the biodiversity patterns of remote Antarctic habitats is the collection of baseline biodiversity data from unsurveyed ice-free regions. Due to high costs of sample retrieval, biological research in Antarctica is mainly focussed on the proximity of research stations. Also, biodiversity research often employs manual sorting and visual inspection of samples. Such methods perform well at analysing a small number of samples. Yet, as a consequence, the few projects attempting to understand biodiversity patterns across large spatial scales lack adequate tools to efficiently gather biodiversity data from a large number of biological samples. However, in the Antarctic context, the possibilities of modern metagenomic DNA sequencing methods remains unexplored Here we show that such methods are able to provide baseline biodiversity data from a large number of soil samples in relatively short time and without highly specialised equipment.

For the first time ever, we present baseline biodiversity data from the Prince Charles Mountains, retrieved by sequencing 18S and COI amplicons of soil DNA extracts on Illumina and 454 platforms. Our data indicates presence of soil meiofauna and plant life in the area around Mount Menzies, the Mawson Escarpment and adjacent Nunataks, as well as in the Beaver Lake and Lake Terrasovoje areas. While our analyses so far have only focussed on metazoan life forms, our data could also be analysed with regard to fungal or microbial studies. X-ray diffraction and geochemical data enable us to understand biodiversity patterns in the context of soil mineral and nutrient composition.

Our results are a major leap forward in understanding the soil biodiversity of remote terrestrial Antarctic habitats and these methods could well serve a continent-wide biodiversity assessment, as required for continent-wide species distribution modelling.

## The role of sea ice in structuring the under-ice food web during Antarctic winter 2013

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Primarily due to climate warming, sea ice habitats are facing dramatic changes in some parts of the Antarctic Ocean. Sea ice constitutes an important habitat for numerous species. Furthermore, sea ice hosts a specific algal community that can serve as a critical carbon source for Antarctic krill *Euphausia superba* and other species. Therefore, changes of sea ice habitats can have a significant impact on ecosystem functioning. During a winter expedition in the Weddell Sea in 2013, we studied the community composition of under-ice fauna using a Surface and Under-Ice Trawl (SUIT) equipped with a bio-environmental sensor array. The sensors enabled a real-time characterization of physical habitat properties over large (1-3 km) distances. With these closely linked datasets we are investigating the role of sea ice in structuring the under-ice communities. In a second approach, we are analysing the structure of the ice associated food web using stable isotope composition. Linking community data in relation to sea ice habitat properties with food web structure will give first insights on the role of sea ice habitat properties on ice-associated carbon flux under different environmental regimes.

## Recovery of soft-bottom community following defaunation in Antarctic waters: An experimental approach in Admiralty Bay, King George Island

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Shallow-water colonization patterns in Admiralty Bay are especially influenced by the mechanical effect of ice. This can include the freezing of the intertidal area, as well as the impact of icebergs, evidenced by scars, disturbing or even removing benthic organisms. In order to understand nearshore biological community colonization following impact events that affect the distribution and occurrence of species and subsequent recovery a manipulative experiment was set up in King George Island. This work aimed to study colonization patterns of benthic macrofauna in defaunated soft sediment, comparing them with occurrence patterns of macrofaunal benthic organisms found in the natural soft sediment of adjacent areas, in shallow waters of Admiralty Bay, King George Island, Antarctic Peninsula. For this, a manipulative field experiment was installed through SCUBA diving at 22 m depth in front of the Antarctic Brazilian Station. Samples of defaunated and natural soft-sediments were analyzed. Defaunated soft sediment in plastic boxes ( $a = 0.02 \text{ m}^2$ ) were deployed in the seabed and examined after 6, 12 or 18 months. Natural soft-sediment collected with cylindrical corers of 10 cm in diameter ( $a = 0.08 \text{ m}^2$ ), in adjacent areas at the experiment installation and during the changing and removal of the experimental boxes, were also analyzed. Altogether, 20,680 organisms belonging to 6 phyla among 42 species were identified. Thirty three taxa out of the 42 recorded were common in both natural and defaunated sediment types, 6 taxa occurred only in natural sediment and 3 taxa only in defaunated sediment. The most abundant groups throughout the experiment were: Oligochaeta, Polychaeta, Bivalvia, Gastropoda and Crustacea. In the natural sediment a total of 10 species were considered **Constant**, 8 species **Accessory**, 21 species **Accidental**. In the defaunated sediment 14 species were **Constant**, 4 species **Accessory**, 18 species **Accidental**. Analysis of variance indicated significant differences in total abundance and in **Torodrilus** sp. abundance in the periods of 6 and 18 months, and MDS analysis showed a clear separation between natural and defaunated treatments. **Torodrilus** sp. was the taxon with the highest relative contribution (26%) in natural sediment. In the defaunated sediment treatments, the most common taxa were cumacean Leuconidae morphotype 1 (19%) and the bivalve **Yoldia eightsi** (Couthouy, 1839) (18%). The statistical results indicated significant differences between the natural and defaunated treatments with respect to benthic macrofaunal associations. Species richness and abundance in defaunated treatment were less than in natural treatment. The results suggest that recovery levels in Antarctic waters after events of defaunation are very low and in order to be of value experiments may need to be for longer periods.

## **Sponge richness, diversity and associated faunas along environmental gradients at shelf areas of the Antarctic Peninsula, in comparison with biodiversity hotspots in the Eastern Weddell Sea**

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Benthic communities on the Antarctic shelf are dominated by siliceous sponges. Both in vivo and after death, these sponges structure the sea floor and provide habitats for numerous fauna and microbial communities, which are also linked with the diversity and abundance of the specific sponge taxa. Richness and composition of the Antarctic sponge faunas around the Antarctic Peninsula depend largely on substrates, nutrient availability, and sea water temperature.

Our current research project is designed to analyse the impact of climate change, specifically the disintegration of permanent ice-shelves, on the diversity of sponges within the Antarctic shelf communities. This research includes analysing sponge response to gradients and changes in sea water temperatures, currents and nutrition regimes, and the impact of differing substrate types.

During several expeditions to the western Weddell Sea shelf and around the Antarctic Peninsula, we have sampled the sponge communities, including the sponge-associated fauna, and now analyse and compare these with sponge diversity hotspots in the eastern Weddell Sea.

These newly investigated sponge communities, recorded from different geographic regions and depths, show distinct differences in terms of species richness and diversity at generic and higher taxonomic levels. A strong gradient both in species and higher taxa richness exists between shallow and deeper stations at the Weddell Sea stations, whereas in the Bransfield Strait, both the shallow and deeper stations were found to be species rich. The Drake Passage stations yielded an impoverished Antarctic sponge assemblage, and included very few Atlantic faunal elements. This composition is similar to what was previously found at some stations in the Larsen Shelf area (Gutt et al. 2011) and may indicate a starved shelf community, which is in sharp contrast to the diverse fauna, including many large sponges, typical of Weddell Sea shelf areas. Further detailed analyses of this new Antarctic Peninsula and former Larsen ice shelf sponge fauna will be completed in the near future and compared with the better-known, highly diverse sponge faunal communities of the Eastern Weddell Sea

## Associated infauna of selected Porifera from the Weddell Sea, Antarctica

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Associated infauna of fifteen individuals of the sponge species *Mycale (Oxymycale) acerata* Kirkpatrick, 1907, *Rossella antarctica* Carter, 1872 and *Rossella racovitzae* Topsent, 1901 sampled during ANT-XXIV-2 (SYSTCO I) expedition at the deep Ekström Shelf in the South-Eastern Weddell-Sea, Antarctica was investigated. A total of 11,463 infauna specimens was extracted and identified whereupon all abundances in this study are standardized to a sample volume of 100 ml. The sponge-associated infauna consisted of representatives of the following phyla: Foraminifera, Nematoda, Polychaeta, Mollusca and Arthropoda. The infauna commonly comprised high abundances of polychaetes, amphipods and foraminiferans. Statistical methods were used to calculate  $\alpha$ - and  $\beta$ -diversities and compare standardized abundances, the number of species and also the specificity of infauna communities relating to sponge species. Our results show significant differences and demonstrate the host specific constitution of infauna communities of all investigated Antarctic sponge species.

## **New insights and directions in Southern Ocean sponge biogeographic research**

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Senckenberg Research Institute

Significant updates in our knowledge and understanding of Antarctic and sub-Antarctic sponge diversity and distributions are reviewed within the new CAML and SCAR-MarBIN Biogeographic Atlas of the Southern Ocean. This major collaborative scientific initiative has enhanced biological data collection and access, as well as revolutionising our ability to visualise and analyse spatio-temporal patterns and processes in Southern Ocean biogeography.

Southern Ocean sponge biogeography has been re-assessed by utilising these new and more comprehensive biological databases. New analyses re-define both the boundaries of this distinct biogeographic region, and the level and nature of faunal connectivity within this region and with adjacent regions. Key analyses includes a re-examination of the patterns and processes driving circumpolar and eurybathic ranges in Southern Ocean sponges; an updated assessment of Southern Ocean sponge endemism and taxonomic diversity; and the recognition that certain regions could potentially be key centres of Southern Ocean sponge genera evolution and speciation.

Future research directions in Southern Ocean sponge biogeography research are discussed. These include the increased utilisation of molecular techniques coupled with morphological taxonomic research to enhance sponge systematics and the continued expansion of research programmes that improve methodological approaches to resolve specific Southern Ocean biogeographic questions.

## Larval environmental suitability and its influence on species distribution shifts with climate change

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Climate change in the Southern Ocean affects a suite of environmental conditions including temperature, pH, sea-ice extent and the salinity of continental shelf waters. These changing conditions will potentially affect the ocean biota, with altered physiological processes, survival rates, phenology or distribution ranges. The most widely employed approach to estimate changes in distribution is through the generation of species distribution models (SDMs) which reflect the environmental suitability of a particular species that can be projected onto future climate conditions. For benthic species, which often reproduce through planktonic larvae, altered distribution patterns would be a result of environmental conditions affecting both life stages, each exposed to a different environment. However, to date SDMs have only been estimated using benthic records, as the hurdle of larval identification results in a scarcity of georeferenced larval records, which are essential for model generation.

We applied SDMs to two life stages of *Bathylasma corolliforme*, an acorn barnacle endemic to the Southern Ocean, and project these distributions into future climate conditions. These projections revealed that planktonic life stages are more sensitive to the forecasted changes in the environment, which could translate in a loss of population connectivity across Antarctica and, if prolonged in time, result in local extinctions.

Implementing this approach in a wider array of taxa requires increasing the number of larval records identified using molecular techniques, which would shed more light on the consequences of climate change to Antarctic benthos.

## **Ecological relationship by microfungi with bryophytes species in Scientific Station Pedro Vicente Maldonado-Ecuador**

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Several species of micro fungi are in a direct relation to many different types of organisms such as algae, bryophytes, vascular plants, vertebrates and invertebrates, where they function as symbionts. The present study is focused on an analysis about the interrelationship among species of bryophytes and micro fungi and micro fungi that are cultured within the Scientific Station Pedro Vicente Maldonado and the surrounding area where the samples were collected. Sampling stations were applied in squares of 4 x 4 meters on sectors of Greenwich Island, Dee, Torres and Barrientos within the geographical coordinates 21 E 0358219 UTM 3072765, 21 E 0358776 UTM 3072693, 21 E 0349134 UTM 3072322 , 21 E 0358062 UTM 3077718, 21 E 0356285 UTM 3075473, 21 E 0358999 UTM 3076957. Sets of samples have been collected to study ecological relationships that benefit to both organisms as important members of the Antarctic ecosystems. It is interesting to investigate how these micro fungi. They can maintain themselves in a state of latency by enzymatic action and help other agents to keep them safe during icy periods. Bryophytes become small biomes for the growth of micro fungi and they are shelter and food for invertebrates, finding exubias among bryophytes. Studying these organisms gives us cues to recognize their importance as bioindicator organisms of climate change, by observing every year whether their populations are suffering ecological changes, or if they additionally show possible immediate changes expressed in genetic variability caused by these environmental phenomena.

## Linkages between sea-ice cover and humpback whale stock D and E migratory patterns

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A number of migratory and resident Antarctic krill predators including Humpback whales, *Megaptera novaeangliae*, use the Antarctic ecosystem as their main feeding grounds, thus are influenced by the local dynamics that influence the distribution and access to euphausiids aggregations on which they feed during austral summer (Nicol et al. 2008, Friedlaender et al. 2011). There are seven HBW breeding stocks that feed in Antarctic waters (IWC 1998), two of which frequent Australian coastlines during winter months to breed (Chittleborough 1965, Baker et al. 1986, Frankel et al. 1995, Jenner et al. 2001, Barlow 2006). These stocks feed along particular regions around the Antarctic known as management area IV and V and migrate along the west and east coast of Australia respectively. Even though these stocks migrate north after feeding around the Antarctic at similar times of the year (Chittleborough 1965), the time at which the bulk of the migration passes a particular locality off the Australian coast varies between years (Dawbin 1966); timing that is influenced by annual variability in food resources around the Antarctic. Annual variability and availability in euphausiids is related to: 1) this species life cycle and the corresponding migratory behavior to and from offshore ice-free waters to inshore ice covered areas, and 2) ice formation and deformation dynamics that constrain top predator's access to these aggregations (Chittleborough 1965, Nicol et al. 2008, Massom and Stammerjohn 2010). Here acoustic sampling of male humpback whales singers during their northbound migration towards their tropical breeding grounds in winter 2013, was used to investigate spatial and temporal patterns in singer occurrence, and explore linkages between the timing of migration and preceding sea-ice patterns including sea-ice areal cover, and time of ice advance and retreat. Results suggest that a longer sea-ice season throughout management area IV in the Antarctic could have contributed to a delayed migration for humpback whale stock D that year. These linkages provide a means to better understand humpback whale migration and set the baseline knowledge to manage resources and anthropogenic impact throughout both their migratory corridors, feeding and breed grounds by assessing when and where the bulk of the migration will occur.

## Complete molecular phylogeny in *Nacella* (Patellogastropoda: Nacellidae) in the Southern Ocean

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The genus *Nacella* includes 11 recognized species currently distributed different provinces of the Southern Ocean (Antarctica, South America, sub-Antarctic oceanic islands). Half of these species are found in particular oceanic sub-Antarctic islands such as Marion (*N. delesserti*), Kerguelen (*N. kerguelenensis*, *N. edgari*), Heard (*N. macquariensis*, *N. kerguelenensis*), Macquarie (*N. macquariensis*) and Campbell (*N. terroris*). The rest of the species are distributed in maritime Antarctica (*N. concinna*) and South America (*N. magellanica*, *N. deaurata*, *N. mytilina*, *N. flammea*, and *N. clypeater*).

Here we present the complete phylogeny of *Nacella*, including a putative new species from Patagonia, based on mtDNA (COI, Cytb) and nucDNA (28S rRNA) sequences and different reconstruction methods (MP, ML and Bayesian Inference). Two main lineages were recognized in the biogeography of *Nacella*, the first one includes the Antarctic and oceanic sub-Antarctic islands species and the second one comprises South American ones. These major groups were subdivided into nine clades: Antarctica (*N. concinna*), Marion (*N. delesserti*), Kerguelen I (*N. edgari*), Kerguelen II (*N. kerguelenensis*), Macquarie (*N. macquariensis*), Campbell (*N. terroris*), Patagonia I (*N. yaghana* n. sp), Patagonia II (*N. magellanica*, *N. deaurata*, *N. mytilina*, *N. flammea*), and Central Chile (*N. clypeater*). These results support the existence of transoceanic discontinuities in *Nacella*, especially between provinces of the Southern Ocean.

The separation of *Nacella* from its sister genus *Cellana* took place ~30 Ma close to the Eocene/Oligocene boundary. The diversification of *Nacella* occurred after the Middle Miocene Climatic Transition (~ 12 Ma) long after the physical separation of the analyzed areas of the Southern Ocean. Lineage through time analyses indicate that the diversification of *Nacella* occurred in two main rounds. The first one at the end of the Miocene (9 to 5 Ma) with the diversification in Antarctica, Kerguelen and South America. The second round includes a radiation in Patagonia (2 to 0.4 Ma) and the colonization of oceanic sub-Antarctic islands (Marion, Campbell and Macquarie) during the Pleistocene.

Major evolutionary processes are clearly recognized in the biogeography of *Nacella* including: (1) vicariant oceanographic processes between Antarctic and sub-Antarctic provinces probably mediated by the intensification of the Antarctic Circumpolar Current after the Middle Miocene Climatic Transition. (2) Recent events of long-distance dispersal including the colonization of Marion, Macquarie and Campbell islands. (3) Recent ecological mediated radiation in Patagonia where at least four Evolutionary Significant Units are recognized.

## End of the trend: Two decades of cold desert ecosystem response to climate variability in the McMurdo Dry Valleys

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The McMurdo Dry Valleys (MDVs) of Antarctica, represent a cold desert ecosystem defined by extensive soils, glacier meltwater streams, and closed-basin, ice-covered lakes. Despite cold temperatures and very little precipitation, a vibrant ecosystem exists across these landscape units. Previous work in the McMurdo Dry Valleys, Antarctica documented significant responses of local aquatic and terrestrial ecosystems to a decadal scale cooling trend prior to 2000. However, an exceptionally high melt year occurred in 2002, influencing stream flow, lake dynamics and terrestrial ecosystems. Here we describe inter-annual variation in Dry Valley ecosystems, focusing on the contrasts in drivers of ecological responses pre- and post-2002, i.e., the flood year. Mean annual summer temperatures have been consistent and comparatively cool since 2002, compared to the cooling trend prior to 2002. Annual mean solar radiation has been consistent and relatively high since 2002, compared to the decade prior to 2002. In streams, black Nostoc mats were observed to be decreasing in ash-free dry mass (AFDM) and chlorophyll-a concentration prior to 2002, increasing in AFDM since. No trend in chlorophyll-a concentration has been observed since 2002. Three MDV lakes were decreasing in volume and increasing in total chlorophyll-a mass in the photic zones prior to 2002 and have been increasing volume and decreasing total chlorophyll-a mass ever since. Soil nematode communities were decreasing prior to 2002, and show no significant trend since, but increased inter-annual variability. Since 2002, the MDV ecosystem has ceased responding to only a local decadal cooling trend and is responding to several high-flow years with new trajectories in some cases and increased variability in others.

## Antarctic crabs: Invasion or endurance?

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British Antarctic Survey

Recent scientific interest following the 'discovery' of lithodid crabs around Antarctica has centred on a hypothesis that these crabs might be poised to invade the Antarctic shelf if the recent warming trend continues, potentially decimating its native fauna. This 'invasion hypothesis' suggests that decapod crabs were driven out of Antarctica 40-15 million years ago and are only now returning as 'warm' enough habitats become available. The hypothesis is based on a geographically and spatially poor fossil record of a different group of crabs (Brachyura), and examination of relatively few Recent lithodid samples from the Antarctic slope. In this paper, we examine the existing lithodid fossil record and present the distribution and biogeographic patterns derived from over 16,000 records of Recent Southern Hemisphere crabs and lobsters. Globally, the lithodid fossil record consists of only two known specimens, neither of which comes from the Antarctic. Recent records show that 22 species of crabs and lobsters have been reported from the Southern Ocean with 12 species found south of 60°S. All are restricted to waters warmer than 0°C, with their Antarctic distribution limited to the areas of seafloor dominated by Circumpolar Deep Water (CDW). Currently, CDW extends further and shallower onto the West Antarctic shelf than the known distribution ranges of most lithodid species examined. Geological evidence suggests that West Antarctic shelf could have been available for colonisation during the last 9,000 years. Distribution patterns, species richness and levels of endemism all suggest that, rather than becoming extinct and recently re-invading from outside Antarctica, the lithodid crabs have likely persisted, and even radiated, on or near to Antarctic slope. We conclude there is no evidence for a modern-day 'crab invasion'. We recommend a repeated targeted lithodid sampling program along the West Antarctic shelf to fully test the validity of the 'invasion hypothesis'.

**Biodiversity, distribution, mineralogy and geochemistry of the fjordic bryozoan community: (Admiralty Bay, King George Island, South Shetlands, West Antarctic)**

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Qualitative faunal analysis of the Antarctic glacial fjord bryozoan community based on 11 samples chosen from 80 collected during the 12<sup>th</sup> Polish Antarctic Expedition in 1988 with the beam trawl from depth range of 15 to 280 m was performed. 37 species of cheilostomes dominated by ascophoran umbunulomorphs and lepraliomorphs, 4 cyclostomes and one ctenostome were analysed with extensive use of SEM. The taxonomic and distribution data were analysed together with the previous results carried out in the same region (Moyano 1979; Pabis et al. 2014).

The spatial variability in the bryozoan community structure, species richness and biomass are strongly associated with the number of environmental factors such as substrate type, water depth, location within the basin, hydrodynamic regime, influence of the suspended matter inflow or glacial disturbance.

Undoubtedly, four bryozoan assemblages were discerned. The limited in species number was shallow-water, sublittoral assemblage which colonized rocky with some gravel and algae substrate by occurrence of dominant epibenthic umbunulomorphs of *Inversiula* and *Arachnopusia* as well as bugulids in the central part of the basin of 15–60 m depth. The second assemblage, distributed in the shallow sublittoral of the inner fjords of Mackeller and Martel inlets of 60-120 m included 14 bryozoan species which mostly settled the muddy bottom, with some stones and they were represented by umbunulomorphs and lepraliomorphs with the rooted adeoniform colony growth-form. Flustrids, bugulis, and cellarioideans represented by cellariids were also common. The species richness (27 species), biomass and diversity were the greatest is the third assemblage from 120-200 m, where the fauna settled on the muddy substrate with some stones, in the central basin of the fjord. The dominant colony form is adeoniform represented by 12 species which form erect, bilamellar plates, frondose or folded sheets, branched or lobate zoaria accompanied by numerous erect bugulids, attached by bundles of chitinous rhizoids. Small epibionts settled on the large bryozoans occur with great frequency. The fourth assemblage at 240-280 m, is represented by the scarce lepraliomorphs of Lykothoporidae and Smittinidae bryozoans settled on the muddy bottom.

Mineralogically, the bryozoan skeletons from the Admiralty Bay are cheilostomes composed of intermediate magnesian calcite (IMC) where the Mg content ranges from ca. 4.3 to 6.5 wt% MgCO<sub>3</sub>. The bryozoans skeletons exhibit d<sup>18</sup>O and d<sup>13</sup>C values typical of cool marine waters. Their d<sup>18</sup>O ranges from ca. 2.25 to 4.3‰ PDB, with most data clustering between 3 and 4 ‰ PDB. The d<sup>13</sup>C varies from ca. – 1 to + 1.5‰ PDB with most data plotted between + 0.5 and +1.5‰ PDB (Hara et al. 2010).

## Plankton changes in the East Antarctic, but the Ross Sea does its own thing

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The SCAR Southern Ocean CPR Survey started in 1991 to map and monitor spatial patterns and temporal trends in zooplankton biodiversity. The highest concentration of sampling has been in the East Antarctic region, notably between 60 and 160°E (south and east of Australia) using vessels from Australia (*Aurora Australia*) and Japan (*Shirase* old and new, *Umitaka Maru*, *Kaiyo Maru*, *Hakuho Maru*). New Zealand joined the Survey in 2006 conducting regular tows in the Ross Sea region (160°E to 150°W) using the *Tangaroa* and fishing vessel *San Aotea II*. Zooplankton abundances and community composition were compared between the Ross Sea and the East Antarctic regions, with the expectation that within the Antarctic Circumpolar Current, the Ross Sea region would show similar patterns to zooplankton upstream in the East Antarctic. However, the Ross Sea region proved to be quite different. Latitudinal patterns in species composition were similar between the two regions and with previous publications, but the Ross Sea area had substantially higher abundances than in the East Antarctic region, and higher than predicted from models built from previously-collected CPR data. Chlorophyll-*a* concentrations were also higher in the Ross Sea region as shown in both CPR Phytoplankton Colour Index and ocean colour satellite data. There is also an indication that variability in zooplankton abundance in the Ross Sea region is higher than in the East Antarctic. For example, very high zooplankton abundances occurred in December 2009 as a result of a >10-fold increase of larvacean *Fritillaria* spp. numbers, which corresponded with unusually high chl-*a* throughout the Ross Sea. There were statistically significant trends of increasing zooplankton abundance in all zones of the East Antarctic region since 1991, i.e. Sub-Antarctic Zone, Polar Frontal Zone, Open Ocean Zone, and Seasonal Ice Zone. There were also corresponding significant trends towards larger copepod species in all zones based on the Copepod Community Size index. There were no similar trends in either abundance or Copepod Community Size in the Ross Sea region. Despite being downstream in the ACC, the Ross Sea region appears to be substantially different ecologically.

## Ecology and phylogeny of a novel pigmented yeast species found in a glacier system in the Greenwich Island, and its potential use as a biomarker for UV radiation in the Antarctic

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During summer 2012 in the Antarctic Peninsula, in Greenwich Island, close to the Ecuadorian Scientific Station "Pedro Vicente Maldonado", 122 yeast isolates, belonging to eight different species, were isolated from a glacier's system composed by a glacier, a stream, a lagoon and the seashore waters where the lagoon overflows.

Most of the yeasts community species belongs to oligotrophic, slow-growing, and metabolically diverse basidiomycetous and ascomycetous genera. About 24% of such isolates were found to correspond to a hitherto non described pigmented yeast species of the basidiomycetous *Rhodotorula* genus. This pigmented yeast species presents high tolerance to freezing-thaw cycles and halotolerance.

Moreover, this pigmented yeast is able to remain in dormancy within the deepest layers of the glacier's ice, which suggests that they can survive to freeze and high pressure for long periods of time, maybe tens or even hundreds of years.

The carotenoid pigments metabolized by this genus of yeasts are generally regarded as protective molecules against damages of DNA caused by UV radiation, which induces the metabolism of such molecules in yeasts.

After a molecular identification of species and characterization of the community, an ecological analysis revealed the "index of abundance" ( $I_a$ ) and the "index of specialization" ( $I_s$ ) of every single yeast species belonging to the community. Additionally, the phylogenetic analysis of the pigmented yeasts showed that there are at least three different strains of the same species coexisting in the glacier's system. The novel species showed to be ubiquitous along the glacier system and exhibited the highest  $I_a$  and the lowest  $I_s$  for this particular set of habitats.

This initial research aims to the understanding of the yeasts community dynamics in the Greenwich glacier's system, as the basis for the forthcoming study of deep layers of glacier's ice to recover pigmented yeasts which would provide valuable information about the biological response to UV ray radiation along the time. Lab scale experiments aiming to understand the biological response of this yeast species to radiation showed a correlation between UV radiation time and pigment production.

Thereafter, we suggest that this novel yeast species, which can be recovered from deep layers of ice, may be regarded as a potential biomarker of the changing conditions related to the evolution of the UV radiation in the Antarctic continent.

## **Preliminary study on the meiofauna communities in surface sediments of Prydz Bay, Antarctica**

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Meiofauna communities from the top 10 cm of the surface sediment layers at fifteen stations in Prydz Bay, Antarctica, were investigated during the 29th CHINARE cruise in 2013. The depth of the stations were between 155 m to 3421 m. Tubes with 2.9 cm diameter inside, which were refitted from plastic injectors, were used to obtain the sediment cores prepared for the analysis of meiofauna. Sediment cores were sliced in to three layers by 0-2 cm, 2-5 cm and 5-10 cm from the surface to the deep on the spot, and all samples were stored in 5% formaldehyde solution.

The preliminary results showed that 10 meiofauna groups were found, which included Nematoda, Copepoda, Polychaeta, Kinorhyncha, Bivalvia, Ostracoda, Oligochaeta, Acari, Ophiura and Indet., and nematoda which took 94.80% in abundance dominated the samples. The total meiofauna average abundance was  $1176.13 \pm 1821.13$  ind/10cm<sup>2</sup> (ranged from 12.12 ind/10cm<sup>2</sup> to 5783.23 ind/10cm<sup>2</sup>) and the average biomass was  $582.82 \pm 199.85$   $\mu\text{g}\cdot\text{dwt}$  /10cm<sup>2</sup> (ranged from 8.18  $\mu\text{g}\cdot\text{dwt}$  /10cm<sup>2</sup> to 2480.88  $\mu\text{g}\cdot\text{dwt}$  /10cm<sup>2</sup>), but both of them were quite uneven distribution among the 15 stations. Both the abundance and the biomass decreased gradually from the stations inside of the bay to the outside, so did the numbers of the meiofauna groups. According to the distribution of the abundance and the biomass, three areas could be divided in Prydz Bay: 1) the area inside of the bay (IS area), with the abundance ranged from 721.01 ind/10cm<sup>2</sup> to 334.03 ind/10cm<sup>2</sup>, and the biomass ranged from 5783.23  $\mu\text{g}\cdot\text{dwt}$  /10cm<sup>2</sup> to 2480.88  $\mu\text{g}\cdot\text{dwt}$  /10cm<sup>2</sup>; 2) the deep-sea area outside of the bay (OS area), with the abundance ranged from 12.12 ind/10cm<sup>2</sup> to 216.61 ind/10cm<sup>2</sup>, the biomass ranged from 8.18  $\mu\text{g}\cdot\text{dwt}$  /10cm<sup>2</sup> to 105.42  $\mu\text{g}\cdot\text{dwt}$  /10cm<sup>2</sup>; and 3) the continental shelf area that between the two (CS area), with the abundance ranged from 169.65 ind/10cm<sup>2</sup> to 763.42 ind/10cm<sup>2</sup>, the biomass ranged from 188.19  $\mu\text{g}\cdot\text{dwt}$  /10cm<sup>2</sup> to 663.06  $\mu\text{g}\cdot\text{dwt}$  /10cm<sup>2</sup>.

Compared to the other seas around the Antarctica, meiofauna abundance and biomass in the CS area was similar to those in Ross Sea, but higher than those in Weddell Sea. Compared with elsewhere, meiofauna abundance and the biomass in the IS area was higher relatively, which showed a more prosperous meiofauna communities there.

## **Spatial distribution of the macrobenthos at the Mackellar Inlet - King George Island: Explanations using systematic and trophic groupings approaches**

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The Admiralty Bay – King George Island is one of the most sampled sites within the West Antarctic Peninsula, and its macrobenthic communities have been subject to several studies as the region is considered a climate change sentinel. The structure of a community has usually been studied under a systematic approach; yet, this scope doesn't always reveal the processes that can be occurring in the area under study.

The use of a functional trophic group classification, which focuses on specific groups with functional relationships, can provide the suitable means to associate them with the environmental parameters and their dynamics.

In the present study, the macrobenthos composition of Mackellar Inlet was analyzed at 11 sampling stations across the bay during the summer of 2011 using a systematic and a trophic-grouping approach. Species diversity was higher from the outer to the inner fjord, however, community assemblages did not show any particular pattern when using systematic approach. Nevertheless, the trophic community structure, which was mainly ruled by the filter, deposit-feeders and predators groups seem to respond to the pattern of currents seen at the fjord.

The use of a systematic approach, as an indicator of ice-influenced phenomena over the benthic community, resulted ineffective in this particular short-scale study in which the trophic role of the biota and the pattern of currents seemed to explain better the arrangements perceived in the community. Nevertheless the influence of the glaciers might be indirect as the currents could carry elements and resources which in turn will influence the community structure. The present study shows that the use of a functional approach could be useful when applying it to different spatiotemporal scales studies, allowing a better understanding on how the communities might change due to variations of the environmental parameters. This research was funded by the Peruvian Ministry of Foreign Affairs.

## **Emiliana huxleyi variation and its expanse in Southern Indian Ocean during austral summer of 2009, 2010 and 2012**

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*Emiliana huxleyi*, a widely distributed coccolithophore, well perceived for its morphological and physiological divergence, plays a key role in the biological carbon pump. In the Southern Indian Ocean (SIO), meticulous sea surface water sampling (at every one degree interval) was carried out during two Southern Ocean Expeditions (SOE) (2009, 2010, between 39°S and 64°S along 57.3°E and 48°E) and on an Indian Scientific Expedition to Antarctica (ISEA) (2012, between 43°S-66°S, 29°E-75°E). The sea water sampling was performed to study *E. huxleyi* variability, its relationship to the existing environmental conditions and its poleward extent. During each consequent expedition, *E. huxleyi* morphotypes were identified; quantified and preference of each morphotype to existing environmental factors was assessed by the Canonical Correspondence Analysis (CCA). The increase in *E. huxleyi* morphotype abundance was documented throughout all three expeditions in the Subtropical (STF), Subantarctic (SAF) and Polar Frontal (PF) regions of the SIO. The utmost *E. huxleyi* abundance ( $0-1545 \times 10^5$  cells/l) was documented during SOE-2010 followed by ISEA-2012 ( $0-569 \times 10^5$  cells/l) and SOE-2009 ( $0-17 \times 10^5$  cells/l). During these expeditions, *E. huxleyi* morphotypes A and B subjugated in the warmer waters north of the southern Subtropical Front (SSTF), viewing their affinity to the warm oligotrophic waters whereas, *E. huxleyi* morphotypes B/C and C dominated in the SAF and the PF regions highlighting their preference to the elevated nutrient entailing regions. Elevated *E. huxleyi* abundance in the oceanic frontal regions of the SIO is credited to the enhanced nutrient concentrations. *E. huxleyi* abundance during the SOE-2010 is ascribed to high nutrient concentrations whereas the abridged *E. huxleyi* abundance during the SOE-2009 is attributed to the alteration in nutrient ratios, heterotrophs grazing pressure and possibly to other causes. During ISEA-2012, south of the PF, elevated silicate concentration and diatom abundance affected *E. huxleyi* presence and its abundance. The alteration in *E. huxleyi* southern extent during subsequent years indicates its poleward expansion as far as the Antarctic coastal region and is sternly time reliant, which is perhaps contingent on the regional oceanographic settings.

## Comparison of small animals between Sea Ice Floe and Water Column in the Seasonal Ice Zone

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In the marine ecosystem of the Southern Ocean, sea ice is a dominant environmental factor. During the summer, the sea ice extent is reduced by 80% in winter. Within the sea ice, unique assemblage of small animals has been reported. Therefore, they will be released into water column as seasonal melting and the distribution patterns of zooplankton at water column would be affected by their emigration. However, the mechanisms of biological production after the sea ice has melted, even the basic data such as the distribution, are not clear.

We investigated the abundance and distribution of zooplankton assemblages within the sea ice floe and water column in the seasonal ice zone (along a line 110°E and southward from 60°S) in the summer of 2013 during the cruise of the 'Umitaka-maru', a vessel of the Tokyo University of Marine Science and Technology. Zooplankton samples were collected in the water column using a closing net (mesh size 60 µm) at 10 stations. The net was vertically hauled from four layers (0–50, 50–100, 100–200 and 200–500 m). At the ice edge, we selected seven ice floes (approximately 20×20×20 cm<sup>3</sup>) that were observed to be colored by algae and simultaneously carried out zooplankton sampling in this region (mesh size 60 µm) from a depth of about 5 m to the surface. Onboard the vessel, the four sea-ice samples were crushed, melted and fixed immediately with buffered 5% formaldehyde in seawater.

In the floating sea-ice samples, we identified high densities of Foraminifera, Harpacticoida, *Paralabidocera antarctica* and their nauplii, and *Stephos longipes* (mean total density  $390 \times 10^3 \pm 9 \times 10^3$  ind m<sup>-3</sup>). In contrast, except for Foraminifera, zooplankton was in remarkably low abundance in the water column (max. 970 ind m<sup>-3</sup> at the sea ice edge) and the composition of the zooplankton assemblage was quite different from that of the sea ice. The density of Foraminifera at the surface decreased progressively toward the north (i.e., with time since the sea-ice retreat) although it was a dominant component of all samples. In particular, foraminiferans were highly abundant near the ice edge (max. 94% of the total zooplankton assemblage). One species of Foraminifera, *Neogloboquadrina pachyderma*, was dominant in both environments.

## Dynamic of growth processes of initial lichen stages in long-term experiments

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The lichen and bryophyte floras and their ecological associations at Antarctic terrestrial sites have been described previously. However, detailed studies of long-term processes of growth and development as well as their dynamic under defined environmental conditions are lacking. Lichens and mosses form the dominant vegetation across Antarctica that has been described as the coldest, windiest and remotest continent on earth. Studies of lichen growth, in particular, require extended periods. Lichens are characteristically slow-growing organisms, a feature that appears to be intensified at Antarctic locations. Our studies have taken place near to the southern boundary of the maritime Antarctic (Ryder Bay, Adelaide Island, c. 68°S) and further south at the southern end of Alexander Island, Antarctic Peninsula. The study presented focuses on long-term experiments of *Usnea* species, a genus distributed at terrestrial sites throughout the Antarctic. Diaspores of the lichen species *Usnea lambii* and *U. antarctica* have been cultured *in situ* for several years at different natural habitats to follow the dynamic of the developmental process and the growth rate in dependence of the respective environmental conditions at the southern border line of the maritime Antarctic. The growth rate seems to be much slowed down towards the south of Alexander Island compared with sites of the northern maritime Antarctic. The experiments and their results are unique for the Antarctic. The results give relevant information on the growth rate of epilithic lichens at these Antarctic terrestrial sites. The knowledge provides a baseline for the recognition and interpretation of the consequences of environmental change in this area in future decades.

## Species diversity and distribution of Malacostraca in the Antarctic glacial fjord (Admiralty Bay; South Shetland Islands) with a special focus on euphausiids

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In the Antarctic pelagic waters, apart from copepods or salps, one of the main components of zooplankton are also specimen representing of Malacostraca, including krill. In such areas like Admiralty Bay, which is a glacial fjord, analyse of that group of crustaceans are unfortunately rare and fragmentary. Taking into account the fact that Antarctic krill or amphipods can be the significant elements of fishes or penguins diet, there is a great need to intensify research of these crustaceans. Moreover, Admiralty, because of its specific hydrological conditions, is an interesting area also for that kind of biological studies.

The presented data are based on samples which were collected during Polish Antarctic expedition to the H. Arctowski station in the Antarctic summer, from November 2008 to March 2009. Material for analysis were caught by WP2 net with mesh size of 200  $\mu\text{m}$ . Sampling stations were located in the central part of Admiralty Bay, in Ezcura Inlet and in the smaller coves of the Bay.

In the area of investigation Malacostraca were represented mainly by euphausiids, such as *Euphausia superba*, *E. frigida*, *E. crystallorophias* and *Thysanoessa macrura*. *E. frigida* and *E. crystallorophias* were found mainly closer to the shore - in smaller coves of the Bay (eg. Herve, Monsimet, Goulden, and Cardozo). *Thysanoessa macrura*, which occurred in a highest numbers in Admiralty Bay, was recorded in all stations and was the only species represented by every developmental stages. Morphometric analysis of juvenile stages of this species showed non typical size in comparison to the literature data.

In general, our study showed that unique fjord character of Admiralty Bay (strong currents, tides, bottom topography) can strongly impact on the Malacostraca species diversity, abundance and their distribution. Newly acquired morphometric data can also fill the gap which is still existing in this part of knowledge.

**Population structure of *Salpa thompsoni* (Tunicata: Thaliacea) in the Drake Passage (Southern Ocean) in the summer season 2010**

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Relatively simple Antarctic food web is based mostly on the Antarctic krill – *Euphausia superba*. However, in the last few decades significant changes in functioning of this ecosystem have been observed, presumably as a result of climate change. One of the most striking result of these modifications are currently recorded changes in distribution and abundance of *Salpa thompsoni* and the decline of krill population.

In this study specimens of *Salpa thompsoni* recorded in the Drake Passage in summer 2010 were analysed. During laboratory studies, morphological, as well as the population analyse were made, including a level of development of the blastozoids embryos, or the number of buds present at reproductive stolon of oozoids.

The results of analyses showed that horizontal distribution of Salpidae in the Drake Passage was uneven, and the structure of population of these animals was strictly dependent on the area in which samples were collected.

In the northern parts of the Drake Passage (near South America) were recorded both blastozoids and oozoids, in various stages of development (from the buds of the mature specimens, being at the V stage of development), which can indicate that the development cycle of these animals was very effective in this area. The central part of the Drake Passage was characterized by the strong dominance of blastozoids, which embryos were during various stages of development. Only population which was observed near the South Shetland Islands characterized by slower reproductive processes, which was caused probably by the low temperature of water, which were recorded in this area.

In comparison to literature data, much more effective development of *Salpa thompsoni* oozoids and blastozoids in the Drake Passage in summer 2010 was probably induced by a relatively higher water temperature and intensive primary production.

## Application of UAV drone technology in terrestrial Antarctic landscapes

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The ice-free deserts of the McMurdo Dry Valleys in east Antarctica support a unique biota. This ecosystem is linked with major contributions to regional bio-geology and climate. The biotic component is dominated by microbial and lower plant biomass, and this may be spatially heterogeneous and occupy cryptic niches. Assessments of vegetation are therefore costly in terms of deployment duration due to the need for on-ground visual assessments. We anticipate the need for a rapid and broad scale approach that can reliably detect vegetation. This will allow longitudinal ecological monitoring and inputs to change models.

A collaborative venture between AUT University and SkyCam UAV has resulted in development of unmanned aerial drone (UAV) technology that was successfully deployed in the McMurdo Dry Valleys during the 2013-2014 austral summer. We successfully flew the Kahu Hawk (rigid airframe) and Swamp Fox (poly-foam airframe) aircraft, and evaluated battery life, autopilot and payload efficiency in the low-temperature Dry Valleys environment. We optimized 40-minute flights for the Swamp Fox at altitudes between 350 ft and 5,500 ft and wind speeds up to 30kph, over a range of rocky and ice-covered terrain. We successfully negotiated use of airspace with Mac-Ops and developed a protocol for use of UAV in the McMurdo Dry Valleys airspace. Emergency procedures for temporary and permanent loss of telemetry were also evaluated and protocols established for Antarctic deployments.

In-flight data for air temperature and humidity were successfully acquired. A range of cameras for ground-recording were evaluated, these included RGB, near-IR and vegetation-stress cameras. In addition, a hyperspectral camera forms part of ongoing payload modification. Camera data from UAV were ground-truthed against on-ground measurements and satellite data that was acquired via re-tasking of the Worldview 2 satellite. Considerable success was achieved in delineating cyanobacterial mats, lichens and moss cover. Future deployments will develop field monitoring further and also the GIS interface for data visualization and interpretation.

## East Antarctic benthic habitats

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Data from surveys along the East Antarctic margin will be presented to provide insights into the diversity and distribution of benthic communities on the continental shelf and slope, and their relationship to physical processes. Seabed video and still imagery collected from the George V shelf and slope and the sub-ice shelf environment of the Amery Ice Shelf indicate that the benthic communities in these regions are highly diverse, and are strongly associated with the physical environment. Variations in seafloor morphology, depth, sediment type and bottom circulation create distinct seabed habitats, such as muddy basins, rugged slope canyons and scoured sandy shelf banks, which are, in turn, inhabited by discrete seabed communities. The infauna dominated muddy basins contrast sharply with the diverse range of filter-feeding communities that occur in productive canyons and rugged inner shelf banks and channels. In the sub-ice shelf environment, differences in organic supply, linked to the circulation patterns, cause distinct differences in the seabed communities.

The strong association between benthic communities and seafloor characteristics allows physical parameters to be used to extend our knowledge of the nature of benthic habitats into areas with little or no biological data. Comprehensive biological surveys of benthic communities in the East Antarctic region are sparse, while physical datasets for bathymetry, morphology and sediment composition are considerably more extensive. Physical data compiled within the proposed network of East Antarctic Marine Protected Areas (MPAs) is used to aid our understanding of the nature of the benthic communities. The diversity of physical environments within the proposed MPAs suggests that they likely support a diverse range of benthic communities. This research has been conducted in support of Australia's Antarctic Science Strategy (Stream 3.4, Protecting Marine Biodiversity) and Geoscience Australia's Marine Bioregional Planning priority.

## Population status and body size of a large marine mammal

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It is well documented for terrestrial mammals that populations' status (increasing, decreasing or stable) influence population mean body size, however little is known on this subject for large marine mammals. Southern elephant seal populations experienced major population declines between the 1950s and 2000s throughout most of their breeding range. While most populations declined (e.g. Macquarie - MAC and Marion Island - MI) others remained stable (e.g. South Georgia - SG) and a few increased (e.g. Peninsula Valdes - PV). Food availability, environmental change and interspecific competition are regarded as plausible explanations' for the decline. Theory predicts a somatic trade-off between population size and body size; due to competition and resource limitations. However little is known on population declines influenced mean population body mass.

We photogrammetrically "weighed" 93 adult male southern elephant seals from three different circumpolar populations (MAC n=15, MI n=16 and PV n=62) at the end of their annual breeding season. Males from MAC were the largest ranging from 1313.22kg to 2525.70kg (mean=1973.56kg  $\pm$  361.80kg) followed by MI ranging from 741.46kg to 2466.61kg (mean=1662.30kg  $\pm$  407.09kg) and PV ranging from 802.15kg to 1937.94kg (mean=1317.30kg  $\pm$  265.07kg). Mass differed significantly between all populations; however body length did not significantly differ between two populations (MI and PV).

Males from MI are in better condition at the end of the breeding season than those of similar length at PV, we attributed this to lower male breeding competition at MI. Historical population status (1950 to 2000) and standard body length are correlated with body mass. Males from the previously declining but currently stable populations (MAC and MI) were significantly larger than those from the increasing PV population. We provide evidence of inter-population mass differences in a large marine mammal as a result of somatic trade-off between population size and body mass.

## Antarctic anemones discovered living in the lower surface of the Ross Ice Shelf

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Extensive field surveys were conducted in Antarctica from November 2010 through January 2011 as part of the ANDRILL (ANTarctic geologic DRILLing) Coulman High Project. A series of combined United States – New Zealand field camps were established at sites located approximately 120 miles from McMurdo Station on the Ross Ice Shelf northeast of Ross Island. The ANDRILL hot water drill system was used to melt access holes through 250-270 meters of ice shelf to allow oceanographic instruments, sediment corers, and the Submersible Capable of under-Ice Navigation and Imaging (SCINI) remotely operated vehicle (ROV) to be deployed into the ice shelf cavity. The SCINI vehicle was deployed down a ~30 cm-diameter hole at two sites, located ~10 km and 6 km from the ice shelf edge. The goal of the deployments was to explore the underside of the ice shelf while conducting operational testing of the ROV. This was the first time, to our knowledge, that an ROV was deployed through an ice shelf in Antarctica into the ice shelf cavity below.

SCINI cameras discovered and explored a unique biological community dominated by sea anemones living inside burrows in the lower surface of the ice shelf. An improvised suction sampler was used to recover biological samples. These samples and extensive images from the cameras on the ROV have been used to provide an initial assessment of the spatial distribution and nature of these organisms and to begin to evaluate environmental influences on the life cycle and ecology of these organisms. *Edwardsiella andrillae* n. sp. (Daly, et al., 2013) lives with most of its column in the ice shelf, with only the tentacles crown extending into the seawater below. *Edwardsiella andrillae* is the only Antarctic representative of the genus, and is distinguished from all other species of the genus in the number of tentacles and in the size and distribution of cnidae. The anatomy and histology of *Edwardsiella andrillae* present no features that explain how this animal withstands the challenges of life in such an unusual habitat. This unexpected discovery at the base of the Ross Ice Shelf highlights the importance of serendipity in scientific research and points to the significant opportunities that interdisciplinary investigations can provide in these remote environments.

References: Daly, M., F.R. Rack, R. Zook, 2013. *Edwardsiella andrillae*, a new species of sea anemone from Antarctic ice. PLoS ONE, 8(2):e83476-e83476.

## Diversity and Structure of Rich Pycnogonid Communities off Terre Adélie and George V Land, East Antarctica

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Pycnogonids are a prevalent and diverse component of the Southern Ocean benthos. Around 20% of the world species are found in Antarctic and subantarctic waters. The benthic diversity from the East Antarctic region is relatively unknown compared to other regions such as the Antarctic Peninsula and Ross Sea. The Collaborative East Antarctic Marine Census (CEAMARC) was conducted by Australia, Japan, France and Belgium in 2007/08 and aimed to investigate and document the biodiversity of benthic and pelagic communities present in the Dumont d'Urville Sea, between the Mertz Glacier and Dumont d'Urville. Pycnogonids were collected at 67 of 74 benthic trawl stations, in depths between 100 and 2050 m, accounting for more than 2000 individuals in 77 species and 14 genera. The study added fourteen species as first records from East Antarctica and found at least four species new to science. The genus *Nymphon* was the most diverse (20 spp.) and also the most abundant. Almost 60% of all pycnogonids were *Nymphon australe*, this dominant species was found at 70% of the sites. *Colossendeis* was the second most diverse genus with 17 species, followed by *Ammothea* and *Pallenopsis* with 14 and eight species respectively.

Species diversity tended to decrease with depth, particularly on the shelf edge. Adélie Bank off Dumont d'Urville appeared highly diverse compared to Mertz Bank, the George V Basin and the coastal areas subject to ice scouring. Multivariate analyses separated *Nymphon*-dominated from *Colossendeis*-dominated clades while *Pallenopsis*, *Achelia* and *Pycnogonum* were characteristic of the shelf edge sites.

Compositional patterns were most strongly related to sediment properties, with depth and other variables of secondary importance. This result differs to those from a Weddell Sea study in which a clear bathymetric pattern in species composition and abundance was found. The analyses of video transect data from a subset of sites provided insights into the relationships between pycnogonid community composition and benthos cover including abundance of corals, sponges and bryozoans.

This study has revealed a high species richness of pycnogonids on the East Antarctic region compared to other better sampled Antarctic areas. Considering pycnogonids are a bizarre, phylogenetically distinct class in the phylum Arthropoda, these communities add enormous conservation value to the largely diverse benthic 'gardens' off Terre Adélie and George V Land in the East Antarctic.

## Trends of the distribution and concentration of chlorophyll a in the area of Gerlache Strait, Antarctic Peninsula

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In the Antarctic, there are seasonal and regional variations in primary productivity and chl-a concentration. Regional variability could be related with differences in nutrient contents and physical-chemical phenomena. The Antarctic Peninsula, has high levels of primary production during spring and summer, unlike the open ocean. Gerlache Strait is a region of high phytoplankton biomass compared to neighboring areas (e.g. Bransfield Strait). It is a relatively protected area of oceanic influences and has mixture of seawater and marine glacier melting, which could favor the development of high rates of productivity and chl-a.

To date numerous oceanographic cruises have been carried out in the area of the Antarctic Peninsula.

However, the information obtained from the Gerlache Strait area remains isolated and sparse, and not integrated in space and time. So taking oceanographic data obtained from several oceanographic cruises from 1981 to 2010, we want to identify and characterize the trends in distribution and variability of oceanographic variables and chl-a. Standard oceanographic processing and visual quality control were realized to the data to obtain profiles and sections of temperature, salinity, chl-a, and density.

Warmer sea surface temperature is at the northern area. In the south, the surface temperature is colder due mainly to the local contribution of glacial melting. At greater depths there is a evident oceanic water masses influence. Central and southern areas show higher chl-a concentrations. In time, the Chl-a concentration is highly variable to 20 m deep. No clear correlations was possible to determine with the fluctuations of temperature and salinity in time.

The results obtained suggest that the trend in the distribution and concentration of chl-a in the region, is influenced by a complex oceanographic pattern, where eddy circulation, inputs of colder meltwaters, and oceanic water masses come together. Considering a homogeneous entrance of nutrients and light, the eddy circulation promotes retention of phytoplankton, and colder waters from glaciers, enhanced the developments of shallow mixed layer, that generate the conditions of stability for the phytoplankton blooms.

## Monitoring the floral development of two alien vascular plants (*Poa annua* and *Cerastium fontanum*) along an altitudinal gradient on sub-Antarctic Macquarie Island

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Floral development of two alien species (*Cerastium fontanum*, *Poa annua*) were monitored through the summer of 2013/14 at three different altitudinal sites (coastal, hillside and plateau) on the North eastern end of sub-Antarctica Macquarie Island. All sites were selected to have a north-east aspect and low or moderate slope. Differential biotic and abiotic conditions directly or indirectly related to altitude were regularly measured with e-buttons and through surveys at each site. Previous studies showed an ascending gradient of unfavourable thermal conditions (decreased temperature at higher sites) and increased humidity. At each of the three sites seven plots (grid 50 x 50 cm) for each species were created. The relative coverage of all species in these plots was measured. Three reproductive stems were tagged in each plot respectively, with most advanced stage of the contained inflorescences examined fortnightly. In addition, the most generalized flowering state observed at each plot was monitored. Plant height, the length of tagged reproductive stems, and either the total number of inflorescences (for *P. annua*) or the maximum diameter of plants (for *C. fontanum*) was measured for each plant once.

Plant cover, size and number of inflorescences were constrained in both species at increased altitude. However, a delayed general development of floral structures was more prominent in *Cerastium fontanum*. *Poa annua* plants showed a higher capacity to flower throughout summer at each of the three sites, while the flowering period of *C. fontanum* plants was shorter. It is hypothesized that abiotic factors related to altitude largely drove both total vegetative and reproductive growth and delayed sexual development for *C. fontanum*. In contrast, *P. annua* was less constrained by altitudinal effects in terms of floral development, showing a strong capacity to reproduce quickly in all environments despite adverse conditions that lead to restricted total growth. *Poa annua* shows a highly versatile colonist strategy while *C. fontanum* has a more synchronic strategy, with both species growing successfully under a range of conditions. These traits facilitate invasion in different environments, thus reinforcing the need to prevent the spread of these kinds of species to other favourable sites in the Antarctic and Sub-Antarctic where intensive management may not be feasible.

## Potential abiotic niche modelling for terrestrial non-native species in Antarctica

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Biological invasions are currently recognized as a major threat to Antarctic ecosystems. Consequently, effective tools need to be developed and applied to the region to understand, predict and manage their impacts. Abiotic niche modelling identifies the susceptibility of different areas to colonization by invasive species, and therefore can inform biosecurity for vulnerable areas. These modelling techniques rely on extensive biogeographic information which is globally available and can make robust predictions. Antarctic is rarely included in these types of analyses, yet they offer potentially substantive opportunities to improve conservation outcomes in the region.

Non- native vascular plants are among the most significant invasive species in the terrestrial sub-Antarctic and Antarctic ecosystems. However, established alien vascular plants in Antarctica are restricted to one persistent (*Poa pratensis*) and one invasive (*Poa annua*) species. The capacity of these grasses to withstand Antarctic conditions make them excellent pilot candidates for modeling the potential for future spread. We present the first biogeographic models and the implications for these two species. Future research and management will largely benefit from these approaches, which can also be extended to include alien cryptograms and invertebrates. These models are also important under future climate change scenarios. This work is consistent with core research priorities of the SCAR Ant-Eco program.

## Population dynamics of Antarctic krill in winter/early spring in the Weddell Sea

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The condition, survival and recruitment of Antarctic krill (*Euphausia superba*) depend to a large extent on overwintering success. In winter, much of the krill habitat is ice covered. Models suggest that sea ice properties during the late winter – spring period have the largest effect on recruitment. During this period, larval and juvenile krill survive largely by feeding on sea ice biota. The under-ice surface layer, which is not sampled by pelagic trawls or sonars, has formerly been identified as an important habitat of one-year-old juvenile krill. This surface layer was specifically sampled with the Surface and Under Ice Trawl (SUIT) during Antarctic winter 2013. Using several sensors during under-ice fishing, a suite of environmental parameters was measured, including ice thickness and spectral light transmission. With this unique dataset the population structure and recruitment of larval and juvenile krill was investigated using length frequency distributions in relation to environmental parameters. Our analysis focuses on how the population structure is influenced by various factors, such as geographic location, diurnal vertical migration, habitat structure, and population origin.

## Species richness in macrofaunal molluscs from the Ross Sea (Antarctica): results of fine-mesh sampling and new insights from the application of novel statistic techniques

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Species richness is notoriously an elusive quantity to measure, its perception being confounded by a variety of factors comprising, among others, the scale, extent and grain size chosen in a study. The comparison of species richness between sites/large areas is also a not straightforward task, as very biased results can be produced if specific methods accounting for differences in sampling intensity and design are not taken into account.

In recent years, several research voyages have been performed in the Ross Sea between 2004 and 2008, which brought an impressive amount of new distributional records of mollusc species previously unknown in the area, as well as of new species.

Thanks to this new material and to the existence of SOMBASE, a database compiling historical data about Southern Ocean mollusc distributions, our research group has undertaken a review of the knowledge of the Ross Sea Mollusca, with the final aim of obtaining a robust reference baseline and put in evidence possible pitfalls that prevent the achievement of sound assessments of richness and diversity at the geographical scale of the Ross Sea.

To do this, we've focused on grid cells of 1° of latitude by 1° of longitude and considered only those which have at least 20 sampling events (which account for only a 2.31% of the total number of cells).

We have therefore used this set of well-sampled grid cells and novel statistical techniques to evaluate: i) the number of expected species (through rarefaction and extrapolation analyses with iNEXT; ii) the species turnover (through the SDR-simplex methodology); iii) the sampling effort needed to reach the asymptote of the species accumulation curve (through Turing's frequency formulas).

From the obtained results it emerges that most effective sampling can be obtained by deploying a variety of different gears in the same area (a strategy that maximized the opportunities of collecting species with a different catchability), and by using sampling gears which have a small mesh size.

We advocate the use of fine-mesh trawling gears for routine sampling activities in future Antarctic expeditions to assess the full marine biodiversity as they represent the most effective method to establish a reference baseline getting closer to the asymptote of the expected number of species.

**Settlement preferences of marine invertebrate larvae from the Western Antarctic Peninsula: influences of depth, site and coralline algae**

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The structure of benthic marine communities relies largely on the demographics, mode of dispersal, and settlement/recruitment preference of organism propagules. The near shore environment of the subtidal western Antarctic Peninsula is composed of many diverse benthic communities, typically dominated by macroalgae in the shallow habitats (<20-35 m) and by dense invertebrate assemblages in deeper waters (>35m). Crustose coralline algae are abundant in these habitats as they are on tropical and temperate reefs where they are important contributors to reef structure and community dynamics. Because many factors play into the recruitment and settlement of marine propagules we set out to investigate the influence of coralline algae extracts, depth, and site on the distribution of dominant invertebrate taxa along the western Antarctic Peninsula. Potential effects of ocean acidification on coralline algae extracts were also investigated using a mesocosm study. Results are one of few analyses of invertebrate recruitment in this region and shed light on factors structuring these benthic communities.

## Benthic biotopes of the Vestfold Hills nearshore marine environment

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An integrated analysis of geoscience information and benthos data has been used to identify benthic biotopes (seafloor habitats and associated communities) in the nearshore marine environment of the Vestfold Hills, East Antarctica. High-resolution bathymetry and backscatter data were collected over 42km<sup>2</sup> to depths of 215 m using a multibeam sonar system. Epibenthic community data and *in situ* observations of seafloor morphology, substrate composition and bedforms were obtained from towed underwater video. Analysis of the datasets was used to identify statistically distinct benthic assemblages and describe the physical habitat characteristics related to each assemblage, with seven discrete biotopes identified. The biotopes include a range of habitat types including shallow coastal embayments and rocky outcrops which are dominated by dense macroalgae communities, and deep muddy basins which are dominated by mixed invertebrate communities. Transition zones comprising steep slopes provide habitat for sessile invertebrate communities. Areas of flat sandy plains are relatively barren.

The relationship between benthic community composition and environmental parameters is complex with many variables (e.g. depth, substrate type, longitude, latitude and slope) contributing to differences in community composition. Depth and substrate type were identified as the main drivers of benthic community composition, however, depth is likely a proxy for other unmeasured depth-dependent parameters such as light availability, frequency of disturbance by ice, currents and/or food availability. Sea ice cover is also an important driver and the benthic community in areas of extended sea ice cover is comprised of sessile invertebrates and devoid of macroalgae.

This is the first study that has used an integrated sampling approach based on multibeam sonar and towed underwater video to investigate benthic assemblages across a range of habitats in a nearshore marine environment in East Antarctica. This study demonstrates the efficacy of using multibeam sonar and towed video systems to survey large areas of the seafloor and to collect non-destructive high-resolution data in the sensitive Antarctic marine environment. The multibeam data provide a physical framework for understanding benthic habitats and the distribution of benthic communities.

This research provides a baseline for assessing natural variability and human induced change on nearshore marine benthic communities (Australian Antarctic Science Project AAS-2201), contributes to Geoscience Australia's Marine Environmental Baseline Program, and supports Australian Government objectives to manage and protect the Antarctic marine environment.

## A synthesis of metacommunity dynamics in the McMurdo Dry Valleys, Antarctica

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An overarching goal of the McMurdo Dry Valleys (MCM) Long Term Ecological Research (LTER) program is to understand the ecological processes that drive biodiversity patterns, and how dominant species sorting processes vary across organisms (e.g., soil bacteria, nematodes, stream diatoms) and ecosystem types (e.g., streams vs. arid soils). The metacommunity concept represents a major advance in ecology because it provides a framework to link ecological processes with biodiversity patterns at multiple scales. Metacommunities consist of assemblages of interacting species, typically linked over broad spatial scales by dispersal. The structure of a metacommunity is an emergent property of demographic processes (i.e., births, deaths, emigration, immigration) that are influenced by the habitat at local and regional scales, and is represented by measures of local (alpha) and regional (gamma) diversity, and species turnover (beta-diversity). The objectives in this study were to (1) develop a general model linking biodiversity patterns to metacommunity dynamics (e.g., dispersal, immigration rate, environmental filtering, and (2) place MCM biodiversity in a global context by synthesizing metacommunity dynamics inferred from biodiversity data sets across the LTER network.

We designed a package for the R statistical environment to simulate metacommunities to quantitatively assess how metacommunity characteristics such as patch similarity, inter-patch dispersal, and species similarity relate to diversity outcomes. We used simulation outcomes to evaluate the sensitivity of different biodiversity metrics to model parameters. We then trained neutral networks on the simulated data to create a set of models that could be used to infer metacommunity characteristics from diversity outcomes. We assessed the accuracy of the neural networks using both simulated and observed datasets. Biodiversity patterns suggest microbial communities in arid soils (e.g., edaphic bacteria) in the Dry Valleys are more interconnected than aquatic communities (e.g., stream diatoms), thus, stream communities may be more susceptible to the increase in connectivity among landscape units that is predicted by the overarching hypothesis of the current MCM LTER project. Generally, we found that commonly used measures of biodiversity can be used to make inferences about some metacommunity dynamics (e.g., the degree of ecological equivalence among species in the regional pool, local and regional recruitment pool sizes), but not others (e.g., heterogeneity in assemblage size, dispersal kernel shape). This approach offers much potential to understand how context (e.g., study design and methods, ecosystem type, organism type) influences our interpretation of biodiversity patterns, as well as a predictive framework to forecast shifts in biodiversity associated with climate change.

## Species composition and carbon biomass of phytoplankton blooms in the vicinity of James Ross Island, east of Antarctic Peninsula

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The vicinities of James Ross Island (JRI), east of the Antarctic Peninsula, show ice-melting processes that establish a strong vertical stratification leading to high chlorophyll-a (Chla) concentrations during the warmer season. These phytoplankton blooms can be often detected from ocean color images. However, the phytoplankton community composition associated with those features in that region is poorly known. Here we relate the phytoplankton composition and biomass with environmental factors near JRI for two late summer periods. Physical, optical and biogeochemical properties were measured during one cruise carried out in 2008 (1–3 March) and other in 2009 (17–20 February). Upper mixed layer (UML) depth was derived from density profiles and, wind information (direction and intensity) was obtained through the satellite sensor QuikSCAT. Relationships between Chla, sea ice and cloud coverage were determined using remote sensing data from both summers. Intense patches of Chla were observed by means of remote sensing and field data, being that the highest value of  $7.61 \text{ mg m}^{-3}$  was measured in 2009. Those patches were associated with shallow UML (33–50 m in 2008 and 23–29 m in 2009). Sea surface temperatures were relatively lower in 2008 ( $-1.19^{\circ}\text{C}$  –  $0.62^{\circ}\text{C}$ ) than in 2009 ( $> -0.93^{\circ}\text{C}$ ). Based on remote sensing data, sea ice coverage was much extended in summer 2008 than in 2009, implying an earlier sea ice retreat latter year. This led to higher average Chla in 2009 ( $5.25 \text{ mg m}^{-3}$  in the field) than in the previous year ( $2.63 \text{ mg m}^{-3}$  in the field). On the other hand, both late summers were characterized by an increasing salinity gradient from the JRI eastward, accompanied by a decreasing trend in Chla levels and other bio-optical indicators such as fluorescence and beam attenuation. Taking all these features into consideration, the phytoplankton blooms observed near JRI might relate to melting from both sea ice and glacial ice that have led to shallow UML. In addition, that JRI region appeared to be relatively sheltered from westerly winds, which can partly prevent disruption of water column stratification and maintain high biomass levels in surface layers. Across the whole study region, diatoms dominated the phytoplankton community, mainly in terms of carbon biomass. Nevertheless, in late summer of 2009 there was a conspicuous presence of large diatom species (e.g. *Odontella weissflogii*, *Eucampia antarctica* and *Thalassiosira* spp.) typical of an advanced ice melt condition. Considering a mean relative contribution to total carbon biomass of phytoplankton community, a similar diatom species composition was found for both late summer periods and for the whole study region, including lower-salinity-higher-biomass and higher-salinity-lower-biomass areas.

## Meridional and interannual variations of the seasonally modulated zooplankton diel vertical migration in the Lazarev Sea and their possible physical-biological controls

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Acoustic Doppler current profilers (ADCPs) not only take measurements of the water velocity components but also of the backscatter strength, which can be used to infer distribution patterns of zooplankton and small nekton. Here we present results obtained from ADCPs that were moored at 64°S, 66.5°S and 69°S along the Greenwich Meridian during the three-years period February 2005 until March 2008. A diel vertical migration (DVM) pattern – downward at dawn and upward at dusk - of two distinct groups of migrators persisted during most part of the years at all moorings sites, closely related to the astronomical daylight cycles. While the DVM was symmetric around local noon, the annual modulation of the DVM was asymmetric relative to the summer/winter solstices at the three mooring sites. This annual asymmetry resulted from a change in the migration behaviour that occurred in late spring (October - November), when the DVM ceases for around three months. In contrast to many previous studies in other regions, DVM at our observation sites persisted throughout winter, even at the highest latitude during the polar night. Using in-situ physical and biological data collected during deployment and recovery of the moorings, ice-thickness time series measured by Upward Looking Sonars, and satellite maps of remotely sensed sea ice coverage and surface chlorophyll concentration we can explain part of the seasonal to interannual variations in the inferred zooplankton distribution patterns by environmental cues. For a more complete explanation of the observed organisms' behaviour, however, we hypothesize controls by internal drivers that need also be taken into account.

## Anatomical and physiological responses and differential expression of SOS genes in *Deschampsia antarctica* DESV. under NaCl treatments

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*Deschampsia antarctica* Desv., is one of two vascular plants that live in the Maritime Antarctic. This plant survives under hostile environmental conditions, such as high radiation combined with low temperature, desiccant winds, frequent frost, frozen ground and saline sea spray. *D. antarctica* plants grow on the coast where it is often covered by waves or exposed to large amounts of sea spray during high winds. However, there is limited information about salt tolerance response of this species. We hypothesize that *D. antarctica* present anatomical changes, osmotic adjustment and regulation SOS genes in response to NaCl treatment. To test this hypothesis, we evaluate anatomical changes in the leaf epidermis through scanning electron microscopy, content of free proline, sodium accumulation, photosynthetic efficiency and analysis of differential expression of SOS genes in *Deschampsia antarctica* plants exposed to different NaCl concentrations (0.5 M, 1.0 M) for 21 days.

We observed change in epidermal cells of leaves through of induction of trichomes only in adaxial surface of plants subjected to 0.5 M NaCl treatment and in both leaf surfaces of plants subjected to 1.0 M treatment. Trichomes arise from leaf epidermal cells forming hook-shaped or prickle distinctive structures (62  $\mu\text{m}$  in length approximate) under NaCl treatments. It was observed an increased level of free proline and sodium content in leaves of plants subjected to 1.0 M, this increased was of up 36.1 and 13 times more than the control plants, respectively. Increased of proline, could have an osmotic effect that helps to counteract the NaCl effects. The photosynthetic efficiency was only affected in plants exposed to 1.0 M NaCl after 21 days of treatment. A decreased expression in SOS2, was observed under treatment conditions. However the expression of SOS1 increased in the leaves and roots of plants treated with 1.0 M of NaCl. This would indicate that SOS1 could be involved in  $\text{Na}^+$  transport mechanisms in *D. antarctica*, which would permit tolerating higher  $\text{Na}^+$  levels in the soil. We observed an increased of expression of SOS3 only in root of plant treated with 0.5 M of NaCl at 21 days, this could lead to an increased activity of protein SOS3, that could activate the  $\text{Na}^+$  transport mechanisms in the plant in response to stress conditions caused by NaCl.

These results show that *Deschampsia antarctica* responds to NaCl treatment through mechanisms that include anatomical changes, through trichomes formation, osmotic adjustment mechanisms through proline accumulation in leaves, and SOS1 and SOS3 genes activation, involved in sodium transport in the plant. These response mechanisms might be involved in the ability of *Deschampsia antarctica* has to withstand high salt concentrations in the Antarctic Territory.

## Population changes in pinnipeds (Mammalia: Carnivora) around Maldonado Scientific Station (Ecuador), South Shetland Islands, Antarctica

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In the austral summers between 2010 and 2014 a population study was conducted regarding five species of pinnipeds: Antarctic Fur Seal (*Arctocephalus gazella*), Leopard Seal (*Hydrurga leptonyx*), Weddell Seal (*Leptonychotes weddellii*), Crabeater Seal (*Lobodon carcinophaga*) and Southern Elephant Seal (*Mirounga leonina*), present in the vicinity of Maldonado Scientific Station (Ecuador), located on Greenwich Island, South Shetland Archipelago, Antarctica. The study was conducted in seven localities of five islands: Aitcho, Cecilia, Dee, Greenwich (northwestern and northern areas), and Robert (northwestern), and Discovery Bay (Bahía Chile). The study was conducted for approximately a month between January and March, for five years. It has over 1,800 observations of counted individuals. The dominance during the month of January was for *Mirounga leonina* (more than 70 % of the results), while in February, and especially March, the dominant species was *Arctocephalus gazella* (with 40 to 70 % of total entries). For the five species of pinnipeds, the population size, distribution and preference of seating areas and sexual composition was determined. This study presents the bases for a long-term monitoring to infer possible changes due to global warming in the Antarctica, as well as conservation recommendations.

## Antarctic marine invertebrates-associated microorganisms: assessing three domain diversity and community composition

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Antarctic ecosystem, a large, mostly pristine and extreme environment, offers a particularly attractive environment for marine invertebrates-microorganism symbioses research. In this environment, marine sponges harbor dense and diverse microbial communities with considerable ecological significance. Although the majority of the studies have been focused on the bacterial communities, studies among three domain diversity of Antarctic marine invertebrates-associated microbial communities are scarce.

In this study, the microbial community associated to sponges and its surrounding seawater was analyzed through ribosomal small subunit hypervariable regions V4 and V9 Illumina tag sequencing, aiming to capture the microbial diversity across the three domain: bacteria, archaea, and eukarya.

Different sponge species from Bahía Fildes, King George Island, Antarctica, were collected and their microbial associated community was characterized and compared with those from the surrounding water. Deep sequencing of 16S and 18S markers, allows to comprehensively capture the complex microbial communities associated to Antarctic sponges, as determine by asymptotes for most cases in rarefaction curves.

Results show differences in diversity and composition of microbial communities associated to distinct sponge species from the same sampling site, and also compared with the surrounding water. Diversity of bacterial/archaeal sequences shown to be higher than those from eukaryote. However, further standardization are needed due to differences in SSU rRNA copy numbers between domains. These results allow us to describe the rare biosphere and to establish a useful base for further functional analyses in these particular communities. To our knowledge, this is the first report of simultaneous three domain Antarctic sponge-associated microbial communities using high throughput sequencing approaches.

## ROV observations on Antarctic fish at Terra Nova Bay

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### ROV observations of Antarctic fish at Terra Nova Bay

During the austral summer from January 25 to February 4, 2014, two ROV (Remotely Operated Vehicle) transects were conducted at Terra Nova Bay, Ross Sea, under the umbrella of the GEOSMART project (Italian Program for Antarctic Research -PNRA). One transect was conducted between 225 and 300 meter depth in the Gerlache Inlet area, the other between 20 and 120 meter depth in the Adelie Cove; both transects had a length of about 1000 meters and lasted 3 hours. ROV "Pollux III" (Stella di Mare srl) is equipped with a navigation low resolution camera, a second high resolution Sony camera and a Canon photo camera in separate housings. A USBL (Ultra Short Base-Line) underwater position system (Linkquest Tracqlink 1500 MA) is installed to show and record the geographic position of the vehicle with a one-second frequency. Each fish sighting was recorded and species classified on the basis of visual features from the post processing analysis of high definition videos and images. A total of 151 individuals were observed, accounting for 12 different taxa. Most of observations referred to *Trematomus bernacchi* (52%) and *Chionodraco hamatus* (13%). Some specimens of the cryopelagic species *Pagothenia borchkrevinki* and of the pelagic Antarctic silverfish *Pleuragramma antarcticum*, were found in the deeper transect (280m depth), swimming very close to the sea bottom, providing new insights on their behavior. Differences in the fish abundances resulted from the two sites: in the Adelie cove, the number of species is lower but the number of fishes greater (7 taxa, 121 fishes), in the Gerlache Inlet area we encountered a lower number of fishes (31) belonging to 9 different taxa. For some fish species we obtained interesting observations on their reproductive behavior. In two occasions we found *T. bernacchi* involved in the guard of eggs deposited inside the osculum of large-size volcano sponges (*Rosella* sp.); we also observed one specimen of the channichthyid species *Pagetopsis macropterus* actively patrolling its nesting site, consisting in a flat rock covered by a large single layer of eggs. ROV observations were biased by water turbidity that characterizes these underwater environment also at depth during the austral summer, and by difficulties to observe cryptic species like smaller individuals of the *Trematomus* genus and the *Arteidraconidae* family in such a complex habitat formed by massive and large sponges, and well developed bush-like gorgonians. Despite this limitation, ROV provides a unique opportunity to collect information and observe *in situ* the behavior of these fish species.

## The Biogeographic Atlas of the Southern Ocean

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The Southern Ocean has a long history of exploration. While the first species were described as early as the 19<sup>th</sup> century, there is still much to learn as shown by the number of species discovered during the Census of Antarctic Marine Life (CAML).

The initial efforts of synthesizing and mapping the Southern Ocean biogeography dated back to the Antarctic Map Folio Series (1968-1974). Despite the robustness of the emerging biogeographic schemes, these attempts are now largely outdated in face of the exponential development of the occurrence record datasets in recent decades, the new insights provided by the molecular and phylogeographic approaches, and the availability of new methods of analysis, visualization, modelling and prediction of biogeographic distributions.

The scope of the multi authored Biogeographic Atlas of the Southern Ocean is to present a concise synopsis of the current knowledge on the distributional patterns of all the major Antarctic benthic and pelagic taxa and of key communities, in the light of biotic and abiotic factors operating within an evolutionary framework. Each section has been written by the most pertinent experts in their field, relying on vastly improved occurrence datasets from recent decades, as well as on new insights provided by molecular and phylogeographic approaches, and new methods of analysis, visualization, modelling and prediction of biogeographic distributions.

## Seasonal changes in the macrozooplankton and micronekton community in the Lazarev Sea

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For the understanding of ecosystem functioning in the Southern Ocean including carbon flux and carbon cycling, knowledge on seasonal changes in zooplankton communities in combination with species biology is vitally important. Knowledge about the seasonal variability in Antarctic pelagic communities, however, is still limited, mainly due to a lack of multi-seasonal studies in the same geographic area.

The macrozooplankton and micronekton community of the Lazarev Sea (Southern Ocean) was investigated at 3 depth layers during austral summer, autumn and winter: (1) the surface layer (0–2 m); (2) the epipelagic layer (0–200m); and (3) the deep layer (0–3000m). Altogether, 132 species were identified. Species composition changed with depth from an euphausiid-dominated community in the surface layer, via a siphonophore-dominated community in the epipelagic layer, to a chaetognath-dominated community in the deep layer. The surface layer community predominantly changed along gradients of surface water temperature and sea ice parameters, whereas the epipelagic community mainly changed along hydrographical gradients. Although representing only 1% of the depth range of the epipelagic layer, mean per-area macrofauna densities in the surface layer ranged at 8% of corresponding epipelagic densities in summer, 6% in autumn, and 24% in winter. Seasonal shifts of these proportional densities in abundant species indicated different strategies in the use of the surface layer, including both hibernal downward and hibernal upward shift in the vertical distribution, as well as year-round surface layer use by Antarctic krill. These findings imply that the surface layer, especially when it is ice-covered, is an important functional node of the pelagic ecosystem that has been underestimated by conventional depth integrated sampling in the past. The exposure of this key habitat to climate-driven forces most likely adds to the known susceptibility of Antarctic pelagic ecosystems to temperature rise and changing sea ice conditions

## Density and distribution of plankton smaller than 20 micrometre in the Bransfield Strait and Elephant Island (Southern Ocean): January 2013

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During January 2013, within the activities of the “Southern Ocean Benthic Observation” Project, the plankton community of western Antarctic Peninsula was analyzed to describe and evaluate their spatial variations among four sampling sites: north of Elephant Island (EL), east, centre and west of Bransfield Strait (BS); and at seven depths (0-150m) on bathymetric regions of 700-800m. Vertical profiles of temperature (T), salinity (S) and dissolved oxygen were acquired by a CTD/rosette system (with Niskin bottles), which also collected water samples for analyzes of chlorophyll *a* (Chl*a*), dissolved nutrients and plankton community (<20 μm). Aliquots for pico (0.2-2.0μm) and nanoplankton (>2-20μm) were fixed (2% glutaraldehyde f.c.), stained (DAPI), filtered (0.22 and 1.0 μm polycarbonate black membrane respectively), mounted on microscope slides, frozen and analyzed by epifluorescence microscopy. Cell densities were estimated by counting random fields and organisms were identified according to their trophic category. The plankton community was dominated by <2μm organisms (>98%), of which, 97% were heterotrophs. The densities of pico ( $5.4 \pm 2.2 \times 10^8$  cel/L) and nanoplankton ( $3.6 \pm 2.9 \times 10^6$  cel/L), positively correlated with T ( $p < 0.01$ ), presented a decreasing gradient with depth and a negative correlation with upper mixed layer depth (UML) ( $p < 0.01$ ), reflecting the variability in their distribution through the water column. The cooler ( $-0.03 \pm 0.5^\circ\text{C}$ ), salty ( $34.19 \pm 0.2$ ) and oxygenate ( $8.1 \pm 0.1 \text{ mL/L}$ ) waters indicate the presence of Transitional Zonal Waters with Weddell Sea (TWW) influence at the BS, explaining the similarities in physical and biological parameters at the same depth across sampling stations ( $p > 0.05$ ), except for EL upper 25m. EL surface waters showed low T ( $-0.42^\circ\text{C}$ ) and S (33.64) associated with ice melt around the Island, resulting in a shallower UML with a strong stratification, trapping most of the phytoplankton community within the euphotic zone, which explains the highest densities of autotrophic pico ( $7.2 \times 10^8$  cel/L) and nanoplankton ( $9.1 \times 10^6$  cel/L), as well as Chl*a* ( $2.39 \text{ mg/m}^3$ ) in this location. Nanoautotrophs ( $2.8 \pm 2.5 \times 10^6$  cel/L) accounted for most of the Chl*a* biomass ( $p < 0.01$ ), despite its low concentrations ( $0.45 \pm 0.6 \text{ mg/m}^3$ ), as well as for nitrate ( $19.7 \pm 2.9 \mu\text{M/L}$ ) and phosphate ( $1.4 \pm 0.2 \mu\text{M/L}$ ) depletion ( $p < 0.01$ ). This group was also associated with light availability, evidenced by the decreasing in cell abundances with depth ( $p < 0.01$ ). This work detected the presence of TWW at BS, indicating that differences in depth of the UML and strength of vertical stratification between Elephant Island and the other three stations in Bransfield Strait, determine the density of organisms smaller than 20μm.

## **The Antarctic intertidal zone. An overlooked environment**

**Waller C**

University of Hull

The intertidal zone is a relatively understudied component of the Antarctic nearshore system. Historically it has been perceived as too inhospitable to support anything more than a few opportunistic invertebrates, however recent studies have shown that a true intertidal community can persist over multiple seasons and survive winter conditions. The Antarctic peninsula is one of the fastest changing places globally with over 85% of the glaciers in retreat. As more ice free intertidal habitat is becoming available for colonisation the importance of understanding this component of the ecosystem is increasing. The presentation will review the current level of knowledge of this habitat, consider biogeographical patterns and present preliminary findings from a study resurveying sites that were sampled ten years previously.

## Unveiling biogeographic patterns of Antarctic cyanobacteria by 454 pyrosequencing

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Cyanobacteria are often considered as the dominant phototrophs in Antarctic lacustrine environments, primarily occurring in benthic or floating microbial mat communities. Previous studies have indicated the presence of endemic cyanobacteria in the Antarctic Realm, but the extent and patterns of cyanobacterial bioregionalisation, if any, is still largely unknown. Therefore, our objective is to assess the cyanobacterial diversity in Antarctic lacustrine microbial mats using 454 pyrosequencing, in order to determine if cyanobacterial biogeographic patterns are similar to those observed for multicellular organisms. This will be useful also as baseline data, for later comparisons and assessments of the impact of global change.

First, calibration of the bioinformatic pipeline was carried out using two artificial cyanobacterial communities, to ensure a correct assessment of microbial diversity. These were constructed using DNA isolated from 22 cyanobacterial strains, pooled at equal (Art1) or tiered (Art2) concentrations. Following amplification of the V3-V4 hypervariable region of the 16S rRNA gene and amplicon sequencing, data was analyzed using several variations of the mothur, QIIME and UPARSE pipelines. Average sequence length and number of observed OTUs varied greatly, with the mothur and QIIME pipelines generating a high number of spurious OTUs (up to 20x more OTUs than expected). On the other hand, community structures observed with the UPARSE protocols were consistent with the expected results. These findings show the importance of assessing the performance of different bioinformatic pipelines using artificial communities, in order to reduce the effects of PCR and sequencing errors, which can lead to distorted community structures estimates.

In the framework of the CCAMBIO project (**C**limate **C**hange and **A**ntarctic **M**icrobial **B**iodiversity) funded by BELSPO (**B**elgian **S**cience **P**olicy **O**ffice), the diversity and biogeographic zoning of cyanobacteria in Antarctic lakes will be assessed along a wide geographic and climatic gradient, encompassing samples from all Antarctic bioregions. Samples were selected using a stratified sampling approach and Principal Component Analysis, to ensure that we capture the main limnological gradients present in Antarctica. Pyrosequencing data have been already obtained for a subset of the samples, and DNA extraction, amplification and sequencing of the remaining samples are currently being performed.

## Insights on Antarctic gorgonian's biogeographic patterns

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Sessile suspension feeders dominate benthic communities of the Antarctic continental shelf. They form complex communities composed by groups of sponges, bryozoans, ascidians, hydroids and corals. These organisms provide a high biodiversity, occupy large areas, and stabilize the substrate forming a favourable habitat for the settlement of other species.

In Antarctica, gorgonians are the dominant corals. Among the gorgonian families, Primnoidae is one of the richest in genera and species, and dominates together with the family Isididae the high latitudes of the Southern Hemisphere. Up to now the number of primnoids in the Southern Ocean is estimated in 69 species and 27 genera, of which more than 80% and 50% are endemic. The high grade of endemism reveals a low dispersion grade beyond the Subtropical Front, and a high level of speciation. The isolation, habitat heterogeneity and reproductive strategies with a non-pelagic lecithotrophic larval stage makes the dispersion of these organisms very limited.

The biogeographic study of the Antarctic primnoids provides an overview of the distribution of the most important group of gorgonians in the Southern Ocean. In the present study 582 cites have been taken into account for the biogeographic analyses. The majority of the cites are around Peninsula Antarctica, Ross Sea, Davis Sea, Cape Norvegia, South Shetland Island and Orkney Islands, Falkland Islands and Tierra del Fuego in South America. However 3 main vast areas show none or a few primnoid localities, from Cape Norvegia to Pritz Bay, from Budd Coast to Adelie Land, and from the Ross Sea to Peninsula Antarctica (Bellingshausen and Amundsen Sea). This lack of records may be due to the low sampling effort carried out in those areas. More sampling and accurate identifications are needed to have a better approximation of the real primnoids distribution at the Southern Ocean.

Despite of this, first results report the Antarctic region with a higher percentage of circumpolar species than the Subantarctic, and also with the greatest number of endemic species restricted to deep bottoms, suggesting a previous dispersion of the species around the Antarctic region where the environmental conditions are more stable and a subsequent flux of radiation from the continental shelf to the deep, where thanks to the Antarctic Bottom Water, primnoids may have dispersed to the Subantarctic region and adjacent oceans.

## Ecology of holothurians along the Southern Polar Front derived from fatty acid and stable isotope measurements

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Ocean surface production builds the basis for the majority of deep-sea food webs. The strong seasonality and uneven distribution of phytoplankton blooms during austral summers across the Antarctic Polar Front provides us with the opportunity to investigate coupling processes between different surface production regimes and the underlying deep-sea floor. As these settings are highly sensitive to any potential climatic changes, studying such coupling processes can furthermore provide basic information on any potential corresponding reactions of deep-sea ecosystems. Suitable model organisms to analyse such processes are holothurians. Not only are they a dominant component of the abyssal fauna, but many of these echinoderms consume phytodetritus and organic matter deposited on the seafloor. In order to study coupling processes, the SYSTCO II (SYStem COUpling in the Southern Ocean) expedition was conducted on board R/V *Polarstern* in austral summer 2012. Deep-sea fauna was sampled in different productivity regimes in ca. 4000 m depth along an east-west transect at approximately 52°S. The major aim of this study was to measure if, and to what extent differences in surface productivity can be traced down to the deep-sea floor.

For the current study, fatty acid and stable isotopic compositions of the sampled deep-sea holothurians, sediment surface and particulate organic matter collected at stations with differing primary production regimes were measured. These methods are well-suited to investigate an organisms' diet integrated over an intermediate timescale.

The analysed animals show distinct fatty acid compositions depending on their feeding types. Furthermore, divergent fatty acid patterns were detected for holothurians belonging to the same (or closely related) species sampled at different locations. Especially the values of fatty acid markers typical for phytoplankton vary clearly. These differences are underlined by the results of the stable isotope measurements. Concerning  $\delta^{15}\text{N}$ , ratios range from 5.96 to 14.07, thus covering 2 trophic levels. The differences can to a great extent be assigned to different holothurian species. In case of  $\delta^{13}\text{C}$ , ratios between -17.09 to -24.10 were measured. Here the differences are linked to the different sampling areas. The results of this study show clear differences in the magnitude of pelagic-benthic coupling traced in holothurians from different stations.

## S20: ANTECO: DIVERSITY & CONNECTIVITY & SPATIAL ANALYSES OF ANTARCTIC BIODIVERSITY

### Phylogenetic relationships and phylogeography in Antarctic symbiotic polychaetes

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While the role of host preference in ecological speciation has been investigated extensively in terrestrial systems, e.g. in plant–insect associations, very little is known on marine organisms, especially in Antarctic ecosystems.

We have focused our attention on one of the most common Antarctic symbioses, involving polynoid polychaetes living on cnidarian hosts. These symbiotic polychaetes belong to the complex of *Polyeunoa laevis* McIntosh, 1885, for which several species names have been proposed on a morphological-based classification. However, no genetic studies have been performed so far on this group and its phylogenetic systematics, and the phylogeographic patterns remained unknown.

We have therefore used two mitochondrial genetic markers (COI and 16S) to disentangle the taxonomic status of these polychaetes. The main aims of this study were to clarify: i) the species diversity in the *P. laevis*-complex, ii) the phylogenetic relationships within this group and ii) the potential role of the host in speciation processes of these symbiotic polychaetes.

Taxon sampling was performed trying to maximize the geographical coverage and samples were collected from a variety of locations in the Ross Sea at shelf, slope and abyssal depths. This Antarctic dataset was then integrated with samples of *Polyeunoa*-like polychaetes from New Zealand waters.

Our molecular results clearly indicate the existence of previously unrecognized cryptic lineages, corresponding to not less than 5 species in the *P. laevis*-complex. Furthermore, based on the association data, we have scored a general low specificity for the host in this group of polychaetes, which are clearly polyxenous.

From a phylogeographic point of view, there are indications that this group of symbiotic polychaetes likely originated in deep water basins off New Zealand and colonized Antarctica only secondarily, through 'polar emergence'. After this step, possibly in coincidence with glacial maxima, some clades were forced to colonize seamounts off Antarctica, and one reached again the deep-water basins off NZ.

From an ecological point of view, it is worth noting a 'host recycling' phenomenon where two different species, belonging to the most basal and the most derived clades, respectively, were found on the same gorgonian species, *Tokoprymno maia* Bayer, 1996. This is the first time that under a 'host-jump speciation scenario' a host is the subject of a symbiotic association twice and involving two, only distantly related clades.

## First evidence for multi-million year persistence of mosses in Antarctica

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Glaciological reconstructions suggest that thick ice sheets covered most terrestrial areas of Antarctica during the Last Glacial Maximum (LGM; ~22–18 ka), as well as during previous glaciations through the Pleistocene, Pliocene and Miocene. This has led to the assumption that most contemporary terrestrial biota must have (re-)colonised Antarctica since the LGM. However, recent genetic biogeographic research focusing on invertebrates and some microbiota suggests that much of the contemporary terrestrial biota has a long-term history *in situ* in Antarctica, with timescales of persistence ranging through pre-LGM to Gondwana-breakup (~65 mya). Mosses, a major component of the Antarctic flora, currently appear to stand distinct from these patterns. Their low species endemism levels (5-10% at most) suggest today's moss biota are recent colonists.

We investigated the phylogeography of several Antarctic moss species, with an emphasis on the cosmopolitan species *Bryum argenteum*. Using the molecular marker ITS combined with worldwide geographic sampling and a molecular clock analysis, we here present the first evidence of long-term *in situ* persistence of mosses in Antarctica. Evidence for multiple colonization events of Antarctica by this moss is presented, with estimated colonisation times ranging from at least four million years for the oldest lineage to half a million years for the youngest lineage. This strongly supports the survival of *B. argenteum* throughout glacial cycles within the Pleistocene, Pliocene and possibly even the late Miocene. Despite low apparent endemism levels, mosses may have had a much longer persistence in the Antarctic than has been thought previously.

## Monitoring vegetation growth and change in Antarctica

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Detecting vegetation growth rates and change is important for identifying environmentally distinct regions in Antarctica and for monitoring the biological response to climate change. The cold and remote environment in Antarctica makes such monitoring difficult, which is compounded by the limited biology and growth forms - there are no tree trunk diameters that can be easily measured.

We have tested several techniques that analyse vegetation change at a range of scales. Lichen growth rates, measured using image analysis functions within GIS and rock crystals as geographical reference points, provide a quantitative method that is inexpensive and easily reproducible. The current growth rate of lichens in the Dry Valleys is estimated to be 0.01 mm per year, but this is predicted to dramatically increase with climate change. Moss and algae growth can be estimated using 1m<sup>2</sup> quadrats, but relatively rapid shrinkage and expansion relating to fluctuating moisture levels means that it is only practical to use qualitative visual assessments. Vegetation flush areas can also be mapped in GIS using photography captured using conventional aircrafts, drones, and possibly satellite imagery. These techniques require measurements, at the very least, over three different time periods to detect changes in growth rates.

We have established baseline GIS data at three Antarctic Specially Protected Areas (ASPAs); Cape Hallett (ASPAs 106), Botany Bay (ASPAs 154), and Canada Glacier (ASPAs 131). To understand such a biological response to climate change and support management decisions, it is important to establish baseline data for long term monitoring that is internationally networked across the Antarctic continent. A working paper was submitted to the Committee for Environmental Protection (CEP) (ATCM XXXV/CEPXV, WP20) inviting the CEP to consider the use of GIS as a method for monitoring vegetation changes. The Committee agreed to establish a network of sites for monitoring species distribution and abundance with priority afforded to ASPAs and recognised the value of applying consistent methodologies for comparisons between sites continent wide (CEP XV Final Report, ATCM XXXV).

## Evolutionary history of the snail *Neobuccinum eatoni* in the Southern Ocean: an example of fauna derived from adjacent deep sea?

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The establishment of oceanographic, geographic and bathymetric barriers that isolated the Antarctic continent shaped the evolution and diversification of benthic macrofauna of the Southern Ocean (SO). Nevertheless the fauna inhabiting antarctic current is composed by taxa with different biogeographic origins: (1) Relict fauna; (2) Fauna derived from adjacent deep areas; (3) Fauna that scattered from South America through the Scotia Arch and; (4) Antarctic fauna that progressed towards northern areas by the Scotia Arch. Recent studies propose that the origin of several SO species (with long dispersal capacity) were driven by dispersal events from Subantarctic areas that occurred more recently than the tectonic separation of the Antarctic continent. However, this general biogeographic scenario is not fully understood because the scarce data from species without free larval stage.

The Antarctic snail *Neobuccinum eatoni* (Smith, 1875) presents a large distribution around the Antarctic continent, in the Kerguelen Archipelago and in some islands from the Scotia Arc in the Subantarctic province. Moreover, *N. eatoni* presents a notable eurybathic distribution and extended egg masses development of approximately 15 months. Therefore *N. eatoni* is a good study model to understand how the climatic and oceanographic processes have influenced the evolutionary history of a marine benthic fauna in the SO.

Samples of *N. eatoni* were collected in two biogeographic zones: (i) South Shetland Islands (Antarctic zone) and (ii) Kerguelen Island (Subantarctic zone). We used the mitochondrial gene Cytochrome c Oxidase subunit I (COI), to determine genetic diversity indices, genealogical relationships within and between biogeographic zones and the time since last population expansions.

We observed a high global genetic diversity and a subtle differentiation between biogeographic zones. Following our results, the current *N. eatoni* populations in Antarctic and Subantarctic islands seems to be derived from refugia at great deep zones around Antarctica, which is also consistent with its eurybathic distribution (extended to 2000 m). These results suggest that the current genetic diversity might be the result of colonization processes influenced by Pleistocene glacial cycles.

## Crinoid (Echinodermata) diversity in the Southern Ocean: a barcoding approach

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Recent expeditions associated to significant research efforts in the Southern Ocean have demonstrated that this ecosystem may be considered a hot spot of diversity for benthic invertebrates. The Southern Ocean has been isolated from other oceans since the onset of the Antarctic Circumpolar Current several million years ago. This oceanographic isolation associated to the cycles of glaciations is suspected to have driven the observed species richness and high endemism.

Crinoids constitute, among the suspension-feeding Antarctic mega-epibenthos, a well-diversified but under-studied group. More than 45 species are known from the Southern Ocean, the greatest diversity being reported from the Weddell Sea and the Peninsula. Half of the crinoid species are brooders. A few species are very abundant and represent over 80% of the total crinoid biomass. The aim of our study is to describe the diversity of this group with the use of the barcoding approach, and critically revise the morphological criteria used to differentiate species.

A total of 2599 specimens are selected from 22 species sampled over the whole Southern Ocean. Cytochrome Oxidase I (COI) is sequenced for each specimen and barcoding and phylogeographic tools are used to assess species clusters and describe the spatial distribution of the genetic diversity.

Results show that several geographically isolated genetic entities can be recognised from a number of morphologically defined species. We find evidence of cryptic divergence in a number of taxa, most of which being suspected to brood their young.

## Recurrent cladogenesis in a brooding benthic invertebrate: how many species and where do the fossils fit?

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The Antarctic continental shelf has undergone cycles of glaciations for millions of years since the onset of ice sheets about 35 Mya. This succession is suspected to have driven cycles of genetic divergence within benthic species, and enhanced the Antarctic “biodiversity pump”. The use of DNA sequencing and molecular analyses for the Antarctic benthos in the last decade has revealed the presence of a number of divergent clades within morphologically-defined species, that are thought to be cryptic species. These findings seem to provide evidence for recurrent cladogenesis and formation of complexes of closely related genetically divergent and morphologically similar species. It is a suggestion that cryptic speciation is rather common among Southern Ocean benthic invertebrates. Recognizing cryptic species, or at least understanding the genetic structure of species, may become crucial when trying to understand the rate of cladogenesis and extinction in Antarctic taxa. It may also have a direct impact on the attribution of fossils to extant taxa, which in turn may hinder the timing of divergence points in phylogenies.

Here, we explore the genetic diversity at the population level of *Notocrinus virilis* (Crinoidea, Echinodermata), a common Southern Ocean, shelf dwelling, brooding species. We use one mitochondrial molecular marker (COI) and one nuclear molecular marker (ITS) to test for the existence of one panmictic or several lineages within this morphologically-defined species. We also analyze the spatial patterns of the genetic diversity to test for 1-population geographic segregation and 2-recent biogeographical processes.

We also explore the position of the genus in the phylogeny of the crinoids using COI, 16S and 28S molecular markers. This approach is coupled to a detailed morphological analysis using X-rays tomography of one representative of each *Notocrinus* lineage, including two lineages of *Notocrinus mortenseni*.

We show that *Notocrinus virilis* is structured into four lineages that may represent four different species. Lineages are segregated into geographical areas, and the Ross Sea – Terre Adelie lineage seems closely related to the Weddell Sea lineage giving further ground to the trans-Antarctic seaway hypothesis. The genus *Notocrinus* is separated into two morphologically recognizable entities, and a number of morphological characters are shown that may reconcile the fossil record to the extant taxa.

## Subantarctic transoceanic dispersal: Patagonia-Kerguelen connections

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With the fragmentation of Gondwana, geographic distances between continents increase and tend to physically separate Southern-Ocean benthic faunas. This huge geologic event explains the phylogenetic link between remote marine faunas, but is also at the origin of their differentiation and of the abundant endemic species in the Southern Ocean. The establishment of the Antarctic Circumpolar Current (ACC) and the oceanic fronts together with the cooling of the Antarctic represent some barriers impeding exchanges between Subantarctic and Antarctic benthic faunas. However the eastward drift of the ACC drives water masses all along the subantarctic area and connects remote lands (and benthic faunas).

Long distance dispersal depends on intrinsic capacities of species to survive enough time to reach a coast, fit the new environment and settle, but also depends on the probability of happening. So it may be biologically possible but scarcely probable or conversely, if the physical connection between remote places is on, the species may not be able to travel/settle there. Subantarctic long distance dispersal was highlighted for giant kelp and associated invertebrates lacking pelagic stage (the role of passive rafting is involved), but also for several broadcasting invertebrates.

The sense of circulation of ACC and the lack of nearby benthic faunas in the South Pacific make migrations toward the Southern tip of South America improbable: Patagonian coasts are mostly sources of benthic faunas. We here explored the dispersal capacities of several genera of subantarctic benthic invertebrates between Patagonia and Kerguelen Islands: the mytilids *Mytilus* spp. and *Aulacomya* spp., the echinoid *Sterechinus* spp., the gastropods *Nacella*, *Margarella* and *Kerguelenella*, the latter two genera being the unique brooders of the study. Mitochondrial DNA was used to compare genetic diversity, establish phylogenetic relationships and highlight genetic structure.

Our results show that mytilids and echinoid share haplotypes between Patagonia and Kerguelen Islands, as do the brooding gastropods (*Margarella* and *Kerguelenella*). However, *Nacella* species from Patagonia and Kerguelen belong to well-distinct mitochondrial lineages. If larval survival may be involved for broadcasters (except *Nacella*) to allow gene flow toward Kerguelen, it is not the case for the brooders. So passive rafting is the most likely way of traveling across the Southern Ocean. However, *Nacella* larvae from Patagonia are not able to maintain gene flow with Kerguelen congeners. The explanation may lie in the way adults/larvae hang on the kelp.

As a conclusion, common biogeographic patterns are identified in benthic faunas from distinct groups, with distinct reproductive strategies and dispersal capabilities. Present day patterns of long distance dispersal are first driven by extrinsic factors such as the ACC enhancing the oceanic transport and also by intrinsic traits such as the way species follow kelp, allowing them to travel, or not.

**Extinction and recolonization of maritime Antarctica in the limpet *Nacella concinna* (Strebel, 1908) during the last glacial cycle: toward a model of Quaternary biogeography in shallow Antarctic invertebrates**

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Quaternary glaciations in Antarctica drastically modified geographic ranges and population sizes of marine benthic invertebrates and therefore affected the amount and distribution of intraspecific genetic variation. Repeated ice advances and retreats dramatically limited the availability of suitable habitats on the continental shelf leaving characteristic demographic signatures in shallow benthic Antarctic invertebrates.

Here, we present new genetic information concerning the glacial demographic history of *Nacella concinna* (Patellogastropoda: Nacellidae), one of the dominant Antarctic benthic species along shallow ice-free rocky ecosystems. For this purpose, we examined the patterns of genetic diversity and structure in this broadcast spawner sampled from nine localities along maritime Antarctica and from the peri-Antarctic island South Georgia.

Analyses of a fragment of the mitochondrial Cytochrome c oxidase I gene (COI), indicate that *N. concinna* represents a single panmictic unit along maritime Antarctic, from Adelaide Island to South Orkney Island. Low levels of genetic diversity characterize this population; its median-joining haplotype network shows a typical star-like topology, a short genealogy and a dominant haplotype broadly distributed in all the sampling localities. In contrast, we detect significant levels of genetic differentiation between South Georgia Island and the rest of the analyzed localities from maritime Antarctica. Moreover, higher levels of genetic diversity, a more expanded genealogy, and the presence of more private haplotypes in South Georgia Island population support the hypothesis of glacial persistence of *N. concinna* in this peri-Antarctic island. Likewise, the distribution of pairwise differences, as well as Bayesian Skyline plot analyses recognized an older demographic history in South Georgia than in maritime Antarctica. Furthermore, Approximate Bayesian Computations did not support the persistence of *N. concinna* along maritime Antarctica during the last glacial period but its resiliency in peri-Antarctic refugia, such as South Georgia Island.

We propose a model of Quaternary Biogeography for Antarctic marine benthic invertebrates characterized by shallow and narrow bathymetric ranges that includes (1) the extinction of maritime Antarctic populations during glacial periods, (2) the persistence of populations in peri-Antarctic refugia and (3) the re-colonization of maritime Antarctica following the deglaciation process and related to rapid population expansion.

## Divergence between Antarctic and South American marine invertebrates: what molecules tell us about Scotia Arc geodynamics and the intensification of the Antarctic Circumpolar Current

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Continental drift processes and major gateways openings have been historically advocated to explain the distribution of marine benthic taxa in the Southern Ocean. The separation between Antarctic Peninsula and the southern tip of South America together with the onset of the Antarctic Circumpolar Current (ACC) represent the final step for the complete isolation of the Antarctic region. However, there is still controversy concerning the timing and mode of these processes, and especially about the role of the Scotia Arc geodynamic in the development of a full-deep and intense ACC circulation. Based on COI sequences obtained from different invertebrate groups, we performed molecular comparisons between Antarctic and South American relatives to provide independent time estimations of Antarctica's isolation. We include in the analyses congeneric Antarctic and Patagonian species of the genus *Nacella* (patellogastropoda) and *Sterechinus* (echinoid). At the same time we performed comparisons between Antarctic and Patagonian populations of *Yoldia eightsi* (bivalve) and *Parbolasia corrugatus* (nemertean). Finally, we include molecular comparisons between Antarctic (*Trophonella*) and Patagonian (*Xymenopsis*) muricid gastropods. Four of these groups are characterized by the presence of a dispersive larval phase (*Nacella*, *Sterechinus*, *Yoldia*, and *Parbolasia*), while muricids are direct developers. Based on the levels of genetic divergence between relatives from both regions and assuming the molecular clock hypothesis, we estimated the onset of their respective separations. On one hand, similar levels of genetic distance in broadcasters belonging to different phyla (7% - 8.3%) support the hypothesis that the installation of an effective barrier between Antarctica and South America occurred almost simultaneously for these groups. Moreover, divergence time estimations based on specific substitution rates indicate that the separation occurred near the Mio-Pliocene transition, long after the physical separation of Antarctica and South America. Genetic distance and divergence time estimation in muricid groups (brooder) indicate an older separation time, close to the mid-Miocene. Even when the analyzed groups included broadcaster and brooder organisms, the divergence between Antarctic and South America lineages more than be related to continental drift geologic processes, seems to be more associated to major changes in the Southern Ocean such as the evolution of the Scotia Arc and the deepening of the Drake Passage. Accordingly, these results support a genetic continuity between Antarctica and South America, probably along the Scotia Arc, until the middle Miocene and a late ACC intensification at the Mio-Pliocene boundary.

## Genomic approaches to examining diversity, connectivity and circumpolar distributions of marine invertebrates in the Antarctic

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A primary challenge of conducting evolutionary or population genetic work in the Southern Ocean is the ability to obtain enough representatives of a given species across the geographic distribution. In examining whether several marine invertebrate taxa that live on the continental shelf have circumpolar or very broad distributions, we have recently sampled the Bellingshausen, Amundsen and Ross Seas to obtain more complete sampling from the Western Antarctic. These samples are being examined with traditional molecular approaches (e.g., CO1 phylogeographic analyses) as a first pass to assess diversity between Western Antarctic regions. Additionally, we are using high-throughput genomic sequencing approaches that offer the ability to sample hundreds to thousands of loci simultaneously, allowing examination of connectivity and genetic structure on a much finer scale. These approaches can help reduce the number of individuals needed to exam gene flow and evolutionary trends. Target species under examination include *Astrotoma agassizii*, *Sterechinus* species, *Ophionotus victoriae* among others. At present we are primarily focusing on connectivity and genetic structure from the Antarctic Peninsula to the Ross Sea. These efforts are being coupled with high-throughput genomic and transcriptome sequencing to build genomic resources for select marine Antarctic taxa. Some of these resources will be introduced.

**Phylogeography of *Pallenopsis cf. hodgsoni* (Arthropoda: Pycnogonida) along the Antarctic Peninsula and Western Antarctic coastal regions**

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The phylogeny of the genus *Pallenopsis* (Pycnogonida) remains highly unresolved, with insufficient morphological data available to elucidate evolutionary relationships between *Pallenopsis* and other pycnogonid genera. Additionally, little is known about genetic connectivity within Antarctic *Pallenopsis* species populations. This study seeks to describe genetic structure of *Pallenopsis* populations of the Antarctic Peninsula and Western Antarctic coastal regions including the Bellingshausen, Amundsen, and Ross Seas. In this study, we will present the results of sequence data derived from the mitochondrial COI gene and 16S rRNA gene that show gene flow patterns between these populations, and we will provide a molecular basis for phylogenetic assessments of the genus *Pallenopsis*, with a focus on *P. cf. hodgsoni*. Examination of genetic characters in conjunction with traditional morphological taxonomic procedures will undoubtedly provide increased resolution to the evolutionary history of *Pallenopsis*, and may lead to descriptions of new or cryptic species. Future sampling along other areas of the Antarctic coastline will provide an even broader context for the phylogeny of *Pallenopsis*.

## Genetic connectivity of Southern Ocean amphipods: circumpolarity, eurybathy, bipolarity and (pseudo)cryptic speciation

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Using molecular analyses based on COI, 16S and 28S rDNA sequences, species' distributions were assessed in view of the paradigms emitted for Antarctic invertebrates: circumpolarity and eurybathy.

In several lysianassoid amphipod species of the genera *Abyssorchomene* and *Pseudorchomene*, a genetic homogeneity was found among specimens from remote sampling sites in the Southern Ocean, indicating a widespread or even a truly circum-Antarctic and/or eurybathic distribution. In other lysianassoid species, genetically divergent lineages and (pseudo)cryptic taxa were revealed, of which some were restricted to certain geographic and bathymetric zones whilst others were characterized by a widespread distribution. For several species of the genus *Orchomenella*, genetically divergent lineages and possibly cryptic taxa were detected.

The giant deep-sea lysianassoid *Eurythenes gryllus* appeared to be composed of several overlooked species, one of which being characterized by a bipolar distribution. This represents the first molecular evidence for a bipolar distribution in a macro-benthic organism. Moreover, within the Southern Ocean, three distinct species of *Eurythenes gryllus sensu lato* coexisted, of which two seemed restricted to abyssal waters whilst the bipolar species was found only in the bathyal zone. In this case, a clear genetic break occurred around 3000 m, rejecting the previously assumed eurybathy of *Eurythenes gryllus*.

Finally, phylogeographic and population genetic analyses were conducted on the pelagic hyperiid amphipod *Themisto gaudichaudii*, a key species of the Southern Ocean pelagic realm. Three distinct, sympatric lineages were detected in the Atlantic sector of the Southern Ocean, possibly associated with distinct feeding behaviours and morphological divergences.

Hence, species diversity is still largely underestimated for amphipods and undescribed species or additional species-level clades are likely to be uncovered with an increasing sampling effort. As polar regions are more affected by climate change than others, studies investigating spatial genetic structure are of particular importance since they may serve as a basis for monitoring and conservational efforts.

## Cretaceous origins of the Southern Ocean philobryid bivalves: Hidden biodiversity, ancient persistence

Jackson J, Linse K, Whittle R, Griffiths H

British Antarctic Survey

Philobryids (Bivalvia: Arcoida) are one of the most speciose marine bivalve families in the Southern Ocean and are common throughout the Southern Hemisphere. In the Southern Ocean, three genera (*Adacnarca*, *Philobrya* and *Lissarca*) are widely distributed. Among these, *Philobrya* and *Adacnarca* only turn up in the Antarctic Recent fossil record, so it is not known whether these genera entered the Southern Ocean recently, or whether they have a long persistence not yet recorded in the fossil record. Here we present the first molecular investigation of the Philobryidae in the Southern Ocean. Two nuclear loci (18S and 28S) were amplified from 40 Southern Ocean *Adacnarca* and *Philobrya* taxa, with a combined sequence length of 2,282 base pairs (bp). Members of the genus *Adacnarca* were resolved as a strongly supported monophyletic group. Genus *Philobrya* fell into two strongly supported groups ('*sublaevis*' and '*magellanica/wandelensis*'), paraphyletic with *Adacnarca*. 28S analyses resolve Philobryidae as a strongly supported monophyletic clade and sister taxon to the Limopsidae, as anticipated by their classification into the superfamily Limopsoidea. Bayesian relaxed clock analyses of divergence times suggest that *Adacnarca* and *P. magellanica/wandelensis* clades began to radiate in the Southern Ocean at the end of the Cretaceous, while the *P. sublaevis* clade radiated in the Miocene.

**First genomic survey of Antarctic brittle star *O. antarctici* using double-digestion RAD sequencing technology**

**Jackson J**, Sands C, Dömel J, Biersma E, King M, Fitzcharles E

British Antarctic Survey

Brittle star *O. antarctici* is one of the most abundant ophiuroid species in the Southern Ocean, yet nothing is yet known about its population history and structuring. Here we describe a preliminary genomic survey of this species, using double-digestion RAD tagging to generate multiple SNP loci in order to investigate brittle star population structure with high precision across the Weddell Sea.

## **nzTABS: Complex drivers of biodiversity in the McMurdo Dry Valleys**

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The McMurdo Dry Valleys of Antarctica harbor a unique ecosystem in which biotic interactions are inherently limited, and physicochemical factors likely have a prominent role in determining the diversity and distribution of biology. However, studies of the Dry Valley ecosystem to date have predominantly employed a *hotspot* approach, where areas of interest are identified *a priori* and subject to intense characterization and/or monitoring. This approach assumes that sufficient understanding of the ecosystem exists to allow reliable identification of biological hotspots and that there is negligible biomass and diversity outside these hotspots. Molecular genetic evidence has contradicted such assumptions and shown that Dry Valley soils in fact harbor considerable active microbial biomass and unexpectedly localized diversities. These findings imply that a landscape-scale approach is required for a robust understanding of the ecology of Antarctica's ice-free areas.

The New Zealand Terrestrial Antarctic Biocomplexity Survey (nzTABS) aims to describe the composition and distribution of biological communities in the Dry Valleys and to elucidate ecosystem drivers at the landscape level. To achieve these goals, teams of international researchers across a wide range of disciplines carried out the largest and most comprehensive terrestrial ecosystem survey ever undertaken. A 220 km<sup>2</sup> study area comprised of Miers, Marshall, and Garwood Valleys was divided into a mosaic of "tiles" on the basis of geographical and geological information acquired through remote sensing. Over two Austral summers, more than 600 tiles were surveyed and sampled, obtaining data on soil geomorphology, geochemistry, local flora and fauna, and microbial communities through DNA-based analyses. The sampled tiles encompassed all combinations of geographical and geological heterogeneities to enable characterization of the Dry Valley ecosystem using structural equation modeling (SEM).

The primary SEM, which included all biota surveyed, explained observed biological heterogeneities and revealed significant contributions from spatial processes and biotic interactions to these heterogeneities. Meanwhile, additional SEMs constructed for specific taxa revealed different levels of influence from spatial processes and biotic interactions in shaping taxa-specific diversity and distribution. These findings highlight the complexity of drivers acting at disparate levels across the Dry Valleys ecosystem.

## Antarctic foraminiferal biogeography from a molecular perspective

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Micropaleontological studies have long suggested the presence of analogous benthic foraminiferal assemblages inhabiting distant parts of the Antarctic shelf. These similarities have been explained by the presence of circum-Antarctic circulation patterns, as well as comparable environmental settings at remote locations. Recent molecular studies, carried on material from McMurdo Sound (Ross Sea) and Admiralty Bay (South Shetlands), show the presence of the same genotypes among several species of single-chambered allogromiid and multi-chambered calcareous foraminifera. These genetic data from distant ends of West Antarctica suggest a wide, probably circum-Antarctic, distribution among some of the key benthic foraminiferal species. This uniformity is in sharp contrast to distinct molecular differences between most foraminifera inhabiting Admiralty Bay and the Beagle Channel in Patagonia. Despite their morphological similarities, our data suggest the presence of different genotypes among several foraminiferal species on opposite sides of Drake Passage.

## High-resolution terrestrial habitat models for *Pygoscelis* Penguins

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As climatic conditions on the Antarctic Peninsula change, we are seeing shifts in both population size and geographic ranges of all three pygoscelid penguin species.

While species distribution modeling can provide some insight into the geographic ranges available to species and, when combined with climate models, may predict broad-scale shifts in breeding range, traditional species distribution models (SDMs) use data on environmental conditions at scales that may not be relevant to individual penguins making decisions about where to nest. In particular, most SDMs for the Antarctic focus on marine conditions as the primary drivers of suitability, and ignore the terrain requirements for successful nesting.

Organisms exist in a complex three-dimensional environment, and their interactions with the topography of the terrain may be as important to successful reproduction as regional scale variables such as temperature. In fact, habitat suitability must be seen as a complex balance between the fine-scale three-dimensional structure of the terrain and the surrounding marine conditions, which are typically measured at larger spatial scales.

High-resolution satellite imagery offers an opportunity to determine both presence and absence data for all occupied nesting territories in a colony, as well as detailed information about the three-dimensional landscape at which breeding actually occurs. Using these data and accessory environmental data relevant to habitat suitability, we construct use-availability models for *Pygoscelis* penguins across all spatial scales, using those variables relevant to individual penguins making decisions about where to nest (e.g., single point metrics such as elevation, slope or aspect, and derived neighborhood measures of terrain only available with high-resolution terrain information). These models will allow us to better understand which factors are important in defining “suitable” pygoscelid penguin habitat, establish where currently unoccupied but suitable habitat might exist, and support the generation of range forecasts that include both marine and terrestrial factors important to individual-level decision-making.

## Terrestrial bioregionalisation for the Ross Sea region

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Landcare Research

Building on the Environmental Domains for Antarctica classification, a second generation bioregionalisation is under development that includes biological observation data to delineate biogeographical regions for the Ross Sea region. This bioregionalisation is nearing completion and will incorporate new knowledge on soil, landform, climate, and biological diversity and abundance into a terrestrial classification for the region.

Using a mixture of on-the-ground validation and remote sensing, we have developed a range of abiotic geospatial data layers that capture the biogeographic variation within the region that focus on three broad areas, Climate; Landform; and Soil.

While the process shares similarities, the multivariate two-stage process used in the original classification has been revised to accommodate the unique challenges the region provides. In addition the process now explicitly incorporates biological diversity and abundance information through a Gradient Forest approach (Ellis et al, 2012) that is used to improve the level of biogeographic variation captured in the new classification.

This paper will outline the new spatial layers, classification process and the way biotic information is used in the classification; and present an interim version of the classification for the Ross Sea Region.

### References:

Nick Ellis, Stephen J. Smith, and C. Roland Pitcher 2012. Gradient forests: calculating importance gradients on physical predictors. *Ecology* 93:156–168. <http://dx.doi.org/10.1890/11-0252.1>

## Spatial distribution of pinnipeds based on an aerial survey in 2008/09, Elephant Is., South Shetlands

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Accurate population estimates are essential to the conservation and management of wildlife. The association of the spatial distribution of and abundance individuals in a given area provide even more relevant estimates because they allow evaluation of the use/occupation of the natural environment. We analyze some aspects of the spatial distribution and demography of pinnipeds on Elephant Island (61°55'S 13°52'3"W), South Shetlands, Antarctica during the austral summer of 2008/09 based on aerial photographs. This particular study analysed images taken in January 2009 from one of Squirrel Helicopter (30knts constant speed and 50m above ground). Antarctic fur seals (AFS, *Arctocephalus gazella*), Weddell Seals (WS, *Leptonychotes weddellii*), Crabeater seals (CS, *Lobodon carcinophagus*), Leopard Seals (LS, *Hydrurga leptonyx*) and Southern Elephant seals (SES, *Mirounga leonina*) were identified, counted, and referenced geographically and mapped. Occurrence, group composition and patterns of distribution were also recorded and whenever a possible developmental stage of individuals was determined (adult, juvenile, pups and undetermined). The coastal region of the island was divided into six sectors (Cape Valentin, Endurance Gl., Stinker Pt, Cape Lindsay, Cape Yelcho and Cape Wild) which were subdivided into 16 sections according to known geographic features. From the images we were able to estimate the distribution throughout the island and identify preferential and exclusion areas. Three thousand and ninety six individuals were distributed around the Island with the exception of areas with dense ice coverage such as glaciers. SESs accounted for 54.0 %, AFSs 43.9 % while other phocids (CS, WS and LS) accounted for 1.1 %. This ratio differs from what has been described for Stinker Pt. where SES accounted for 95 % of pinnipeds present, AFS 3.3% and other phocids represented 1,7%. The total number SESs recorded for the Island represents an 8 % increase from previous estimates for the same period. On the other hand, the present study suggests that contribution of each species in the different areas evaluated represents a marked difference in the occupation of the island during the summer and around the Island suggesting a strong influence of substrate availability. As expected, AFSs have a preference for rocky substrates while SES, WS and CS prefer sandy areas. LS on the other hand exhibit a marked preference for the ice (iceflows). The aerial survey allowed for counting and estimating individuals that use Elephant Island not only as a breeding and molting ground but also as a stop-over or resting place on route to foraging grounds. This indicates the need to look at the Elephant Is. as a critical habitat for conservation of pinniped species in the region.

## Geo-ecological units in Elephant Point Peninsula (Livingston Island, Maritime Antarctica)

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Elephant Point is a small ice-free area of 1 km<sup>2</sup> in the SW corner of Livingston Island (South Shetland). The land surface in this peninsula is exposed thanks to the retreat of the Rotch dome glacier during the Holocene. Today, it is a maritime permafrost environment where periglacial processes are widespread.

We analyze the distribution of geocological units in Elephant Point. Geomorphological units were used as the basis for mapping the distribution of the different ecological areas.

Up to the 6 units were identified from the Rotch glacier to the coast:

- Glacial dome, with vertical fronts falling to the sea and gentle slopes in the central area. Limited biological activity in the margins of the glacier along the coast: presence of petrels, penguins and Weddell seals.
- Proglacial area. This recently deglaciated environment is structured by two proglacial streams flowing towards the E and W of the peninsula. Biological activity is limited: incipient lichens, birdlife and presence of elephant seals only close to the coastline.
- Moraine. It constitutes the transition area between the glacier and the environment under marine influence. Very active periglacial processes are reworking these unconsolidated sediments, which impedes vegetation colonization. Biological activity consists mainly of birdlife and the presence of mosses surrounding flooded areas in the moraine ridge.
- Bedrock plateaus. The rock surfaces are widely covered by lichens. Several colonies of petrels, skuas and arctic terns are present in these plateaus. Abundant ornithogenic soils are densely covered of mosses and lichens. In areas where cryosoils exist, large areas of patterned ground landforms are distributed.
- Marine terraces. Five levels of marine terraces were identified. Semi-permanent lagoons also occupy some of these terraces. Wildlife is abundant, with colonies of penguins and elephant seals. It is interesting to mention the erosive action of elephant seals on the terraces, creating scars on its way between the sea and the colonies existing in the highest terraces.
- Present-day beach. Characterized by the absence of vegetation and intense use by wildlife, namely elephant seals and birds. Specimens of Weddell seals, Antarctic fur seals and leopard seals were also observed.

Despite its reduced size, this ice-free constitutes an excellent example of the interaction between the major morphogenetic systems, plant communities and fauna typical of the South Shetland archipelago.

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## Biogeographical patterns in Southern Ocean gastropods with different developmental modes

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The evolution of the Southern Ocean marine benthic fauna and its biogeography is the result of complex interactions between abiotic and biotic elements in space and time. Continental drift and major gateway openings shaped past and present oceanographic circulation in this region. The Antarctic Circumpolar Current (ACC), delimited by two main boundaries; the Antarctic Polar Front (APF) and the sub-Antarctic Front (SAF), plays a major role in the biogeography of the Southern Ocean. On one hand, the ACC represents an important barrier for many invertebrate taxa between Antarctic and sub-Antarctic areas. On the other hand, the ACC can transport organisms between geographically distant sub-Antarctic areas, especially in those species with high active and passive dispersive potential. Recent biogeographical reviews recognized the high level of endemism of the Antarctic biota, as well as the marked differentiation among sub-Antarctic, low Antarctic and Antarctic/high Antarctic marine species. Here we present new biogeographical comparisons based on mtDNA sequences among provinces of the Southern Ocean (Antarctica, South America, and sub-Antarctic island) in different groups of marine benthic gastropods. Most of analyzed groups (*Nacella*, *Neobuccinum*, *Margarella*, and *Trophonella*) exhibited a high degree of genetic divergence between Antarctic and sub-Antarctic provinces. Divergence time estimations suggest a separation in these groups for more than 5 million years ago. Surprisingly, while the broadcaster *Nacella* exhibit high divergence between South America and subantarctic islands, some of the brooders such as *Margarella* and *Kerguelenella lateralis* showed a high degree of genetic cohesiveness among these areas, suggesting the importance of long-distance dispersal by rafting in the biogeography of these genera. According to our results, the current biogeographical pattern in Southern Ocean gastropods is not related to a particular group but to historical oceanographic/climatic processes, as well as contemporary ones including the likelihood of long-distance dispersal.

## Cryptic speciation in East Antarctic mosses

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Mosses are the dominant plants in Continental Antarctica but their phylogeny and species limits are not well elucidated. We constructed phylogenies for the three most common moss species in the Windmill Islands of East Antarctica: *Bryum pseudotriquetrum*, *Ceratodon purpureus* and *Schistidium antarctici*. Phylogenies were constructed based on the chloroplast ribosomal protein subunit 4 (rps4) and nuclear non-coding internal transcribed spacer (ITS) genes. Analyses were carried out separately on each species using a Bayesian Markov-chain-monte-carlo (MCMC) analysis and, where sufficient multilocus data was collected, a coalescent-based species delimitation was performed.

*Bryum pseudotriquetrum* was the only species for which sufficient multilocus data were obtained to perform both Bayesian MCMC analysis and coalescent-based species delimitation. For *B. pseudotriquetrum*, these analyses indicated cryptic species in the Bunge Hills, Windmill Islands and Prince Charles Mountain regions of Antarctica, when compared to the Northern Hemisphere holotype. For the remaining two species sufficient multilocus data were not obtained to perform both analyses. Instead Bayesian MCMC analyses were carried out on *C. purpureus* rps4 data and *S. antarctici* ITS data. Analyses indicated that *C. purpureus* populations from East Antarctica are most closely related to populations from Australia and Heard Island, and that populations from the Antarctic Peninsula are most closely related to populations from the Northern Hemisphere. For *S. antarctici* analysis incorporating ITS data from all other *Schistidium* species, revealed that *S. antarctici* is a distinct species, separate from all other *Schistidium* species incorporated into the analysis. Furthermore, it was revealed that the most closely related taxa to *S. antarctici* are cold climate Northern Hemisphere species. This study established that either rps4 or ITS could be used to accurately identify *C. purpureus* and *S. antarctici*. However, insufficient variation in the rps4 gene indicated that it could not be used alone to unambiguously identify *B. pseudotriquetrum*.

## Contrasting genetic signatures of 3 octopod species across the Scotia Arc

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Recent studies investigating drivers of population genetic structure around the Scotia Arc have highlighted the importance of oceanography, bathymetry and glacial cycles in shaping populations. To further investigate the contribution of these processes we used microsatellites and partial sequences of the mitochondrial cytochrome oxidase 1 gene to examine genetic structure in three direct developing, endemic Southern Ocean octopod species; *Pareledone charcoti*, *Pareledone turqueti* and *Adelieledone polymorpha* sampled across the Scotia Arc. These species differ in their maximum known depths; these being ~200m, ~1100m and ~1500m respectively. Counter to expectations, no genetic structure was evident across the known range of *P. charcoti* and intermediate levels of structure was evident in the *A. polymorpha*. The strongest population structure was evident across populations of *P. turqueti*, known from intermediate depths. These patterns of genetic differentiation are compared and contrasted across these species and discussed in context of oceanography, bathymetry and their phylogenetic history.

## Spatial characterization of microbial communities in Fildes Bay, King George Island, Antarctica

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Within the vast diversity of microorganisms that inhabit marine Antarctic ecosystems, microbial communities (eukaryotic and bacterial) have an essential role to primary productivity and bioenergetics cycles.

Although analysis were performed on both eukaryote phytoplankton and bacterial community composition in the Southern Ocean separately, little is known about the microbial diversity, assessing these two key microbial groups together. Specifically, studies on spatial characterization of microbial communities in Fildes Bay, King George, have not been done. As the polar systems are especially susceptible to climatic changes occurring globally, it is of great interest to study the microbial communities and their effect in these environmental alterations.

The objective of this work is to characterize the spatial diversity and taxonomic composition of both phytoplankton and bacterial communities in Fildes Bay, King George Island, Antarctica. This study combines molecular fingerprinting tools for analyzing microbial diversity along with Next Generation Sequencing (NGS) approaches.

The study was conducted during February 2012. Seventeen sampling points homogeneously distributed within Fildes Bay were analyzed using the general 16S rRNA and chloroplastial 16S rRNA genes in order to perform diversity and community composition analysis of bacterial and eukaryote phytoplankton communities, respectively. Analysis were performed with the technique of Terminal Restriction Fragment Length Polymorphism (T-RFLP), supplemented by massive sequencing by 454 Junior Roche and Illumina MiSeq).

In term of phytoplankton diversity, T-RFLP analysis showed that the communities had a high spatial homogeneity. Community composition of selected sampling points assessed by 454, showed to be dominated by three phyla: Heterokonts, Haptophyta and, to a lesser extent, by Cryptophyta. However, using this NGS data, a spatial microbial community structure was observed.

Referring to bacterial diversity analysis, the T-RFLP, showed the existence of 3 clusters that can be related with the geographic location of sampling stations, and with an onshore to offshore tendency.

Bacterial community composition revealed that differences between generated clusters within the bay were determined by microorganisms mostly belonging to Proteobacteria and Actinobacteria. Moreover, 4 dominant classes were detected: Gammaproteobacteria followed by Betaproteobacteria, Alphaproteobacteria and Actinobacteria.

This study tended to enrich the knowledge of the phytoplankton and bacterial communities in marine extreme environments and more specifically in the Antarctic coastal ecosystem.

## Genetic information at different spatial scales

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The importance of recognizing patterns at different spatial scales is often overlooked in molecular ecological studies. The Antarctic and sub-Antarctic region presents a unique model for understanding genetic patterns at various spatial scales. At large spatial scales, understanding evolutionary patterns is often confounded by inaccurate taxonomy. A case in hand is the Amerenothroid mite group where molecular data highlight the need for a taxonomic revision for the group. The pattern for *Azorella* is also discussed where the different islands have very different genetic diversity patterns. At intermediate spatial scales (the scale of the island), patterns are complex as a results of heterogeneous landscapes and different climatic and glacial histories. Here I will focus on Marion Island as a model. The genetic patterns for various springtails, mites as well as a flightless moth will be compared and results placed within our current understanding of the history of the island. Finally, at small spatial scales local climatic conditions significantly affect gene flow. For this, the cushion plant *Azorella selago* serves as a model. There is a significant correlation between gene flow and the prevailing wind direction at four sites across Marion Island. The genetic neighborhood, or gene flow distance, is surprisingly small probably as a result of frequent rainfall events.

## Antarctic rotifers, tardigrades and nematodes: assessing molecular and morphological diversity at a continental scale

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Terrestrial life on Antarctica has been described to be one of the simplest on Earth, and is basically restricted to soil microfaunal populations composed by rotifers, tardigrades and nematodes. Several studies have postulated that the lack of diversity is due to the extreme environmental conditions and believed to be driven mostly by abiotic factors. Habitat composition and molecular analyses are needed to study relationships between populations, and to delimit species boundaries and dispersal patterns further. Only with this information can we make more precise assessments of the patterns and processes of Antarctic microfaunal biodiversity. Species diversity of micro-invertebrates remains underestimated because original taxonomic work has not been reviewed in current years despite descriptions of new species and re-description of known species. However, it is evident that species diagnosis is difficult in most cases due to the conservative morphology of these animals. Here we examine morphological and molecular data for microfaunal groups across Antarctica. Our data shows that a molecular (COI mitochondrial gene) approach is vital to discern between species and to delineate species boundaries (widespread vs endemic) for microfaunal groups. Here we reveal hidden diversity levels for Antarctic microfauna represented by over 100 mitochondrial lineages and 240 unique haplotypes. Our study shows bdelloid rotifers to be the most diverse and widespread group across a wider range of habitats, followed by tardigrades and nematodes.

## Use of morphological traits to identify sex and evaluate geographical variation in Chinstrap penguin (*Pygoscelis antarctica*)

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*Pygoscelis antarctica* (Chinstrap penguin) is a species that presents sexual monomorphism in terms of plumage color traits, making it difficult to determine the sex of individuals. One method to easily determine gender is to develop discriminant functions using morphometric data. However, geographical morphological variations between colonies could cause misidentification of sexes. Therefore, we developed a different discriminant function for each locality. This is the first study in Chinstrap penguins to take geographical morphological variation into account when developing discriminant functions for sex identification. A blood sample was collected and 8 morphometric traits were measured from each of 275 adult Chinstrap penguins from three different localities near the Antarctic Chilean base: Shirreff (n=98), Narebski (n=85) and Kopaitic (n=92). We amplified a region of the CHD1 gene in the sexual chromosomes W y Z by using the primer pair 2550F/2718R to molecularly identify the sex of all individuals. Additionally, we used the eight morphometric traits to evaluate the morphological variation between the sexes and between the three localities. We found significant morphological differences in both cases. These results indicate that it is not advisable to use only one general discriminant function to determine the sex of these birds. Therefore, we established one discriminant function for each locality. These equations present a high percentage of efficacy. Even though it is more advisable to use specific discriminant functions for each locality, we also made a general discriminant function to be able to predict the sex of Chinstrap penguins in localities that are not included in this study. All the functions created here are useful tools for future studies that require a fast sex determination of Chinstrap penguins.

## Genetic homogeneity among Gentoo penguin colonies throughout the west Antarctic Peninsula and South Shetland Islands

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The Gentoo penguin (*Pygoscelis papua*) occurs throughout the Antarctic Peninsula, sub Antarctic Island, and peri-Antarctic Islands. The natal philopatry reported in Gentoo penguins suggest significant genetic differentiation among colonies. However, the *P. papua* distribution is changing due global warming with increase of population size and expansion of its range mainly to higher latitudes. Therefore, the demographic displacement of individuals towards higher latitudes should reduce the genetic differences between Gentoo penguin colonies. Using five new microsatellite markers for 185 individuals from 8 colonies distributed throughout Antarctic Peninsula and South Shetland Islands we estimated levels of genetic diversity and population genetic structure. The breeding colonies showed locus-specific allelic diversity ranges from 4 to 7 alleles and observed heterozygosity ranges from 0.5250 to 0.6400. The  $F_{ST}$  values between pairwise populations were reduced or not significant suggesting a lack of population genetic structure for the Gentoo penguin populations. Moreover, the assignment tests suggest substantial level of admixture between populations. Therefore, the genetic homogeneity among the colonies to Antarctic Peninsula and South Shetland Islands can be explained by gene flow, where all populations may be important sources of migrants.

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## Lipid dynamics in early life stages in the icefish *Chionodraco sp.* in East Antarctica

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In Southern Ocean waters, early life stages are critical in fish life history. Larval survival can be estimated from assessment of larval condition by quantifying biochemical constituents used as energy substrates, e.g. lipids and in most cases triacylglycerols (TAG). TAG fluctuate with the animal's nutritional status and fit quickly to changes in food availability or quality: energy from exogenous feeding can be stored as TAG when exceeding immediate metabolic needs, whereas endogenous TAG is catabolized when exogenous energy is insufficient to sustain basal metabolism. Because the TAG content is body mass dependent, it is standardized by body weight or by structural lipids, as in Fraser's TAG:Chol ratio (1989) where cholesterol (Chol) is not catabolized during starvation and thus is independent of nutritional condition. This ratio reflects the larvae's ability to cope with variation in food availability. Finally, in polar marine organisms, TAG are short-term energy stores whereas waxes are a long-term storage, reflecting two strategies to cope with environmental constraints.

Here, in addition to studying lipid dynamics of the Antarctic icefish (*Chionodraco sp.*) larvae, fatty acid composition of TAG was also analysed to determine its diet over several weeks and identify effectively assimilated preys. This qualitative approach is based on specific signatures of a potential prey: marine primary producers present fatty acid patterns that can be transmitted conservatively to primary consumers and herbivory markers thus disappear as carnivory increases at higher trophic levels. *Chionodraco sp.* larvae were sampled during two ICO<sup>2</sup>TA (Integrated Coastal Ocean Observations in Terre Adélie) campaigns in 2010 and 2011 in the Dumont d'Urville Sea (East Antarctica).

We find that TAG storage is dominant in *Chionodraco sp.*, suggesting steady resource availability throughout the year and a mobilization of energy resources in the short term. Also, cholesterol is not a metabolic invariant but contributes significantly in lipid dynamics. This result precludes the use of the TAG:Chol ratio as a nutritional condition index. Lipid dynamics observed is thus a result of somatic growth: hence a Chol:TAG ratio is proposed as a larval growth index : high Chol:TAG ratios are observed in small larvae (<25 mm SL) suggesting that somatic growth is a priority among young larvae to lower the risk of predation and increase the number of potential preys, while low Chol:TAG ratios in larger larvae show that the accumulation of energy reserves is favoured. These findings suggest an ontogeny in energy allocation between somatic growth and storage of energy reserves for survival. The trophic markers analysis suggests a carnivorous diet (18:1n-9 > 18:1n-7), not associated with representative markers of *Calanus* but probably dominated by larval stages of nototheniidae *Pleuragramma antarcticum*.

## Historical population trends in Antarctic penguins and seals: implications for conservation

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Large areas of Antarctic sea ice will be lost by 2100, greatly reducing the available habitat for marine species that rely on sea ice for breeding and foraging, such as Emperor penguins and Weddell seals. In order to implement effective management plans for these animals we need a much better understanding of the likely impacts of climate change. To address this need, we used genetic data to understand how populations have responded to past periods of climate change and their current capacity to migrate and adapt. The mitochondrial control region and cytochrome *b* were sequenced for 110 Weddell seals and 120 Emperor penguins from colonies across East Antarctica. Extended Bayesian Skyline Plots were used in conjunction with ancient DNA and molecular clock methods to investigate historical population trends and how these might be related to environmental events. We determined present day gene flow including the nature, magnitude and direction of movement for populations of seals and penguins. Despite their similar habitat requirements we found very different population structures for Emperor penguins and Weddell seals. In the case of Emperor penguins the entire 4000km of East Antarctica constitutes a single breeding population (overall  $F_{ST} = 0.00481$ ;  $p = 0.271$ ; pairwise  $F_{ST}$  amongst localities  $p > 0.05$ ). In contrast, Weddell seals are highly structured across the same spatial scale, with East Antarctica hosting at least six distinct breeding populations (overall  $F_{ST} = 0.10524$ ;  $p < 0.001$ ). We discovered that Emperor penguins underwent a large population expansion following a bottleneck approximately 20,000 years ago, coinciding with a period roughly 13°C colder than today. There was no evidence of a similar expansion for Weddell seals, however phylogenetic analysis did reveal three ancestral lineages of seals, one of which exhibited signals of a refugium. The most recent common ancestor of this lineage was dated at approximately 78,000 years ago, coinciding with a period of global climate fluctuation. Our data on Weddell seals and Emperor penguins shows that past climate events have had a major influence on the structure of present day Antarctic marine species, although there appears to be no consistent pattern among species. In combination with data on present day population sizes and migration ability, this new information will enable predictions of how key Antarctic marine species may respond as habitat availability changes under future climate change scenarios, and will allow us to assess the risk of local or widespread extinction.

## Morphological vs Molecular phylogeny: the Primnoidae family

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Primnoidae is one of the richest gorgonian families in genera and species, and dominates together with the family Isididae the high latitudes of the Southern Hemisphere. To infer evolutionary relationships two approaches have been undertaken in this study, phylogenies based on morphology and on DNA sequences. In our study more than 25 macroscopic and microscopical characters have been compared among the 39 valid primnoid genera. Access to viable DNA material is still scarce for some genera, and we could only perform molecular analysis on 16 of the 39 genera, all of them from Antarctic and Subantarctic waters. Two mitochondrial genes (*mtMutS* and *COI*) and two nuclear regions (28S and DNA fragments containing the transcribed spacers *ITS1* and *ITS2*, including gene 5.8S) were amplified.

Morphological phylogeny reveals that all assumed primitive genera are present in the Southern Ocean, four of them restricted to that ocean, and a slight tendency where temperate and tropical genera are located in more recent clades has been also observed. This tendency might suggest that the origin of the family Primnoidae might have been from the Southern Ocean. However molecular analysis in the most speciose genera of the family pointed out the ancestor origin in tropical and temperate waters, suggesting a subsequent colonization of the Southern Ocean. The hypothesis would suggest that primitive Primnoid genera would have been originated from the Antarctica and spread across other regions, then diversificate and subsequently some species/genera would have come back to the Southern Ocean.

## S21: ANTECO: MICROBES, DIVERSITY, AND ECOLOGICAL ROLES

### Soil nutrients structure patterns of bacterial community assembly in an Antarctic polar desert

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Selection or changes in community structure caused by deterministic fitness differences between taxa is an immense force shaping microbial community assembly. However, only a few environmental variables, including pH, salinity, and C substrate quality are known to drive diverse bacterial communities. In addition, drift or the stochastic changes in taxa through time also structures communities. While these forces are often considered independent and mutually exclusive, both act in concert to determine community composition. In an attempt to identify how resources other than C structure communities and disentangle selection from drift forces, we created five resource addition treatments in cold desert soils of the McMurdo Dry Valleys Long-Term Ecological Research site in Taylor Valley, Antarctica. The treatments included: C—mannitol; CN—mannitol, and  $\text{NH}_4^+$  and  $\text{NO}_3^-$ ; CP—mannitol and  $\text{Na}_3\text{PO}_4$ ; N—  $\text{NH}_4^+$  and  $\text{NO}_3^-$ ; P—  $\text{Na}_3\text{PO}_4$ ; W—water; and a control. After maintaining the treatments for more than a decade, we tested the effects of resource on community structure using multivariate statistics on community composition via 16S rRNA gene sequencing. Based on PERMANOVA results, nutrient treatments did select for specific communities ( $F=3.51$ ,  $P<0.001$ ,  $df=6$ ), but only CN ( $F=5.85$ ,  $P=0.09$ ,  $df=1$ ) and CP ( $F=1.64$ ,  $P=0.09$ ,  $df=1$ ) selected for communities different from the control. CN drastically shaped community structure by predominantly selecting one bacterium, an *Arthrobacter* species (phylum: Actinobacteria order: Micrococcaceae), which comprised  $47.4\% \pm 5.64$  of the community. *Arthrobacter* species are common bacteria found in Adelie penguin guano and are most likely copiotrophs that bloom only when N limitations are alleviated. Other orders were also only selected by the CN treatment such as Xanthomonadaceae, Nocardiodaceae, and Oxalobacteriaceae. Treatment P and CP selected for taxa in the order Chitinophagaceae (chitin-loving taxa in Bacteroidetes) and Trueperaceae (extremely radiation resistant taxa in Deinococcus), suggesting that P additions may stimulate the hydrolyzation of chitin from soil fauna and help with UV protection and DNA integrity. Selection accounted for 59% of the community structure in the CN treatment and 23% in the CP treatment based on relative recovery differences between the nutrient and control treatments from 57 bacterial orders. Selection in the single nutrient additions (i.e., C, N, P, and water) accounted for no more than 11% of the community structure, and drift, or other environmental conditions that we did not measure, dictating more than 88% of the community composition. Our findings suggest that selective forces predominately occur when C substrates are combined with another presumably limiting nutrient, and that selective forces by individual nutrient additions alone are not necessarily strong enough to shape bacterial community composition.

## Expression of lipase gene from a psychrotrophic *Pseudomonas isolate*

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Lipase enzyme produced from psychrophilic and psychrotrophic microorganisms have been an interesting field of study. This is due to the fact that the enzyme can work efficiently at lower temperatures therefore capable of fulfilling the variable needs of the industries. Furthermore, the structure solving of these enzymes can provide an answer on how these enzymes adapt to cold temperature. A *Pseudomonas* isolate obtained from polar soil proved able to produce lipase enzyme at 25°C. The gene was amplified through PCR and the full length gene was produced through genomewalking. Cloning of this 1.1kb gene was done in pGEMTeasy vector. Expression of this enzyme is currently being carried out in pET-22b(+) and pCold expression vectors to overproduce this enzyme for crystallization in enzyme structure-function study and comparative study with lipase from mesophilic and thermophilic counter parts.

## Isolation and characterization of potential hydrocarbon degraders from Antarctic soils

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Soils and water contaminated with toxic xenobiotics, such as phenols, can pose serious threat to the environment and ecosystem health. The presence of phenols in Antarctica has been reported on the soils and pack ice. Bioremediation of the contaminant using native microorganisms are necessary since the polar regions are unique and other physical/chemical remediation strategies are expensive. The objectives of this study are (i) to isolate and characterize Antarctic microorganisms capable of utilizing phenol as carbon source and (ii) to measure growth and degradation kinetics of potential isolates on phenol. The contaminated soil samples from Antarctic region will be inoculated in modified basal saline culture media with phenol as the sole carbon source at 10°C. Phenol will be also used in the enrichment step to support the growth of hydrocarbon-degrading bacteria. Bacterial strains capable of growth in the diesel enriched media within a period of 3-4 days will be further isolated and characterized. The optimization study on pH, temperature and concentration of carbon source will be conducted. The bacterial growth and degradation of phenol will be fitted to different kinetic models such as Monod and Haldane. The data provided from this study can be used as a guideline for the bioremediation and biodegradation of hydrocarbon pollutants globally, comprising polar regions and the tropics.

## The relationship between changes in temperature and secretion of secondary metabolites in cold-environment soil fungi

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The fungal kingdom consists of diverse species that are known for its unique and unusual biochemical pathways, one such product of these pathways, are the low molecular weight secondary metabolites. In contrast to primary metabolites, secondary metabolites are often bioactive compounds produced at specific stages of morphological differentiation which are not essential for the growth or the survival of the producing organism. In many instances the roles of these compounds to the ecosystem in which they exist remain unclear but they have been hypothesized to be carriers of chemical communication among soil inhabitants and some have been known to have antimicrobial properties. The ability of fungal communities to produce secondary metabolites has been extensively studied at lower latitudes. However, little is known about the occurrence, function and adaptation of soil fungi from the polar regions, despite the predominance of microbial ecosystems in these regions, or how these may respond in a rapidly changing environment. Therefore, in the current study we i) screened for antimicrobial properties of cold-environment Arctic and Antarctic soil fungi; ii) identified how the secretion of secondary metabolites changed in respond to temperature variation. A total of 40 soil fungal strains originally isolated from King George Island (South Shetland Islands, maritime Antarctic) and Hornsund (Svalbard, High Arctic) were obtained from the National Antarctic Research Centre culture collections. The plug assay technique was used to screen for antimicrobial potential against Gram positive and Gram negative human pathogenic bacteria. Strain HND 11R 8-1, a *Penicillium* sp. sample from Hornsund, showed good activity against two Gram positive and two Gram negative bacteria. This strain showed an inhibition zone of 13mm against *Bacillus subtilis*, 10mm against *Bacillus cereus*, 11mm against *Pseudomonas aeruginosa* and 25mm against *Escherichia coli*. Antarctic fungal strain of *Geomyces pannorum* sp showed good activity against *B. subtilis* with an inhibition zone of 15mm, and strain AK07KGI 2001 R2-1 Sp 1 showed inhibition zone of 8mm against *E. coli*. Two Antarctic strains AK07KGI 102 R2-1 and AK07KGI 1001 R3-2 samples showed inhibition zone of 10mm against *B. subtilis*. In addition to culture based screening of secondary metabolites, molecular screening of genes responsible for the production of major classes of secondary metabolites such as Non-Ribosomal Peptide Synthases (NRPS) and Polyketide Synthases Type I (PKS) would also be carried out. Active fungal strains are then subjected to secondary metabolites profile analysis after culturing at different temperatures (5°C, 15°C, 25°C) using the MECSUS protocol to identify changes in the pattern of secondary metabolite production. These data will allow us to examine the connection between predicted levels of environmental change (temperature), secretion of secondary metabolites, and impacts within the overall soil microbial ecosystem.

## Antibacterial activity of Antarctic bryozoans in a clinical and ecological perspective

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Fouling is an ecologically complex process of chemical interactions between hosts and unicellular and multicellular epibionts. Hence, the first stages of fouling, the bacterial colonization on clean surfaces, plays an important role in this success, given that microbial films are essential for fouling by most larvae. In this sense, antibacterial activity may be a good strategy for avoiding the negative effects of fouling on marine invertebrates, such as the collapse of filter feeding systems. In particular, the antibacterial activity of Antarctic bryozoans and the ecological functions of the chemical compounds involved remain largely unknown. To determine the significant ecological and applied antimicrobial effects, 16 ether and 16 butanol extracts obtained from 16 samples that belonged to 13 different Antarctic bryozoan species were tested against six Antarctic and two standard pathogenic bacteria. The Antarctic bacteria included *Psychrobacter luti*, *Shewanella livingstonensis* and 4 newly isolated strains that were most closely related to *Micrococcus sp.*, *Bacillus aquimaris*, *Paracoccus sp.* and *Oceanobacillus sp.*, according to 16SrRNA gene sequencing. Results of our bioassays revealed that all ether extracts exhibited antibacterial activity against some bacteria at natural concentration. Only one butanol extract belonging to *Stylenopora contracta* did produce inhibition, thus indicating that antibacterial compounds in these bryozoans are mainly lipophilic. The Antarctic bacterium BAC03 was resistant to all bryozoan species extracts. Ether extracts of the genus *Camptoplites* inhibited the majority of studied bacterial strains, indicating a broad-spectrum of antibacterial activity. Different intra/interspecific patterns of antibacterial activity were occasionally detected. Moreover, most ether extracts presented activities against standard bacteria, suggesting a potential use of these extracts as commercial antibacterial drugs against pathogenic bacteria.

## Antifouling activity of selected Antarctic invertebrates measured by "in situ" experiments at Deception Island, South Shetland Islands, Antarctica

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Some marine organisms, such as corals, sponges, and ascidians, have been shown to produce antifouling substances which in nature maintain them free from undesirable encrusting organisms. The ubiquity of fouling organisms in the marine environment and the negative consequences of fouling are likely strong evolutionary pressures for marine organisms to develop defenses to protect their surface from fouling. To determine the significant ecological and applied antifouling effects, fifteen hydrophilic extracts were evaluated in an "in situ" experiment in the Antarctic waters of Deception Island. Eight species of sponges, two cnidarians, one tunicate and one bryozoan were selected. We analyzed the antifouling activity of the extracts through genetic analysis and confocal laser scanning microscopy (CSLM) of the bacteria growing in plates under the sea. We observed significant differences in the bacterial communities (abundance and biodiversity) within treatments and controls after one month underwater. We detected antifouling activity in different species. A particularly strong activity was found in the cnidarian *Eudendrium* sp. and in the sponge *Phorbas glaberrima*, where we located the activity only in the external part, in agreement with the Optimal Defense Theory. Different intraspecific patterns of antifouling activity were occasionally detected, probably indicating that antifouling activity was not species-specific, but site-specific. These results suggest that some Antarctic benthic invertebrates are important factors in determining the biomass, growth and diversity of fouling bacterial communities.

## Bacterial genome-wide horizontal gene-transfers provide co-evolution and adaptation strategies of biosphere in ultra-oligotrophic Antarctic lake

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We isolated some of psychrophilic or psychrotolerant bacteria from a "Moss Pillar", unique tower-like form biosphere consisted of aquatic mosses and prokaryotic / eukaryotic microorganisms in an ultra-oligotrophic lake at Skarvsnes in East Antarctica. Genome sequence analysis of these bacteria showed unique features comparison with genomic data of related species isolated from other continents. They have a large number of horizontally transferred genes, at least 3-8% of entire genes was assigned one beyond the taxonomy class, 2-23% was suggested one over the taxonomic order / family level and 18-47% was unique one, only 37-75% was conserved gene with same genus one by BLAST homology search. Toward the understanding of these bacterial genomic features, we focused the carbon-nitrogen cycle genes which are considered as biologically essential systems of adaptation to ultra-oligotrophic lakes in Antarctica. Many kinds of gene-clusters related with the known carbon-nitrogen cycle ones were found on the *Rhodofera* sp. MP4 ( $\alpha$ -proteobacteria; Burkholderiales) genome and suggested horizontal gene-transfers as described below, CO<sub>2</sub>-fixation enzyme RuBisCO gene (*cbbM*) and nitrite reductase (*nirS*) from *Sulfuritalea* sp. ( $\alpha$ -proteobacteria; Rhodocyclales), nitrogen-fixation nitrogenase gene-cluster (*nifHDK*, *nifENX*, *nifA*, *nifB*, *nifW*) from *Polaromonas* sp. ( $\alpha$ -proteobacteria; Burkholderiales), nitric oxide reductase gene-cluster (*cnorBC*) from *Pseudomonas* sp. ( $\alpha$ -proteobacteria), nitrous oxide reductase (*nosZ*) from *Thiobacillus* sp. ( $\alpha$ -proteobacteria; Hydrogenophilales), while nitrate reductase gene (*narG*) and nitric oxide reductase one (*qnorB*) were existing as conserved *Rhodofera* genes. As a result, this strain had completed the genes set of denitrification process, converting nitrate to nitrogen gas, corresponding to *narKGHJI*, *nirS*, *cnorBC/qnorB* and *nosZ*, followed by nitrogen-fixation process for *nifHDK*, *nifENX*, *nifA*, *nifB*, *nifW*) on the genome by horizontal gene-transfers. It would be considered that gene-sharing or gene-accumulation on bacterial genomes by horizontal gene-transfers provides co-evolution among the symbiotic communities and a kind of efficient adaptation strategies for the biosphere to be continuously developing life-systems in Antarctic ultra-oligotrophic environments. We would like to discuss also about comparison with other cases in *Cryobacterium* sp. MP5 (Actinobacteria; Actinomycetales), *Polaromonas* sp. MP7 ( $\alpha$ -proteobacteria; Burkholderiales), *Devosia* sp. MP8 ( $\alpha$ -proteobacteria; Rhizobiales) and *Phenylobacterium* sp. MP11 ( $\alpha$ -proteobacteria; Caulobacteriales) genomes.

## Characterization of psychrotrophic bacteria occurring in soil and water environment at James Ross Island, Antarctica

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Antarctic soils and fresh waters harbour a pool of psychrotrophic taxa which may be rich sources of new cold-adapted enzymes, pigments or other active biomolecules. Reliable knowledge of taxonomy of microorganisms in Antarctic environment is a fundamental prerequisite for their investigation, bioprospecting and efficient co-operation between different fields of basic and applied microbiological research.

This biodiversity study was focused on investigation of soil and fresh water psychrotrophic cultivable prokaryotes originating from James Ross Island, Antarctica. We have isolated a wide spectrum of gram-negative and gram-positive bacteria and the polyphasic approach was applied for their taxonomy including extensive phenotyping, manual and/or automated ribotyping by RiboPrinter, analysis of whole cell proteins by SDS-PAGE, 16S rDNA phylogenetic study, *rpoD* and *rpoB* sequencing and metabolic fingerprint by Biolog kit. More than 1200 isolates from expeditions in 2008 – 2013 years are available now. They are mainly members of the class *Gammaproteobacteria*, a predominant bacteria there. The second most often group of isolates represented yellow or orange pigmented psychrophilic sphingobacteria and chryseobacteria.

A small set of 46 rose-red colored, oligotrophic and psychrophilic isolates of gram-negative bacteria was studied with polyphasic approach strategy and members of *Pedobacter* spp., *Hymenobacter* spp. and *Massilia* spp. were proved in Antarctic samples. The similarity in *Pedobacter* sp. cluster was 99.4 – 100%, in *Massilia/Duganella* sp. 99.7-100% and in *Hymenobacter* 92.7–96%. Reliable identification to the species level was not possible using the 16S rDNA sequencing and isolated strains probably denote new taxa related to mentioned genera. The detail characterization and taxonomic status of isolated rose-red pigmented bacteria will improve our knowledge of the phylogenetic structure, population variability and diversity of microorganisms inhabiting the James Ross Island soil and fresh water environment. Moreover, this knowledge enables *ex situ* preservation of cold-adapted environment-born bacterial strains representing a valuable source for biotechnology and bioremediation.

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## Biosynthesis of nanoparticles by the psychrophilic Antarctic microorganism ID17

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The microbiological biodiversity and mechanisms of adaptation of Antarctic microorganisms force us to re-evaluate our understanding of the biochemical and microbiological processes that take place in nature. Among the biochemical processes observed that are performed by several Antarctic extremophilic microorganism is the biosynthesis of nanoparticles. On the contrary to industrial chemical synthesis, the biosynthesis allows an efficient control of size, shape and composition of the generated particles. Even more, this process is ecologically-friendly and has low energy requirements. Biosynthesized nanoparticles display good surface bioactivity, a remarkable property for biomedicine and health care applications.

In this work, we have study a psychrophilic bacteria belonging to genus *Geobacillus* able to biosynthesize Au<sup>0</sup> nanoparticles. The Antarctic bacterium ID17 was used for the biosynthesis of Au<sup>0</sup> and Ag<sup>0</sup> nanoparticles incubating cells with Au<sup>3+</sup> or Ag<sup>3+</sup> salts at 65 °C for 12 h. The appearance of an **intense purple or brown colour, respectively, indicated the reduction of the salt**. Elemental analysis of particles localization and composition was verified using transmission electron microscopy analysis and energy-dispersive X-ray analysis. FT-IR analysis was utilized to characterize the chemical surface of nanoparticles. The reduction using NADH as substrate was tested.

Colour changes in the media from colourless to purple and brown was observed after incubation, indicating Au<sup>3+</sup>, Ag<sup>3+</sup> reduction, respectively. Energy-dispersive X-ray analysis showed the presence of metallic particles in their elemental state. Transmission electron microscopy analysis showed that the predominant shapes of Au<sup>0</sup> nanoparticles were quasi-hexagonal (ranging 5-50 nm). When the surface of biosynthesized nanoparticles was analysed by FT-IR, an associated protein type of compound was detected, indicating that protein(s) are probably involved in the process of salt reduction or in the stabilization of nanoparticles. The reductions of Au<sup>+3</sup> and Se<sup>+2</sup> were obtained from crude extracts in a NADH-dependent manner.

### Acknowledgements

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**The influence of light intensity and wavelength on the proteorhodopsin-bearing bacteria *Psychroflexus torquis*: a response to the environmental stresses of Antarctic sea ice**

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Proteorhodopsin (PR) is a photoactive membrane protein which functions as a light-driven proton pump. This establishes an electrochemical membrane gradient, which has the potential to drive ATP synthesis as protons reenter the cell through the ATP synthase complex. Since its discovery in 2000, the PR gene has been found in up to 70-80% of marine bacteria and spans a diverse geographical range including the Atlantic, Pacific and Southern Oceans. Furthermore, in 2010 PR-bearing bacteria were discovered to inhabit the unique and complex environment within Antarctic sea ice. Despite the wide spread nature of this gene, the active contribution of PR *in vivo* is debatable. Light induced growth or enhanced survival is generally observed under sub-optimum conditions such as limited DOC or variation in salinity. This has led to the hypothesis that PR has multiple functions, and PR-bearing bacteria become most prevalent under conditions of stress. The microbes that inhabit Antarctic columnar ice are exposed to a vast range of environment stressors, such as vertical gradients of light, temperature and salinity. We hypothesise that the bacteria in this environment may utilize PR to promote survival and enhance energy inputs, when exposed to these harsh conditions. *Psychroflexus torquis* is a psychrophilic PR-bearing bacterium that naturally inhabits the brine channels of Antarctic sea ice. Through a series of cold-temperature incubations under light and dark conditions, the effect of irradiance on the growth of *P. torquis* is currently being examined. If the influence of PR is greatest under environmentally stressful conditions, a higher light:dark proportion of growth is expected at the coldest incubation temperature. Concurrently, a novel *in situ* incubation experiment conducted in the annual sea ice surrounding Ross Island, Antarctica in November 2013 examined the effect of light intensity and wavelength on the growth of *P. torquis*, when incubated within their natural habitat. Although analysis of this dataset is still in progress, preliminary results suggest the highest rate of growth occurred under blue-light conditions.

## Global-scale microbial dispersal characterized through genetic analysis of the fumarolic soils of Tramway Ridge, Mt Erebus, Victoria Land

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High-altitude, geothermally heated fumarolic fields in Antarctica are analogs for similar environments that may have supported pockets of life during "Snowball" periods in Earth's history or that exist today on icy terrestrial planets. These habitats provide a valuable resource for studying the evolution of mechanisms that enable global-scale dispersal between such sites and the resulting assembly of thermophilic microbial communities. At these locations, geothermal heat flux forms islands of warmth and liquid water in an otherwise extremely cold and dry environment.

Our study has focused on Tramway Ridge (ASPA 130), a fumarolic field near the summit of Mt. Erebus, the southernmost active volcano on Earth. In order to better understand the composition, distribution and function of organisms within this community, we utilized amplicon and metagenomic sequencing of bulk environmental DNA. We found that surface-associated genetic signatures closely match signatures for thermophilic microbial mat taxa and mesophilic soil bacteria found widespread across Earth, whereas the subsurface is dominated by novel Archaea and members of poorly understood Bacterial candidate divisions that are closely related to those found in geothermal features at Yellowstone National Park (USA) and El Tatio Geysir Field (Chile).

These distributions imply that aeolian processes readily disperse viable organisms to Antarctica and that several subsurface-associated thermophilic lineages possess currently unknown adaptations that enable planet-wide dispersal. An ongoing metagenomic effort has resulted in the reconstruction of over 20 partial to nearly complete draft genomes, which are being used to elucidate the general mechanisms by which these particular organisms survive desiccation and UV exposure during aeolian transport between geothermal habitats

## Biological activity in snow and ice-bound ecosystems on Signy Island, maritime Antarctica

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Continued warming of the maritime Antarctic is leading to large areas of snow and ice becoming increasingly biologically active, resulting in an increased flux of microorganisms and nutrients from snow and ice-bound habitats to the marine environment. Microbial abundance on the surface of glacier ice alone is estimated to be  $10^{14}$ - $10^{17}$  cells  $\text{km}^{-3}$  making it the largest freshwater reservoir of microorganisms on Earth. Due to the recent rapid regional warming in West Antarctica and around the Antarctic Peninsula in particular, large masses of ice and snow have been lost into the surrounding ocean ( $\sim 180$  Gt  $\text{year}^{-1}$ ). With this ice, around 16 Gg of organic carbon are also released every year and transferred into the ocean, but the ecological implications of such loading for the marine ecosystem remain unclear.

We aim to assess climate forcing on biogeochemical activity in snow and ice-bound ecosystems in the maritime Antarctic, and to estimate nutrient and biomass export by glacier meltwater into terrestrial habitats and coastal waters. Microbiology, nutrient economy and productivity of snow and ice surface habitats were assessed at two major glaciers on Signy Island (South Orkney Islands). These sites represent the broad range of melting and nutrient gradients found along much of the Antarctic Peninsula's west coast and associated archipelagos. Microbial community structure and biomass changes were studied in snowpack, slush and superimposed ice during the austral summer 2012-13 using molecular techniques, phospholipid fatty acid analysis and flow cytometry. Fluxes of carbon, nitrogen, phosphorus and iron were also monitored throughout the season within snowpacks and the runoff they produced, in order to estimate the timing and magnitude of nutrient transfer into the nearby coastal waters. Net ecosystem production, respiration and photosynthesis of the snow and ice-bound habitats were evaluated using radioisotope labelling ( $^{14}\text{C}$  and  $^3\text{H}$ ) and  $\text{CO}_2$  flux measurements. This multidisciplinary approach enabled us to calculate the internal biological production and biogeochemistry of snow and ice-bound ecosystems on Signy Island and to estimate the significance of the nutrient and microbial loading from these melting icy habitats into the surrounding coastal ecosystems.

## Identification of microbial and viral-like rhodopsin sequences in sediments from four cold coastal environments

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Bioprospecting of genes encoding microbial rhodopsins have a biotechnological interest for its future applications as solar energy transducers and fluorescence voltage-indicators probes.

Here, we describe a diverse group of microbial rhodopsin sequences identified in a metagenomic dataset from sediments of four high-latitude coastal environments of the world: a) Adventfjord (Svalbard Archipelago, Norway; 78° 14.2' N-15° 40.6' E and 78° 14.6' N-15° 39.4' E), b) Värtahamnen (Baltic Sea, Sweden; 59.21.48 N-18.06.69 E and 59.21,667 N 018.06,291 E), c) Ushuaia Bay (Tierra del Fuego, Argentina, 54° 48.656' S 68° 17.731' W and 54° 48.256' S 68° 17.296' W) and d) Potter Cove (King George Island, Antarctic Peninsula; 62° 13' 50" S 58° 39' 22" W and 62° 13' 55" S 58° 39' 18" W). The dataset included 23 surficial sediment samples (0-5 cm) obtained at a 9.5-50 meters depth range, sequenced using an Illumina HiSeq 1500 platform and processed at the **metagenome annotation pipeline of the Joint Genome Institute**. The assembled dataset, which includes 1.4E+07 protein coding genes, was explored to identify genes associated in their functional characterization with COG5524 (bacteriorhodopsin in Clusters of Orthologous Groups), and depurated using BlastClust. Transmembrane helices in proteins were predicted using the TMHMM program. Further alignment of 128 putative rhodopsin sequences from this work together with a set of reference sequences from data banks was performed by using Muscle program. Phylogenetic analysis was made using online PhyML.

Rhodopsin sequences were not identified in all sediment samples. Bacterial, archaeal, eukaryotic and viral-like rhodopsins sequences were detected in 18 out of the 23 metagenomes. A high diversity of rhodopsin sequences was observed when these sequences were compared with those previously reported.

To our knowledge, this is the first report about microbial rhodopsins from costal marine sediments. A selection of the more divergent kind of rhodopsin sequences for further cloning and functional characterization would be necessary to evaluate their possible biotechnological applications.

## Microbiota (archaea, bacteria and foraminifera), geochemical composition of sediments and methane fluxes in fumaroles, Deception Island, Western Antarctica

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Deception Island (DI) is an active volcano located in Bransfield Strait. Fumaroles are common at DI and at low tide, steam rises from seawater and beach sediments in Fumarole Bay (FB) and Whalers Bay (WB). In FB and WB, a sampling campaign was carried out in January 2013 and 2014.

Geophysical datasets were acquired by a single beam (Kongsberg EA400) and multibeam (EM302) echosounders and sub-bottom profiler (SBP120). Videos of seafloor and ebullitive activity in shallow waters have also been captured. Sediment samples from supratidal (background sample - BG), intertidal and subtidal zones were collected for grain size, geochemical and microbiota analyses. CH<sub>4</sub> flux was measured using static chamber and headspace techniques. CH<sub>4</sub> concentrations were quantified by gas chromatography.

Gravelly sand occurred in FB (65 to 92%) whereas gravelly mud prevailed in deeper zones of FB (55 to 82%) and WB (65 to 80%). Sediments were mainly composed of basaltic-andesitic fragments. High concentrations of C (0.5%) and CaCO<sub>3</sub> (41%) were observed only in the deepest zone, located in FB. In others areas C (0.01-0.17%) and CaCO<sub>3</sub> (<25%) concentrations were low. Except for samples from WB intertidal zone (0.3-0.2%), total S concentrations in all zones of FB and WB were low (0.01-0.09%).

Cluster analysis identified 2 groups based on major and trace elements and rare earth elements: a) one station in WB at 29m depth with the highest values of As, Au, Cr, Co, Mn, Mo, Ti, Y and b) a group with 4 subgroups of stations located in intertidal and supratidal zones; shallow zones (9-13m); stations distant from the shore (40-90m); and the deepest zone (120m). This last subgroup is separated from the others due to high concentrations of Cu, Rb, Sc, Sr, V, Zn.

Assemblages of foraminifera are restricted to deeper areas, being dominated by agglutinated and calcareous species. Anaerobic cultures of FB and WB sediment under methane atmosphere incubated at 4°C showed methane consumption of up to 94% (FB) and 58% (WB) after 374 days of enrichment with one addition of CH<sub>4</sub> at day 311. Comparison with control tube indicated biological consumption of CH<sub>4</sub>. Microscopic analysis revealed cell aggregates autofluorescent under UV light, characteristic of methanotrophic archaea. The average CH<sub>4</sub> flux on the fumaroles of FB intertidal zone (68mg m<sup>-2</sup>d<sup>-1</sup>) is significantly higher than in BG (1mg m<sup>-2</sup>d<sup>-1</sup>).

Flux measurement in shallow water is higher (17mg m<sup>-2</sup>d<sup>-1</sup>) than in areas located far from the shore (1.4mg m<sup>-2</sup>d<sup>-1</sup>). Regarding to dissolved CH<sub>4</sub> in water, the highest values were observed in deeper zones (0.11µg/l) and the lowest in subaerial fumaroles (0.05µg/l). These results suggest that the methane in the deeper zone is transported in water column by diffusion from biogenic production, possibly being subjected to microbial anaerobic oxidation. In fumaroles of the intertidal zone, the flux is ebullitive due to local geothermal activity. PROANTAR (557036-2009-7)

## Lake ecosystem of Ulu Peninsula, James Ross Island, Antarctica: Centre of unique biodiversity and ecology

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James Ross Island belongs to a transitory zone between the maritime and continental Antarctic regions. Only the northernmost part of the island, the Ulu Peninsula, is significantly deglaciated. Although we can expect a substantial impact of progressive warming trends in the Antarctic Peninsula region on lacustrine ecosystems, the lakes of the Ulu Peninsula remained largely unstudied. Their origin is related to the last deglaciations of the Antarctic Peninsula ice sheet and to relative sea level changes resulting from postglacial isostatic recovery. Interactions between volcanic landforms and glacial geomorphology during previous glacial-interglacial cycles resulted in the complex present-day lake ecosystem features. Based on these features, a representative set of 29 lakes could be sorted into six different types; a) stable shallow lakes on higher-altitude levelled surfaces, b) shallow coastal lakes, c) stable lakes in old moraines, d) small unstable lakes in young moraines, e) deep cirque lakes and f) kettle lakes. Bedrock type, lake age and morphometry together with altitude were the most important factors underlying the high limnological diversity.

Significant relationship between lake type and photoautotrophic community structure was observed. The floors of old stable lakes are covered with massive photosynthetic microbial mats composed of cyanobacteria and microalgae (diatoms and chlorophytes) with a high proportion of species that are considered as Antarctic endemics at present. The diverse character of mats could only partly be explained by environmental characteristics. In two lakes, unique calcareous organosedimentary structures (stromatolites) were described that are characterized by the presence of calcium carbonate monocystals with a layered structure. On the contrary, phytobenthos is poorly developed in young lakes due to high disturbance; however, phytoplankton also occurs in some of these lakes. The lake biota was further characterized by the common occurrence of the crustacean *Branchinecta gaini* (Anostraca) in shallow lakes and *Boeckella poppei* (Calanoida) both in shallow and deep lakes.

To conclude, the Ulu Peninsula represents a significant limnological site in the Antarctic Peninsula region characterized by a high biodiversity connected with unique ecological features.

## Geological connectivity drives microbial connectivity in Eastern Antarctica

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Antarctic polar desert landscapes are diverse, ranging from highly connected high latitude systems to relatively flat disconnected sites separated by frost-sorted polygons or frost boils. While microbial ecology studies are widespread in terrestrial Antarctica, the spatial dynamics of the resulting microbial communities in soils from landscapes with varying degrees of connectivity are not known. The low diversity of Antarctic soil, combined with a high degree of patchiness and Antarctica's geographical isolation makes it an ideal model ecosystem for investigating the flow of nutrients and microbes across landscapes. We thus investigated the spatial distribution of bacteria and fungi in connected and patchy landscapes in order to examine the effect of connectivity on the flow of nutrients and microbes between landscape types. We used tag pyrosequencing targeting the bacterial 16S rRNA and the fungal ITS genes within soils sampled from 3 locations from the Windmill Island region of Eastern Antarctica. One of these locations represented a patchy disconnected landscape (Browning Peninsula) consisting of frost-sorted polygons between 2- 10 m in diameter. The two other locations (Mitchell Peninsula and Robinson's Ridge) were highly-connected. Following the discovery of major differences in the similarity of the resulting microbial communities we also investigated a connected and a patchy polar desert location from the high Arctic, Svalbard Island, Norway. We will show that on a global scale, bacterial and fungal community composition from the connected locations exhibited a strong correlation to environmental variables and geological distance compared to patchy sites, which were more fragmented. Partitioning of variation and microbial co-occurrence networks also revealed a significant difference in community profiles between both types of landscapes. Our results suggest that microbes in connected landscapes are responding to drivers of community composition in a more consistent fashion than those in fragmented sites. This apparent disconnectivity may be due to the geological disruptions to the flow of nutrients and the dispersal of bacteria and fungi across the patchy landscapes.

## **Purification and screening of exuded antibacterial protein activity from Antarctic *Pseudomonas sp.* against classic and multi drug resistant bacteria**

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Antarctic microorganisms can synthesize, likely as a result of environmental stress, a broad range of extracellular antimicrobial compounds that would grant a particular advantage in reducing interspecies competition. Although both, Gram-positive and Gram-negative bacteria can produce small heat-stable bacteriocins, they have been less frequently observed in Gram-negative bacteria. *Pseudomonas* is a bacterial genus characterized by its pathogenicity; however, there is little information about antimicrobial compounds produced by this genus. Nowadays, multi drug resistant (MDR) pathogens are the most challenging problem in the treatment of infectious diseases. Indeed, a notorious increase in the number of antibiotic resistant bacteria has been described in the last two decades.

The present study focuses on the purification and screening of antimicrobial activity produced by an Antarctic *Pseudomonas sp.* from King George Island against both MDR and classic pathogens.

The pseudomonad studied in this work was selected from a total of twenty-four bacterial isolates, whose antibacterial activity was assayed by Agar Spot Test. Identification was accomplished by 16S rRNA sequencing and was further completed biochemically by API tests. The strain was then cultured in 400 mL LB broth at 14°C, during 5 days in agitation until stationary phase of growing. Cell free media was recovered and then eluted through a C-18 column with increasing concentrations of acetonitrile. Fractions were lyophilized and re-suspended in water. Semi-purification of the active compound was performed in a C-18 Kromasil column (4,6x250 mm 100Å) using an acetonitrile gradient (20% – 60%) in HPLC. Antibacterial activity was measured in 96 well microplates and growth inhibition was calculated over bacterial growth without the inhibitory compound. Results of antibacterial activity were compared using one-way ANOVAs. Treatment with proteases was used to ascertain the proteinaceous nature of the active compound and Tris-Tricine-Urea-SDS-PAGE was used to characterize peptides in the fraction.

Identification via 16S rRNA gene sequencing revealed 99% of similitude with *Pseudomonas fluorescens*. The isolated *Pseudomonas sp.* showed high antimicrobial activity against *E. coli* and *S. aureus*, inhibiting near 100% of bacterial growth, similar to positive control, peptide 759, isolated from snake venom. Regarding MDR bacteria, the semi-purified peptide showed variable but positive antimicrobial activity. Treatment with proteases caused loss of antimicrobial activity and Tricine-Urea-SDS-PAGE of the semi-purified active fraction evidenced the presence of a low molecular weight protein.

These findings could be the first report of antibacterial activity by antimicrobial peptides in Antarctic maritime *Pseudomonas* representing a major advance towards the control of relevant classic and MDR pathogens.

## Shifts in benthic microbial assemblages along steep environmental gradients in Lake Fryxell, McMurdo Dry Valleys

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Lake Fryxell is a perennially ice-covered lake in Taylor Valley, South Victoria Land, Antarctica which, like many dry valley lakes, is characterized by minimal disturbance. Beneath 3-5 m of ice wind driven turbulence is virtually absent, and a salinity stabilized water column means that convective mixing is largely absent. This stability allows steep environmental gradients to develop, with the depth at which the lake transition from oxic to anoxic a key discontinuity at ~9.8 m. Thick, laminated photosynthetic microbial mats cover the lake floor from immediately below the ice cover to at least 10.4 m depth. These mats span the oxycline, forming a range of complex emergent morphologies, the nature of which closely parallel the shifts in oxygen concentration. Mats at 9 m grow with ambient oxygen concentration of up to 20 mg L<sup>-1</sup>, form a network of cm-scale ridges and pinnacles, are formed mainly by narrow-trichome cyanobacteria. Below 9.6 m, as oxygen decreases to 0.3 mg L<sup>-1</sup>, a "honeycomb" mat that is primarily flat with cm-scale, near circular, anoxic pores, rich in precipitated manganese forms. Finally flat green and gold mats are present at 9.8 m depth, when the bulk water was anoxic – though traces of oxygen were present within the mat matrices. This transition in mat types occurred over a 1 m vertical range, but the gentle slope of the lake bottom at the transect site amplified this to 25 m horizontally. Here we describe the shifts in the structure and composition of these microbial mats, based on microscopy and pigment analysis, in the form of a transect from shallow to deep water. We use a sequencing approach to characterize the microbial communities in various laminae within the microbial mats. We specifically examine the hypothesis that vertical zonation of microbial communities within mats mirrors zonation of surface communities of mats along the depth gradient.

In recent years the level of Lake Fryxell has been rising due to climate-related increases in meltwater inflow. Since 1980 the lake has risen by approximately 2 m. Evidence is presented that the oxycline has also risen up to 1 m through the lake over this time, with associated shifts in the distribution of microbial communities. Rising lake level appears to be cascading to a series of environmental changes in this lake, though at present these are being accommodated by vertical movement of organisms.

## Newly developed fungal LSU sequence database and its application to understand fungal community in Antarctic environments

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Recent advances in sequencing technology allow deep sequencing of environmental samples. This large-volume DNA information helps us better understand microbial community structures in diverse environments when coupled with a well-curated reference sequence database. Databases such as RDP, Silva, Greengenes, and EzTaxon-e provide reliable 16S rRNA sequences for prokaryotes. However, a similar reference database is absent for the study of fungal diversity and ecology. Although the UNITE system provides ITS sequences across almost all fungal groups, the ITS region is highly variable and therefore yields poor sequence alignments between distant fungal species. Considering the remarkable fungal diversity in nature, we chose the more conserved LSU rRNA gene as a standard genetic marker to study metagenome-based fungal diversity and ecology. In order to build a fungal reference sequence database called MycoDE, tens of thousands of LSU sequences were collected, filtered, aligned and phylogenetically analyzed. The manual phylogenetic inspection showed that the majority of fungal taxonomic groups are polyphyletic. The taxonomic names of monophyletic fungal groups were determined by referring to the current nomenclature system. On the other hand, non-monophyletic fungal groups whose appropriate scientific names were not available were temporarily named using our own rules of nomenclature, which was developed from an ecological point of view. Now, a new fungal taxonomic hierarchy with reliably aligned LSU sequences is available at the MycoDE website (<http://mycode.kopri.re.kr>). In addition, this website provides an identification tool to assign taxonomic names to the large-scale fungal LSU query sequences. The usefulness and reliability of the MycoDE database was preliminarily tested on lichen microbiome and soil samples that were collected from Antarctic environments.

## **Lean and mean: The efficiency of organic carbon utilization by soil microbes in the maritime Antarctic**

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The Antarctic Peninsula and associated islands have numerous seasonally snow and ice-free pockets of land with soil and vegetation cover. The Antarctic Peninsula has experienced the fastest rate of warming in recent decades. Data on the sizes and activity rates of the soil microbial communities are both important to understand environmental change and the factors regulating microbial activity under harsh environmental and relatively resource-poor conditions prevalent in Antarctica. We have measured the biomass and activity (respiration) of microorganisms, and the amount and decomposition rate of soil organic matter content for soils along a 1500 km latitudinal gradient comprising over fifty sites from South Georgia to land around the Ronne Entrance (54 to 72° S). Although the total soil organic C contents were generally small by comparison with soils elsewhere in the world, the proportion of C in both the labile fraction of the soil organic C and the living biomass were very large by comparison with worldwide data. These observations indicate that the soil microbial communities were both unusually large and unusually efficient at organic C utilization relative to the small amount of organic substrate available. The data represent the most comprehensive sample set of soil microbial data ever collected in the maritime Antarctic.

## A microbial biodiversity hotspot: Mitchell Peninsula, Eastern Antarctica

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Mitchell Peninsula (66°31'S, 110°59'E) is located at the south of the Windmill Islands, Eastern Antarctica. Mitchell Peninsula is a polar desert with maximum altitude of 100 m, it is located approximately 5 km from well-studied Casey station and has had very little human impact. While the microbial diversity in many locations of the Antarctic are well described, very little information is available on the bacterial or fungal diversity present in this area. Therefore, our aim was to investigate the diversity, abundance and distribution of bacteria and fungi over this site. We used a spatially explicit sampling design along three 300 m transects extended southeast from the coast. We obtained extensive environmental data for each soil sample including soil nutrients, physical characteristics and climate variables. We also carried out qPCR targeting fungal 18S and bacterial 16S rDNA and 454 tagpyrosequencing targeting the bacterial 16S rDNA and fungal ITS genes in order to capture the biodiversity of the site. Our hypothesis was that at Mitchell Peninsula, the soils would be dominated by Proteobacteria, Actinobacteria, Acid bacteria, Firmicutes and Bacteroidetes, and pH and latitude were expected to be driving the microbial community patterns as had been observed in previous soil biodiversity studies.

We will show that Mitchell Peninsula is a microbial biodiversity hotspot, consisting of soil bacterial communities dominated by Actinobacteria, Chloroflexi, Proteobacteria, Acidobacteria and Candidate Divisions WPS-2 and AD3. The abundance of uncultured bacterial lineages WPS-2, AD3 of up to 24% and 17% respectively was surprisingly high and further work is planned to determine what functions they may be involved in. Fungal community was also diverse, dominated by Ascomycota, Basidiomycota, and unclassified fungi. By investigating spatial dynamics, significant differences were found between the low (<20m), the mid (20-40 m) and high (~50 m) elevation soil samples. As the elevation increased, an increased relative abundance of Proteobacteria, WPS-2, AD3 and a decrease in Actinobacteria were observed. Interestingly, the marine associated bacteria Ectothorhodospiraceae, and Cyanobacteria were not present at mid-high elevation groups yet were abundant at low elevation samples and could be due to past sea level changes. For the fungal communities, Ascomycota were most abundant at the low elevation groups, with the lichen-associated class Lecanormycetes gradually decreasing being replaced by Leotiomyces and Eurotiomyces as elevation increased. In conclusion, Mitchell Peninsula is a microbial diversity hotspot in Antarctica; it harbors a unique blend of bacteria and fungi species and should be a protected site in the future.

## Trophic relationships under sea ice: stable isotope-based dietary study in early spring off East Antarctica

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An understanding of sea ice trophic interaction may help us to predict how the Southern Ocean ecosystems will respond to environmental changes. We examined  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  signatures of eight common zooplankton species, together with particulate organic matter (POM) from both the sea ice and the underlying water column. Samples were collected from East Antarctica (110-130°E) during two Sea Ice Physics and Ecosystem eXperiments (SIPEX and SIPEX-2012). The  $\delta^{13}\text{C}$  signatures suggested that most of the zooplankton species heavily rely on water-based POM while a few species utilized sea ice POM as a major food source. The  $\delta^{13}\text{C}$  signatures of Antarctic krill (*Euphausia superba*) also indicated an ontogenetic dietary shift. The  $\delta^{15}\text{N}$  signatures indicated a very clear stepwise enrichment from POM to carnivorous species. Two euphausiid species *Euphausia superba* and *Thysanoessa macrura* had very similar  $\delta^{15}\text{N}$  profiles, which also highlighted an omnivorous diet for both species. These results illustrated a complex food web in the zooplankton community, with pelagic species using both sea ice and under-ice water column organic matter as food sources. This study highlights the importance of the sea ice zone to krill and other zooplankton during the winter-early spring transition.

## Antarctica cyanobacteria: from Scott's discovery expedition to microbialites in Dry Valley Lakes.

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Antarctic terrestrial aquatic ecosystems in the McMurdo Dry Valleys, Southern Victoria Land and Ross Island include meltwater ponds and perennial ice-covered lakes, and their biology is dominated by benthic microbial mats that often take complex 3-D macroscopic morphologies. Cyanobacteria are key primary producers in these benthic environments and a major structuring agent of these multilayered three-dimensional structures. Recent findings have shown the sensitivity of these inland ecosystems to climatic-driven environmental change, and a better understanding of the distribution and response of cyanobacteria and other microbes to environmental gradients, will likely assist in evaluating the resistance and resilience of Antarctic freshwater benthic biology to change.

Therefore, cyanobacterial mats collected during R. F. Scott's Discovery Expedition (1901-4) from the McMurdo Ice Shelf and Ross Island allowed the comparison of historic specimens with present-day cyanobacterial communities using next generation sequencing from similar geographic regions in Antarctica to identify changes in cyanobacterial diversity over the last 100-years since onset of human activity and climatic change. In addition, perennially-ice covered meromictic lakes in the McMurdo Dry Valleys, Antarctica, are useful models to study the relationship between cyanobacteria and environmental variables, because they have rich benthic cyanobacterial mat accumulations and stable stratification of physical and chemical conditions. We therefore evaluated the cyanobacteria and microbial mats using 16S rRNA gene clone library and next generation sequencing analyses. Our results suggested that the 16S rRNA gene cyanobacterial composition in benthic flat mats varied across environmental gradients in Lakes Vanda, Joyce and Hoare, however most lakes shared the majority of taxa. In Lake Vanda, microbialite structures cyanobacteria dominating most layers followed Proteobacteria. Bacteroidetes, Chloroflexi, Planctomycetes, and Verrucomicrobia including also potentially niche specific taxa such as a recently discovered basal cyanobacteria group in the inner microbialite layers. In conclusion, the benthic microbiology of Dry Valley Lakes is diverse; and its microbial assemblages are made of taxa with likely niche specific growth requirements and microbial groups such as cyanobacteria with broad environmental tolerance to climate-driven environmental change.

## Toxic cyanobacteria in the polar regions: distribution, diversity and toxins

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In temperate and tropical regions, toxin production by cyanobacteria is a common phenomenon and constitutes a serious health hazard to animals and humans. In contrast, toxin production has rarely been reported for cyanobacteria originating from the Arctic and the Antarctic and toxic strains from these regions have not-yet-been identified.

In this study we assessed cyanobacterial samples from various localities in the Arctic (Svalbard Archipelago and Baffin Island, Canadian Arctic) and the Antarctic (Byers Peninsula and Adelaide Island) for their toxic potential by applying molecular, immunological and chemical approaches. Their diversity was assessed using 16S rRNA gene pyrosequencing and automated ribosomal intergenic spacer analysis (ARISA).

Three cyanobacterial toxins (microcystin (MC), cylindrospermopsin (CYN) and saxitoxin (STX)) were detected and their corresponding gene clusters identified in Arctic and Antarctic cyanobacterial mat samples. The hepatotoxic microcystin was detected by enzyme-linked immunosorbent assay (ELISA) in 26 out of 27 cyanobacterial mat samples (10-300 ng/g organic mass) on Adelaide Island and in one sample from Baffin Island. Baffin Island was the only locality for which neurotoxic STX was detected and parts of the STX gene cluster (*sxtA*) were identified. CYN was detected for the first time in the Antarctic in 21 of 30 mats (2-156 ng of CYN/g of organic mass) from Adelaide Island. The latter finding was confirmed for one mat sample via liquid chromatography-mass spectrometry and by the presence of the *cyrAB* and *cyrJ* genes.

Cyanobacterial diversity was generally high with between 8 and 33 cyanobacterial OTUs per sample on Adelaide Island. Statistical analysis demonstrated that cyanobacterial diversity was not linked to the presence of toxins but was more similar for samples obtained from closely adjacent locations, suggesting a biogeographic pattern for their diversity.

This study confirmed that cyanobacteria from extreme environments produce a similar range of cyanotoxins as their temperate counterparts. Additionally, the highly diverse mats are likely to harbour a variety of secondary metabolites that could have useful biotechnological application. Screening for a range of the latter is planned.

**Polar and Alpine Microbial Collection (PAMC): a culture collection dedicated to polar and alpine microorganisms**

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The number of microbial strains isolated from polar and alpine areas is increasing and they are recognized as valuable resources in fundamental studies, such as ecology, physiology, and – omics. Thus, the necessity of culture collection dedicated to the polar and alpine microorganisms has increased. Korea Polar Research Institute (KOPRI) established the Polar and Alpine Microbial Collection (PAMC) to share biodiversity information and bio-resources collected from polar and alpine areas in science and public communities. Approximately 2,000 out of 6,500 strains maintained in PAMC have been identified and belonged primarily to the phyla *Actinobacteria*, *Bacteroidetes*, *Firmicutes*, and *Proteobacteria*. Many of the microbial strains of PAMC can grow at low temperature and produce proteases, lipases, and/or exopolysaccharides. PAMC provides search tools based on keywords such as taxonomy, geographical origin, habitat and physiological characteristics. Biological materials and information provided by PAMC will be important resources for those who have had no opportunity to visit polar and alpine areas and are expected to contribute to the development in the extreme life sciences (Grant: PE14080)

## The ecological dichotomy of ammonia oxidizing archaea and bacteria in the hyper-arid soils of the Antarctic Dry Valleys

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The McMurdo Dry Valleys of Antarctica are considered to be one of the most physically and chemically extreme terrestrial environments on Earth. In such harsh conditions, microorganisms dominate and are believed to drive all processes in the system; however little is known about the organisms and genes involved in the nitrogen processing of these environments. In this study we investigated the diversity and abundance of archaea (AOA) and bacteria (AOB) ammonia oxidizers, by using phylogenetic and molecular quantitative tools for AOA and AOB *amoA*, in four McMurdo Dry Valleys with highly variable soil geochemical properties; Miers Valley, Upper Wright Valley, Beacon Valley and Battleship Promontory. Results revealed generally low AOB and AOA *amoA* gene diversity; from a total of 210 clones of archaea (AOA) and bacteria (AOB) *amoA* only four AOA and three AOB OTUs were recovered in the four McMurdo Dry Valleys. However, *amoA* qPCR quantification revealed clear differences in the relative abundance of AOA and AOB between the Dry Valleys evaluated. While AOB *amoA* genes dominated the ammonia-oxidizing community in soils from Miers Valley and Battleship Promontory, AOA outnumber AOB at Upper Wright and Beacon Valleys, characterized by the most extremely harsh conditions. In fact, correlations between environmental variables and abundance of *amoA* gene copy numbers as examined by redundancy analysis (RDA) revealed that higher AOA/AOB ratios were closely related to soils with high salts and Cu contents, lower pH and with higher soil moisture. This study suggested a highly dispersed distribution of AOA and AOB ammonia oxidizers within the Dry Valleys ecosystems and indicated an importance of nitrification processes in driving Dry Valleys microbial functionality.

## Ammonium oxidizing populations dominate benthic microbial assemblages in sediments previously covered by the Larsen A Ice Shelf

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Sub-ice shelf environments experience limited organic carbon input due to the exclusion of phytoplankton productivity in the overlying water column. Ice-shelf loss along the east coast of the Antarctic Peninsula over recent decades has brought new sources of carbon and energy to the marine benthos likely resulting in profound changes in sediment geochemistry and microbial community composition. To better understand the long-term effects of ice-shelf loss in this region we conducted a five-station survey along a 160 km transect following the historic path of retreat of the Larsen A ice shelf. A minimum of nine sediment megacores were collected per station and sectioned at 0.5 to 2 cm intervals to depths typically exceeding 24 cm. Over 700 sediment samples were used for pore water chemical analysis and microbial assemblage characterization via 16s rDNA targeted next-generation sequencing. We are correlating the abundance of specific taxonomic groups with local geochemistry to infer the function of dominant microbial populations and to assess the major drivers of change in the microbial communities following ice-shelf loss. Initial results indicate the dominance of ammonia oxidizing archaea (AOA) *Nitrosopumilus* (and other Thaumarchaeota) at mid-transect stations where low ammonium levels and the presence of high pore water nitrate suggest aerobic ammonia oxidation is prevalent. At the outermost stations, high ammonium and the emergence of the Planctomycete candidate genus *Scalindua* indicates a switch to anaerobic ammonium oxidation (ANAMMOX).

## Molecular characterization of Antarctic microorganisms and bioprospecting of yeasts isolated from the South Shetland Islands Antarctica

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This study focused on the molecular identification and bioprospecting of bacteria, yeasts, and microfungi isolated from the South Shetland Island in the Antarctic continent. Soil samples were collected in the islands Torres, Dee, Barrientos and Greenwich. Samples were processed by culture and molecular techniques including 454 pyrosequencing.

Soil samples were plated onto different culture media and isolates were identified by PCR amplification and sequencing of the ribosomal 16S region of bacteria or the ITS1, 5.8S, and ITS2 DNA region of fungi. Pyrosequencing was also carried out and results were analyzed using the Quantitative Insights Into Microbial Ecology QIIME software. Yeast bioprospecting was performed by incubating each isolate at 20 °C on mineral media enriched with urea, casein/gluten, starch, or fat to test for ureases, peptidases, amylases, or lipases respectively. Fermentation of sugars was tested using sucrose, fructose, glucose, maltose, lactose, and glycerol. Various fermentation temperatures were tested including 5, 10, 15, 25 and 30°C.

The highest identity percentages (98% identity or above) from BLAST were achieved on 16 species of bacteria belonging to the genera *Pseudomonas*, *Brevundimonas*, *Arthrobacter*, *Pantoea*, *Sphingomonas*, *Bacillus*, *Rhodococcus*, *Janthinobacterium*, *Duganella*, and others; as well as 19 species of fungi of the genera *Geomyces*, *Mortierella*, *Antarctomyces*, *Verticillium*, *Penicillium*, *Cadophora*, *Pseudeurotium*, *Cryptococcus*, *Candida*, and *Rhodotorula* among others. A potential new yeast species (CIBE 1b.1) was found with only a maximum of 76% similarity and significant variations in the distribution of the internal organelles when compared to the closest yeast (*Rhodotorula* spp.). Pyrosequencing results showed OTUs assigned to 628 genera of bacteria, 23.7% were not assigned to any group, and the most representative were: *Lactobacillus* (6.4%), *Pseudomonas* (3.10%), *Psychromonas* and *Phormidium* (2.3%), *Variovorax* (0.6%), *Psychrobacter*, *Methylibium*, *Polaromonas* and *Salmonella* (0.3%). The yeasts *Cryptococcus* spp., *Candida* spp., and *Rhodotorula glacialis* showed cellulase activity; *Candida*, *Cryptococcus* and *Rhodotorula glacialis* had catalase activity; *Cryptococcus gastricus*, *Cryptococcus* spp., and *Candida sake* were positive for urease; only *Candida* spp., was positive for proteases with gluten substrate. *Candida* species were positive for amylase using both cassava and corn starch substrates; only *Candida sake* fermented sucrose, fructose, glucose and maltose sugars with an optimum fermentation temperature of 24°C. The highest fermentation yield (240 µL CO<sub>2</sub>/day) was reached with glucose and fructose substrate. Similar yields were obtained using grape juice as substrate, showing a potential application in the production of alcoholic beverages.

## Lipases from Antarctic thermophiles: Effect of ionic liquids

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Fundación Científica y Cultural Biociencia

Lipases catalyze the hydrolysis and synthesis of triglycerides. These types of reactions are widely used in the industry. On the other hand, the industry has explored the use of ionic liquids in order to improve the catalytic properties of several enzymes. However, the effect of these liquid salts on kinetic parameters of lipases has not been studied before.

In this work, four lipases were purified from supernatant of the strain ID17, a thermophilic bacterium isolated from Deception Island, Antarctica that belongs to genus *Geobacillus*. Lipase production was maximum during stationary phase of growth when tryptone was used as carbon and nitrogen sources at pH 7,5. Under these conditions, four different peaks with lipase activity were eluted (Lip1-4). All of them were optimally active at temperatures over 65 °C and alkaline pH. Lip1 was the most thermostable and retains about 80% of its initial activity after 8 h of incubation at 70 °C. Furthermore, its activity can be raised in the presence of 1 mM SrCl<sub>2</sub>. Kinetic parameters of Lip1 were modulated by the use of ionic liquids BmimPF<sub>6</sub> and BmimBF<sub>4</sub>. The maximum reaction rate of Lip1 increased in the presence of both salts. The highest effect was observed when BmimPF<sub>6</sub> was added in the reaction mix, resulting in a higher catalytic efficiency. However, the catalytic efficiency was not changed by BmimBF<sub>4</sub>. The higher reaction rates registered for Lip1 promoted by these ionic liquids could be related to possible changes in the structure of Lip1. This effect was observed by changes in the intensity of tryptophan fluorescence of Lip1 when incubated in presence of both liquids salts.

In conclusion, hydrolytic activity of Lip1 is modulated by the ionic liquids BmimBF<sub>4</sub> and BmimPF<sub>6</sub>, which improve the reaction rate and the catalytic efficiency of this enzyme. This effect is probably due to changes in the structure of Lip1 induced by the presence of these ionic liquids, stimulating its catalytic activity.

## Sea ice influence in winter microbial community around Elephant Island

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An oceanographic survey was conducted during late winter of 2012 and 2013 in the Elephant Island region to investigate the microbial ecology as it relates to ecosystem processes. Elephant Island is characterized by the confluence of waters coming from the Weddell Sea, Bransfield Strait and Antarctic Circumpolar Current, shaping a unique gradient of physicochemical parameters. Dynamic sea ice conditions and limited light availability were critical for photoautotrophs in winter. Here, we report the primary environmental conditions and describe the structure, distribution and abundance of picoplankton characterized as autofluorescent picoeukaryotes and bacteria + archaea in the upper 750 m of the study area. Discrete water samples were collected at 6 - 7 stations in the same region each year, and sea ice was sampled in 2 stations of 2013. Flow cytometry and epifluorescence microscopy techniques were employed to enumerate the picoplankton. The mixed layer depth was  $87 \pm 12.5$  m and  $82.6 \pm 14.8$  m, for 2012 and 2013 respectively, with cold wintertime surface waters comprising the upper mixed layer throughout the region. In 2013 significantly higher levels of chlorophyll *a*, and concordantly diminished levels of ammonium and silicate were found. Inter-annual differences in sea ice concentration and typology were significant. This work contributed new insights into winter Antarctic microbial ecology, in particular with respect to the abundance of picoeukaryotes ( $\sim 10^3$  cells per mL), though at the same time calls attention to the need for a better understanding of the community interactions and trophic status of the microbial plankton components in order to define major drivers and metabolisms characterizing the seasonal shift in the area.

## Ecosystem processes through the "eyes" of Antarctic Peninsula bacterioplankton during winter

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High latitude ecosystems experience an annual transition that reshapes energy and carbon flow through the ocean system. The biological players that mediate these processes go through repeated successional cycles as a result of seasonal sea ice which together with low sun angles limits illumination of the upper ocean, leading to low levels of photoautotrophic production. Recent work has shown that surface waters in the coastal Antarctic Peninsula harbor diverse bacterioplankton assemblages – more so than the summer counterparts sampled the same year; and that some of these bacteria and archaea encode the potential for chemolithoautotrophic primary production, while others may be able to utilize semi-labile carbon to sustain energetic demands over the winter. To improve the understanding of wintertime coastal Antarctic Peninsula bacterioplankton processes regarding carbon cycling in particular, we conducted several experiments with natural samples and seawater incubation experiments over the austral winter of 2008. This report synthesizes the results of assays to measure bulk rates of protein production and carbon fixation, exoenzyme hydrolysis, and polysaccharide hydrolysis of three model compounds (laminarin, xylan and chondroitin) in light of physiochemical parameters. Rates were about 20 fold lower in winter compared to summer for chl *a* and protein production, and were low but variable over the 2 month time period for <sup>14</sup>C-bicarbonate incorporation into biomass (ranging from 2.8 to 33.6 pMC x day<sup>-1</sup>). Enzyme hydrolysis rates were low but above detection limits for the winter assemblages. More surprising however, was the response of the bacterioplankton assemblage which was remarkable for the seawater incubation experiments, especially in the presence of light and phytoplankton, demonstrating that the potential for rapid response to new substrates is encoded in the membership of the over-wintering microbial assemblage. This research will provide a reference winter endpoint for comparison with other polar winter studies in the future, and may be a useful contribution to quantitative biogeochemical and ecosystem modeling efforts, as winter processes are typically neglected.

## Microbial synergy for material cycling in an Antarctic moss pillar inferred from metagenomic data

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Aquatic mosses of the *Bryum* and *Leptobryum* species form unique tower-like structures called “moss pillars (Koke Bouzu in Japanese)” in ultra-oligotrophic Antarctic lakes. The pillars consist of distinct redox-affected sections, that is, oxidative exteriors and reductive interiors. The redox gradient and boundary in this double-layered structure are thought to be important site for driving biological production and material cycling. Our previous studies based on fatty acid composition and 16S rRNA gene sequences showed that bacterial communities differed among the exterior, upper-interior, and lower-interior sections, and that more than 60% of obtained 16S rRNA phylotypes were novel taxa at species, genera, or class levels (Nakai *et al. Polar Biology* 35: 425-433). In addition, 18S rRNA-based analysis revealed that a wide range of unique eukaryotic phylotypes related to algae, ciliates, fungi, nematodes, rotifers, and tardigrades were present in the pillar ecosystem (Nakai *et al. Polar Biology* 35: 1495-1504). Thus, we had proposed that a “pillar” is a community and habitat of phylogenetically diverse organisms. Here, we report the diversity of functional genes encoding the CO<sub>2</sub>-fixing enzyme RuBisCO, nitrogenase (*nifH*), nitrite reductase (*nirK* and *nirS*), and nitric oxide reductase (*qnorB*), all of which are involved in carbon and nitrogen cycling in a pillar. In total, 85 PCR clone libraries were constructed from microbial DNA from an entire pillar, and approximately 6500 clones were sequenced. Phylogenetic analyses revealed certain cyanobacterial RuBisCO genotypes found exclusively in the exterior of the pillar, whereas genotypes related to purple sulfur bacteria were detected in the lower-interior sections. Furthermore,  $\gamma$ -proteobacterial *nifH* showed pillar-wide distribution, while cyanobacterial *nifH* sequences were specific to the exterior, and sulfate-reducing  $\delta$ -proteobacterial *nifH* sequences were subdominant in the interior. Such layer-specific distributions were also found during *nirK*, *nirS*, and *qnorB* sequence analyses. These results suggest that different phylogenetic groups participate in biogeochemical processes such as CO<sub>2</sub> assimilation, nitrogen fixation, and denitrification within each layer. As this study is currently in progress, we plan to report the more metagenomic sequence data in the presentation.

## ***Pseudomonas* isolates from South Shetland Islands inhibit the growth of food-borne and opportunist pathogens: a preliminary evaluation**

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Bacteria inhabiting extreme ecosystems have been recognized as valuable sources of novel bioproducts. Production of inhibitory compounds against pathogenic bacteria by *Pseudomonas*, one of the dominant taxa in Antarctic, has been widely demonstrated in low and middle-latitude ecosystems but barely investigated in polar regions e.g. only a few reports have described Antarctic *Pseudomonas* isolates with antagonistic properties and none of them has focused particularly on this taxon. Thus, the aim of this work was to isolate psychrotrophic *Pseudomonas*-type bacteria from soil samples collected in different ecosystems of South Shetland Islands and selected those with the ability to produce growth-inhibitors against food-borne and opportunist bacterial pathogens.

Sixty-three soil samples collected during Chilean Antarctic Scientific Expedition #50 were directly inoculated on two solid media: selective *Pseudomonas* PSIA and King B (KB). Cultures were incubated at 15°C for 5 days. Seventy-seven fluorescent *Pseudomonas*-type isolates were obtained on PSIA and 112 on KB master plates. Growth inhibition was determined using the deferred antagonism procedure and *Listeria monocytogenes*, *Staphylococcus aureus*, *Pseudomonas fluorescens* and *Pseudomonas aeruginosa* were used as potentially susceptible strains. Nine isolates (11.7%) from PSIA and 10 (8.9%) from KB were confirmed as being growth inhibition producers against at least one indicator strains. One isolate obtained from PSIA master plates showed broad inhibitory spectrum given that inhibited the growth of all tested indicator strains. Interestingly, members of the same group of the producers (*Pseudomonas*) appear being the most susceptible strains tested.

The detection rates for growth inhibition producers obtained in this study were considerably higher than those reported in the literature for Antarctic microbiota screenings, thus highlighting the importance of this group as a source of potential novel antimicrobial compounds in Antarctic. To our knowledge this is the first screening of bacterial growth inhibition producers with special respect to genus *Pseudomonas* and its fluorescent members in Antarctic. Further work is needed to characterize the nature of the inhibitors and their host spectrum.

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## Patterns in microbial diversity in marine sediments from Admiralty Bay, King George Island, Antarctica across space and time

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Little is known about microbial communities in Antarctic marine sediments including their species composition, interactions and its importance in global weather processes. This project aims to compare variability of microbial communities across space and time in marine sediments from Admiralty Bay (ASMA No.1), King George Island by molecular techniques and next-generation sequencing. Samples were collected at four distinct sites (Botany Point – BP, Ullman Point – PU, Refuge 2 – R2, and Antarctic Station Comandante Ferraz – EACF) at 30 m isobaths during austral summers 2007, 2010 and 2012. Sites EACF, PU and BP are located in Martel Inlet and represent increasing distances from possible anthropogenic impact from Comandante Ferraz Brazilian Scientific Station. Site R2 is located at MacKellar Inlet and therefore is not only distant from the other studied sites, but also subjected to a different marine current. Total DNA from 0.3 g of each sediment sample was extracted using FastDNA Spin Kit for Soil (MP Bio Laboratories) and amplified with PCR specific primers targeting 16S rRNA gene. The Bacterial and Archaeal community profiles were analyzed by Denaturing Gradient Gel Electrophoresis (DGGE) using primers 338GCF-518R and 344GCF-915R, respectively. The microbial community structure was analyzed by 454 pyrosequencing with barcoded universal primers 519F-1068R. DGGE band profiles were compared in BioNumerics v 5.0, and ~114,000 tag-sequences were analyzed in Mothur v1.31. When comparing sites (spatial scale), DGGE revealed different Bacteria and Archaea profiles at each analysed sample. However, pyrosequencing results showed that differences were not significant between sites. Considering the temporal scale, microbial community at EACF showed less variation than in other sites, as observed both through DGGE and pyrosequencing analysis. At BP, PU and R2 sites, a shift in dominant taxa occurred between 2007 and 2012, and BP. In general, marine sediments showed dominance of Gammaproteobacteria (41.3% mean abundance), followed by Deltaproteobacteria (19.1%), Alphaproteobacteria (15.4%), Firmicutes (7.4%) and Verrucomicrobia (6.2%). Interestingly, sample BP 2007 showed a significant higher abundance of Alphaproteobacteria (54.7%), while samples PU 2010 and R2 2010 showed Deltaproteobacteria as dominant group (59 and 53%, respectively). Archaeal sequences counted for less than 1% in all samples. These results indicate that microbial communities are dynamic in Admiralty Bay, especially at BP, PU and R2, and that EACF had a relatively more stable community during the studied period. Combined analysis of these results with environmental data may help elucidate if proximity to the scientific station is influencing microbial community composition at the site.

## The effect of guano on nitrogen fixation of biological soil crusts in Ardley Island, King George Island, South Shetlands

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The main source of nitrogen to lichens, mosses and liverworts that compose biological soil crusts (BSC) in Ardley Island is of atmospheric origin; either via ammonia volatilization from penguins guano, or alternatively via symbiotic nitrogen fixation (SNF) by diazotrophic bacteria. Given that SNF is a high energy demanding process, our main hypothesis is that it is inhibited by its products such as ammonium, coming from ammonia volatilization in the penguin colony. Ardley Island represents a natural laboratory to test this hypothesis as the landscape is composed by a vegetation gradient that goes from a close vicinity to a penguin colony located in North-east shore of the Island (200 m), intermediate sites (400-1100 m distant to the penguin colony), towards a set of different ages paleo-beaches located about 1500 m against the wind direction in the south-west shore of the Island.

The main objective of this study was to test the hypothesis that BNF is inhibited in the BSC close to the penguin colony, and therefore guano addition would inhibit BNF in BSC away from the penguin colony. We will also test the hypothesis that ammonia input in the precipitation will be negligible in sites more distant from the penguin colony allowing the development of non-ornitogenic BSC. We measured acetylene reduction activity to estimate biological nitrogen fixation in BSC during February 2012 and 2013 by *in situ* and laboratory assays.

The results show that ammonia concentration in precipitation is only significant within the penguin colony and in its nearest site. We found a negligible acetylene reduction activity in the BSC closest to the penguin colony, but significant rates of nitrogenase activity were found in the BSC in the oldest paleo-beaches and intermediate sites (111.5-244.0 nmol ethylene/g DW/day). The addition of guano to BSC *in situ* and in the laboratory assays significantly reduced N fixation in the oldest paleobeach and the intermediate sites. The species with the highest rates of nitrogenase activity was the cyanolichen *Placopsis contortuplicata* (360-602 nmol ethylene/g DW/day) followed by *Sterocaulon alpinum* (190 nmol ethylene/g DW/day) and at lower degree in *Psoroma hypnorum* (30 nmol ethylene/g DW/day) all dominant species in the paleobeaches, but almost absent in the site nearest to the penguin colony. Using a theoretical stoichiometric conversion factor of 1:3 (acetylene : nitrogen reduction), we estimated an annual rate of nitrogen fixation by BSC in 0.7 in the youngest to 2.5 kg N/ha/year in the oldest paleo-beach.

We conclude that the main factor shaping the distribution of BSC and therefore nitrogenase activity of diazotrophs in Ardley Island is the penguin colony, because of the almost absence of ammonium content in precipitation in the sites distant from the penguin colony.

Inach T01-11

## Diversity and bioprospection of Antarctic fungi: antibacterial, antifungal and antiprotozoal activities of fungal communities from different substrates from Antarctica

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The diversity of fungal communities from different substrates in Antarctica were studied and their capability to produce bioactive compounds. One hundred and one fungal isolates were identified by molecular analysis in 35 different fungal taxa from 20 genera. *Pseudogymnoascus* sp. 3, *Pseudogymnoascus* sp. 1, *Penicillium* sp., *Peniophora* sp. and *Mortierella alpina* were the most frequent taxa identified. The fungal communities displayed high richness, diversity and dominance indices. Additionally, the rarefaction curves indicated that not all of the fungal diversity present was recovered. All fungal isolates were cultured to produce ethanolic extracts, which were screened against different target organisms to detect antimicrobial, cytotoxic and antiprotozoal activities. Twenty extracts showed moderate to high and selective antifungal activity against the human pathogenic fungus *Paracoccidioides brasiliensis*. The extract of *Purpureocillium lilacinum* displayed high trypanocidal, antifungal and antibacterial activities with moderate toxicity over normal cells, in which a preliminary <sup>1</sup>H NMR spectral analysis using proton nuclear magnetic resonance spectroscopy indicated the presence of compounds containing a highly functionalized aromatic ring system. Our results suggest that the Antarctic Peninsula represents a rich habitat for obtaining extremophile fungi that may have unique metabolic systems with the ability to produce bioactive compounds.

Financial support: CNPq, PROANTAR, FAPEMIG, INCT CRIOSFERA

## Fungal community present in oligotrophic cold-arid soil of continental Antarctica: taxonomy, diversity and bioprospection of bioactive compounds

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We surveyed taxonomy, diversity and capability to produce bioactive compounds of the fungal community isolated from cold-arid oligotrophic soil of continental Antarctica. A total of 115 fungal isolates were obtained and identified in 11 taxa of *Aspergillus*, *Debaryomyces*, *Cladosporium*, *Pseudogymnoascus*, *Penicillium* and *Hypocreales*. The phylogenetic analysis suggests that three taxa of *Cladosporium*, *Pseudogymnoascus* sp. and *Hypocreales* sp. may represent new fungal species. The fungal community showed low diversity and richness as well as high dominance indices and *Hypocreales* sp., *Penicillium brevicompactum* and *Aspergillus sydowii* were the most abundant species. *Cladosporium* sp. 3, which may be a new species, was isolated on DG18 medium at 5°C and may represent a species adapted to cold-arid conditions of continental Antarctica. All fungal isolates were cultured and their extracts prepared to bioprospection of bioactivity secondary molecules. The extracts of *Aspergillus sydowii*, *Penicillium allii-sativi*, *Penicillium brevicompactum*, *Penicillium chrysogenum* and *Penicillium rubens* showed antimicrobial and antitumor activities. Our results show that Antarctic fungal communities include few dominant species, which may have important implications for understanding eukaryotic survival in cold-arid oligotrophic soils. We hypothesise that detailed investigations may provide a more comprehensive understanding about the evolution and relationships among the Antarctic fungi with other organisms described for the region; also these unique fungal communities might use over the time as model to available of climate changes in continental Antarctica. Additionally, different fungal isolates of the same species displayed interesting intra-specific capability to produce bioactivity compounds and may represent potential sources of prototypes molecules to use in drug discovery studies.

Financial support: CNPq, PROANTAR, FAPEMIG, INCT CRIOSFERA

## Responses to UV and gamma radiation of an actinobacteria strain isolated from the phyllosphere of *Deschampsia antarctica*

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Antarctic terrestrial biota is periodically exposed to enhanced solar UV-B, and its effects may cause damage to plants and microorganisms. The daily influx of solar UV radiation (UVR) is particularly inhibitory to microbial community from leaf surfaces. Some bacteria in UVR-exposed habitats have the ability to effectively repair DNA damage. Stratosphere ozone depletion in the austral springs and early summer increases UV-B radiation reaching Antarctica by up to 50%. The objectives of this study were to isolate UV-C resistant epiphytic bacteria associated of the Antarctic plant, *Deschampsia antarctica*, one of only two native flowering plants occurring throughout maritime Antarctica, and to determine the effect of UV and gamma radiation on these bacteria. The sensitivity to UVR of bacterial isolates was assayed by determining the minimal inhibitory dose of UVC (254 nm) radiation (MIDc). This method can be used in a simpler way to substitute UVB radiation *in vitro*. For gamma radiation resistance, the bacterial cells received 1 KGy, 3 KGy, 4 KGy, 5 KGy, 6 KGy and 7 KGy furnished by a Cobalt-60 Bomb, from Center of Nuclear Energy in Agriculture-CENA/ University of São Paulo. Six bacterial strains showing high level of UV-B resistance, and only one showed resistance to UV-C, with 40% of survival rates when exposed to 90 J.m<sup>-2</sup>, and in relation to gamma radiation, the strain exhibited a survival rate of 5% under 7 KGy. This strain, identified based on its 16S rRNA gene sequencing, showed belong to the genus *Rhodococcus erythropolis* (P27). The partial genome of this actinobacteria strain was sequenced, demonstrating genes related to the resistance to ionizing and nonionizing radiation (Genome Announc. 2013 Sep-Oct; 1(5): e00763-13). Members of the **Rhodococcus** genus have been intensively studied owing to their ability to survive under extreme conditions. It was also verified that this strain produced high amount of EPS with the addition of trehalose into the culture medium.

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## Patterns and drivers of microbial community structure in Antarctic fast ice

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The complex community of algae and bacteria that proliferate in sea ice are important primary producers in the Southern Ocean and they play a central role in the assimilation and regulation of energy through the Antarctic food web. However, little is known of changes in community composition through the sea ice, the role of microbial loop in sea ice, and the influence of the environment on these communities. Here, the sea ice microbial community structure was investigated using microscopic identifications (algae) and terminal restriction fragment length polymorphism analysis (T-RFLP) of the active (rRNA) and total (rDNA) community (bacteria) using the 16S rRNA gene. Bacterial extracellular enzyme activities were also investigated using synthetic fluorogenic substrates. The relationships between nutrient concentration and changes in bacterial community structure and function were also assessed. Algal species compositions varied over long and short periods, with geographical location, and with vertical position within the ice. The highest biomass was always found in the bottom 10cm of the sea ice while increasing snow cover correlated with decreased algal and EPS biomass, as well as with changes in species composition. Bacterial community T-RFLP profiles for both the rRNA and rDNA communities varied within and between zones in the sea ice core, with a psychrophilic bacteria more prevalent in internal sections of the ice core. Algal biomass and extracellular polysaccharide substances (EPS) biomass were strongly correlated indicating algae were the main EPS producers, however as algal biomass increased, the relative contribution of EPS to Total Organic Carbon (TOC) declined. Phosphate levels were limiting in sea ice, driving bacteria to assimilate phosphate containing macromolecules, and furthermore degrading proteins over carbohydrates. Together these observations suggest that the Antarctic sea ice community structure is strongly influenced by the environment.

## Diversity patterns, ecology and biological activities of fungal communities associated with the endemic macroalgae across the Antarctic Peninsula

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We surveyed diversity patterns and engaged in bioprospecting for bioactive compounds of fungi associated with the endemic macroalgae, *Monostroma hariotii* and *Pyropia endiviifolia*, in Antarctica. A total of 239 fungal isolates were obtained, which were identified to represent 48 taxa and 18 genera using molecular methods. The fungal communities consisted of endemic, indigenous and cold-adapted cosmopolitan taxa, which displayed high diversity and richness, but low dominance indices. The extracts of endemic and cold-adapted fungi displayed biological activities and may represent sources of promising prototype molecules to develop drugs. Our results suggest that macroalgae along the marine Antarctic Peninsula provide additional niches where fungal taxa can survive and coexist with their host in the extreme conditions. We hypothesize that the dynamics of richness and dominance among endemic, indigenous and cold-adapted cosmopolitan fungal taxa might be used to understand and model the influence of climate change on the maritime Antarctic mycota.

Financial support: CNPq, PROANTAR, FAPEMIG, INCT CRIOSFERA

## Fungal communities associated with Antarctic lichens: taxonomy, diversity, bioprospection of bioactive compounds and astrobiology studies

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This study assessed the diversity, distribution and bioprospection of fungi associated with the endemic lichens *Usnea antarctica* and *Usnea aurantiaco-atra* across the Elephant, King George and Deception Islands in the Antarctic Peninsula. Three hundred and fourteen fungal isolates were purified and identified by analysis of nuclear rDNA ITS region sequences as belonging to 20 different genera. The most frequently isolated taxa were *Pseudogymnoascus* sp., *Penicillium* sp., *Thelebolus globosus*, *Fusarium* sp., *Antarctomyces psychrotrophicus* and *Cladosporium cladosporioides*. In general, the fungal communities associated with Antarctic lichens displayed high richness and dominance diversity indices; however, rarefaction curves indicated that not all of the fungal diversity present was recovered. Eight taxa showed low similarity with sequences of fungi deposited in GenBank database or high similarities with unidentified fungi and may represent new fungal species. The extracts of *Antarctomyces psychrotrophicus* and *Leptosphaeria sclerotiioides* displayed selective antibacterial activities against *Escherichia coli* and *Staphylococcus aureus*, respectively; also, preliminary spectral analysis using proton nuclear magnetic resonance spectroscopy indicated the presence of highly functionalized aromatic compounds in the extract of *L. sclerotiioides*, which may represent potential bioactive antibacterial molecules. In the Antarctic environments, *U. antarctica* and *U. aurantiaco-atra* are constantly exposed to a high flux of ultraviolet radiation and for this reason we have submitted the fungi associated with both lichens to different irradiation tests. Among the fungi screened, the yeasts *Cryptococcus victoriae* and *Rhodotorula arctica*, taxa present in cold environment, were able to resist until 900 J/m<sup>2</sup> in the UVC region, suggesting that these species may be promising eukaryote models to astrobiology, expanding the use of Antarctica as an analogue environment for space exploration. Our results suggest that endemic Antarctic lichens shelter rich and complex fungal communities, including endemic and cosmopolitan/mesophilic cold-adapted species, which have been reported as symbionts, saprobes and parasite/pathogen fungi. Within these fungal communities, we detected some taxa able to produce antibacterial molecules, which may be potential source of bioactive compounds to drug discovery researches. Additionally, the fungi able to resist to UVC radiation will be submitted to new astrobiology assays, including the capability to resist to UVC in vacuum as it occurs in the outer space or on the surface of planetary bodies, like on Mars.

Financial support: CNPq, PROANTAR, FAPEMIG, INCT CRIOSFERA, NAP/Astrobio (PRP/USP)

## On the Rocks: diversity, bioprospection and astrobiology of rock-inhabiting fungi of continental Antarctica

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In order to study the diversity of rock-inhabiting fungi of ecosystem extreme, rock samples around the Ellsworth Mountains in West continental Antarctica were obtained in January 2013. The rocks were processed and the fungi isolated by serial dilution technique in different culture media. All samples were processed and incubated at 15°C for up to 60 days. A total of 55 filamentous fungi and 17 yeasts isolates obtained were grouped according to their morphology characteristics and identified as species of the genera *Penicillium*, *Cladosporium*, *Debaromyces* and *Rodothorula* using molecular techniques. All fungi were grown using solid state fermentation for extracting secondary metabolites, which were evaluated for antimicrobial activity against bacteria and fungi of clinical and agriculture interest. The extract of the unidentified fungi UFMGCB 10021 showed strong antifungal activity against pathogenic yeast *Candida albicans*. Additionally, the rocks surface in the continental Antarctica are constantly exposed to a high flux of ultraviolet radiation and for this reason we have submitted the rock-inhabiting fungi to different irradiation tests. Among the fungi screened, the yeast *Rhodotorula mucilaginosa* was able to resist until 900 J/m<sup>2</sup> in the UVC region, suggesting that this species may be promising eukaryote models to astrobiology, expanding the use of Antarctica as an analogue environment for space exploration. Our results suggest that rocks in Antarctica shelter a limited fungal community, including cosmopolitan/mesophilic cold-adapted species. However, within these fungal community, we detected species able to produce antifungal molecules, which may be potential source of bioactive compounds to drug discovery researches. Additionally, the yeast *Rh. mucilaginosa* able to resist to UVC radiation will be submitted to new astrobiology assays, including the capability to resist to UVC in vacuum as it occurs in the outer space or on the surface of planetary bodies, like on Mars.

Financial support: CNPq, PROANTAR, FAPEMIG, INCT CRIOSFERA, NAP/Astrobio (PRP/USP)

## Benthic microalgae communities in Greenwich, Dee and Barrientos Islands, South Shetland Islands, Antarctica

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Benthic microalgae communities from small streams and ponds in Greenwich, Dee and Barrientos islands (South Shetland Islands, Antarctica) were studied during January 2013, through the analysis of their photosynthetic pigments using High Performance Liquid Chromatography (HPLC). Granulometry and elemental analysis of Carbon, Hydrogen, Nitrogen and Sulphur in surface sediment, and concentrations of major ions and physicochemical parameters in water samples were also determined, in order to identify environmental factors affecting the distribution and composition of freshwater autotrophic communities.

Pigment concentrations in surface sediments were comparable to those reported for other antarctic locations. Microbial mats contributed to the greatest amount of algal biomass (122.29  $\mu\text{g g}^{-1}$ ). Diatoms had a broader distribution. They were in Greenwich and Barrientos islands, with naturally enriched waters and in ponds of Punta Ambato and Dee island with ultraoligotrophic features. Cyanobacteria, Chlorophyta, Cryptophyta, Chrysophyta, Prasinophyta and anaerobic photosynthetic bacteria were also detected. Microbial mats were constituted by filamentous cyanobacteria of the genera *Oscillatoria*, *Phormidium* and *Leptolyngbya*, and several species of diatoms. The Canonical Correspondence Analysis showed that the water chemistry and the particle size of sediment were the main variables influencing the benthic microalgae communities' distribution.

## Taxonomic characterization, physiology and biotechnological potential of yeast strains isolated from Nella Lake sediments, East Antarctica

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Scientist-D

Lake Nella is an ultra-oligotrophic lake located in the Broknes peninsula, Larsemann Hills region, East Antarctica. Yeast isolates were obtained from the different sediment layers of the core cored up to a depth of 90 cm. The isolates were white to cream in colour. They were grouped based on their cultural characteristics and carbon source utilization abilities. Sequence analysis of the ITS and D1/D2 domains identified the species as *Cryptococcus albidus*, *Cryptococcus antarcticus* and *Rhodotorula* sp.. The three *Rhodotorula* strains (Y-23, Y-36 and Y-37) have closest similarity with *Rhodotorula* sp. YSAR15 (GenBank: AM922292).

Physiological tests such as effect of temperature, pH and salinity (NaCl) on growth of the isolates were studied. All isolates grew at 4 to 22°C and good growth between pH 4 to 9. Carbon sources such as D-glucose, Sucrose, Raffinose, Dgluconate, D-ribose, DL-Lactate, Myoinositol, Maltose, Cellobiose, Mannitol, D galactose, L-rhamnose and L-arabinose were utilized by all the strains. D-xylose, Melezitose and D-glucuronate were utilized by all isolates except *Cryptococcus albidus* Y-34 while D-arabinose and Lactose were utilized by all except *Cryptococcus antarcticus* Y-33. Amongst the different isolates, the four *Cryptococcus* strains utilized about 18 to 20 while *Rhodotorula* utilized 21 to 24 of the total 25 carbon sources tested. Assimilation of the other carbon sources by the strains varied. All the cultures showed varying degree of growth in the presence of the different nitrogen sources tested.

Enzymatic screening of the isolates showed their ability to degrade complex macromolecules such as proteins, carbohydrates and lipids, indicating their probable ecological role. Esterase activity was observed in 7 strains while protease was observed in all. Urease activity was seen in all strains of *Rhodotorula* but in none of the strains of *Cryptococcus*. Only one isolate (*Cryptococcus albidus* Y-32) exhibited phosphatase activity.

The isolates were also subjected to antibiotic susceptibility testing using antifungal agents. Two clinically important classes of antimycotic drugs, the polyenes and the azoles were tested for their effect against the isolated Antarctic yeast strains. All isolates tested were sensitive to Amphotericin B and Nystatin antibiotics. Overall, the test demonstrates that the polyene class of antifungal antibiotics can more effectively control the growth of Antarctic yeast strains as compared to the azole class.

With best of our knowledge this is a first documentation of yeast in the sediment cores of lake from the Broknes peninsula, Larsemann Hills region, East Antarctica.

## Motile cyanobacteria under black stones in the Antarctic desert (Dry Valleys)

Sun H

Desert Research Institute

Photosynthetic microorganisms in deserts, as a rule, are not motile. They typically grow adhered to soils or rocks. Indeed, endolithic lichens and cyanobacteria, which live beneath translucent rock surfaces, thrive in the Antarctic desert. Here, I report a somewhat unexpected finding from a recent field expedition: a community of motile filamentous cyanobacteria living beneath a pavement of opaque basalt clasts. Field observations indicate that the pavement is kept moist by snow melt from a nearby slope, but liquid water occurs only around noon in the austral summer and lasts a short duration. The organisms are phototactic, which presumably allow them to move in and out the stone for optimum light intensity. DNA analysis indicates that the dominant species belong to the genera *Leptoglyngbya* and *Pseudophormidium*. Attempts to culture the organisms are not yet successful. Further research is needed to understand how these fundamentally aquatic organisms survive in a desert.

## Exploring protists in the McMurdo Dry Valley soils

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Soil protists are essential in maintaining the structure of soil microbial communities. Unfortunately, the complexity of most ecosystems limits more comprehensive investigation of their interactions with other soil biota. The relatively low biodiversity of McMurdo Dry Valley soil ecosystems of Victoria Land, Antarctica, however, offer a unique opportunity to study and unravel these interactions.

Here, we report on the diversity and distribution of protists present in the McMurdo Dry Valley soils. Samples were taken from Taylor, Wright, and Garwood Valleys; DNA was extracted and sequenced using the 454 Roche sequencing platform. Resulting sequences were processed and taxa were identified using public databases. Ecological functioning of each taxon was inferred by phylogenetic affinity to known species.

Although diversity is low in comparison to other terrestrial ecosystems around the globe, we found that representative taxa from most protist phyla are present in the dry valley soils. Environmental sample sequencing recovered numerous taxa with low sequence abundance and a few taxa with high sequence abundance. To investigate the impact of abiotic factors on distribution, we compared taxon diversity to soil pH and soil moisture for each sample site.

Our preliminary findings point to the ecological significance of protists in dry valley microbial soil communities, and will improve food web and habitat suitability models developed for MDV soil ecosystems.

## CCAMBIO: Climate Change and Antarctic Microbial Biodiversity

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The BelSPO funded project CCAMBIO is aimed at studying the diversity, biogeographic zoning, evolutionary history, and genomic make-up of lacustrine microbial mat communities in the Antarctic Realm. Samples were obtained from understudied regions in collaboration with colleagues from Australia, United Kingdom, New Zealand, South Africa, Japan, Spain, Czech Republic, Bulgaria and France. For cyanobacteria, a pilot NGS study using Roche 454<sup>®</sup> amplicon pyrosequencing was carried out on 4 samples already studied by DGGE and clone libraries within previous projects as well as on mock communities. The use of different sets of cyanobacterial primers, DNA extraction methods and PCR protocols was assessed. The NGS analyses revealed a higher richness than what has been described in previous studies using DGGE and clone libraries. For the bioinformatics analysis we composed and optimized a custom pipeline using the latest insights and state-of-the-art software (such as Mothur, QIIME, UPARSE, USEARCH, RAxML, CREST). An SQL database was developed and coupled to this pipeline and the R environment for multivariate analyses. We have optimized analysis settings and tested alternative identification databases, which has led to a significant reduction in the number of unidentified sequences and the discovery of a number of new uncultivated bacterial groups. The newly obtained samples are being prepared for an Illumina MiSeq<sup>®</sup> analysis. Our existing diatom database was extended with samples and/or data from Marion Island, Macquarie Island and Dronning Maud and several diatom genera have been revised. Well-pronounced biogeographic patterns are starting to emerge, with a significant difference between Continental and Maritime Antarctic floras as well as between the three Sub-Antarctic Provinces. An existing molecular phylogeny of the oldest known diatom species complex, *Pinnularia borealis*, was extended with samples from Marion Island and the Antarctic Peninsula. No less than seven lineages, presumably species, were recovered from the Antarctic Peninsula and one from Marion Island. These lineages were spread throughout the *P. borealis* phylogeny, suggesting multiple colonization events in or out of the Antarctic continent since the first known lineage splitting 22 Ma. Our results will provide the biodiversity data needed to assess the resilience and local and regional responses of Antarctic microbial communities to global change.

## Bacterial activity in subsurface sediment from Admiralty Bay - Antarctica

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The aim of the present study was to quantify the number of vegetative microbial cells and bacterial endospores in deep biosphere sediment from Admiralty Bay, Antarctica, in addition to the turnover times of bacterial biomass, bacterial necromass and TOC.

The expedition recovered sediment at depths of up to 240 centimeters below the sea floor (mbsf). Concentrations of total hydrolysable amino acids (THAA), and amino acid enantiomers (L- and D-form) of aspartic acid were analysed by high-performance liquid chromatography (HPLC). Cell numbers were determined by epifluorescence microscopy after DNA staining with 49-6 diamidino-2-phenylindole.

Turnover times of bacterial necromass and vegetative cells, as well as carbon oxidation rates were estimated by use of the D:Lamino acid racemization model. Diagenetic indicators were applied to evaluate the diagenetic state of the sedimentary organic matter.

The contribution of amino acids to total organic carbon indicate increasing degradation state of the organic matter with sediment depth and age.

Most of the amino acids (97%) could be ascribed to microbial necromass, i.e. the remains of dead bacterial cells. Model estimates showed that the turnover times of microbial necromass were in the range of 0.5–1 \_ 105 years, while turnover times of vegetative cells were in the range of tens to hundreds of years. The turnover time of the TOC pool increased with depth in the sediment, indicating that the TOC pool became progressively more refractory and unavailable to microorganisms with depth and age of the organic matter.

## Comparison between lipid and fatty acid composition of the sea ice and water column in early spring in East Antarctica

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To understand the sea ice community complex we need to also understand the availability of key and essential nutrients to consumers. Baseline biochemical data are therefore required in order to gauge any impact the reduction of sea ice will have on the sea ice community. Here we compare lipid class, fatty acid and sterol content and composition of sea ice and water column samples collected during early spring in East Antarctica during the Sea Ice Physics and Ecosystem eXperiments (SIPEX II 2012) expedition (110-130°E). The availability of key essential omega-3 long-chain ( $\geq C_{20}$ ) polyunsaturated fatty acids, including - 20:5 $\omega$ 3, eicosapentaenoic acid, EPA and 22:6 $\omega$ 3, docosahexaenoic acid, DHA - the major constituents of cell membranes, were found to be limited during late winter and early spring, particularly in the water samples. The ramifications for sea ice obligate organisms such as larval krill are discussed.

## 'Ex-situ' conservation of Antarctic cyanobacteria : a culture collection to explore diversity and bioactivity

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Cyanobacteria appear as the dominant phototrophs in Antarctic terrestrial and freshwater ecosystems. Since 2011, the Belgian Science Policy Office has funded the BCCM/ULC public collection of (sub)polar cyanobacteria. It is currently holding 102 Antarctic cyanobacterial strains and the catalogue is available on [http://bccm.belspo.be/db/ulc\\_search\\_form.php](http://bccm.belspo.be/db/ulc_search_form.php). A Quality Management System was implemented and an ISO9001 certificate was obtained for the public deposition and distribution of strains. The strains are kept as living cultures, and their cryopreservation is in progress.

The Antarctic cyanobacterial strains were isolated from samples of the three main biogeographic provinces. The purpose of this public collection is to gather a representative portion of the cyanobacterial diversity with different ecological origins (limnetic microbial mats, soil crusts, cryoconites, endoliths, etc.) and make it available for researchers to study the diversity, evolution, adaptations to the environmental conditions, and genomic make-up. Three cyanobacterial orders are represented: Chroococcales, Oscillatoriales and Nostocales. This is particularly important in view of the emerging use of metagenomic approaches on environmental samples, where the comparisons with the genome sequences from well-defined strains is very useful. They could also serve as references for compounds such as fatty acids and pigments.

In addition, cyanobacteria produce a range of secondary metabolites (e.g. alkaloides, cyclic and linear peptides, polyketides) with different bioactive potential (e.g. antibiotic, antiviral, anticancer, cytotoxic, genotoxic). Bioassays have shown antifungal activities of the cell extracts of strains *Plectolyngbya hodgsonii* ULC009 and *Phormidium priestleyi* ULC026. Due to the geographic isolation and the strong environmental stressors of the habitat, the exploration of these metabolites in Antarctic cyanobacterial strains seems especially promising for biotechnology or biomedical applications.

In summary, the BCCM/ULC public collection could serve as a general reference for Antarctic cyanobacteria with multiple applications, as well as a resource for novel bioactive compounds.

## Effect of lindane on the growth and photosynthetic performance of Antarctic, arctic and tropical microalgae

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Lindane is a persistent organochlorine pesticide that is widely distributed throughout the world, even in the remote polar regions where they have never been used. As a result of various transport routes from the terrestrial system, lindane residues have been detected in water columns where its toxicity is often extended to non-target aquatic organisms. In this study, the 96-h acute toxicity testing of lindane was conducted on three strains of *Chlorella* isolated from the Antarctic (UMACC 237), Arctic (UMACC 263) and tropics (UMACC 001). The three *Chlorella* strains were obtained from the University of Malaya Algae Culture Collection (UMACC). The cultures were grown in Bold's Basal Medium (BBM) added with 0.01, 0.1, 1 and 10 µg/mL of lindane for 96 hours. The toxicity markers assessed were growth response, chlorophyll a content, carotenoid content, dry weight and photosynthetic performance. At the highest concentration of lindane tested (10 µg/mL), the specific growth rates of the Antarctic, Arctic and tropical *Chlorella* decreased by 33.3, 22.3 and 12.8%, respectively, compared to the control. Results showed that there was a marked decrease in chlorophyll a contents of both Antarctic and Arctic *Chlorella* when exposed to lindane at 10 µg/mL. The dry weight of the three *Chlorella* strains decreased with increasing concentration of lindane. No significant effects on the photosynthetic performance were observed in the tropical *Chlorella* in terms of maximum quantum yield ( $F_v/F_m$ ), electron transport rate (ETR) and non-photochemical quenching (NPQ) at all concentrations of lindane assayed. The maximum quantum yield of the Antarctic *Chlorella* showed a more pronounced decrease when exposed to 10 µg/mL of lindane, compared to the two other strains. The sensitivity of the three *Chlorella* strains to lindane was as follows: Antarctic *Chlorella* > Arctic *Chlorella* > tropical *Chlorella*.

## Diversity, new species and genomics of bacteria from the Antarctic Sea

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There are abundant and various microorganisms in the land and sea of Antarctic despite the extreme conditions. We isolated a large number of bacterial strains from the water, ice and sediments of the Antarctic Sea, and diversity, new species and genomics of some Antarctic bacteria were analysed.

We identified six new bacterial species from the water, sediments and ice of the Antarctic Sea, including *Puniceibacterium antarcticum* gen. nov., sp. nov., *Zhongshania guokunii* sp. nov., *Neptunomonas antarctica* sp. nov., *Zhongshania antarctica* gen. nov., sp. nov., *Marinobacter antarcticus* sp. nov., *Pseudorhodobacter antarcticus* sp. nov.. Among them, *Puniceibacterium antarcticum* gen. nov., sp. nov. and *Zhongshania antarctica* gen. nov., sp. nov. represent two novel bacterial genera.

Although protease-producing bacteria play a vital role in degrading organic nitrogen, the diversity of protease-producing bacteria and bacterial extracellular proteases in the sea still remain large unknown. We investigated the diversity of cultivable protease-producing bacteria and of bacterial extracellular proteases in the sediments of Maxwell Bay, King George Island, Antarctic. The cultivable protease-producing bacteria reached  $10^5$  cells/g in all eight sediment samples, which were mainly affiliated with the phyla Actinobacteria, Firmicutes, Bacteroidetes, and Proteobacteria. The predominant genera were *Bacillus* (22.9%), *Flavobacterium* (21.0%) and *Lacinutrix* (16.2%). Among these strains, *Pseudoalteromonas* and *Flavobacteria* showed relatively high protease production. Inhibitor analysis showed that nearly all the extracellular proteases from the bacteria were serine proteases or metalloproteases.

Two psychrophilic species of the *Glaciecola* genus, *Glaciecola pallidula* ACAM 615<sup>T</sup> and *Glaciecola punicea* ACAM 611<sup>T</sup>, have been isolated from Antarctic. To analyze their cold-adapted mechanism at gene level, we sequenced the genome sequences of these two strains, and eight close relatives in genus *Glaciecola*. Comparative genomic research indicated that species in the *Glaciecola* genus have high diversity in genome size, gene content and genetic relatedness. Species of *Glaciecola* had some common genomic features related to cold adaptation, which enable them to thrive and play a role in biogeochemical cycle in the cold marine environments.

## S22: SCIENTIFIC ADVICE FOR POLICYMAKERS & EVIDENCE-BASED CONSERVATION

### Geo-conservation in Antarctica

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With improving accessibility to Antarctica, the need for proactive protection and management of sites of intrinsic scientific, historic, aesthetic or wilderness value is becoming increasingly important. Environmental protection and conservation practise in the Antarctic is globally unique and is managed by provisions contained within the Antarctic Treaty. Whilst these provisions have been primarily utilised to protect sites of biological or cultural significance, sites of geological or geomorphological significance may also be considered. However, in general, sites of geological and geomorphological significance are underrepresented in conservation globally, and, particularly, in Antarctica. Wider recognition of sites of geological significance in Antarctica can be achieved by development of a geo-conservation register, similar to geological themed inventories developed elsewhere in the world, to promote and recognise intrinsically valuable geological and geomorphological sites. Features on the register that are especially fragile, or otherwise likely to be disturbed, threatened or become vulnerable by human activity, can be identified as such and area management protocols for conservation, under the Antarctic Treaty, can be more readily invoked, developed and substantiated. Area management should mitigate casual souveniring, oversampling and accidental or deliberate damage caused by ill-advised construction or other human activity. The recognition of significant geological and geomorphological features within the Antarctic, and their protection, is identified under the current Australian Antarctic Science Strategic plan (under Stream 2.2; Vulnerability and spatial protection)

## Biological invasions: changing terrestrial ecosystems in the Antarctic

### Convey P

British Antarctic Survey

Most ice-free habitats on land in Antarctica and the sub-Antarctic are effectively islands surrounded by hostile ice and ocean. Terrestrial ecosystems are extremely isolated, and have developed unique and striking features. True terrestrial vertebrates are generally absent, meaning that most foodwebs consist only of producers and invertebrates. Ecosystem structure is generally simplified, with few true native herbivores or predators present, and the predators in particular having very limited impact on their prey species.

Over the last two centuries human activities have led to the accidental introduction and establishment on land of many non-indigenous species of vertebrate, invertebrate and plant, particularly to the ecosystems of the sub-Antarctic islands. These introductions have encompassed a range of trophic functions, some of which are poorly or not represented in indigenous ecosystems. In some cases these have led to drastic alterations in ecosystem structure and function. A smaller number of introductions are already apparent in parts of the Antarctic Peninsula, and the sub-Antarctic provides a direct warning of the likely trajectories of these and any future establishment events.

The current Antarctic Specially Protected Area System is not immune to these threats but, in combination with recent advances in understanding of the complex structure of Antarctic terrestrial diversity, can provide a tool in the protection of habitats from invasive species. This presentation will give an overview of the impacts of non-indigenous biota in Antarctic ecosystems to date, and their implications in a future where these ecosystems are also faced by some of the most rapid rates of environmental change on the planet.

## Systematic conservation planning to inform MPA design in the Ross Sea region, Antarctica, under the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR)

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Ministry for Primary Industries

This paper describes the scientific and methodological approach developed and implemented by New Zealand to inform the design of a proposed Marine Protected Area (MPA) in the Ross Sea region, Antarctica, under the auspices of the Convention for the Conservation of Antarctic Living Marine Resources (CCAMLR). Formal MPA proposals jointly prepared by New Zealand and the United States were submitted to CCAMLR in 2012 and 2013.

'Systematic conservation planning' (SCP) is a transparent, objectives-driven spatial planning framework designed to identify optimal spatial management solutions to complex conservation planning problems. SCP is ideally suited to the needs of the CAMLR convention, which requires a balance between ecosystem protection and rational use (harvest) of Antarctic marine living resources.

CCAMLR has recognized the potential value of MPAs to achieve three types of protection objectives: i) *representativeness* (i.e. protecting a proportion of each habitat); ii) mitigating or eliminating particular ecosystem *threats* from fishing; and iii) establishing *scientific reference areas* to better understand the ecosystem free from human interference. In the New Zealand SCP approach, spatial data depicting environmental, biological, and fisheries patterns were used to define and map 27 spatial *protection objectives* and to assign numerical *protection targets* (i.e. the proportion of each mapped objective to be protected). Customised GIS software was developed and used to evaluate alternate *MPA scenarios* and seek optimised spatial solutions, i.e. to achieve *protection targets* for each objective while minimising *cost* to rational use (i.e. displacement of fishing effort).

This process was applied initially in domestic stakeholder consultations to develop a New Zealand MPA scenario submitted to CCAMLR in 2011 and a formal proposal in 2012, and subsequently to inform discussions with other CCAMLR Member countries, and the development of formal joint NZ-USA proposals in 2012 and 2013. Throughout this process, the priority assigned to individual *protection objectives* has been altered (and their corresponding *protection targets* adjusted accordingly) to reflect the advice of the CCAMLR Scientific Committee; changes to MPA boundaries in subsequent proposals were a logical outcome of these adjustments within the SCP framework. Most aspects of the most recent joint NZ-USA proposal (October 2013) are now supported by the CCAMLR Scientific Committee.

The development of the Ross Sea region MPA proposal within CCAMLR illustrates how SCP can inform the transparent and scientifically rigorous development of spatial solutions to complex conservation management problems, and can facilitate consensus in multi-lateral settings where competing management objectives are valued differently among the interested parties.

## Data and marine protected area planning

Douglass L, Beaver D

The Centre for Conservation Geography

The effort to establish marine protected areas to conserve the unique polar habitats and species of the Southern Ocean has gained momentum recently. The first entirely high seas marine protected area (MPA) in the world has been created on the South Orkney Islands shelf. Marine protected area proposals for the Ross Sea and East Antarctica are being considered the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) who is the main body designating MPAs within the region. CCAMLR requires that such proposals are supported by “best available science”. Data and expert knowledge important for MPA planning are being collated including circum-Antarctic pelagic and benthic bioregionalisations and six MPA workshops sponsored by CCAMLR. Three workshops held in 2012 initiated MPA planning for five of the nine Southern Ocean planning regions. MPA planning processes now cover almost all of the 35 million km<sup>2</sup> Southern Ocean region.

We show how scientific data can be used to support these important planning processes and provide objective advice to policy makers, by discussing how we have collated, mapped and analysed data. Our research has included generating a circum-Antarctic map of the general biodiversity patterns of the benthos. We have used the resulting environmental types of this analysis along with other data to assess the representativeness of MPAs, identify locations where spatially restricted environmental types occur and to plan for the future placement of MPAs in the Southern Ocean. Some of our research findings are outlined here: <http://conservationgeography.org/>. Our research is most relevant to SCAR open science conference themes 24, 27, 40, 42 and 46.

## Finlandia Foothills: identifying important biological areas using remote sensing

Fretwell P, Hughes K

British Antarctic Survey

The Antarctic Specially Protected Area (ASPAs) network was established to protect the many environmental, scientific, historic, wilderness and aesthetic values present in Antarctica. However, the Antarctic protected area system is still immature relative to other areas of Earth with only 73 marine and terrestrial ASPAs with a total area of c. 3767 km<sup>2</sup>. Large regions of Antarctica have few if any ASPAs and many values are still poorly represented. Antarctic Conservation Biogeographic Region No. 4 (ACBR 4), Central South Antarctic Peninsula is a region that presently has only two ASPAs, neither of which are designated as important bird areas. Within ACBR 4 lies Finlandia Foothills, which is a substantial area of comparatively low-lying ice-free ground (c. 24 km<sup>2</sup>) on Alexander Island. It contains many environmental, wilderness, aesthetic and scientific values, foremost of which is the rich vegetation cover and the high density of bird life, both of which have been identified by new satellite methodologies that allow us to quantify the extent of vegetation and bird areas. A particular feature of this area is the low level of human activity in the vicinity, with parts of Finlandia having never been visited, and therefore of value as a pristine location for future sophisticated scientific research techniques.

## Antarctic environments portal

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The Antarctic Environments Portal ([www.environments.aq](http://www.environments.aq)) is the link between the growing body of scientific research on Antarctica and the governance work of the Antarctic Treaty System, in particular through the Committee for Environmental Protection (CEP).

The CEP is mandated to advise the Antarctic Treaty Parties on measures to enhance the comprehensive protection of the Antarctic environment. The Portal is structured around the CEP's priority topics. These include managing risks associated with non-native species in Antarctica, considering the implications of climate change and maintaining awareness of and responding to threats to biodiversity. The Portal also provides a mechanism for scientists to raise emerging issues of relevance to the CEP.

The Portal includes summaries of the state of knowledge on issues, the management of those issues and environmental pressures. Information in the Portal is based on peer reviewed science. The content is non-technical, a-political, and subject to a robust editorial process.

Contributions to the Portal will have an impact on policy development and will support the informed management and governance of the Antarctic. The involvement of the science community in this project is fundamental to its success. The project supports SCAR's mission to provide independent, sound, scientifically-based advice to the Antarctic Treaty System, but depends on the science community's interest in communicating their work.

The Portal is operating in a beta phase, and will be fully functional by June 2015.

We will give a demonstration of the Portal, provide additional information, and outline how scientists can be involved the project.

## Stakeholder perspectives on Antarctic conservation: A common pool resource framework approach

Gomez Fell G, Stewart E, Espiner S

Lincoln University

'The commons' are at the core of many of the world's most pressing environmental issues, from climate change to biodiversity loss. Few places illustrate the complexities of a global commons better than Antarctica, where challenges such as ocean acidification, economic utilisation of natural resources and threats to its unique biodiversity imply a 'tragedy' in the making. This proposed study utilises a number of common pool resource management frameworks to understand stakeholder perspectives on both the current and future state of Antarctic conservation.

In Garrett Hardin's (1968) "tragedy of the commons" he claimed that resources held in common management are destined to be over-used. By contrast, Elinor Ostrom drawing mainly on examples of small-scale, locally governed commons observed that individual users do restrict their use of resources and share the benefits of 'the commons' through collaborative action. According to Ostrom (1990), under certain conditions groups will behave altruistically for everyone's long-term benefit, although the applicability of her framework to larger scale, more complex commons, such as Antarctica, needs examination. The research proposed in this presentation seeks to explore a variety of stakeholder perspectives (policy-makers, scientists, managers, ENGOs) on Antarctic conservation through a common pool resource lens and, using both qualitative and quantitative data collection methods, aims to identify potential future scenarios for Antarctic conservation. The poster presents preliminary findings outlining the contribution that common pool resource management frameworks can make to help understand the current and desired outcomes of Antarctic conservation.

## 612. Conservation decision-making in Antarctica: managing invasive species using a Bayesian Belief Network approach

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Despite the Antarctic Treaty System attempts to prevent non-native species introduction several non-native species are established in Antarctica. Furthermore these incursions are likely to increase given accelerating climate change and rapid increases in human activities in Antarctica. The Committee for Environmental Protection has suggested that, where practicable, eradication of the established non-native species is necessary to conserve Antarctic biodiversity and intrinsic value.

When undertaking invasive species eradications it is important to consider unforeseen and unwanted impacts of management actions. Due to the low diversity of Antarctic ecosystems, such management interventions could impact the terrestrial ecosystems. For example mechanically disturbed ground may create ecological niches for new invasions and disturb slow-growing native species and chemical control may contaminate and have adverse effects to native biodiversity.

In conservation decision making, the consequences of management interventions and potential adverse effects should be explicitly considered and assessed. We are constructing a Bayesian Belief Network model (BBN) (a probabilistic graphical model), which serves as a framework of the system displaying the causal web of interacting factors. BBNs offer a highly visual tool that enables policy-makers, stakeholders and scientists to communicate and work coherently. Alternative management scenarios and the possible consequences can be assessed and evaluated through the BBN model to support decision making. However, for biological invasions in Antarctic terrestrial ecosystem, empirical information is sparse or there are knowledge gaps. There may be severe uncertainties in this dynamic system. Expert scientific judgments will be incorporate as a source of information to parameterize the BBN model. A structured elicitation process allows expert opinion to be obtained in a transparent, rigorous and repeatable way.

This study will increase our understanding of the role of the non-native species in a whole under the Antarctic ecosystem context; and the Bayesian Belief Network model will enable the assessment of eradication and other management activities in terrestrial Antarctic ecosystems. This will provide a paradigm for future research on similar management problems, and can help to inform policy related to the responses to non-native species in Antarctica.

## Population structure of *Sanionia uncinata* moss: Genetic approach for management and conservation in Patagonia and Antarctica

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Designation of an Antarctic Specially Protected Area (ASPA) is based on the protection of outstanding environmental, scientific, historic, aesthetic or wilderness values. Nevertheless, for the later it remains to be assessed whether these ASPAs are representative of the genetic pool for many species in Antarctica. To address this issue questions as like: how the genetic structure looks like?, how these populations are related to each other through gene flow or migrants to be resilient over time particularly influencing genetic diversity and ecosystem function?, must be answered. We used *Sanionia uncinata* moss as model to contribute to the management and conservation efforts using molecular data. This specie is cosmopolitan and grows in Antarctica and South America in patches or isolated in many different environments. It has a great morphological plasticity and rarely generate sporophytes in Antarctica. Thus the establishment must occur mostly by vegetative gametophytes and hence it is expected a high clonal-asexual reproduction. During the Scientific Expeditions (2010-12) organized by the Chilean Antarctic Institute (INACH) we surveyed populations across sites in the South Shetlands and James Ross Islands and Patagonia, analyzing the population structure of this moss.

Levels of inter and intra-population genetic variability was analyzed through AFLPs. The data showed low levels of heterocigosity showing the importance of asexual reproduction in this specie. A moderate genetic differentiation ( $F_{st}=0,13$ ) was observed. Private alleles were identified in populations from Robert, King George and Livingston Islands more than from Patagonia sites, suggesting a strong growing population. The AMOVA analysis shows 95% within genetic diversity and 5% among populations. No genetic diversity was linked to regions. Through a Mantel test we could not observe isolation by distance, fact which was supported by the recognition of migrants from Isla Riesco and Karukinka (Patagonia) into Antarctica, and migrants from Antarctica into Patagonia, flying over 1600 km. Also, migrants were found between islands within Antarctica. Results suggest that regions of Patagonia and Antarctica must be managed as a whole, leaving out the idea of a successful conservation considering only an isolated Antarctica. This suggests the consideration of buffer zones like Riesco Island in Patagonia, to avoid the vulnerability of the moss Antarctic ecosystem.

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**614. Learning from past practices to improve biosecurity to the Antarctic region: alien invertebrate transfer**

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Alien species pose an increasing threat to biodiversity in the Antarctic region. Several alien taxa are now established in the Antarctic and many more in the sub-Antarctic. Some of these established aliens represent novel functional groups such as pollinators or predators and are impacting on Antarctic ecosystems.

We examined invertebrates collected in association with cargo and passenger transport to three research stations in East Antarctic and to sub-Antarctic Macquarie Island. We quantified the unintentional introduction of alien invertebrates to the Antarctic region between 2000-2013 through the Australian Antarctic Program. We also implemented a stratified trapping program on supply vessels and at a cargo facility in Australia during the 2012-13 austral summer field season.

We identified a taxonomically diverse suite of invertebrates being introduced to the Antarctic region. A total of 1280 individuals from at least 98 invertebrate families were detected or trapped during the study. Many individuals were collected alive. Diptera, Coleoptera and Lepidoptera were the most common taxa with 986 individuals collected (77% of the collection). The most detected families were Phoridae (small flies) and Noctuidae (moths). Individuals from 38 different families were repeatedly introduced over time, some in high numbers. Of the pathways of introduction identified, food and large cargo containers harboured the most individuals.

Following on from this work we undertook an audit of the new Australian Antarctic cargo handling facility during the 2013-14 season. We implemented a multi-technique invertebrate trapping regime to test recent advancements in biosecurity mitigation. This research assists in improving biosecurity protocols for Antarctica.

## 615. The designation process for Antarctic Specially Protected Areas

Hughes K

British Antarctic Survey

According to Annex V to the Protocol on Environmental Protection to the Antarctic Treaty, any marine or terrestrial location within the Antarctic Treaty area can be designated as an Antarctic Specially Protected Area (ASPAs) to protect '*outstanding environmental, scientific, historic, aesthetic or wilderness values, any combination of those values, or on-going or planned scientific research*'.

Annex V also states that ASPAs should be identified within a systematic environmental-geographical framework. Some such frameworks have been put in place already with the development of the Environmental Domains Analysis (EDA) and Antarctic Conservation Biogeographic Regions (ACBRs).

Nevertheless, with only 73 ASPAs designated to date, the ASPA network is still some way off a comprehensive protection of values across the whole of Antarctica. The primary values protected in the majority of ASPAs are biological (marine and terrestrial habitat, bird colonies, etc.), with a smaller number of ASPAs also focusing primarily on historical, geological/geomorphological and physical values.

Natural and social scientists may be aware of locations that have values worthy of short or longer-term protection and inclusion within the ASPA network. However, the practical steps for ASPA designation may not always be clear to those not connected directly with the Antarctic Treaty Consultative Meeting (ATCM) and Committee for Environmental Protection (CEP). The process of ASPA designation, including the requirement for the preparation of an ASPA Management Plan, will be outlined in this presentation.

**616. Development of scientific advice to inform the review of the South Orkney Islands Southern Shelf MPA**

Grant S, Trathan P, Silk J, **Hughes K**

British Antarctic Survey

The South Orkney Islands Southern Shelf marine protected area (MPA) was designated in 2009 by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). It provides strict protection for a marine area of 94,000 sq km, and was the first such area to be designated entirely within the high seas anywhere in the world. The first scheduled (5-yearly) review of this MPA is due to be undertaken by CCAMLR in 2014. It will assess whether the MPA objectives are being achieved, and new management measures or additional protected zones may be proposed if required. To inform this review, we have collated and analysed new information on the foraging ranges of Adélie and chinstrap penguins from satellite tracking, the distribution and abundance of krill from acoustic surveys, the influence of sea ice extent on krill fishing activity in the region, and oceanographic data from a mooring recently situated in the area targeted by the krill fishery.

This work will contribute to a range of policy outputs, including: i) an MPA Management Plan containing details of specific objectives and features within the MPA, as well as management measures, ii) a Research and Monitoring Plan detailing the types of information and ongoing monitoring needed to determine whether the MPA is fulfilling its conservation objectives in the future, and iii) proposals for additional spatial management within CCAMLR Subarea 48.2, to include scientific research zones contrasting fished and un-fished areas. CCAMLR has further agreed that MPA Reports should be used as a standardised tool to consolidate and maintain up-to-date scientific information about existing MPAs. The information we have collated will therefore form the basis of a new MPA Report for the wider Scotia Sea and Western Antarctic Peninsula region (CCAMLR MPA Planning Domain 1).

The MPA review process demonstrates an important mechanism by which scientific information is used to formulate advice to policymakers, and can make a significant contribution to applied policy outputs. The CCAMLR requirements for MPA review and monitoring will rely heavily on cooperation between its Members, as well as with other organisations such as SCAR, to ensure that all relevant information can be incorporated.

## The science - policy interface of Marine Protected Areas (MPAs) in the Southern Ocean

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The Southern Ocean is the home of unique and high biodiversity, but the conservation of its ecosystems are faced with serious challenges. The Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR), the ecosystem-based governance system of the Southern Ocean, has agreed to create a representative system of Southern Ocean Marine Protected Areas (MPA) by 2012, including no-take zones. So far, this ambitious goal has not been achieved as only one MPA has been established around the South Orkney Islands and several proposals have been stalled due to international political disputes. Understanding and improving the interactions between science and policy actors could provide a way forward in this process.

In the social science literature on environmental governance, a debate takes place on the character and effectiveness of the interaction between the domains of science and policy. Models differ from a linear transfer of knowledge from science to policy, to knowledge brokering and joint knowledge production where science and policy actors actively cross the boundaries of their domain. The science-policy interface of Antarctic environmental governance is not properly understood and is of special interest because of the dominant role of science in this part of the world.

This paper explores the establishment of the South Orkney Islands MPA by relating the practices and views of science and policy actors to several models of science-policy interactions. Next to reviewing relevant documentation, semi-structured interviews have been conducted with key actors involved in and around this process from the United Kingdom, Belgium, France and the Netherlands. We analyze the roles and expectations of scientists, policy makers and environmental NGOs in the Antarctic science-policy interface and recommend how interactions can become more effective. Our study demonstrates that the linear model, with knowledge flowing from science to policy, is perceived by many actors as the way the science-policy interface should ideally function. Nevertheless, interviewees also report that boundary crossing and knowledge brokering is occurring regularly and also needed. This paradox may be explained by the dominance of natural sciences in Antarctic science and policy. Following the international literature, we argue that good practices in crossing boundaries do exist, which can lead to higher appreciation of those involved and effectiveness of MPA decision-making.

## **Geological heritage and Antarctic environmental protection. Criteria for inventory, classification and assessment**

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In Antarctica, as in the rest of the world, there are geological features whose uniqueness and intrinsic value recommend their consideration within the protection of the natural environment. Moreover, Antarctica is a key piece to reconstruct the geological history of the Earth and the geodynamic evolution over hundreds of millions of years. Therefore, a series of geological elements should be protected against possible damage by human activities. The characteristics of Antarctica produce a particular framework in regard to the treatment and protection of the geological heritage. For regulation and management of Antarctic geological heritage, factors as scarcity of ice-free areas, wide geographical dispersion, low human presence, and limited threats must be taken into account. Also, the existing environmental regulation (in particular the Madrid Protocol and its annexes) and the network of Antarctic Specially Protected Areas (ASPAs), form a particular framework for the management and protection of the geological heritage. In this paper, the status and adequacy of the protection of the Antarctic geological heritage is discussed, in general and in particular in connection with the ASPAs. The type and significance of the geological values in the ASPAs is analyzed, as well as the possibilities of regionalization. A number of selection, classification and assessment criteria for the inventory and catalog of the geological heritage in Antarctica are proposed.

## The McMurdo Dry Valleys ASMA as a case study for establishment of Geological Heritage sites

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The SCAR Standing Scientific Group for GeoSciences has established the Geological Heritage and Conservation (GeoHeritage) Action Group. The McMurdo Dry Valleys (MDV) form the largest ice-free region on the continent, and contain unique geological features and sedimentary deposits including sand dunes, desert pavement, and glacial, lacustrine and marine sediments containing valuable records of climatic and geologic change. The MDV were designated as an Antarctic Specially Managed Area (ASMA) following consultation amongst those operating in the region, in particular NZ and US scientists and program managers, and internationally through SCAR and the Antarctic Treaty. During that process several geologic sites were designated as 'Special Features'. The ASMA Management Plan was revised in 2011 and Special Features were recategorized as either Scientific Zones (SZ) or Restricted Zones (RZ) depending on their sensitivity to potential impacts. Together with Antarctic Specially Protected Areas (ASPAs), zoning under the ASMA management plan allows for varying levels of protection. The strictest protection is provided by ASPAs, which require permits for entry. Five ASPAs are designated within the MDV, with entry to ASPA No. 123 Barwick and Balham Valleys the most strictly controlled because it is considered pristine and serves as a reference area. Sensitive geological landforms and cryptoendolithic communities on Linnaeus Terrace are also strictly protected under ASPA No. 138. Other sensitive sites of geological and ecological importance are managed through the less restrictive zoning system. These sites may be easily disturbed without attention to agreed access protocols. Zone designations help raise awareness of site sensitivities, and although access permits are not required guidelines should be followed. Two SZs and eight RZs are designated in the MDV. For example, sites such as Prospect Mesa (RZ) and Argo Gully (RZ) contain records of marine pecten fossils which have significance for understanding geologic and climatic processes. Don Juan Pond (RZ) has a distinct geochemistry and is one of the most saline water bodies on earth. Boulder Pavement (SZ) performs an important ecological role as a 'biofilter' on the Onyx River. We discuss how consensus on the MDV ASMA plan was built to establish the classification of this important earth science location. We review the MDV geological features under management and within the discussion of the Action Group.

## **A multi-stakeholder approach to understanding and addressing conservation challenges in a changing environment**

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<sup>1</sup> International Union for Conservation Nature, <sup>2</sup> Antarctic and Southern Ocean Coalition

The conservation of the Antarctic natural environment continues to be a challenge for policymakers as human activities grow and diversify. The scientific and ecological importance of this region has long been recognized, as well as its fragility to a variety of stressors. Today the Antarctic continues to change through an increase in resource extraction, shipping, tourist activities, non-native species, and bio-prospecting. These human activities, combined with observed climate variability and environmental change, are affecting the regions' flora and fauna. This presentation and open discussion will explore ways to better communicate science and monitoring needs to implement conservation measures, discuss potential barriers to advancing conservation objectives, and address opportunities for scientists, conservation managers, government and business to exchange ideas to advance common goals.

## **Strategic interest and role of the development of Malaysia's policy on Antarctica in influencing international regime of polar governance**

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Malaysia is pioneering its legacy on Antarctica in 1982 with foreign policy intervention. Malaysia initiated its diplomatic relations with Antarctica by raising the 'Question of Antarctica' on the Antarctica Treaty System (ATS) for a number of years in United Nation General Assembly (UNGA). Starting in the year 1997, a parallel policy was pursued by Malaysia in strengthening its position on Antarctica – Foreign Policy and Science Policy. After about 30 years of involving itself in the pillar of Antarctica which included diplomatic and scientific aspects, Malaysia officially became a member of the Antarctic Treaty with the accession occurring on 31st October 2011- Malaysia was the first ASEAN country to accede to the Antarctica Treaty System. Currently, Malaysia appears set to implement the Malaysia's Antarctic Act, ratify the Madrid Protocol and become the Consultative Parties in ATS. Without a proper analysis and planning, contextualization an international agreement in the Malaysian policy system may turn out to be a daunting task. The move to those planning therefore begs a number of inter-related institutional and policy research questions, based on the assumption that the formulation of a national Antarctic policy would commit Malaysia to clear objectives and better coordination of research activities. First, what are the strategic implications for Malaysia's public policy on the implementation of Malaysia's Antarctic Act, ratification of Madrid Protocol and accession of ATS Consultative Party? Second, what is the appropriate institutional framework-administrative and funding – to govern Malaysia's scientific interest on Antarctica? Third, in consideration of the earlier questions, how a best frame for a long term plan for the production of scientific knowledge on Antarctica in Malaysia? This paper will trace the development of Malaysia's policy on Antarctica, emphasizing the strategic interest and role of an upper middle income state such as Malaysia and other developing countries in influencing an international regime of polar governance.

## Antarctic ecology one century after the conquest of the South Pole: how much have we advanced?

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The knowledge derived from Antarctic ecology may be fundamental to face the complex environmental future of the world. As an early warning system, a deep understanding of Antarctic ecosystems is therefore needed, but Antarctic ecology as a field is still very young and currently under consolidation. Around the world 55 nations are involved in this task through their research programs, and considering the importance of this joint effort, we evaluate some basic trends of their publications through a wide bibliographical review of Antarctic ecology. All ecology-related Antarctic papers published for 106 years (ISI-Web database, 1904-2010) were reviewed. A lack of population and ecosystem research was observed, even in Animalia, the most studied kingdom. Publications originated mainly in developed countries; however, developing countries are increasing their participation in recent years. The current trends of Antarctic ecology as a field show a constant, but low representation in both Antarctic science and ecology.

## Landscape rehabilitation in the Vestfold Hills over 30 years

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Excavator pits and tracks from a 1983-1984 soil investigation are scattered across the western end of Broad Peninsula in the Vestfold Hills near Davis Station. The pits and spoil heaps, deep wheel ruts and piles of boulders from this time are only slightly modified by natural processes and the visibility of depressions is enhanced by salt crusts around their edges and fine sediment accumulations in low parts. Preservation of features appears to depend on the cohesion of the sediments affected; sandy, non-cohesive sediment shows redeveloped desert pavement in most settings, with excavations and tracks defined by the unnatural distribution of boulders, while clayey, cohesive sediment preserves wheel ruts and some imprints of excavator tracks. Boot prints have disappeared completely in all soil types.

Following obligations under the Antarctic Treaty (Environment Protection) Act 1980, a recent similar investigation (2012-2013) designed field methods aimed at eliminating, as far as possible, any future visibility of substrate disturbance. Effective remediation was achieved through avoiding sites on slopes to prevent erosion by run off or seepage, and holes were refilled with the surface layers returned to their original position, with hole edges re-contoured to avoid steep edges. Pebbles and boulders were placed close to their original distributions with attention to colour differences between the exposed and underside of clasts. Rakes and shovels were used to smooth boot prints and mechanical equipment tracks, and to break up sediment blocks. These sites, and a remediated old pit site, were inspected during the 2013-14 season and were very difficult to detect. This lack of visibility proves that soil remediation is possible in the Antarctic environment.

The difference in approach from 1983-1984 to 2012-2013 reflects a significant change in attitude and management of the physical Antarctic environment since the early 1980s and demonstrates that remediation of disturbed sites can be successfully achieved.

## What does the structure of the Ross Sea food-web tell us about the potential for ecosystem change in Antarctic shelf-seas?

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NIWA

A quantitative trophic model of the Ross Sea was developed, with validation by stable isotopes. The balanced trophic model used to investigate the network characteristics of the food-web of the Ross Sea continental shelf and slope. We investigated: (1) biomass and productivity of the system by trophic level; (2) linkages between groups in the ecosystem using mixed trophic impact (MTI) analysis; and (3) overall relative trophic importance of groups. The Ross Sea food-web was found to be a partially inverted pyramid with a pronounced peak in biomass in the lower-middle part of the food-web.

The six groups with the highest indices of trophic importance were (in descending order of importance): phytoplankton, mesozooplankton, Antarctic silverfish, small demersal fishes, Antarctic krill and cephalopods. Small pelagic fishes and crystal krill also had high trophic importance. Changes to these groups due to climate variability/change or fishing are likely to have far reaching consequences to Southern Ocean shelf-sea ecosystems. Basal (phytoplankton) and middle trophic level groups (mesozooplankton, small fishes including silverfish, krill and cephalopods) should hence be the priorities for monitoring change in Antarctic shelf-sea ecosystems.

The overall trophic importance of Antarctic toothfish in the Ross Sea ecosystem was close to the middle of all groups. However, the strongest top-down (predation) interaction in the Ross Sea food-web based on multi-step MTI analysis was the impact of changes to toothfish on medium-sized demersal fishes (mainly grenadiers and icefish in the Ross Sea continental slope region). For understanding changes to Southern Ocean ecosystems arising from fishing top piscine predators such as toothfish, monitoring the target species and their prey and predators is likely to be crucial.

Our analysis was limited in that it did not resolve interactions between species at smaller spatial and temporal scales than the underlying trophic model, and did not investigate effects concerning only parts of populations. We also present the main results of a review of interactions between toothfish and its likely predators in the Ross Sea region (Weddell seals and type-C killer whales) which shows that MTI analysis will likely underestimate bottom-up effects of the toothfish fishery on these predators.

## Managing our backyard - the protection of biological communities at Scott Base

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Research stations in Antarctica may be considered 'sacrificial' sites where environmental impacts are unavoidable and therefore not managed.

Scott Base was established in January 1957 on Pram Point, Ross Island. Since then, the area around Scott Base has been heavily impacted by human activities. The construction, extension and removal of new and old buildings, structures and storage areas began in 1957 and continue today. Major earthworks were undertaken within the area and a road between Scott Base and McMurdo Station was completed in 1967 and is still in use.

Despite significant ground disturbance and activities that have occurred at Pram Point over nearly 60 years of base operations, mosses, lichens and algae can still be found in the area between Scott Base and the road to McMurdo Station.

A preliminary assessment in the 2007/08 season confirmed that the area contains moss, lichen and soil invertebrate taxa. A detailed topographical survey of Pram Point was undertaken in the 2012/13 season in order to describe accurately the topography of the landscape, natural features and the visible human impacts associated with both historic and present operations surrounding the main operational areas of Scott Base. A vegetation density survey was undertaken in parallel during the 2012/13 and 2013/14 seasons.

As an immediate management measure, a Scott Base operational footprint around the station and storage areas has now been defined. Activities outside this area have been restricted to minimise further impacts to the biological communities.

We demonstrate here how, by using high accuracy mapping and basic survey and documentation techniques, better management of our 'backyards', even for stations that have been operational for several decades, may ensure that biological communities can recover and continue to persist, even within highly disturbed environments.

## Science vs Conservation: an example of conflicting interests within a highly sensitive Protected Area in Antarctica

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Antarctica possesses a diversity of natural values, some of which are very localized. Deception Island, South Shetland Islands, boasts the largest number of rare bryophyte species, within a relatively small area, in Antarctica. However, the volcanic nature of the island offers substantial opportunities for research in a wide range of biological, geophysical and geological disciplines. Inevitably, some of these scientific values often overlap. Following an inspection of Caliente Hill, above the inner west coast of the island's caldera (Port Foster) in February 2012 we documented visual impacts resulting from inadvertent trampling of a unique moss assemblage associated with local geothermal activity. After taxonomic examination of the most severely damaged mosses on the disrupted ground those species affected included *Schistidium deceptionense*, an endemic species so far known only from within this diminutive site. This is the solely moss considered a single-island endemic in Antarctica.

In 2002 the Environmental Protocol to the Antarctic Treaty Annex V was effected to prevent any disturbance of the Antarctic native flora that significantly affect their local distribution or abundance. Moreover, Antarctic Specially Protected Area 140 was specifically designated to protect geothermal bryophytes species and communities on Deception Island with restricted access, limited to scientific and management purposes. Caliente Hill is designated Sub-Site C. This protective legislation is intended largely to reduce human impacts on selected Antarctic organisms and their habitats. However, certain rare species confined to very specific sites may still be threatened by a conflict of scientific purpose. Our photographic assessment suggests that cumulative trampling, even at a low level of impact, if it continues over several consecutive years, will almost certainly destroy the very restricted population of the endemic *S. deceptionense* and its highly vulnerable habitat. Furthermore, uncontrolled or careless intrusion into the site will probably severely affect the range of several other Antarctic rarities reported from this site, notably *Racomitrium subsecundum*, *Pohlia wahlenbergii*, *Dicranella hookeri*, *Ditrichum ditrichoideum* and *Bryum orbiculatifolium* which are only known from one or a few localities in Antarctica.

On these premises we encourage developing further actions for effective protection of this and other vulnerable sub-sites within ASPA 140. The designation of Deception Island as Antarctic Specially Management Area N°4 provides the appropriate framework to approach the mutual protection of multiple values which pose different scientific problems. Finally, a suite of management tools identified as relevant to effective site protection are discussed. In this regard the Spanish Polar Program has already taken some preventive measures during the 2013-2014 campaign to minimize its impact. Prioritization of values in conflict under the Antarctic Treaty regulations may be essential in such small and sensitive protected areas.

**627. Supporting management measures on scientific information: a case study developed on Barrientos Island (South Shetland Islands)**

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Thousands of tourists visit certain Antarctic sites each year. Human presence generates diverse impacts, which must be properly controlled. Applied management measures may be based on the best available scientific knowledge to make them effective. We present a case study developed on Barrientos Island in which a measure aimed to limit the damage caused by visitors ends up creating a bigger problem.

Two routes were compared. Both crossed an extensive moss carpet that cover the central part of the island and that is very vulnerable to trampling. The first path has been used by tourists and scientists since more than a decade and has a marked route. The second one was more recently created. It was proposed in the site guidelines for visitors developed by the Secretariat of the Antarctic Treaty for Barrientos Island as the best option to cross this area, since this runs in part along bedrock and the course of a small stream.

Several physical and biological indicators were applied in order to assess the environmental conditions for both paths. Results showed that width of the first path does not vary significantly along the summer season. C-biomass, microbial activity (measured throughout dehydrogenase, urease, phosphatase, and  $\beta$ -glucosidase activity) and soil respiration were lower for this route. Moss communities located around the track were also less diverse ( $H' = 1.32$  vs  $1.62$ ,  $E_H = 0.26$  vs  $0.33$ ), and there were not alternative stretches or visible damages produced by trampling. In the other route, several injured areas were observed on the surrounding moss carpet because visitors tend to leave the path when it becomes muddy with trampling or the stream flow is abundant. Ten alternative stretches were registered, running 327 meters over mosses and affecting  $385 \text{ m}^2$ . Soil biota (collembolan) was more abundant (2,186 specimens vs 98) and richer (4 species vs 3) in this track.

Based on these data, the creation of the second path was probably a wrong decision because a) it runs over a more vulnerable area with more outstanding biological features (e.g. microbiota, flora and fauna), b) this route produces greater impacts than the initial (e.g. alternative stretches), and c) the human footprint has doubled by creating a second path. This study reinforces the necessity of apply an adequate environmental monitoring plan to previously assess the effectiveness and suitability of those management measures proposed for particularly vulnerable sites located in Antarctica.

## Area protection in Antarctica: how can conservation and scientific research goals be managed compatibly?

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The footprint of human activities within Antarctica is increasing, making it essential to consider whether current conservation/protection of environmental and scientific values is adequate. The Antarctic protected area network has developed largely without any clear strategy, despite scientific attempts to promote protection of representative habitats. Many Antarctic Specially Protected Area (ASPAs) Management Plans do not state clearly if conservation or science is the priority objective. This is problematic as science and conservation may have conflicting management requirements, i.e. visitation may benefit science, but harm conservation values.

We examined recent estimated mean annual levels of visitation to ASPAs. On average, ASPAs protecting scientific research interests were visited twice as often as ASPAs conserving Antarctic habitat and biological communities. However, ASPAs protecting both science and conserving habitat were visited three times as often as ASPAs conserving habitat alone. Examination of visitation data showed that the proportion of visitors entering ASPAs for science, environmental management and/or education and tourism purposes, did not reflect the primary reason for designation, i.e. for science and/or conservation. One third of APSAs designated since the Environmental Protocol entered into force (1998) did not describe clearly the main reason for designation. Policy makers should consider for all Management Plans (i) stating unambiguously the reason an area has ASPA designation, e.g. either to protect habitat/environmental values or scientific research, in accordance with adopted guidance, (ii) designating new protected areas where visitation is kept to an absolute minimum to ensure the long-term conservation of Antarctic species and habitats without local human impacts (possibly located far from areas of human activity), and (iii) encouraging the use of zoning in ASPAs to help facilitate the current and future requirements of different scientific disciplines

## The Antarctic marine wilderness: Concept, pressures, and protection

Roura R<sup>1</sup>, Tin T

<sup>1</sup> Antarctic and Southern Ocean Coalition, <sup>2</sup> Independent

The wilderness values of the Antarctic region are recognized by the Protocol on Environmental Protection to the Antarctic Treaty (the "Protocol"), which designates Antarctica as "a natural reserve, devoted to peace and science". Building from earlier work (Tin et al., 2008), in this presentation we focus on the concept of wilderness as it applies to the Antarctic coastal areas and adjacent Southern Ocean ("Antarctic marine wilderness"). The dynamic nature of the Southern Ocean and the transient (but periodic or continual) characteristic of human activities there require special consideration in the definition of wilderness and the notion of human pressure on this area. The characteristics of the Antarctic marine wilderness also pose particular protection challenges.

There is no formal definition of "wilderness" or "wilderness values" in the Protocol or anywhere else in the Antarctic Treaty System, although there is a general understanding of the key attributes of wilderness as being remoteness and a relative absence of both people and indications of past and present human presence or activity. These attributes are generally directly applicable to inland and coastal locations, whereas their application to a purely marine context require consideration of the characteristics of human activities at sea.

Marine access and exploitation of marine living resources have been long-standing components of human involvement in Antarctica. While most human activity in Antarctica today concentrates in the ice-free coastal areas, there remains substantive activity in the marine environment. Based on our ongoing work in Antarctic environmental advocacy and drawing from global experience in the protection of marine wilderness (including for example, the WILD Water Project.), we review the human activities that are taking place in the Southern Ocean – primarily fishing, science, tourism, and whaling - and discuss their impacts on the Antarctic marine wilderness. This includes addressing the distinct spatial and temporal patterns of shipping activities and consideration of the Southern Ocean as an interface between Antarctica and the more populated parts of the planet.

We contend that the values of the Antarctic marine wilderness should be preserved both as a lasting natural legacy as well as an "associative cultural landscape" in the sense of UNESCO's World Heritage Convention, and suggest some practical mechanisms to achieve this in the context of the Antarctic Treaty System.

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## Environmental NGOs and ocean governance: Linking the public and decision makers in Antarctica's Southern Ocean

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Environmental non-governmental organisations (ENGOS) are one of the stakeholder groups in the governance of Antarctica's Southern Ocean, and participate as observers in meetings of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), the body that regulates fishing in the region.

Fishing in the Southern Ocean is regulated by the 1980 Convention on the Conservation of Antarctic Marine Living Resources (CAMLR Convention). Conservation is a key element of the Convention, and while conservation is defined as to include "rational use", any harvesting shall follow strict conservation principles including the precautionary principle and ecosystem based management. For the past decade, CCAMLR has been working on the establishment of a network of Antarctic marine protected areas (MPAs). This presentation discusses the work of ENGOS to promote the successful completion of these negotiations by CCAMLR, and the impact of the ENGOS's public campaign on the CCAMLR MPA process to date.

Antarctica lacks permanent populations that could have an active role in environmental protection in this remote region, and in particular the Southern Ocean is far away from the public eye. CCAMLR discussions are conducted with limited public participation and no media access, and most CCAMLR documents are not publically available. In this context, one of the key roles of ENGOS is to inform the public about developments in the region, and to serve as a link between the public and decision makers.

Formed in 2011, the Antarctic Ocean Alliance (AOA) is a coalition of 30 leading environmental organisations and high profile individuals calling for large-scale protection of critical marine habitats. AOA's public campaign uses a combination of traditional media and digital platforms such as social media. The AOA's international media outreach has brought CCAMLR and the protection of the Southern Ocean into the international spotlight for more than two years. AOA's online presence has built a growing, active and engaged community that is holding governments accountable for their actions.

After years of steady progress towards the establishment of a network of MPAs, discussions have slowed since 2012 at the point of making decisions about concrete MPA proposals for East Antarctica and the Ross Sea. Most CCAMLR Members are "already on board", while the consensus of a few others is "critical to success". Given the substantive and growing public interest on this issue it is unavoidable that decision makers will have to reach consensus on MPA adoption. The presentation concludes with a call for CCAMLR Members to listen to public opinion and to adopt ambitious, lasting MPAs that ensure the sustainability of the Southern Ocean.

## **A Marine Protected Area in the Weddell Sea, Antarctica: A proposal by environmental non-governmental organisations**

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The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), the body that regulates fishing in Antarctica's Southern Ocean, is working on the establishment of a network of Antarctic Marine Protected Areas (MPAs). Environmental non-governmental organisations (ENGOs), under the umbrella of the Antarctic Ocean Alliance, are contributing to this work through the development of its own proposals for marine protected areas and no-take marine reserves in 19 specific areas in the Southern Ocean around Antarctica. Formed in 2011, the Antarctic Ocean Alliance is a coalition of 30 leading ENGOs and high profile individuals calling for large-scale protection of critical marine habitats.

The ENGO submissions have no formal status but are meant to inform official proposals by providing robust arguments for conservation planning based both on current scientific knowledge and scientific uncertainty, in accordance with the provisions of the 1980 Convention on the Conservation of Antarctic Marine Living Resources.

This presentation describes the Alliance's vision for Weddell Sea region as outlined in its most recent report, the fourth in a series of "Antarctic Ocean Legacy" proposals from the Antarctic Ocean Alliance since 2011. The report describes the Alliance's proposal and the rationale for the Weddell Sea's designation as a Marine Protected Area, including fully protected marine reserves. The Weddell Sea is a keystone in any future Southern Ocean conservation network, and its designation as a permanent, large-scale marine reserve would be an important and inspirational step for marine protection both in the Southern Ocean and globally.

## Strategic thinking for marine conservation in Antarctica: A case study of the establishment of Marine Protected Areas in the Southern Ocean

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<sup>1</sup> Antarctic and Southern Ocean Coalition, <sup>2</sup> Independent

Baumgartner and Korhonen (2010) defined the notion of “strategic thinking” as characterized by three interrelated and distinct dimensions: strategy process, strategy content and strategy context. We have used this framework to look at wilderness protection in the Antarctic mainland (Roura and Tin 2014). Here, we use this framework to examine how strategic thinking is applied to marine conservation in Antarctica, focusing on ongoing negotiations concerning the establishment of a network of Marine Protected Areas (MPA) in the Southern Ocean.

The Southern Ocean constitutes approximately 15% of the world’s seas. Fishing in this area is regulated by the 1980 Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR Convention), which entered into force in 1982. The Convention forms a framework that can guide strategic thinking for marine conservation in Antarctica. Since 1982, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), composed by 24 states plus the European Union, has arguably adopted strategic thinking approaches in some of its marine conservation initiatives. These have resulted, *inter alia*, in reduction in seabird by-catch mortality; taking actions to combat illegal, unregulated and unreported fishing; and the protection of benthic vulnerable marine ecosystems.

In 2004 CCAMLR began to address the topic of MPAs, and over the years made progress through a number of workshops, the adoption of the first MPA in 2009, and the approval in 2011 of a general framework for the establishment of CCAMLR MPAs. However, three consecutive CCAMLR meetings in 2012 and 2013 failed to reach consensus on two MPA proposals on the table, covering several million square kilometres in the Ross Sea and East Antarctica.

As a whole, the CAMLR Convention and CCAMLR decision makers - building from CCAMLR's record of conservation - should be able to provide the strategic *content* and *processes* that can deliver MPAs. However, progress in Antarctic MPA discussions would require a more suitable strategic *context* in which shared interests in the region, which are the basis for lasting peace, international cooperation and the conservation of the Antarctic marine ecosystems, are given priority over those of individual CCAMLR Members, with long term benefits for all.

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## Towards the identification of protected areas for wilderness and aesthetic values in Antarctica

### Summerson R

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The Madrid Protocol mandates the protection of wilderness and aesthetic values in Antarctica, including the designation of areas to protect outstanding wilderness and aesthetic values. While wilderness and aesthetic values are grouped together in the Protocol, they are different value systems; the former relates to the absence of human activity while, put simply, the latter relates to scenic beauty. While the Madrid Protocol would seem to offer comprehensive protection to these values, in practice little more than lip service has been paid to their protection.

There would seem to be two options for the protection of wilderness: first, the designation of the whole of Antarctica as wilderness, for example as IUCN Protected Area Category Ib. According to the criteria for such areas, and with the possible exception of areas impacted by human activity, Antarctica would meet these criteria. The second approach would be to designate discrete areas as wilderness. While the discrete area approach may be more palatable to Antarctic Treaty Consultative Parties it does not seem logical to nominate discrete areas as wilderness, separated by large areas of default wilderness. The management measures and the potential impact of such a designation on human activity, especially scientific research, will be discussed.

A large number of techniques have been developed to assess landscape aesthetic values, which can be summarised into two broad traditions: "subjectivist" and objectivist". The subjectivist approach relies principally on input from stakeholders, generally through the use of surveys. The objectivist approach relies on expert opinion. Both techniques have been attempted in Antarctica, the former by Summerson & Bishop (2012, 2011) and the latter by Codling (2001). A third technique (e.g. Schirpke et al., 2013) combines terrain data e.g. slopes, elevation, land cover, etc with the results of a survey of aesthetic preferences to create a landscape preference model. Such an approach would be a valuable technique for defining areas of outstanding aesthetic value as well as being a valuable addition to area management tools, such as the development of management plans for Antarctic Specially Managed Areas. The aims and objectives of the Larsemann Hills ASMA (ASMA 6), for example, include "maintaining the wilderness and aesthetic values of the Area". At present, the aesthetic values remain undescribed, except in very broad terms, and unquantified. With aesthetic preference input from expeditioners of the five countries with stations in the Larsemann Hills combined with objective terrain data in a geographical information system, a landscape aesthetics model could be developed that should be acceptable to all parties, all having contributed to it.

## The work of the SCAR ACCE advisory group

Turner J

British Antarctic Survey

The SCAR Antarctic Climate Change and the Environment (ACCE) initiative began almost 10 years ago following the publication of the Arctic Climate Impact Assessment in 2004. The goals of ACCE were to review the present understanding of the physical and chemical climate system of the Antarctic region, the way it varies through time, and the influence of that variation on life on land and in the ocean around the continent. It also considered how the climate of the Antarctic might change over the next century under a range of greenhouse gas emission scenarios and the recovery of the ozone hole, and the impact on the biota. The review was carried out by representatives of three of SCAR's five major scientific research programmes: Antarctica in the Global Climate System, Antarctic Climate Evolution, and Evolution and Biodiversity in the Antarctic. The work culminated in the publication in late 2009 of the 500 page Antarctic Climate Change and the Environment report. Since then brief updates on recent advances in Antarctic climate-related science have been presented to the ATCM meetings on an annual basis. In 2013 a major update of the 'key points' from the original ACCE report was published. Today the SCAR ACCE Advisory Group has responsibility for preparing updates to the ACCE report, coordinating across SCAR on climate-related matters and liaising with external bodies. The talk will describe the work of the Advisory Group and the challenges of communicating complex science to a range of audiences.

## Ecology and management of invasive *Poa annua* on sub-Antarctic Macquarie Island

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*Poa annua* is the most widespread alien species in the sub-Antarctic, occurring on all major island groups and is invasive and spreading on the Antarctic Peninsula. *P. annua* colonises areas disturbed by human activity, seal wallows, penguin rookeries and glacial moraines. It also invades native communities and competes with native species. *P. annua* can withstand heavy grazing enabling it to significantly expand on islands inhabited by alien herbivores. It has a restricted distribution on Heard Island but is common and widespread on Macquarie Island, Australia's two World Heritage Areas. With the call for removal of non-native plants in Antarctica by the Committee for the Environmental Protection, investigating management strategies of this invasive plant is important.

Our study aims to investigate the ecology and management strategies for *P. annua* to assist in development of non-native plant management in the sub-Antarctic and Antarctic and further our knowledge of invasion biology in the region. The results of this study will assist in the development of rapid response techniques for managing future non-native plant incursions in the sub-Antarctic and Antarctica.

In situ and ex situ experiments investigating the response of *P. annua* and native species to manual disturbance are underway and herbicide efficacy and selectivity on *P. annua* and native sub-Antarctic grasses is being assessed. Herbicide movement and persistence in sub-Antarctic soils is also being measured. We are quantifying perennality, seed longevity, seed viability and the soil seed bank. Preliminary results indicate that on Macquarie Island *P. annua* exhibits a perennial growth form and has an abundant seed bank in the top 5 cm of the soil. Seeds have high viability but low longevity. Initial studies indicate that Glyphosate, Rimsulfuron and Trifloxysulfuron selectively control *P. annua* under sub-Antarctic climatic conditions. This work aims to improve management of non-native species in the sub-Antarctic and Antarctic by investigating how invasive species perform, and the impacts of management techniques in the sub-Antarctic and Antarctic terrestrial environments.

## S23: IMPACT OF PAST GLACIATION & BIO-MOORINGS AND SEDIMENT CORES

### Glacial-interglacial climatic variations recorded in the lake sediments of Schirmacher Oasis, East Antarctica: An untold story of magnetic minerals

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We present the first detailed environmental magnetic record of glacial-interglacial climatic variations in the Schirmacher Oasis, East Antarctica. We determined environmental magnetic properties and inter-parametric ratios ( $\chi_{if}$ ,  $\chi_{fd}$  %,  $\chi_{ARM}$ , SIRM,  $\chi_{ARM}/SIRM$ ,  $\chi_{ARM}/\chi_{if}$ ,  $\chi_{ARM}/\chi_{fd}$ , SIRM/ $\chi_{if}$ , S-ratio and HIRM) for sediment samples of a core from the Sandy Lake. Accelerator mass spectrometer (AMS) <sup>14</sup>C dates were obtained on the organic matter from bulk sediment samples. The sediment core spans the past ~ 42.5 cal. ka B.P. The magnetic minerals are mainly detrital and catchment-derived, as there is no evidence for the presence of authigenic greigite, bacterial magnetite or diagenetic dissolution. The glacial regime is marked by a high concentration of ferrimagnetic minerals such as magnetite (high  $\chi_{if}$  and SIRM values etc.) and coarse magnetic grain size (low  $\chi_{ARM}/SIRM$  and  $\chi_{ARM}/\chi_{if}$ ; and high S-ratio values). Deglaciation in the Schirmacher Oasis began around 21 cal. ka B.P. as suggested by the low concentration of magnetic minerals. The Holocene period is characterized by warm climatic events as seen in the low values of magnetic susceptibility which is primarily contributed by fine-grained magnetite resulting from pedogenesis (high  $\chi_{fd}$  % values). Several of the warm and cold events that we deciphered from the environmental magnetic data are correlatable with lake sediment and ice-core records from the Schirmacher Oasis and other ice-free areas in East Antarctica.

## Evidence for the extent and timing of the Last Glacial Maximum on the sub-Antarctic islands and its impact on biodiversity and endemism

Hodgson D

British Antarctic Survey

The extent of past glaciations has helped shape the biodiversity of Antarctic marine, lacustrine and terrestrial environments. Here we review the current state of knowledge on the maximum extent of ice on the sub-Antarctic Islands during the Last Glacial Maximum (LGM) and the implications of this for biodiversity and endemism. Based on a recent PAIS initiative we collated terrestrial and offshore evidence for LGM ice extent, minimum ages for the onset of deglaciation, and separated evidence of deglaciation from LGM limits from those associated with later Holocene glacier fluctuations. Evidence included geomorphological descriptions of glacial landscapes, radiocarbon dated basal peat and lake sediment deposits and cosmogenic isotope ages of glacial features. We propose a classification of the glacial history of the maritime and sub-Antarctic islands based on this assembled evidence. These include: (Type I) islands which accumulated little or no LGM ice; (Type II) islands with a limited LGM ice extent but evidence of extensive earlier continental shelf glaciations; (Type III) seamounts and volcanoes unlikely to have accumulated significant LGM ice cover; (Type IV) islands on shallow shelves with both terrestrial and submarine evidence of LGM (and/or earlier) ice expansion; (Type V) Islands north of the Antarctic Polar Front with terrestrial evidence of LGM ice expansion; and (Type VI) islands with no data. Finally, we consider how this knowledge of glacial history corresponds with current data on biodiversity and endemism.

## Carbon chemistry during the early autumn in the Ross Sea, Antarctica: Implications for carbon export and Ocean Acidification state

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Stanford

In order to understand how climate change will impact the efficacy of the biological pump, it is important to understand the mechanisms and rates of carbon export into deeper waters. Although the Ross Sea sustains high levels of biological productivity and is an important site of Antarctic Bottom Water formation, the efficacy of the biological pump in this region is poorly understood in part because until now there had been no carbon system process cruises in the Ross Sea during the early fall, a critical period when sea ice returns and sediment trap data indicate increased carbon flux to depth. In addition there is a lack of baseline aragonite saturation state measurements to help assess how (and how quickly) Ocean Acidification will impact this dynamic ecosystem.

Here we present the first total alkalinity, pH, dissolved  $O_2$ ,  $pCO_2$ , dissolved inorganic carbon (DIC), and dissolved and particulate organic carbon measurements ever made during the early autumn (Feb/March 2013) in the Ross Sea. We resurveyed the  $76^{\circ}30'$  line that had been sampled during the spring and summer on many previous cruises and we repeatedly sampled three areas that had the highest chlorophyll concentrations during cruise NBP 1302. Along the  $76^{\circ}30'$  line we estimated carbon export for early March 2013 by comparing DIC deficits to the standing stock of organic carbon. Our data indicates continued carbon export between March and April along the  $76^{\circ}30'$  line well after peak primary productivity. In addition the greatest carbon export occurred at Terra Nova Bay. Since Terra Nova Bay is a major source of High Salinity Shelf Water that ventilates the deep ocean, it may represent a significant long term carbon sink that is vulnerable to rapid change if the bordering Drygalski Ice Tongue collapses. Our total alkalinity measurements suggest minimal calcification/dissolution, with implications for interpreting sediment trap time series. Finally our data shows that surface water aragonite saturation state is highly variable ( $\Omega=1.3-2.4$ ) and is largely influenced by biological production.

## Particle fluxes in the Ross Sea: a 20-year synthesis

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We show a synthesis of 20 years of particle flux studies in the Ross Sea based on a compilation of all existing time series sediment trap data and highlight some of the important features and unresolved issues related to integrating particle trap interceptor data with other measures of production, transport and deposition.

Simple sediment traps were first deployed in 1984 and 1986 in the Ross Sea. Since then, USA and Italy have recovered time series sediment trap data on moorings in different regions of the Ross Sea.

This current synthesis makes use of data from approximately 23 sites, and includes about 1000 discrete samples of particles in vertical transit through the water column.

We now have many complete time series that extend through the winter, allowing several important generalizations to be made. For example, annual particle-mediated organic C fluxes to below 200 meters in the Ross Sea average  $4.4 \pm 3.3 \text{ g C m}^{-2} \text{ yr}^{-1}$ . These values are significantly less than export fluxes calculated using short-term surface water mass balance approaches or Th isotope techniques, yet are higher than seabed sediment accumulation rates. Intriguingly, seasonal seabed arrival rates of organic C estimated from in-situ summertime benthic respirometry studies yield C flux values similar in magnitude to those from sediment traps deployed at the same time, lending strong support to trap data. The cause of current disagreements between various methods of flux estimation may in fact not be solved until process studies are accomplished that extend through the austral autumn into winter and/or the biogeochemistry of Th is better understood in coastal area of the Southern Ocean. Nearly all Ross Sea particle flux time series show relative low sedimentation during the periods of highest primary production in surface waters followed by either events or periods of enhanced sedimentation during the latest austral summer and/or autumn.

This high degree of decoupling between production and sedimentation is unusual and may well represent low grazing rates. It is likely that purely physical phenomena associated with the return of winter sea ice are responsible for enhanced autumn sedimentation in the Ross Sea. Compared to the Ross Sea region, biogenic fluxes in the Palmer Basin area of the Antarctic Peninsula are higher, but are more tightly coupled to productivity in surface waters.

## Geothermal activity helped life survive past glacial periods in Antarctica

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Geothermal activity, which can maintain ice-free terrain in glaciated regions, provides a tantalising solution to the question of how diverse life might have survived glacial periods in Antarctica. The continent has experienced repeated glaciations that most models indicate almost completely blanketed the continent in ice, yet many Antarctic species appear to have evolved in isolation for millions of years and hence must have persisted in Antarctica during glacial maxima. Under a hypothesis of geothermal glacial refugia and subsequent recolonisation of non-geothermal regions, we would expect to find greater contemporary diversity close to geothermal sites than in non-geothermal regions, and significant nestedness by distance of this diversity. We used spatial modelling approaches and the most comprehensive, validated terrestrial biodiversity dataset yet created for Antarctica to assess spatial patterns of diversity (estimated species richness) on the continent. Models clearly support our hypothesis, with the best models indicating higher species richness at geothermal versus non-geothermal sites for both plants and fungi, indicating that geothermally active regions have played a key role in structuring biodiversity patterns in Antarctica. These results provide critical insights into the evolutionary importance of geothermal refugia and the history of Antarctic species.

## Holocene paleolimnological changes in Lake Maruwanminami-ike of the Soya Kaigan in East Antarctica

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Studies on paleolimnological and paleoenvironmental changes are important to estimate the possible influence of future global warming induced by human activity. Since the Last Glacial Maximum (LGM, ca.21 ka) geological evidence from land in the Antarctic shows that there were two marked warm periods in the Holocene, one in the 11,500-9,000 years ago, and one in the mid-Holocene called the mid-Holocene Hypsithermal (MHH, 4,000-2,000 years ago). Here we studied Holocene paleolimnological changes inferred from biomarkers and microscopic observation of microalgae and cyanobacteria in a sediment core from Lake Maruwanminami-ike (MwS4C-01, core length 147 cm) in the Soya Kaigan of East Antarctica, along with sedimentary facies and <sup>14</sup>C dating by a Tandetron accelerator mass spectrometry.

The MwS4C-01 core was composed of clayish mud containing laminae between 147-65 cm. This was overlain by organic sediments containing algal mats between 65-0 cm. The mean sedimentation rate and uplift rate were estimated to be 0.78 mm/y and 7.4 mm/y, respectively. The crustal uplift rate of Lake Maruwanminami-ike basin is much greater than those of Lake Oyako-ike (2.2 mm/y) and Lake Skallen Oike basins (2.8 mm/y) in the Soya Kaigan as well as those of lakes in the Lambert Glacier region (1.8-1.9 mm/y) and Vestfold Hills region. Older age (1,150 cal BP) of the core top may be explained by the contribution of glacial clay containing old carbon and/or dead carbon through glacial melt water from the catchment area. The coastal marine period (147-65 cm, 4,800-2,400 cal BP) in Lake Maruwanminami-ike is characterized by low biological production with the predominance of diatoms, while the lacustrine period (65-0 cm, 2,400-1,150 cal BP) is characterized by high biological production with the predominance of cyanobacteria (*Leptolyngbya* spp. and *Nostoc* spp.) and green algae (*Cosmarium clepsydra*). The transition zone from a marine inlet to a freshwater lake was characterized by chemically stratified conditions with the presence of green sulfur bacteria at a depth of 67.8 cm in the bottom of photic zone.

## The Geochemistry of Soils in the Beardmore Glacier Region: Implications for Terrestrial Ecosystem History and Development

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We have analyzed a series of soil samples from different elevations at three locations along the Beardmore Glacier in the Transantarctic Mountains (in order of increasing elevation): Ebony Ridge (ER), Cloudmaker (CM) and Meyer Desert (MD). Bulk soils were analyzed via XRF for their major element geochemistry. Aliquots were also water leached and analyzed for their element/salt concentrations and also nitrate was isolated and its N and O stable isotopic composition was determined. The chemical index of alteration suggests that the samples from the highest elevation site, MD, are the least weathered while the samples from the lower elevation site, ER, are the most weathered. This observation may be related to the availability of liquid water, which appears to be most limited at higher elevation. This conclusion is supported by the leachable salt data as well with MD soils having the highest TDS, and the lower elevation sites at ER and CM having the lowest TDS. MD samples are dominated by nitrate salts ( $\text{NO}_3/\text{Cl}$  ratios > 10) that can be observed in SEM photographs. High  $\delta^{17}\text{O}$  and  $\delta^{18}\text{O}$  values of the nitrate indicate that its source is solely atmospheric origin. It is suggested that nitrate concentrations in the soil may be utilized for age determinations to better assess, not only invertebrate habitat suitability, but also issues related to biogeography and the timing of organism dispersal. We conclude that the highest elevation sites at MD have been exposed soils for the longest times, but because of the salt accumulations may not have been suitable as invertebrate refugia during the LGM.

## The deglaciation of the Byers Peninsula (Livingston Island, Maritime Antarctica) reconstructed from lake sediment records

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The South Shetland Islands are an archipelago at the northwestern tip of the Antarctic Peninsula. Although more than 90% of the land surface of the largest islands is covered by glaciers, the process of deglaciation during the Holocene has created several ice-free areas at the margins of the largest islands.

The Byers Peninsula is the largest ice-free area in this archipelago (ca. 60 km<sup>2</sup>), located in the westernmost part of Livingston Island. It is an Antarctic Special Protected Area (ASPA 126) with one of the highest biodiversities in Antarctica (Antarctic Treaty Secretariat, 2003). The relief of the Byers Peninsula includes a series of large beaches surrounding a relatively flat plateau that has a mean altitude of 80 m asl and contains numerous lakes and other aquatic habitats. As part of the HOLANTAR project, sedimentary sequences were retrieved from four lakes (Chester, Escondido, Cerro Negro and Domo lakes) along an E-W transect from the Rotch Glacier to the west coast of the Peninsula, following a hypothetical route of the deglaciation process. These records, combined with the sediment record of Lake Limnopolar (retrieved in November 2008; Toro et al., 2013), will form the core of the HOLANTAR multiproxy characterization (geochemistry, diatom and chironomid remains) that will establish the detailed deglacial evolution of this key area.

In each lake we recovered the entire Holocene record, reaching basal till deposits, allowing inferences to be drawn about the date of formation. A complete chronological model for all the lakes is being constructed based on several dating techniques (<sup>14</sup>C, OSL, <sup>210</sup>Pb, tephrochronology). According to preliminary results, the deglaciation of the Byers Peninsula started at its western margin in the Early Holocene, followed by the deglaciation of the central plateau during the Mid-Holocene. The lakes distributed next to the present-day glacier front are the most recent ones. The ongoing dating analysis will improve our understanding of the deglaciation process and the postglacial environmental evolution of the Byers Peninsula. These data will also help to refine the regional tephrochronology and better understand Holocene environmental change in the Antarctic Peninsula region.

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## Impact of deglaciation and Holocene climate change on lake ecosystems of the South Shetland Islands

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The western Antarctic Peninsula (WAP) is located in one of the fastest-warming regions on Earth, and is a key area for studying the impact of changing climate on glacier dynamics, sea level and terrestrial and marine ecosystems. As part of the BAS and AWI-IAA-ICBM IMCOAST and IMCONET research programmes, we investigated relative sea level change and bio-geochemical sedimentation processes on Fildes Peninsula and Potter Peninsula, South Shetland Islands. Using lake sediment records from Fildes Peninsula, and recently collected lake, and terrestrial samples from Potter Peninsula, we have: (1) improved existing, and produce new, relative sea level curves for the South Shetland Islands; (2) studied present and past bio-geochemical characteristics of lacustrine and terrestrial sediments on Fildes and Potter Peninsulas; (3) examined rates of deglaciation, and deglaciation-related changes on Fildes and Potter Peninsula, and the erosion of terrestrial deposits into Potter Cove and Maxwell Bay; (4) developed new lacustrine biomarker-based temperature proxies in an attempt to quantify past changes in temperature. Here, we summarise some key findings, including past lake ecosystem and penguin population response to Holocene deglaciation and climate/oceanographic-change across the WAP region. We show that elevated inorganic 'bio'-elements associated with penguin guano were found in lake sediments from Ardley Island during some, but not all, 'warmer' periods of the last c. 9,000 years, and highlight how changes in relative sea level, and volcanic activity could have influenced the distribution of this and other penguin colonies across the WAP.

**645. Coupling settlement time and growth rates of the Antarctic scallop *Adamussium colbecki* (Smith, 1902) with hydrological time-series: a caging experiment on an oceanographic mooring at high latitudes**

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Model organisms and bioindicators are organisms that are amenable to experimental manipulation and have well studied ecologies. Several invertebrate species, especially bivalves, possess these characteristics and are widely used in biomonitoring studies.

Whenever an indicator species is required in a study area, the biomonitoring study can indeed be performed by translocating specimens from a close source area to the monitored one and by keeping these in submerged cages attached to lines moored on the bottom and stabilized by mid-water or surface buoys.

Under the PNRA (Italian National Program for Antarctic Research) "Polar DOVE" (*Variability of abyssal polar ventilation and its impact on the global circulation*) research program (2005-2006), we have realized a caging experiment in order to evaluate: i) the feasibility of a caging experiment with an Antarctic organism with a carbonatic skeleton (in order to use it as a biological proxy for sea water temperature, cross-validated with the instrumental record of temperature by mooring sensors) and ii) the survival and growth performances of the species after one year in the cage.

The species selected for this experiment was the thin-shelled Antarctic scallop *Adamussium colbecki*, a species that can be obtained in quantities at diving depths at the Italian Base at Terra Nova Bay (Mario Zucchelli Station) and has a certain degree of trophic flexibility.

Sixty *A. colbecki* were then caged on an oceanographic mooring by using two 'lanterns' for oyster farming protected by a specially designed PVC case. The mooring was deployed on January 2006 on a 145 m depth bottom and recovered, thanks to acoustic release technology, after 380 days of permanence at sea.

Thanks to the simple but effective design of the cages, the experiment was highly successful and most *A. colbecki* specimens, despite a thin shell, were not damaged at all. 58 specimens out of the 60 caged were retrieved fully vital and healthy, and had a growth performance perfectly comparable to the specimens living *in situ*.

Despite the cross validation of temperature data is still underway, our experiment demonstrates the feasibility of such a caging experiment even at high latitudes and extreme conditions and suggests another use of mooring structures that can represent a platform for caging experiments dedicated to several research fields.

## Seasonally varying dominance and roles of macrozooplankton determined from bio mooring arrays in Amundsen Sea, Antarctica

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Rapid oceanic melting of the ice shelf as well as highly productive polynyas make the Amundsen Sea an ideal environmental setting for investigation of the impacts of climate change in the western Antarctic. Hull mounted acoustics and net samples indicates that euphausiids and other copepods dominate the mid trophic web in this water. They can reach a high level of abundance, exerting significant grazing pressure on the enhanced phytoplankton production during summer. High-temporal resolution profiles of acoustic backscatter collected from a bottom-moored, upward-looking Acoustic Doppler Current Profiler were examined to describe the seasonal pattern in the behavior of biological sound scattering layers while the solar radiation (SSR), sea ice concentration (SIC), and Circumpolar Deep Water (CDW) thickness varied. During summer, dispersed scatterers exhibited a pronounced diel vertical migration whereas much stronger acoustic signals remained close to the bottom (>400 m) during winter. The depth of the maximum mean volume backscattering strength correlated with SSR, SIC, and CDW thickness ( $r^2=0.79$ ,  $p<0.001$ ). The light intensity, largely determined by the sea ice cover, appears to be the principal factor governing this pattern. Fecal material from a sediment trap deployed nearby implies a highly pulsed feeding by krill and other zooplankton during summer. This can be translated to a strong downward carbon flux mediated by macrozooplankton and it should remove a substantial portion of primary production in the polynya from the euphotic layer.

## Particulate barium flux and its relationship with export production on the continental shelf of Prydz Bay, east Antarctica

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Particulate barium fluxes on the continental shelf of Prydz Bay in east Antarctica were measured by using time series sediment trap deployed at two stations with trap depth about 500m during 7/12/2009~15/2/2010 and 16/12/2010~16/12/2011. The annual fluxes were  $12.3 \text{ mg m}^{-2}\text{yr}^{-1}$  and  $18.4 \text{ mg m}^{-2}\text{yr}^{-1}$  for barium, and  $8.9 \text{ mg m}^{-2}\text{yr}^{-1}$  and  $14.9 \text{ mg m}^{-2}\text{yr}^{-1}$  for biogenic barium at two stations, respectively. More than 72% of the barium is from biogenic source. The temporal-spatial variations of biogenic barium flux and the ratio of biogenic barium to organic carbon are related to the variation of organic matter export in the upper water column. Biogenic barium flux and organic matter export are generally positive correlated. However, biogenic barium precipitation is less efficient under conditions of high organic matter exports during times of greater primary productivity, which leads to relatively less cycling of organic carbon and in turn produces less barite formation based on the hypothesis that barite forms through organic matter decomposing in microenvironment. More than 72% of the rained biogenic barium at the trap depth was preserved in the sediment. High preservation efficiency of biogenic barium and good relationship between biogenic barium and organic carbon suggested that biogenic barium could be a reliable proxy for the marine export production. The calculated export productions are  $6.9 \text{ g C m}^{-2}\text{yr}^{-1}$  and  $14.9 \text{ g C m}^{-2}\text{yr}^{-1}$  at two stations respectively using the modified prediction equation, which is more suitable for predicating export production for margin and shelf systems.

## Cryoconites: Refugia for biota during glacial maxima?

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Cryoconites are small, but numerous, aquatic aquaria enclosed in the surface ice of glaciers, which collectively make up an important part of the liquid water and biomass of inland Antarctica. They form when solar-heated surface sediments melt down into glacial ice. They may freeze solid in winter, but contain meltwater during the summer months, while retaining a partial or complete (usually 10-20cm thick) ice cover.

The geochemistry and microbial diversity of Antarctic cryoconites has been studied over a range of latitudes, elevations and distance from open seawater in Victoria Land, to establish whether these environments would be suitable refuge for biota (particularly micro-biota) during the glacial maxima, when terrestrial soils and liquid water environments would have been scarce. 45 cryoconites from the Darwin and Diamond Glaciers (Lat 80°S), the upper and lower Koettlitz Glacier (Lat 78°S), and the Wright Valley Glaciers (Lat 77°S) have been sampled, as well as the host ice and any associated surficial snow.

In Victoria Land, the most common cryoconites were all physically similar, typically perfectly cylindrical holes, less than 1m diameter, approximately 0.5m cm deep and containing 1.5-3 kg of sediment. However, water chemistry was highly variable; pH ranged from 4.8 to 11.9, conductivity from 0.006 to 4 mS/cm, and nutrients from below detection to 367 µg/L DRP and 5810 µg/L NO<sub>3</sub>-N. Major anion shifts from SO<sub>4</sub><sup>-</sup> and NO<sub>3</sub><sup>-</sup>-dominated inland, to Cl<sup>-</sup>-dominated in cryoconites closer to open seawater; a trend particularly evident along the length of the Koettlitz Glacier. Isotopes (tritium, oxygen and deuterium) confirm the origin of the meltwater in the cryoconites as old glacial ice, rather than more recent surface snow.

This geochemical diversity does influence whether cryoconites can provide a suitable habitat for some, but not all, microbial organisms. Bacteria-specific automated ribosomal intergenic spacer analysis (ARISA) of the sediments from these cryoconites indicates that bacterial diversity is directly affected by pH and cryoconite size. Cyanobacteria community composition, however, is not influenced by cryoconite size, pH or geographic location. This is consistent with previous observations of the high degree of tolerance of Antarctic cyanobacteria to a wide range of environmental conditions and transportation mechanisms.

## Diatom distribution and community composition variability on the seafloor in a naturally iron fertilised region of the Southern Ocean

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The Kerguelen Island annual phytoplankton bloom is a naturally produced biological phenomenon in the otherwise High Nutrient, Low Chlorophyll Southern Ocean. Investigations under the KEOPS (**KE**rguelen: compared study of the **O**cean and the **P**lateau in **S**urface water) mission in 2005 found the bloom is caused by high iron concentrations in the surface waters during spring. In this study, seafloor samples from the second KEOPS mission (2011) at seven new locations around Kerguelen Island were analysed, and compared to 21 samples from existing databases in an attempt to confirm the biogeographic signature of diatom distributions and their relationship to the bloom. Of the 56 diatom species encountered across all samples in this study, the distributions of the top five species (~89% of total abundance) were compared with 'physico-chemical' and 'preservation' factors (sea surface temperature, sea floor depth, distance from the island and mixed layer biogenic silica). The relative importance of these factors to diatom distributions was both species and site-specific. *Fragilariopsis kerguelensis*, the most abundant species in the Southern Ocean, showed a preservation-controlled distribution, and was strongly associated with deep-water, non-bloom sites. *Thalassionema nitzschioides* var. *nitzschioides* abundance and geographical distribution was also preservation-related, with distributions restricted to the Island coastline. *Chaetoceros* resting spores distributions were believed to be iron-related, as they were found mostly in the bloom regions, while *Eucampia antarctica* and *Thalassiosira lentiginosa* showed a combination of preservation and physico-chemical controls. Absolute diatom abundance, species diversity and evenness were found to be higher on the Kerguelen Plateau than at surrounding sites.

## Arctic planktonic foraminifera under the stress of climate and ocean chemistry changes in the past and present

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Multiple stressors and their interactions are generating substantial challenges for marine organisms. The most influential stressors are climate changes and associated ocean acidification. Many calcareous organisms may show adverse effects to ocean acidification as their ability to calcify and maintain shells is reduced. Planktonic foraminifera constitute one of the major groups of calcareous marine microplankton. Their shells are highly sensitive to changes in carbonate chemistry, sea surface conditions, and preservation shifts in sedimentary records. This sensitivity makes them one of the most prominent sources of knowledge on past changes in ocean chemistry, climate and ocean circulation.

In the Arctic Ocean, acidification occurs faster than the global average because cold waters absorb more carbon dioxide than warm water and melting sea ice enhances the process by lowering the carbonate ion concentration. In the Fram Strait, the European part of the Arctic Ocean, sea ice and water masses of contrasting properties interact. The eastern Fram Strait is occupied by warm and saline Atlantic waters, whereas the western Fram Strait is dominated by cold and fresher Polar water and sea-ice. The central Fram Strait is dominated by Arctic surface water where Polar and Atlantic waters mix. The three different water masses generate oceanic fronts causing additional environmental stress factors for surface water dwelling planktonic foraminifera.

Samples from zooplankton nets, sediment traps, surface sediment and sediment cores from the central and eastern Fram Strait were used to investigate the effects of the changing arctic environment on planktonic foraminifera. The distribution patterns of fossil and living planktonic foraminifera show strong variability. Preliminary results indicate that sites in the eastern Fram Strait, which are influenced by Atlantic water masses, and sites in the western part show abundant planktonic foraminifera with well-preserved and comparatively heavy shells. These stations show relatively high concentrations of *Turborotalita quinqueloba*. In the central Fram Strait, influenced by Arctic waters masses the polar species *Neogloboquadrina pachyderma* dominates and the preservation of foraminiferal shells is poor and shell weight low.

## S24: ANTERA MACRO TO MICRO ADVANCES IN UNDERSTANDING ANTARCTIC FUNCTIONING

### Estimating ecosystem properties based on incomplete weighted diet data for the Scotia Sea food web

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A trophic interaction takes place when an individual of one species eats another individual of a different or its own species. A food web is a network made by connecting these interactions. Topological network properties summarize the complexity, prevalence of species and diversity of feeding interactions within the food web. These measures are used in food web theory to identify consistent and contrasting patterns between ecosystem types, to describe variation and change within an ecosystem over time, and to connect food web properties to ecosystem stability and function.

Food web construction is limited by available empirical data. As a result, three major criticisms of topological properties arise: (i) they are biased by sampling effort, (ii) they may not account for the strength of interaction between species and, (iii) they are biased by differing levels of species aggregation.

We addressed these criticisms using data from the Scotia Sea food web. First, we collated the most comprehensive available set of quantitative diet data from disparate predator studies collected within the Scotia Sea. Using the diet proportions as a measure of interaction strength, we calculated a quantitative set of topological network properties. Second, we added closure groups, to eat and be eaten by species which had missing predators or diet data. This improved estimates of many network properties thought to be relevant to ecosystem function, particularly the percentage of species which are both predators and prey and the predator-prey ratio. Third, we performed stepwise aggregation on the food web, to test the effect of the degree of aggregation on the set of quantitative and binary network properties. We found that adding closure groups delayed the aggregation of species from different trophic levels.

By introducing closure groups to improve estimates for the trophic position of some under-sampled species, we demonstrated that it is possible to obtain plausible estimates for some binary and weighted topological network properties. Aggregating species in a food web resulted in the system appearing more robust to change because of aggregation-induced changes in topological properties which have been linked to food web stability.

**Can the genetic variability of *Gomphiocephalus hodgsoni* (Collembola) be used to monitor subtle biotic responses to climate change?**

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Springtails are the largest, year-round inhabitants of terrestrial Antarctica. They are particularly abundant in the Dry Valleys, which is the largest ice-free area of Antarctica. To survive cold winter air temperatures, springtails produce antifreeze proteins to lower their freezing point to below that of ambient environmental temperatures. By investing in the production of cryoprotectants, they enter a state of dormancy and are effectively inactive during winter. Physiological studies have shown that there is considerable variation in the cold tolerance of *Gomphiocephalus hodgsoni*, the most widespread springtail species in the Dry Valleys. For example, one individual survived to minus 38°C whereas another individual from the same time/location survived to minus 13°C. There is also considerable genetic variation among *G. hodgsoni* individuals, with over 40 genetic haplotypes recorded for the mitochondrial cytochrome *c* oxidase subunit 1 (COI) gene. Accordingly, we tested the hypothesis that the *G. hodgsoni* mitochondrial haplotypes would correspond to variation in cold tolerance. Individuals that delay cryoprotectant production ('warm-adapted'), and therefore delay the onset of dormancy, will have an extended summer period for growth and reproduction. These individuals may then have a selective advantage over individuals who produce cryoprotectants earlier in the season ('cold-adapted'). Of concern is whether this will result in the warm-adapted springtails eventually out-competing those adapted to colder conditions, thereby reducing overall levels of genetic diversity. During the 2013/2014 season we used pitfall traps to collect over 300 *G. hodgsoni* individuals from Taylor Valley. Measurements of ground temperatures (surface and sub-surface) as well as soil moisture, and photosynthetically-active radiation were taken. Sub-surface ground temperatures during time of collection ranged from 9°C to minus 1.5°C, and more springtails were collected during the warmer periods. Individuals of *G. hodgsoni* were returned to New Zealand and are being sequenced at the COI gene locus. COI haplotype diversity will be correlated with environmental temperatures at time of collection to determine any difference in haplotype frequencies relative to warmer or colder temperatures. We aim to determine whether individuals can be associated with warmer or colder conditions, based on their mitochondrial COI gene sequence. Genetic diversity of populations could then be monitored over time as part of developing observation networks (e.g. AntGEM, AnTOS) as a subtle measure of the effects of global climate changes.

## Cold fusion: Massive karyotype evolution in the Antarctic bullhead notothen *Notothenia coriiceps*

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Most Antarctic Notothenioid fish have 24 haploid chromosomes but the marbled rockcod *Notothenia rossii* has 12 and its congener, the bullhead notothen *N. coriiceps*, has just 11. How did this rapid karyotype evolution occur? Under the “Robertsonian-translocation hypothesis”, each of the 24 ancestral haploid chromosomes fused with just one other chromosome to produce 12 chromosomes in the *N. rossii* lineage followed by another fusion in the *N. coriiceps* lineage. Under the “genome-stirring hypothesis”, a large number of reciprocal translocations, non-reciprocal translocations, chromosome fusions, and inversions greatly mixed the karyotype to end up with half or fewer of the original number of chromosomes. Intermediate models between these extremes are, of course, possible. To test these hypotheses, we made a meiotic genetic map of *N. coriiceps* using polymorphisms present in RAD-tags, which are Illumina-based 100 nucleotide long sequences adjacent to cutting sites for the 8-base pair cutter *SbfI*. The linkage map contains about 10,000 polymorphic markers, which were compared in translating BLAST searches to the sequenced genomes of the platyfish *Xiphophorus maculatus* and the threespine stickleback *Gasterosteus aculeatus*, each of which has the ancestral 24 chromosomes. BLAST searches revealed putative orthologs and map locations defined conserved syntenies. Results identified about a thousand orthologs and revealed that nine of the eleven *N. coriiceps* chromosomes were represented by the fusion of a single pair of ancestral chromosomes. For example, chromosome Nco1 (*N. coriiceps* linkage group 1) is a fusion of Xma5 (*X. maculatus* linkage group 5, which is the same as GacIX, *G. aculeatus* linkage group 9) and Xma9 (GacVIII). These ancestral chromosomes were fused intact, without the mixing of markers from the two chromosomes in either outgroup. Two *N. coriiceps* chromosomes (Nco2 and Nco4), however, consisted of the fusion of three ancestral chromosomes. For example, Nco2 consisted of Xma17 (GacIV), Xma13 (GacX), and Xma21 (GacXXI). The most parsimonious evolutionary scenario is that the *N. coriiceps* karyotype originated in two steps from the ancestral percomorph karyotype of 24 chromosomes. First, chromosomes fused in pairs and only pairs in Robertsonian fusions of centromeres to reduce the karyotype from 24 to 12 chromosomes, likely similar to what is currently found in *N. rossii*. Second, two of the doubled chromosomes broke in two at the new centromere and the two arms (each arm representing an entire ancestral chromosome) joined a pre-existing fused pair to make Nco2 and Nco4, causing the karyotype to go from 12 to 11 chromosomes. An outstanding question is the selective forces that drove, systematically and in a short period of evolutionary time, the regular fusion of chromosome pairs – and initially only pairs – in this Antarctic fish lineage with few subsequent inversions to stir gene orders.

## Fungi DNA isolation and purification with two manual protocols of a collection of Scientific Station Pedro Vicente Maldonado Antarctica - Ecuador

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The extraction of DNA in microfungi species of the scientific station Pedro Vicente Maldonado Ecuador, is difficult because of different properties of the samples, such as an oxidation, large amounts of chitin, natural pigments and complex molecular structures (polysaccharides). Two laboratory methods of DNA extraction were used: 1) Enzymatical lysis with Proteinase K and a combination of a deproteinization method based on complex formation (CTAB) and the use of organic solvents (Phenol:chloroform isoamyl alcohol - Ph:CIA). Following, precipitation of DNA with alcohols; and 2) Chelating ion exchange resin consisting of Chelex® 100 and Proteinase K. For sample preparation a pretreatment was necessary. All samples were overnight incubated using Buffer H containing sucrose and detergents to facilitate the lysis. Afterwards, using a battery micromorter (Kontes, Vineland, NJ) the samples were homogenized. The quantification of the DNA was performed by spectrophotometric analyzes of the samples. Finally, White et al. (1990) reported a PCR protocol we used to amplify a ≈600 bp region utilizing the primers ITS1 and ITS4. The amplicons were visualized by electrophoresis on SYBR Safe DNA-stained 2% (w/v) agarose gel. Expected bands were clearly visible and sharply differentiable. In all PCR reactions, as positive control referring samples of already identified species have been used in every PCR. The Ph:CIA method is widely used in several studies but the toxicity of the components creates problems for the operator. Additionally, residues of phenol generate inhibitions in the PCR. During the quantifications the samples showed traces of phenol and low concentration of proteins. The Chelex protocol used small amounts of sample because the efficiency of the resin was reduced by excessive amounts. In addition, the manipulation times in the laboratory were too different, needing approximately six hours for the Ph:CIA method and two hours for the Chelex method.

## Seabed characteristics under the extinct A and B sections of the Larsen ice shelf: a slow awakening

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In 1995 and 2002 several hundreds of km<sup>2</sup> of the sections A and B of the Larsen ice shelf collapsed due to anthropogenic climate warming. These disintegrations enabled primary production to develop at the sea surface over the continental shelf after hundreds of years of ice shelf coverage. Consequently, there is an ongoing flux of relatively fresh organic matter arriving onto the seabed. Here we present results on phytopigment and radio chemical analyses that demonstrate that this flux is changing the chemical characteristics of the upper sediment column and the composition of the benthic communities dwelling there. On the one hand, Chlorophyll-a concentrations showed that the amount of fresh organic matter is relatively small, whereas on the other hand the <sup>210</sup>Pb and <sup>14</sup>C indicate that the flux is very slow. We propose that, as a consequence of this slow pace, no significant differences were found in the amount of phytopigments and radionuclides among regions A and B despite section A collapsed almost a decade earlier than section B. It has been speculated that the region will turn into a carbon sink area; however, it may take decades to really achieve such status.

## Surface carbon dioxide fluxes in Sub-Antarctic ecosystems

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Field studies were conducted in February and March 2008 in the vicinity of the Russian station "Bellingshausen" (62°12' S, 58°57'40" W, 22 - 48 m asl) on the Fildes Peninsula (King George Island, West Antarctica). CO<sub>2</sub> flows were measured with a portable infrared gas analyzer «Gas-Tech» (Japan) at a resolution of 25 ppm, in the cylindrical chambers 10 cm in diameter and 20 cm in height. Measurements were carried out in the most common types of plant communities: (a) separate spots of fruticose lichens on dry gravelly hills and stones (*Hinantormia lugubris* - *Usnea aurantiaco-atra* with moss *Andreaea gainii* Card.), (b) continuous moss mats and cushions in wet depressions (*Bryum orbiculatifolium*, *Warnstorfia sarmentosa*, *Sanionia uncinata*, *S. georgico-uncinata*, *Brachythecium austrosalebrosum*), (c) algo-bacterial mats and (d) community with the dominance of the grass *Deschampsia antarctica* with mosses *S. georgico-uncinata*, *Bryum pseudotriquetrum*, *Polytrichastrum alpinum*, *P. piliferum*. Continuous permafrost was detected at a depth of 35 to 70 cm. Fluxes of CO<sub>2</sub> emissions were recorded in all habitats and ranged from 0.58 to 134 mg C m<sup>-2</sup> h<sup>-1</sup>. Gross primary production (GPP) flow was not detected at a vegetation-free ground. In habitats with pronounced vegetation the GPP values were higher than those of ecosystem breathing (EB) during a daytime – the sequestration of atmospheric C took place. The greatest values of GPP and EB were detected for tussock communities of *Deschampsia antarctica*. For comparison, in the Antarctic Dry valleys, in extreme conditions, close to Mars, the CO<sub>2</sub> fluxes at the surface soils fluctuated from -4.3 to +6.5 mg m<sup>-2</sup> h<sup>-1</sup> (Parsons et al., 2004). The obtained results give the reason to conclude that the local plant-bacterial communities have a strong trend towards an increase in the EB response even to a small increase in temperature. It can be related to an adaptive strategy for species under conditions of extreme deficit of a heat. GPP and EB of moss communities are 4 times lower than that of communities of *Deschampsia antarctica*. However, mosses predominate among phytocenoses area, accounting for no less than 0.5% of the area of the island, and about 6% of its ice-free territory. These communities also exhibit significant sequestration of carbon (0.4 g C m<sup>-2</sup> day<sup>-1</sup>). In spite of the very high (for cryogenic communities) values of GPP and EB during the growing season the Fildes Peninsula is generally weak, but significant source of C- CO<sub>2</sub> to the atmosphere. This is due to the fact that a large part (95%) of an area is occupied by a barren ground, which contributes only in the EB. This area average value is about 0.01 g C m<sup>-2</sup> day<sup>-1</sup>.

## Response capacities of sub-Antarctic endemic species to climate change

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The sub-Antarctic islands are facing rapid and intense climate change but their isolation also means that dispersal between islands is unlikely to offer an escape route for their floras. Instead the plants on these islands will need to adapt in order to survive. Autochthonous plant species from the Kerguelen Islands are adapted to harsh ecological conditions that include low temperatures, consistent rainfall, and salt spray. These species, especially when growing close to the extremes of their ecological range, may be particularly sensitive to climate change and indeed already exhibit signs of stress during dry summer periods.

In our previous studies we found that species endemic to the Kerguelen province exhibit strong phenotypic integration (i.e. their traits are strongly correlated). Such integration may limit their ability to respond to climate change. The current study focuses on patterns of trait variability and phenotypic integration across abiotic and biotic gradients. Our aim is to estimate the capacity for plastic and adaptive responses in sub-Antarctic plant species.

We performed in situ measurements and experiments in controlled chambers. We measured plant traits and metabolites in situ in populations occupying habitats that differed in both abiotic (pH, conductivity, water saturation) and biotic (diversity of surrounding community) parameters. Populations growing in different environmental conditions show differences in both levels of trait variability and phenotypic integration. We also examined the interactions between these two components and the environment. Experiments characterized tolerance to different combinations of abiotic conditions (light, temperature) using seedlings grown from seed collected on the Kerguelen Islands and those from plants cultivated in growth chambers. We determined trait variability and phenotypic integration within and between populations grown under different conditions.

The significance of phenotypic integration in determining a species ability to adapt to environmental change is not known yet. This goal requires further analyses to determine the relationship between phenotypic integration and plant performance. Understanding this relationship will help to predict the outcomes of climate change for Kerguelen plant species. Considering that environmental changes are more severe at higher latitudes, these insights could be important for the conservation of autochthonous sub-Antarctic species.

## **New results on benthic functions north and east of the Antarctic Peninsula - will they change with benthic community dynamics or food supply?**

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Resolving the main drivers of ecosystem functions is still an unresolved issue in marine ecology. The prevailing current opinion is that functions are largely determined by diversity patterns. Recent results from the Arctic suggested, however, that food supply rather than diversity influences benthic functions, such as remineralisation dynamics (nutrient and oxygen fluxes across the sediment-water interface). Hence, the question arises, whether this pattern is also found in the Southern Ocean, and how benthic systems will respond to environmental variability caused by the loss of ice shelves in response to climate change.

We used an experimental approach to test the influence of an increase in macrofaunal abundance and food supply on benthic functions (nutrient and oxygen fluxes across the sediment-water interface) in soft-sediment habitats around the Antarctic Peninsula. In parallel, we assessed the same benthic functions *ex situ* in regions of different environmental regimes in the Southern Ocean around the Antarctic Peninsula. Here, we present first results on regional differences of benthic processes in the northwestern Weddell Sea, Bransfield Strait and north of the South Shetland Islands, and how these processes may vary with the expected changes in benthic faunal composition and productivity regime. Our results provide new insights on the role and functioning of benthic habitats for ecosystem processes in the Southern Ocean.

**Bottom-up and upside-down: assessment of algal productivity on the underside of coastal sea ice, and the processing of detrital algal food pulses by benthic soft-sediments**

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NIWA

Coastal marine ecosystems in the Ross Sea are dynamic and diverse, with distinct zones of primary production and secondary consumption. In spring, when the water column beneath sea ice contains very little phytoplankton, highly concentrated diatom films can be observed on the underside of the ice and covering the seafloor. The under-ice habitats may be more productive due to higher light availability, whilst the seafloor sediments (areas of active remineralisation) may influence productivity mainly by resupplying required inorganic nutrients. We tested these ideas in November 2013, at Cape Evans (Ross Island), by running simultaneous seafloor, mid-water and under-ice incubation chamber experiments and measuring rates of primary production, inorganic nutrient utilisation/release, and benthic community oxygen demand. After manipulating seawater temperature and pH in the under-ice chambers by +0.5 C and -0.3 pH units, respectively (simulating realistic Antarctic environmental futures), the productivity of the under-ice algae was reduced and the rate of algal sloughing to the sea floor was increased. By injecting concentrated doses of fresh algal detritus into four benthic chambers (paired with four controls), we simulated changes to the rate of detrital algal rain to the sea floor and observed concomitant shifts in rates of oxygen consumption and nutrient release. Although preliminary, these observations represent some of the first explorations of the functional linkages between ecosystem components in ice-covered coastal marine habitats. Quantifying the connectivity between these ecosystem components is imperative if we are to predict responses to environmental change.

## Change in the membrane and thermal adaptation: Evolution of Stearoyl-CoA-desaturase and studies on membrane saturation in Antarctic fish

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The impacts of climate change are dictated by an organism's ability to alter its gene expression in response to environmental variation. However, understanding how organisms adapt to thermal change is lacking. Polar organisms like Antarctic fish may be especially affected by their supposed narrow thermal tolerance and may have limited adaptive potential to rising temperatures. Antarctic fish, such as the notothenioids, have evolved a suite of physiological and biochemical adaptations that allow them to occupy the frigid waters of the Southern Ocean. Homeoviscous adaptation of membrane lipids is one of the major adaptive mechanisms. The desaturase enzyme stearoyl-CoA-desaturase (SCD), which catalyses the synthesis of monounsaturated fatty acids (MUFAs), plays a key role in this process, allowing membrane properties to be altered depending on environmental temperature. In teleosts, the SCD gene has evolved with a complex history of loss and duplication of isoforms due to ancient and recent genome duplications, which has resulted in the loss of SCD2 and duplication of SCD1 into SCD1a and 1b. This study aims to investigate the evolution of SCD in Antarctic fish using comparative genomics, phylogenetics, and gene expression studies. In particular, the physiological impacts and effects on SCD1a and 1b regulation under different environmental conditions will be elucidated. Preliminary phylogenetic studies we have performed strongly support the presence of SCD1a and 1b duplication in Antarctic fish, but a larger panel of Antarctic fish needs to be examined to better understand the timing of this duplication event. Analysis of partial SCD sequences from Antarctic and non-Antarctic fish species reveals amino acid compositions in Antarctic fish which likely contribute to the overall increased conformational flexibility of proteins and reduction of hydrophobicity of internal residues as has been observed in other proteins from polar species. The patterns were found to be more prominent in SCD1b than 1a in the Antarctic fish species examined, indicative of higher cold tolerance in this isoform. To better understand linkages between lipid saturation and thermal adaptation, fatty acid composition and gene expression level changes of SCD isoforms and other gene targets in response to thermal acclimation will also be examined. This project will contribute to understanding of thermal adaptive theory and climate change prognoses for biota.

## Mechanisms of nutrients enclosure inside microbial mat in Antarctic oligotrophic lakes by combination approach of observation data and theoretical study

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The most of water bodies of freshwater lakes in continental Antarctica are considered to be nutrients limited (Hawes et al. 1993). Our previous study on 17 fresh water lakes in Syowa region, Antarctica showed that although the nutrient concentrations of lake water are oligotrophic, the interstitial water of benthic microbial mats surface were 3-220 times higher in DIN (dissolved inorganic nitrogen) concentrations and 2-102 times higher in phosphate than that of the lake water (Tanabe et al. submitted). The nutrient concentrations of the interstitial water in Antarctic lakes are either equaling or surpassing that of temperate eutrophic lakes. Also, there are no correlations between the lake water and the interstitial water in Antarctica, which the nutrient concentrations of the interstitial water have a wide range of variations although lake waters are almost same concentrations among the lakes. Then, it is considered that there are any mechanisms the nutrients hardly discharged from lakebeds to water column in Antarctica such like nutrients enclosure. To reveal the mechanisms, we used vertical profiles of the silicate and ammonium concentration inside benthic mat cores collected from Antarctic freshwater lakes, and examined the following 3 factors considered as controlling nutrients enclosure by model study. The first factor is turbulence on the boundary layer between mat and water, the second is viscosity coating on the mats surface and inside mats, the third is uptake by phototrophs in mats surface layer.

First, to confirm the effect of turbulence on the relation between nutrient concentrations of lake water and interstitial water, we examined that correlation between them affected by the lake surface area and the maximum water depth using GLM analysis and model selection. Then it was revealed that the area and the depth have no effect on the correlation. It indicates that the effects of turbulence are thought to be negligible. Next, we established two diffusion models to represent dynamics of silicate and ammonium in lake water and benthic mat on the vertical axis. The model was used to investigate the distribution of nutrient concentration by molecular diffusion affected by mat viscosity and biological consumption, and was compared with observation data. The silicate model showed a wide range of variations of viscosity, and inherent values of the viscosity depending on each lake were obtained. The inherent kinetics of the ammonium uptake by phototrophs were obtained by applying the viscosity of each lake to the ammonium model, then this indicated that the phototrophs surely take in ammonium in the mat surface layer and the uptake kinetics are largely varied in each lake. Our study by combination of theoretical and observational approach suggests that a mechanism of nutrients enclosure inside benthic mats in Antarctic oligotrophic lakes is caused by viscosity of the mats and uptake by phototrophs.

## Dietary overlap among early juvenile stages in an Antarctic notothenioid fish assemblage at Potter Cove, South Shetland Islands

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To date studies of food overlap in Antarctic fish have been performed on a mixture of late juvenile and adult stages, leaving the young immature specimens (TL ≤ 10 cm) practically unexplored. We studied diet overlap and potential competition among early juvenile individuals in a coastal notothenioid community at Potter Cove, by analyzing the stomach contents of 225 fish of 5 species collected in the summer of 2009-2010. We used frequency of occurrence (F%) and the coefficient “Q” for diet evaluation and the method of Tyler (1973) and the similarity index “S” of Linton et al. (1981) for food overlap. Amphipods of the suborder Gammaridea were the main (Q > 2900) and most frequent (%F) prey for all species, although *Notothenia coriiceps* also consumed gastropods of the Family Littorinidae, mostly *Laevilitorina antarctica*. Secondary prey were algae for *Notothenia rossii* and *N. coriiceps*, calanoid (pelagic) and harpacticoid (benthic) copepods for *T. newnesi* and the latter copepods and isopods of the Family Munnidae for *L. nudifrons*. The reoccurrence of prey among fish species was 39.6% and food overlap between 90% of species pairs was under 58%. Because similarly low values of diet overlap were reported for intermediate/advanced juveniles and adults of the same species at the same site, we conclude that there is no difference in the degree of interspecific food overlap and therefore potential competition between the immature and mature fraction of the fish community. Food competition is avoided by resource partitioning along a depth gradient or by different prey species.

## **The potential formation of lichen biocoenoses and interactions as life traits at southern maritime and continental Antarctic terrestrial sites**

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Antarctica is characterized by severe environmental conditions across the whole continent. At terrestrial sites lichens and mosses form the dominant vegetation. Across the Antarctic Peninsula further south to the continent the lichen communities and populations formed get smaller. With increasing harsh environmental conditions and decreasing size of lichen vegetation lichens tend to form minor and smaller close communities consisting of a variety of interacting species growing adjacent to each other. These communities can become established on rock surfaces as well as on fine gravel often associated with bryophyte cushions. In this study, investigations of different sites across the maritime Antarctic and continental sites (Terra Nova Bay, North Victoria Land) have been carried out. The intimate contact between lichens and bryophytes improves the conditions of the micro niche, including water availability and nutrient supply and, therefore, might make an important contribution to the success of colonization processes in severe environments. The communities, including hyphal contact between the lichen species as well as contact between the lichens and bryophytes are reported. The ecological significance of these interactions within the species' life history strategies as well as the significance of prolonged water availability leading to extended periods of physiological activity will be discussed. The knowledge provides a baseline for the recognition and interpretation of the consequences of environmental change in future decades.

## CO<sub>2</sub> flux from Antarctic Dry Valley soils: Using stable carbon isotopes to explore CO<sub>2</sub> sources and sinks

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Soil CO<sub>2</sub> flux has been proposed as a sensitive and integrative indicator of environmental change in Antarctic terrestrial ecosystems. However, recent discoveries have shown that there are important abiotic components to soil CO<sub>2</sub> fluxes that are obvious on diel and annual timescales, which complicate its interpretation. Use of soil CO<sub>2</sub> flux as a biometric of environmental change will be only be viable when abiotic soil CO<sub>2</sub> processes are well understood and modelled. Only then will it be possible to remove the environmental effects on abiotic processes to reveal changes in soil heterotrophic respiration.

This study presents a multi-day, highly resolved record of surface soil CO<sub>2</sub> fluxes and subsurface CO<sub>2</sub> concentrations at Spaulding Pond, in eastern Taylor Valley. The aim was to provide further insights into the relative proportions of biotic and abiotic influences on soil CO<sub>2</sub> dynamics over the austral summer. We used an automated forced-diffusion chamber coupled with subsurface access tubes to measure soil CO<sub>2</sub> fluxes and subsurface soil CO<sub>2</sub> concentrations, respectively. Measurements were made every 2 hours over a 6 day period. We also manually sampled soil CO<sub>2</sub> from additional subsurface access tubes for carbon isotopic analysis.

The surface flux and subsurface CO<sub>2</sub> measurements generally showed highly regular diel variations consistent with temperature-driven dissolution and exsolution of CO<sub>2</sub> according to Henry's Law. However, a prolonged cloudy period eliminated subsurface temperature changes. During that period, subsurface CO<sub>2</sub> concentrations became consistently less than that of the ambient atmosphere, and surface fluxes became consistently negative. Stable carbon isotope data will be used to explore this as yet unknown abiotic CO<sub>2</sub> sink as well as biological contributions to subsurface CO<sub>2</sub> concentration and surface flux variability.

## Role of nutrients accumulated and recycled by seabirds for phytoplankton productivity in the Southern Ocean

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Great congregations of seabirds in sub-Antarctic and Antarctic coastal areas result in delivery of nutrient-rich guano to marine ecosystems that potentially enhances productivity and supports biodiversity in the region. Guano-derived bio-available micronutrients and macronutrients might be utilized by marine phytoplankton for photosynthetic production, however, mechanisms and significance of guano fertilization in the Southern Ocean are still relatively understudied. Over austral summers of 2012 and 2013 we performed a series phytoplankton incubation experiments with water samples collected from three different water masses in the Southern Ocean: Antarctic waters of the Ross sea and sub-Antarctic waters offshore the Otago Peninsula, both showing iron limitation of phytoplankton productivity in summer, and in the subtropical frontal zone offshore from the Snares Islands, which is generally micronutrient-repleted. Samples were enriched with known concentrations of guano-derived nutrients. Phytoplankton biomass increased significantly in guano-treated samples during all three incubation experiments (7–10 fold increase), while remained low in control samples. This response indicates that seabird guano provides nutrients that limit primary production in the Southern Ocean and that these nutrients are readily taken up by phytoplankton. Guano additions were compared to treatments with Fe and Macronutrients (both added in quantities similar to those in the guano treatment). Phytoplankton biomass increased significantly in response to macronutrient treatment in the subtropical frontal zone, however the response had a smaller magnitude (2.8  $\mu\text{gL}^{-1}$  vs 5.2  $\mu\text{gL}^{-1}$ ) compared to the guano treatment; there was no significant effect of Fe on phytoplankton growth. This suggests the potential importance of synergistic effects of nutrients in guano. Incubation with sub-Antarctic waters indicates that Fe and Macronutrients are equally important constituents of guano responsible for increases in phytoplankton biomass. Analysis of phytoplankton community composition showed that Prymnesiophytes (in particular, *Phaeocystis antarctica*) dominated phytoplankton response in both sub-Antarctic waters and offshore the Snares islands, simultaneously, significant increases in the number of diatoms and photosynthetic pico- and nanophytoplankton were observed. Our study elucidates the potential role of seabirds in enhancing productivity in the Southern Ocean.

## Light quality mediated by terrestrial material cycling changes primary production in Antarctic oligotrophic lakes

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Limitation of productivity by nutrient availability is an established paradigm for lake ecosystems (Carpenter 2008 PNAS, Sterner 2008 Hydrobiology). On the other hand, the productivity of nutrient-poor lake ecosystems is reported to be limited by light climate (Karlsson et al. 2009 Nature). A lot of freshwater lakes are found in Antarctica, and almost lakes are unproductive with oligotrophic water. Despite such nutrient-poor situation, most of the Antarctic freshwater lakes have a few meters of luxuriant vegetation coating the whole lakebeds in some regions. Then, what are the environmental factors controlling sustention and development of benthic vegetation in Antarctic lakes? To dissolve this question, we compared carbon stable isotope ratio ( $\delta^{13}\text{C}$ ) of the phytobenthos as an indicator of primary production with several environmental factors among 17 lakes on continental Antarctica. Then, we tried to reveal the mechanism that limits and promotes the primary production in oligotrophic lakes.

We collected lake waters, benthic mats, and interstitial waters in benthic mats from 17 oligotrophic freshwater lakes on Sôya Coast region, and also measured water temperature and light spectra in water column. Dissolved inorganic nutrients (ammonium, nitrate, nitrite, phosphate) in water samples and  $\delta^{13}\text{C}$  of the benthic mats were analysed. Then, we investigated the correlation between  $\delta^{13}\text{C}$  and nutrients, water temperatures, and light.

There are not any correlations between  $\delta^{13}\text{C}$  and nutrients in lake waters, interstitial water of the mat surface, and water temperature too. However, there is a negative correlation between  $\delta^{13}\text{C}$  and PAR (400-700 nm) at the lakebeds with  $r = -0.63$ , especially there is a stronger negative correlation in UV (300-400 nm)  $r = -0.84$ . The UV energy has a correlation to their catchment area with  $r = -0.91$ . Dissolved organic carbon, DOC is thought to absorb UV in water column. The larger water catchment area the richer DOC inflow into lakes from the land, and this results in high concentration of DOC in lake water and consequently decreasing UV level on the lakebed.

Our study showed that the primary production of phototroph was determined by light environment in Antarctic oligotrophic freshwater lakes, not nutrients. The second important point is that light quality not only light intensity underwater limits the lake productivity. Thirdly, the light quality underwater specific to each lake depends on their catchment area. This means that productivity of lake ecosystems is affected by terrestrial carbon cycling, and lake ecosystems are maintained in a delicate balance. Consequently, changes in terrestrial carbon cycling will have pronounced effects on Antarctic lake ecosystems by mediating changes in light climate and productivity of lakes.

## The globins of cold-adapted *Pseudoalteromonas haloplanktis* TAC125: From the structure to the biological functions

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Evolution allowed Antarctic microorganisms to grow successfully under extreme conditions (low temperature and high O<sub>2</sub> content), through a variety of structural and physiological adjustments in their genomes and development of programmed responses to strong oxidative and nitrosative stress.

The availability of genomic sequences from an increasing number of cold-adapted species is providing insights to understand the molecular mechanisms underlying crucial physiological processes in polar organisms. The genome of *Pseudoalteromonas haloplanktis* TAC125 contains multiple genes encoding three distinct truncated globins exhibiting the 2/2  $\alpha$ -helical fold. One of these globins has been extensively characterised by spectroscopic analysis, kinetic measurements and computer simulation. The results indicate unique adaptive structural properties that enhance the overall flexibility of the protein, so that the structure appears to be resistant to pressure-induced stress. Recent results on a genomic mutant strain highlight the involvement of the cold-adapted globin in the protection against the stress induced by high O<sub>2</sub> concentration, hydrogen peroxide and nitrosating agents.

Moreover, the protein was shown to catalyse peroxynitrite isomerisation in vitro.

The 3D structure of *P. haloplanktis* TAC125 protein in the aquo-met form was determined through X-ray diffraction at 2.2 Å resolution. The fold is typical of the 2/2  $\alpha$ -helical proteins, where the  $\alpha$ -helical sandwich is formed by B-E and G-H helices. The distal water molecule forms a network of hydrogen bonds in the distal cavity, involving Tyr26, Trp93 and other water molecules. The presence of tunnel connecting the external surface with the protein distal site, is restricted to a few cavity.

Next, since only in a very few cases the physiological role of truncated globins has been demonstrated, we also discuss the structural and functional features of the cold-adapted globin in an attempt to put into perspective what has been learnt about these proteins and their potential role in the biology of cold-adapted microorganisms.

## Photosynthetic and photoprotective pigments in Antarctic mosses: associations with ozone depletion

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Mosses are crucial components of Polar ecosystems and some, such as *Sphagnum*- form vast carbon sinks in the northern hemisphere. Ozone depletion occurs at both poles, but especially in the southern hemisphere and full recovery of the ozone layer is not anticipated until 2070. Ozone depletion is associated with reduced growth and increased protective pigments in plants, with the latter cited as the most common response in field studies. These effects are generally attributed to increased ultraviolet (UV-B) radiation. However, ozone depletion is also associated with changes in large scale weather patterns across the southern hemisphere. These weather patterns bring changes in wind and precipitation levels affecting water availability, which is crucial to productivity in mosses.

A range of photosynthetic and photoprotective pigments were investigated in three species of Antarctic mosses over the summer season 2002/03. The pigments include the chlorophylls,  $\beta$ -carotene, the xanthophyll cycle pigments (violaxanthin, antheraxanthin and zeaxanthin), anthocyanins, and intracellular and cell wall UV-B absorbing pigments. Multivariate analyses of these pigments in Antarctic mosses differ between the three species, and seasonally. The three species differ in the location and quantity of their UV-B absorbing compounds, suggesting different photoprotective strategies, the success of which may have implications for community structure. For example, novel biflavones have been isolated in the moss *Ceratodon purpureus*, which have high UV screening and anti-oxidant activity.

Seasonal changes in the pigment data cloud within each species are associated with ozone column depth in addition to other environmental variables. Whilst this season was anomalous in that the ozone hole split in two it is suggested that ozone column depth may be considered as a predictor variable for pigment levels and photosynthetic health in plants.

**The role of cephalopods around South Sandwich Islands: Information from predators diet (*Dissostichus eleginoides* and *Dissostichus mawsoni*) and Stable Isotopes**

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Cephalopods play a key role in the marine environment but knowledge of their feeding habits is limited by a lack of observations. This is particularly true for Antarctic species. Toothfish species are key predators of cephalopods and may be viewed as ideal biological samplers of these species. A total of 256 cephalopod lower beaks were identified from the stomachs of Patagonian toothfish (*Dissostichus eleginoides*) and Antarctic toothfish (*D. mawsoni*), captured in fisheries of South Georgia and the South Sandwich Islands in the South Atlantic. Long-armed octopus squid (*Kondakovia longimana*) and smooth-hooked squid (*Moroteuthis knipovitchi*) were the main cephalopod prey and both were predated upon wherever toothfish were captured, though they appear to inhabit deeper waters at the South Sandwich Islands than at South Georgia. Measurements of  $\delta^{13}\text{C}$  from beak material indicated a clear segregation of habitat use comparing adult and sub-adult sized *K. longimana*. Variation in  $\delta^{15}\text{N}$  with size indicated an ontogenetic shift in the diet of cephalopods and also suggested some trophic plasticity among years. This study provides new insights in to the private life of elusive Antarctic cephalopods in an underexplored region of the South Atlantic.

## Intra-annual variations of the diet of gentoo penguins (*Pygoscelis papua*) at South Georgia (Southern Ocean)

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Understanding the natural variability of a marine ecosystem, and how organisms are able to adapt to environmental change, is crucial to the conservation and management of marine ecosystems. In the Southern Ocean, the network of food web interactions is now recognised as being important in determining the resilience and hence response of marine ecosystems to change due to climate or fisheries. Penguins (Spheniscidae) are a major component of the Antarctic marine ecosystem, constituting approximately 80% of the avian biomass and play an important role, as consumers, on the top of the Antarctic food web. Information on the diet and feeding ecology of penguins is vital to parameterise consumption models in Antarctic food webs. Furthermore, it is currently unknown whether predator behaviour could adapt over the long term to exploit alternative prey types, particularly during the Antarctic Winter (June- September). In this study we assess the feeding ecology of gentoo penguins *Pygoscelis papua* at Bird Island, South Georgia (54° S, 38° W) during the Antarctic Winter of 2009, using scats to assess intra-annual variations in their diets, population dynamics of their most abundant prey and consequences of these results in the conservation of these penguins. The amphipod *Themisto gaudichaudii* was surprisingly the main prey of Gentoo penguins. Gentoo penguins diets were able to show the growth of *T. gaudichaudii* through the Antarctic Winter. As environmental conditions seemed unfavourable to Gentoo penguins, with apparently lack of Antarctic krill *Euphausia superba* in close by waters, these penguins struggled. This was expressed in their attempt to breed in the following Summer 2-3 weeks later. In terms of conservation, if these unfavourable conditions continue to occur during the Antarctic Winter in this region, the population of Gentoo penguins in South Georgia can be affected.

## Managing Southern Ocean fisheries to protect other ecosystem services

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The crustaceans and finfish of the Southern Ocean are a globally significant resource and fishing is one of few direct income-generating activities that take place in the Antarctic. The Convention on the Conservation of Antarctic Marine Living Resources requires decision makers to ensure that fisheries do not compromise ecological relationships or cause irreversible damage to the ecosystem. These requirements effectively mandate the protection of other ecosystem services (i.e. the benefits that mankind obtains from Antarctic ecosystems). These services include the tangible climate regulating role of the healthy, functioning ecosystem and its less tangible but still important “intrinsic value”. The fisheries management strategies that are necessary to meet the Convention’s requirements must be based on high quality scientific evidence, but they also require information about how people benefit from ecosystem services. The debate over the Antarctic krill fishery illustrates the different ways that people perceive these benefits: Some claim that the fishery is a model of ecosystem-based management which balances the needs of the fishery against those of krill predators while others claim that it exemplifies unsustainable fishing. We explore the perceptions of ecosystem services that underpin these opinions, and the associated aspirations for the future state of the ecosystem. We focus on four sectors with an interest in the krill fishery: the fishing industry, conservation organisations, scientists and the media. Despite the apparent polarity, all sectors share an interest in improving the management of the fishery. Their specific ideas provide information which scientists and fishery managers can use to identify the ecosystem states and management objectives that are relevant to the ecosystem services that people value. Antarctic ecosystems are under pressure from climate change and growing global consumption but the management objectives for these ecosystems remain poorly defined. We suggest that the identification of appropriate objectives is now a priority which requires unprecedented cooperation between decision makers, scientists, and beneficiaries.

## S25: ANTERA ANTARCTIC SPECIES TRAITS & EARLY LIFE HISTORY PROCESSES

### Reproduction in cold waters: embryonic development and vitellogenesis in Antarctic demosponges

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Vitellogenesis is a crucial process during the embryogenesis of species possessing lecithotrophic larvae, given that their survival will depend upon their own nutrient reserves entirely. Most demosponges produce lecithotrophic larvae whose yolk could have been produced by either autotrophy or heterotrophy (transferred by nurse cells). Embryos with heterotrophy usually complete the embryonic development at a faster rate and possess more yolk platelets than those in charge of their own yolk formation process. In Antarctica, invertebrates tune their embryonic processes to adapt to cold waters, increasing the duration of the embryonic development and the amount of yolk in the larvae to ensure survival upon hatching. Even though sponges are one of the main components of the Antarctic benthos, their reproduction has been rarely addressed given mainly to collection constraints. Reproduction has been described only for the demosponge *Stylocordyla borealis*, but still the vitellogenesis was not the main point of the study, since the sponge is a direct developer. Here we describe the embryonic development of five species of common sublittoral demosponges inhabiting the rocky coast of Deception Island (South Shetland's Archipelago, Antarctica) of the orders Dendroceratida (*Dendrilla antarctica*), Haplosclerida (an unidentified species), and Poecilosclerida (*Mycale acerata*, *Phorbos areolatus*, and an unidentified species), and we provide details of their vitellogenesis comparing the strategies across the orders. All five sponges are viviparous, brooding their larvae inside the body in large follicles. In the unidentified haplosclerid, large brooding chambers containing 10-15 embryos were observed. The follicle was complex in the poecilosclerids, showing fusion of the follicle cells, and a wide concentration of collagen lining the follicle in all cases. Poecilosclerids showed greater amounts of glycogen in the blastomeres and nurse cells. Vertical transmission of bacteria was observed only in *Mycale acerata* and *Phorbos areolatus*. Yolk was created via both autotrophy and heterotrophy of yolk, observing introgression of nurse cells through the follicle to be phagocytosed by the blastomeres. Embryogenesis in all these selected viviparous species proceeded similarly as in the rest of the members of the orders.

## Ecologically relevant bioactive metabolites from Antarctic organisms

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The sea is a rich source of characteristic bioactive molecules. Most of these compounds have demonstrated an *in vitro* (in the lab) amazing potentiality for medical, commercial and industry use. Consequently, the interest of many scientists has grown on this topic for its applicability: in the pharmacological field pursuing the development of new drugs to fight cancer or inflammatory diseases, or to obtain cosmetics, and in engineering to create natural paints that avoid the adhesion of fouling organisms on boats and marine machinery, to name some.

Marine products, however, did not originate in nature to serve us humans in the first place. These substances most likely appeared in response to ecological constraints, that drove organisms to evolve and maintain secondary metabolic pathways that resulted in the synthesis of particular compounds that enhanced their survival. A common role of secondary metabolites is chemical defense, even if some of them have no apparent activity, and are probably accumulated by-products of biosynthetic routes. Also, some products from the primary metabolism have been found to participate in defense. Out of the many bioactive compounds described from the oceans, only a small fraction has been studied for its ecological significance. Similarly, most allelochemical interactions observed in nature are not well understood, especially in what regards the molecules involved.

Antarctica is no different in these aspects respect to other areas, a part of being much less studied, and much less known in comparison to tropical regions, for instance. Antarctic organisms are prolific producers of defensive metabolites, yet most have not been identified molecularly. In lieu, many pharmacologically relevant products are being reported, from which the ecological activity has not yet been investigated. Among the types of molecules found are terpenoids, alkaloids, peptides, steroids, polyketides, organic acids, and many derivatives, which have yielded activities including antipredatory, antifouling, antibiotic, toxic, photoprotective and reproduction promoters/inhibitors. The most studied groups, as in other zones, are sponges and algae, followed by molluscs, cnidarians, ascidians and echinoderms, whereas other important taxa are notably overlooked in this respect. There is therefore a need to conduct more research to comprehend the ecological significance of marine derived substances in general, and in particular in the Poles.

Here we provide a review on marine natural products that have proved to display ecologically relevant bioactivities in Antarctic waters.

## Resistance of Antarctic lichens and freshwater algae from James Ross Island to radiation, temperature, dehydration, UV-B and salt stress assessed by photosynthetic parameters

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Lichen species *Usnea antarctica*, *Usnea aurantiaco-atra*, *Xanthoria elegans*, and algae *Klebsormidium* sp. and *Zygnema* sp. were investigated in our study by various biochemical and biophysical approaches in order to evaluate their resistance to particular environmental factors. The methods comprised oxymetric, fluorometric (fast (OJIP), and slow Chl fluorescence curves with quenching analysis), spectrophotometric methods (UV screens, photosynthetic pigments, glutathione).

In lichens, short-term photoinhibition using (i) high, (ii) medium light doses were used. Involvement of photoprotective mechanisms was investigated. Chl fluorescence parameters, such  $F_v/F_m$ , yield of PSII, fast transient (OJIP) revealed that *Usnea antarctica* was less susceptible to photoinhibition than *U. aurantiaco-atra*. More pronounced reduction in Chl<sub>a,b</sub> contents was found in *U. aurantiaco-atra* than *U. antarctica*. Total GSH showed an initial increase (first 30-40 min) followed by a decrease (60 min) and an increase during dark recovery. Full GSH recovery was not finished in *U. aurantiaco-atra* even after 5 h indicating lower capacity of photoprotective mechanisms. OJIPs decreased in both species, however, the recovery of their shape was faster and more apparent in *U. antarctica* than in *U. aurantiaco-atra*.

For two algal species, simultaneous measurements of oxygen evolution rate (OER) and effective quantum (PSII yield) were done at different temperatures to gain photosynthetic light-response curves. In both species, OER and yield PSII were well related throughout a range of light (0-500 micromols m<sup>-2</sup> s<sup>-1</sup> of PAR). In a photobioreactor (PSI), repetitive photoinhibition (high light doses) was applied *Klebsormidium* sp. culture by simultaneous measurements of OER and PSII yield. The data revealed large resistance against photoinhibition, however, the courses of respiratory OER and potential PSII yield measured at dark changed with increasing number of photoinhibitory treatments. The effects of NaCl treatment on excitation energy transfer from LHCS to PSII in two Antarctic algae: *Klebsormidium* sp. and *Zygnema* sp. were investigated using Chl fluorescence transients (OJIPs). Short-term salt stress led to significant changes in the shape of OJIPs indicating altered functioning of PSII. With time of exposition to NaCl treatment, the fluorescence yield at the phases J, I and P declined considerably in both species.

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## Lichen resistance to extra-terrestrial conditions beyond Antarctica

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Antarctica is one of the most extreme environments on earth. Habitats which are characterized by drought, cold and polar light regime (high insolation) are colonized by organisms especially adapted to these environmental conditions. The Antarctic vegetation is dominated by mosses and lichens. The latter are symbiotic associations of a heterotrophic fungus (mycobiont) and a photoautotrophic partner (photobiont). In the symbiotic state they are able to thrive across Antarctic habitats due to the lichens' ability for anhydrobiosis and photoautotrophic nutrition. Further adaptive features as UV-screening compounds and peculiarities of thallus structure facilitate survival and reproduction in harsh environments. Due to their remarkable resistance lichens became model organisms in astrobiological research. Four out of five lichen species used in space research originate from Antarctica. Various studies fathomed their limits and limitations towards extreme conditions, including space missions and simulation studies on space and Mars parameters (space vacuum, Martian atmosphere, temperature, UV-radiation, cosmic radiation, simulated impacts). In 2009 lichen samples returned to earth after being exposed to the space conditions outside the International Space Station for 1.5 years. The lichen *Xanthoria elegans* revealed its high resistance by remarkable viability rates assessed by LIVE/DEAD staining analyses and axenic culturability. All previous experiments consistently stress the high resistance of lichens to space parameters. The study presented focuses on three aspects of adaptation that confer resistance to lichens are highlighted: 1) Poikilohydry allows lichens to tolerate desiccation and accompanying factors (as cold, heat, high PAR- and UVR-levels) by passing into anhydrobiosis. 2) Secondary Lichen Compounds act as photoprotectives by absorbing excess PAR (photo-oxidative stress) and UVR (biological damage). 3) Morphological and anatomical characteristics enhance the resistance of lichens to severe environmental conditions. The adaptive capacity is displayed by a variety of growth types and functional thallus structures. The resistance of lichens to the hostile environmental conditions might give a basis for the interpretation of future space missions and on the limits of life in remote terrestrial and putative extraterrestrial habitats.

## Gene and protein expression in larval *Laternula elliptica* exposed to a range of pH and temperature

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In many species, temperature change and hypercapnia may affect physiological processes, particularly in early development. The Antarctic geoduck, *Laternula elliptica* is a large infaunal bivalve with a circumpolar distribution and a significant role in coastal benthic ecosystems. Its aragonitic shell makes it one of the more susceptible benthic species to ocean acidification. Previous work has shown that both adults and early larvae are negatively affected under future predicted ocean acidification conditions. Adult *L. elliptica* increase respiration rates and production of the heat shock protein HSP70 and expression of an enzyme involved in shell formation, under low pH conditions. Our more recent experiments have shown that developing *L. elliptica* larvae are sensitive to change in temperature and pH, displaying increased mortality and delayed development with reduced pH and elevated temperatures. Development to D-larvae stage in particular, the point at which shell formation occurs, is considerably delayed under lowered pH. The mechanisms by which larval development is affected were further investigated by assessing stress protein and gene expression responses in D-larvae under a range of pH and temperatures predicted for the end of the century and beyond. This presentation will describe the results of our most recent experiments and will attempt to provide a 'whole life view' of likely responses of *L. elliptica* to future change in ocean conditions.

## Methane oxidation at low temperature by Antarctic methanotrophic consortia

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Methane gas is one of the most harmful greenhouse gases, emitted by natural (wetlands) and anthropogenic (livestock, landfills, refinery industry) activities. Gas biofiltration is an efficient, environmental friendly and cost-effective biological process which enables to mitigate contaminating gas emissions. Methane removal by biofiltration is based on the development of an active biofilm composed of methanotrophic microorganisms, which have the ability to oxidize the methane molecule to carbon dioxide and water. Currently, methane biofiltration processes are mainly limited by the operation restriction due the necessity of maintaining stable conditions to ensure methanotrophic activity, such as mesophilic operation. In natural ecosystems, methane participates to the global carbon biogeochemical cycles, and thus methanotrophic microorganisms have been isolated from diverse sources. Antarctic soil and sediments are extreme ecosystems where the microorganisms are exposed to frequent fluctuations in temperature, nutrient availability and salinity, providing the possibility to find methanotrophic microorganisms with the potential to oxidize methane under low and changing temperatures, similar to what occurs in industrial biofilters.

In this context, the objective of this study was to investigate the methanotrophic potential of 13 Antarctic soil and sediments samples collected from the South Shetland islands (62°00'S 59°30'O).

The evaluation of methane-oxidation activity was based on the enrichment of methanotrophic consortia through the incubation of 5g-sediment samples in 100 mL-hermetic bottles under 15% v/v methane atmosphere at either low (4°C) or ambient (20°C) temperature during 90 days. CH<sub>4</sub> and CO<sub>2</sub> concentrations in the gas phase were quantified periodically by gas chromatography. The 11 consortia which exhibited significant methane consumption at both temperatures were resuspended in sterile NMS medium (specific for methanotroph growth) and incubated at 4°C and 20°C under 15% methane atmosphere. CH<sub>4</sub> consumption was periodically monitored by gas chromatography. The major methane oxidation activity was obtained at 20°C (219 mgCH<sub>4</sub> m<sup>-3</sup>h<sup>-1</sup>). However, some consortia also exhibited significant methane oxidation activity at temperature as low as 4°C (76 mgCH<sub>4</sub> m<sup>-3</sup>h<sup>-1</sup>). Total DNA was extracted from the consortia with positive methanotrophic activity, and the presence of the particulate methane monooxygenase (pmoA) gene involved in methane oxidation was confirmed by PCR, at both incubation temperatures, which corroborates the presence of methanotroph species in sediments from South Shetland islands.

Globally, our results reveal the psychrotolerant methanotrophic potential of these Antarctic consortia, and open the possibility to use them for low-temperature methane biofiltration.

## The methanogenic potential of Antarctic sediments: Links between psychrophilic methane production and archaeal community structure

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Antarctic soil and sediments host a surprisingly high microbial diversity, still incompletely explored. Extreme environmental conditions selected for adapted microorganisms with particular traits, leading to specific ecosystem service. These original functional capacities offer an interesting potential for low temperature biotechnological applications. This study takes place in the context of anaerobic digestion (AD) bioprocess, which enables the simultaneous purification of wastewater and the production of renewable energy through methane-rich biogas. Methanogenic Archaea play a key role in AD. Most methanogens have mesophilic optima for growth and activity, thus preventing the treatment of contaminated wastewaters at their natural low temperature. Nevertheless, we assume that psychrophilic methanogens enriched from cold environments could be used as inoculum in low temperature AD bioprocess. Methanogen species have been identified in natural cold environments, such as tundra, permafrost, arctic soils. Little information is available to date about methanogenic activity in Antarctic ecosystems

The objective is to evaluate the methanogenic potential of microbial consortia from Antarctic soil and sediments, according to an integrated approach relating the archaeal community structure, the functional activity and environmental variables.

Soil and sediment samples (5-40 cm depth) have been collected from 70 sites among coastal zones of the South Shetland Islands and Antarctic peninsula exposed to annual freeze-thaw cycles, during the Chilean National Antarctic Institute (INACH) scientific expedition of 2013 austral summer. Key physicochemical properties have been characterized. Methane production activity has been measured at 5°C and 37°C under well-defined anaerobic incubation conditions. The archaeal community in the initial sediments and after incubation is investigated through various molecular tools: archaeal 16S DGGE, quantitative PCR of the *mcrA* gene involved in methane production, taxonomic identification by 454 pyrosequencing.

Total and volatile solids, pH, temperature, ammonium, nitrate, phosphate and sulfate contents present a remarkable diversity across the samples. 14 samples exhibited significant methanogenic activity at 5°C, after a lag phase of 10-50 days, reaching methane productivity of  $1\text{L}_{\text{CH}_4}\cdot\text{kg}_{\text{SV}}^{-1}\cdot\text{d}^{-1}$ , while they had no activity at 37°C. These results reveal the psychrophilic nature of the identified methanogenic consortia, contrary to the psychrotolerant/mesophilic nature previously reported from arctic consortia. Estimated growth rates have been compared to literature data. Canonical correlation analysis indicated that, among all the environmental variables, the highest methane production was correlated to high phosphate and organic matter contents. Correlations between the psychrophilic methane production ability and the archaeal community structure, diversity and composition will be investigated.

## Changes in the carbon nitrogen ratio for Antarctic mosses in different sites on the Antarctic Peninsula

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Such as abiotic and biotic agents play an important role in the distribution of available nutrients for the plants. In Antarctica this is not an exception, the low temperatures and water availability limit the distribution and growing of the vegetation, which is mostly composed by cryptogams, such as mosses, having 115 species of this kind of bryophyte in the Antarctic Peninsula, compared to only two species of vascular plants growing in the same territory.

Usually, antarctic soils are very poor in nutrients, like nitrogen, however there's high concentration of phosphorus and nitrogen in the nesting areas of birds and marine mammals colonies. Despite of this heterogeneous nutrient distribution, the bryophyte have been developed both in diversity and abundance across the Antarctic Peninsula, even when this kind of cryptogams are limited in nutrient supply by their poikilohydric method of water regulation, mainly because they need a lower nutrient concentration than the tracheophytes to grow, being dilutions of 10:1 more satisfactory for the bryophyte grow.

The objective of this study was to determine the carbon nitrogen ratio (C:N) in mosses in different sites across the northern Antarctic Peninsula. To accomplish this, there were selected samples of two species of mosses (*Polytrichastrum alpinum* y *Sanionia* sp.) during the summer of 2013 (from January 10<sup>th</sup> to February 28<sup>th</sup>) from different sites: Admiralty Bay, Collins Harbour and Juan Carlos Point in King George Island, Byers Peninsula in Livingston Island, and Biscoe Point in Anvers Island. Then the samples were dried at 70°C ± 5°C in a forced air oven, so the enzymatic process can stop and the tissues can be stabilized. Later, these samples should be placed in a grinder, so they can pass through a 1,0mm sieve, and from each sample we weight 200 mg in tinfoil, forming a closed cone to be load in the TruSpec CN analyzer, LECO corp. The data obtained from this is expressed in percentage of carbon and nitrogen.

The data for the C:N ratio between the two species oscillate, being always the higher for *P. alpinum*, with the maximum (47,65 ± 0,37) and the lowest (29,05 ± 0,48) value found in two sites of the Admiralty Bay. While for *Sanionia* sp. the values for this ratio fluctuate even more, from 13,01 ± 0,21, in Byers Peninsula, Livingston Island, until 40,01 ± 0,55 in Juan Carlos Point, King George Island. In general, the obtained results show significant differences in the C:N ratio between the sites for the two species. This differences may indicate the existence of a higher nitrogen input, showing a lower C:N ratio, mostly in ornitogenic soils. Also the high values of C:N ratio present a high difficulty in the decomposition of the mossy tissues and with this a slower return of the elements to the nutrient cycle.

## ***Colobanthus quitensis*, a model specie of harsh environmental adaptation in Antarctic and South America**

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Terrestrial Antarctic ecosystem has scientific value based in the combination of a set of environmental stressors, like: extreme low temperatures, desiccating winds, freezing, osmotic stress, low nutrients availability and elevated UV radiation. In addition, the global warming generates more complex scenery in Antarctic, i.e. the air temperature of the Peninsula has increased by 2°C over the last 40–50 years, where the localized retreat of some glaciers and permanent ice will offer opportunities for colonization of pristine habitats in newly exposed areas.

Only two vascular plants naturally inhabit in Antarctic, *Deschampsia antarctica* Desv. (Poaceae) and *Colobanthus quitensis* (Kunth) Bartl. (Caryophyllaceae) both have become in recent times in models for understanding biochemistry and molecular mechanism that enable them to survive in these harsh conditions. Besides this, *C. quitensis* has a wide geographical distribution, from Mexico to the north of the Antarctic Peninsula, which also involved stressful environmental habitats. At the southern end of its colonization range occurs at sea level, but towards the north it is growing at high altitudes reaching up to 4200 m .a.s.l., showing a considerable morphologic variability along its wide distribution range, becoming an interesting model for ecotypic differentiation and for intra-specie genetic diversity.

Some physiological, molecular, morphological, genetics properties well as some aspects of the molecular ecology of *C. quitensis* will be shown in order to propose it as a model about the genomic responses to environmental extremes elsewhere on the planet.

## Lichen-dominated soil crusts show changes at multiple levels in stress-related traits across habitats of different severity

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Biological soil crusts (BSC) are close associations of lichens, mosses, algae, and cyanobacteria, with microfungi and bacteria in different proportion, forming a thin veneer within the top few centimeters of soil surfaces. They occur in all biomes but, particularly in arid and semi-arid regions, even in the most extreme climates, like the Mc Murdo Dry Valleys, Victoria Land. The McMurdo Dry Valleys are among the harshest environments on earth, representing a cold desert with limited water resources because of low precipitation falling as snow, high sublimation rates, and low temperatures that further limit the availability of water and provide yet more problems for life.

We assessed BSC response to stress through changes in biotic composition, CO<sub>2</sub>-gas exchange, and carbon allocation in three lichen-dominated BSC from habitats with different stress levels, two more extreme sites in Antarctica and one moderate site in Germany. Maximal net photosynthesis (NP) was identical whereas the water content to achieve maximal NP was substantially lower in the Antarctic sites this apparently being achieved by changes in biomass allocation. Optimal NP temperatures reflect local climate. The Antarctic BSC allocated fixed carbon (tracked using <sup>14</sup>CO<sub>2</sub>) mostly to the alcohol soluble pool (low molecular weight sugars, sugar alcohols), which plays an important role in desiccation and freezing resistance, and anti-oxidant protection. In contrast, BSC at the moderate site showed greater carbon allocation into polysaccharide pool, indicating a tendency towards growth. The results indicate that the BSC of the more stressed Antarctic sites emphasize survival rather than growth. Changes in BSC are adaptive and at multiple levels and we identify benefits and risks attached to changing life traits, as well as describing the eco-physiological mechanisms that underlie them.

The consequences for the conceptual view of lichen life traits in the Dry Valleys are highlighted and future research perspectives are discussed. The results allow new insights in the response of these photoautotrophic organisms to a changing environment.

**Living in the extremes: distribution and upper thermal tolerances of *Parochlus steinenii* (Diptera: Chironomidae: Podonominae) in the South Shetland Islands, Antarctica and sub-Antarctic Navarino Island (55°S), Chile**

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Antarctica and sub-Antarctic regions have become a focus of studies on environmental responses to regional and global change. Freshwater ecosystems in these regions are highly dynamic, and their responses to climate change may be more immediate and evident than in their terrestrial counterparts. In 2008, at Omora Park LTSER (Navarino Island), we began a long-term program to study the phenology and distribution of aquatic insects associated to the steep altitudinal of the Róbalo river watershed, which provides drinking water to the southernmost town in Chile. Results revealed unique life history strategies, such as the first case of multivoltine life cycles in a dipteran species (*Gigantodax rufescens*) at high latitudes in South America. Other dipterans, such as *Parochlus steinenii*, which also occur in maritime Antarctica, appear to show altitudinal shifts in voltinism through these steep gradients. Comparing life history strategies, and in particular determining upper thermal limits of *P. steinenii* could provide valuable insights to develop predictions on distributions and life history changes in sub-Antarctic and Antarctic freshwater ecosystems due to climate change. Little is known about the life history and thermal tolerances of *P. steinenii*, however. The overall goals of this study were to: (1) contribute to the current knowledge on the distribution of *P. steinenii* through the South Shetland Islands, (2) determine upper thermal tolerance limits of *P. steinenii* associated to present-day Antarctic ecosystems. During Jan. and Feb. of 2014 we navigated through the South Shetland Islands, aboard the Chilean AP Aquiles, coordinated by the INACH and its 50<sup>th</sup> Scientific Antarctic Expedition. We thoroughly searched for specimens at every permanent and non-permanent freshwater habitat encountered and characterized them. At King George Island, larval pupae and adults of *P. steinenii* were collected alive. Upper thermal limits were determined using the Critical Thermal Method, which involves changing temperature at a constant rate until a predefined sub-lethal endpoint is reached. In terms of distribution, we provide records for Deception Island and the already described populations of Livingston and KG islands. Larvae and adults reached their upper thermal limit at temperatures averaging 35°C, while pupae at 28°C. We compliment our results with lower lethal temperature records reported by other authors and conclude that *P. steinenii* would have an exceptionally wide thermal range, ranging from -9 to 35°C. Further studies need to be conducted to understand the current distribution and thermal limits of *P. steinenii* in Antarctic and sub-Antarctic habitats. As more knowledge is gained, we aim to generate data on its phenology and voltinism patterns to assess the possibility of using *P. steinenii* as an indicator of climate change in both Antarctic and sub-Antarctic freshwater ecosystems.

## Measuring stress in chinstrap penguins: effects of capture and constraining

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A stressful stimulus often leads to an unconscious and rapid physiological response in individuals, contributing to their survival and the maintenance of homeostasis. Corticosterone (CORT) is the main glucocorticoid indicator of stress level in birds. Capture, constraining, and manipulation are significant stressful events, causing increase in the production or release of CORT. Studies indicate that the levels of CORT start to increase between 3 to 5 min after exposure to the stressor event. This study aimed to record the impact of capture and constraining via the CORT level in chinstrap penguins (*Pygoscelis antarctica*). We measured CORT concentration and its variability in sequential blood samples: CORT\_0 (up to 5min after capture of the bird), CORT\_30 (30 min) and CORT\_60 (60 min), in each case determining the serum profile of CORT secretion in five adult penguins. The animals were sampled in Admiralty Bay, King George Island, South Shetland Islands and the levels of CORT determined by radioimmunoassay (RIA). CORT levels increased significantly over the first 30 mins of constraining (between CORT\_0 and 30), but there was no further significant increase between 30 and 60 mins (0.93 ng/ml, SD 0.56; 6.4 ng/ml, SD 3.14; 9.16 ng/ml, SD 3.3, respectively). These data suggest that the response to stressful events such as capture and constraining can be evaluated after 30min of exposure. We are examining further variables (age, sex and sexual stage) to better understand the physiology of stress in chinstrap penguins.

Keywords: *Pygoscelis antarctica*, King George Island, Antarctica, corticosterone, stress ecology.

## New insights into ecophysiological responses of Antarctic seaweeds

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Physiology of Antarctic macroalgae had become an important matter of study since the last decades mainly due to human driven climate change, especially increased coastal temperature and the reduction of stratospheric ozone. Due to the key ecological role of these organisms supporting the whole benthic community, their physiological performance, anti-stress responses and overall, their life history strategies are central to understand the effects of global climate change on the Antarctic coastal systems.

Due to that inter and subtidal macroalgal assemblages are suddenly exposed to changes in temperature, salinity, nutrients and environmental radiation (UV-R+PAR), initial ecophysiological studies based on laboratory approaches using controlled experiments have, in general, limited resolution. Thus, in the present study, we report on photosynthetic and anti-stress responses (synthesis of photoprotectants) to UV radiation and temperature assessed *in situ* and under outdoor conditions of various endemic and cold-adapted species, especially the difficulty of control and isolate all factors that the environment offers.

Taking advantages of technology available to perform Antarctic ecophysiological research in macroalgae, we have gained important information of *in situ* photosynthetic parameters (e.g. Fv/Fm, electron transport parameters, and related PSII processes) along different spatial scales and environmental gradients, especially depth, distance to glaciers, intertidal levels, etc. Direct assessments of photosynthetic parameters are complemented monitoring environmental variables that will allow interpret in an accurate way the physiological response of intertidal and subtidal Antarctic macroalgal assemblages to different environmental scenarios.

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## Molecular and morphological analysis of embryogenesis in Antarctic notothenioid fishes

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The molecular mechanisms that underlie many novel phenotypes in Antarctic fishes (ventralization of the craniofacial skeleton, neutral buoyancy in certain taxa, etc.) are unknown, as are the effects of oceanic warming on embryogenesis and larval recruitment to adult populations. Our consortium is applying a multi-faceted strategy to these issues.

First, we describe early development of the pharyngeal skeleton in two nototheniid species, the Antarctic silverfish *Pleuragramma antarcticum* and the bullhead notothen *Notothenia coriiceps*, using molecular/cytochemical approaches. We show that both species exhibit a conserved pattern of craniofacial development, including a bias toward development of ventrally positioned structures. Our data suggest that the adaptive morphological radiation in Antarctic notothenioids occurred within the context of the developmental program controlling craniofacial skeletal patterning.

Second, we examine the molecular mechanisms that have led to the evolutionary acquisition of neutral buoyancy in *P. antarcticum* and near neutral buoyancy in the Antarctic icefish *Chaenocephalus aceratus*. We compare craniofacial skeletal development in two pelagic notothenioids, *C. aceratus* and *P. antarcticum*, to that in a benthic species, *N. coriiceps*. Relative to outgroup species, pelagic notothenioids show a delay in pharyngeal bone development, consistent with heterochronic shifts in skeletal gene expression that lead to persistence of the chondrogenic program and delay in the osteogenic program during larval development. We also evaluate the contribution of adipogenesis in the *P. antarcticum* to acquisition of neutral buoyancy by analyzing the expression of genes associated with differentiation of white adipose tissue in larval stages from hatching to 21 days post hatching.

Third, we explore the influence of environmental temperature on embryonic development of *N. coriiceps* at temperatures between  $-1.5$  and  $+8$  °C. Using a thermal acclimation protocol, we show that *N. coriiceps* embryos raised at  $+5$ °C developed  $\sim 3$ X faster than control embryos reared at  $-1.9$ °C. Development at  $+5$ °C appeared normal despite the fact that adult notothenioids acclimatized to  $-1.9$ °C have upper incipient lethal temperatures of  $+5$ – $7$ °C. We also present evidence that *N. coriiceps* embryos subjected to heat shock ( $-1.9$  to  $+8$ °C) at 3.5 months post-fertilization show higher expression of genes involved in energy metabolism, ROS generation, and antioxidant protection, whereas the classical heat-shock response is absent.

Our results set the stage for future molecular analyses of development in the cold-living notothenioids, and they also provide the foundation for understanding the impact of the warming of the Southern Ocean on embryonic development and larval recruitment of this group, which is a key intermediate in the marine trophic system.

## Origin of Antarctic ice-fishes (Teleostei, Notothenioidei): Current controversies and facts

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The Southern Ocean and the Antarctic continent are amongst the most remote and coldest places in the world and are both key elements in any model of Earth processes and climatic changes as well as a site with unique scientific characteristics. The contemporaneous ichthyofauna is dominated by a single teleostean clade, the Notothenioidei, which comprises eight families with approximately 130 species. This suborder is the most abundant in terms of biomass and species diversity in the Antarctic Ocean today and comprises one of the most important elements of Antarctic marine ecosystems. Many of these fishes are perfectly adapted to sub-zero temperatures displaying various morphological and physiological adaptations to these extreme conditions.

The origin of these perfectly adapted fishes, however, still is controversially discussed despite some putative fossil records (isolated skull, jaw fragments) from the Eocene of Seymour Island and either placed into the Eocene or Miocene, respectively (based on molecular analyses using fossils for calibration). Fossil Cenozoic Antarctic fishes are mainly known from Seymour Island (Antarctic Peninsula). Here, early to upper Eocene marine sediments of the La Meseta and Submeseta Formations yielded the most diverse Palaeogene ichthyofauna from the Southern Hemisphere to date. The Eocene Seymour Island fish remains (cranial elements, vertebrae, teeth, otoliths) include the last well-documented teleostean associations before the onset of the isolation of the Antarctic continent and ice-shield formation. Younger marine fossil fish remains from Antarctica are unknown.

Thus, the Eocene Antarctic teleosts are deemed to be crucial for dating the origin of living ice-fishes. Identification of these fossil remains, however, is rendered difficult because no unique osteological features in living notothenioids have been depicted up to now. Here, we present ample morphological information of various living ice-fish taxa and Eocene fish remains providing sound taxonomic information. The Eocene teleostean associations accordingly do not include any remains that undoubtedly can be related to living notothenioids and all remains previously identified as belonging to ice-fishes rather represent gadiforms based on these analyses.

## Does *Sterechinus neumayeri* have the potential to adapt in a changing ocean?

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Climate change is significantly altering marine ecosystems with many studies showing negative impacts of both ocean warming and acidification. Although climate change is occurring faster with respect to species evolutionary history, these studies are unrealistic as they do not consider possibilities of acclimatization and adaptation. Adaptation depends on heritable genetic variance for stress tolerance present in populations. We determined effects of near-future ocean conditions on fertilisation in the Antarctic sea urchin, *Sterechinus neumayeri*, and quantified genetic variation and interactive effects of 24 multiple dam-sire crosses at the blastulation stage in tolerance of warming (+3°C) and acidification (-0.3-0.5 pH units). For fertilisation, both pH and temperature significantly decreased the percentage of embryos fertilised. However, this was greatly dependent on female identity and compatibility between males and females. For blastulae, increased CO<sub>2</sub> decreased the percentage of normal blastulae found. The impact of stressors greatly depended on male and female identity. Antarctic species are considered to be some of the most vulnerable in a changing ocean as higher, colder latitude waters absorb CO<sub>2</sub> more readily and it is therefore interesting that decreased pH was found to be the stressor of significance, contrasting with results for many temperate and tropical sea urchins species.

## The moult in Southern elephant seals: New insights from thermal imaging technology

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The moult in most phocid seals is a gradual process and takes around 3 to 4 months except for a few species. For example, Southern elephant seals (*Mirounga leonina*), experience a catastrophic moult where, as well as replacing their hair, they also shed their skin within approximately one month. The epidermal cells of phocid seals require a minimum temperature of 17 °C for growth, which is well above the temperature of Antarctic seawater, and therefore the seals must haul-out to moult. In our on-going study we are examining the relationship between huddling behaviour haulout location, body size, stage of moult and meteorological conditions.. Using a novel thermal imaging technique, we are trying to determine how elephant seals regulate their body temperature during this critical period of their lifecycle. Fieldwork is being carried out on the Kerguelen Archipelago (49°26'S, 70°23'E) where transect surveys are used to study group formation and huddling behaviour throughout the moult, in relation to local environmental conditions. In addition, 40 individuals were equipped in 2011/2012 and in 2013/2014 with a combination of Argos, VHF, GPS, accelerometers, stomach temperature pills and i-buttons to study their movements and behaviour on land. Seals were also weighed at the beginning and end of their moult to provide body mass loss information. This study will help us understand to what extent Southern elephant seals may be able to cope behaviourally with critical periods in their lifecycle. Results will also provide a means of increasing our understanding of the mechanisms of thermoregulation in marine mammals.

## The Antarctic silverfish early larval development: morphologic clues, morphometric landmarks and ecological inferences

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The Antarctic silverfish (*Pleuragramma antarctica*) is the dominant pelagic fish in the shelf waters of Antarctica, where it plays a key role providing a link between plankton and the top predators. Among notothenioids, it stands out in being the only species in which all developmental stages are pelagic, including early life stages. Indeed, embryonated eggs float in the semi-solid platelet-ice layer underneath the solid fast-ice, where also hatching occurs.

Given its prominent role within the Antarctic coastal marine food web, many aspects of the Antarctic silverfish ecology and biology have been elucidated. The mechanisms and life-history strategies developed to cope with the icy and highly seasonal environment of the High-Antarctic Zone have been widely investigated. However, at present, only scattered information are available on the early life stages. The initial larval development is among the most critical phases of a fish life-cycle, and, in the case of the Antarctic silverfish, it is potentially even more critical due to the still not fully disclosed nature of the association between silverfish early larvae and sea-ice.

We undertook the challenge to provide the first comprehensive description of the early larval development, within a 3 weeks timeframe. Such a period includes a number of crucial developmental steps with ecological implications, such as the delicate transition from endogenous to exogenous feeding. Our task was approached through the analysis of a developmental series generated *ad hoc* in the frame of the Italian Antarctic Expedition at Mario Zucchelli Station. Near-term embryonated eggs were collected in the field through holes drilled in the sea-ice cover, and reared in aquaria with flow-through sea water at ambient temperature; larvae were sampled at fixed time intervals for up to 21 days from hatching. The analysis of the Antarctic silverfish developmental series was performed through a combined quantitative and qualitative approach that integrates morphometric parameters and histological information. Analysis of variance will be applied in order to validate data.

The main outcome of such an analysis is an in depth characterization of the Antarctic silverfish early larvae by integrating information on age, morphometric data and structural status. The body of data is discussed in an ecological context, providing clues to set the first landmarks pertaining to the Antarctic silverfish early life-cycle.

## Constitutively expression Hsp70 chaperone during the heat shock response in the giant isopod (*Glyptonotus antarcticus*)

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Currently has reported a trend of warming between 0.2 °C and 1 °C in the Southern Ocean surface temperature on the Antarctic Peninsula. Predictive models show that the average sea temperature rise by about 3 ° C by 2100, leading to Antarctic marine organisms are exposed beyond their limits of survival and begin to critically losing its functions biological. In fact, some marine Antarctic organisms have lost the inducibility of the heat shock proteins due to the thermal stability of Antarctic waters. A few of heat shock response sequence have been identified in Antarctic crustacean such as the Antarctic gammarid (*Paraceradocus gibber*) and krill (*Euphausia superba*).

We have obtained a partial sequence of 479 pb from hepatopancreas tissue of *G. antarcticus*, that encoded a heat shock protein 70. This nucleotide sequence showed a high identity between 75 and 81 % with *Frankliniella occidentalis* and *Caenorhabditis briggsae*, respectively. By other hand, the amino acid sequence showed a higher identity with crustacean and insect heat shock proteins, *Litopenaeus vannamei* and *Bombyx mori*. The Antarctic isopods were exposed to 3°C and 6°C during 1, 6 and 24h. The control group was fixed at 1°C and samples controls were taken at 1 and 24 h. The expression of this gene was evaluated by qPCR and in parallel using a primary antibody that recognizes both the cognate and inducible forms of Hsp70 by western blot and ELISA.

The expression of Hsp70 gene and protein in the hepatopancreas were permanently expressed in control as well as thermal stress animals. However was not possible to observe a time dependent increase during the thermal stress at 3°C and 6 °C. Our result provide the first molecular evidence that Hsp 70 is expressed constitutively and is non- induced in the Antarctic marine isopod by thermal stress.

## Antioxidant system in the Antarctic sea urchin *Sterechinus neumayeri*: a comparison with subantarctic and tropical sea urchin

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Low temperatures affect the stability of proteins and also the high oxygen concentration, due to increased oxygen solubility could produce the high rate of oxidation by formation of reactive oxygen species (ROS) in polar marine ectotherm. Thus the antioxidants defense of Antarctic marine invertebrates could be more active than temperate marine animals. Sea urchins have been a good model to study the antioxidants defense related to the study of aging because of the existence of species with tremendously different natural life spans. The antioxidants avoid cellular damage caused by ROS, such as hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>), superoxide anion radical ( $\cdot O_2^-$ ) and hydroxyl radical. The Antarctic echinoid *Sterechinus neumayeri* could be a good model for study this antioxidant system in stenothermal animals.

Experiments were conducted to study the expression of antioxidant enzymes superoxide dismutase (SOD) and catalase (CAT) after thermal stress in the context of the global warming. We have obtained the partial DNA sequence for SOD and CAT expressed in different tissues and showed high identity with others invertebrates and sea urchin catalases. The mRNA levels of CAT were increased at 24 h during the thermal treatment, however the transcriptional response of SOD gene don't showed changes at different times. Additionally, we compared the transcriptional expression of CAT from four different sea urchins related to different thermal environmental. *Lytechinus variegatus* (Tropical) and the subantarctic sea urchins (*Loxechinus albus*, *Arbacia dufresnei* and *Pseudochinus magellanicus*). Antarctic sea urchin showed a highest expression of CAT than the others subantarctic and tropical sea urchin. However, when *A. dufresnei* were exposed at 2°C, the expression was similar to the Antarctic sea urchin.

## Ectoparasites of pygoscelid penguin (*Pygoscelis papua*, *P. antarctica*, *P. adeliae*) in the Antarctic continent

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Knowledge about parasites in Antarctic Wildlife is fragmented and scarce; Although there are works with parasitology in Antarctic birds, little is known about their ecology, distribution and host infection. Therefore, the aim of our work was to determine ectoparasite species of pygoscelid penguins in the Antarctic Peninsula, and assess level of host infection. In the Antarctic continent, most of the penguin biomass is made up of gentoo penguins (*Pygoscelis papua*), Adélie penguins (*P. adeliae*), and chinstrap penguins (*P. antarctica*), which have a circumpolar distribution.

During the southern summers of 2011, 2012 and 2013, we examined 900 individuals (300 of each *Pygoscelis* species) at six different localities: Ardley Island, Narebysky Point, Shirreff Cape, Admiralty Bay (included within the South Shetland Islands), Kopaitik Island and Paradise Bay (both in the Antarctic Peninsula). Penguins were captured using a bird net and were examined for external parasites, and the ectoparasites collected – ticks and lice – were placed in individual vials with alcohol 70%. Further, we estimated tick abundance by collecting ticks from under stones and underlying soil for a period of three hours at each locality, totalling 18 hours of sampling effort. Tick density was expressed as the number of ticks found per unit of searching time.

Ticks, identified as *Ixodes uriae* (White 1852), were collected on five gentoo penguins (all from Paradise Bay), but none was found on chinstrap or Adélie penguins. The low prevalence (0.6%) of ticks on the bodies of penguins examined may be due to the fact that our sampling was done towards the end (January and February) of the host breeding season, when most ticks have already fed and dropped from their hosts. However, near the nesting colonies, we collected 2235 ticks (larvae, nymphs and adults) under stones with good drainage and high humidity. From that total, 532 were from the Base G.G. Videla in Paradise Bay, 652 from Ardley Island, 1014 from Shirreff Cape, 137 from Narebysky Point, and 823 from Admiralty Bay, but none was found in the Base Bernardo O'Higgins on Kopaitik Island, where temperatures are the lowest. The absence of *I. uriae* in Kopaitik may be due to the type of soil, without drainage. Except at Shirreff Cape (high presence) and Narebysky Point (low presence), we found no significant differences between the abundance index of ticks  $p > 0.05$ . *Ixodes uriae* is the most important of all ectoparasites of seabirds in terms of its impact on host health. A hyperinfestation of *I. uriae* has been reported as the possible cause of deaths among adult king penguins. Also, this tick is a vector for diseases.

Also, we collected four males and five females of the chewing louse *Austrogoniodes gressitti* Clay 1967 (Phthiraptera: Philopteridae) on the plumage of six gentoo penguins (2%). Further, we collected 58 lice of the same species - *A. gressitti* - on 23 (7.7%) chinstrap penguins.

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## The tick *Ixodes uriae* White 1852: localities, hosts and tick-borne diseases

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*Ixodes uriae* White 1852, known as the seabird tick, is the sole member of the Ixodidae family with circumpolar distribution in both, Antarctic and Arctic latitudes including the Afrotropical, Australasian, Nearctic, Neotropical and Palearctic Zoogeographic Regions and various islands. This tick parasitizes the widest range of seabird species in the world and is vector of a wide range of diseases.

In this study we revised the literature about *I. uriae*, with the aim to summarize the information about localities, hosts and pathogens transmitted by this tick.

In total, *I. uriae* has been found in at least 172 localities, 112 of them from northern hemisphere and 60 in south hemisphere. A total of 65 vertebrate hosts have been reported to date for this hard tick: 61 bird species belonging to seven orders, twelve families, 16 genera and four species of mammals including humans (order Rodentia, Carnivora and Primates), all mammals reports are from the north hemisphere and are considered exceptional hosts. Relative to pathogens, were isolated 88 virus strains belonging to three families, four genus, and five serogroups. Relative bacteria, only *Borrelia burgdorferi* sensu lato, *B. garinii* and one Rickettsia-like were detected in this ticks.

It is necessary to define if *I. uriae* from all different localities belong to a species complex or just one species.

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**Possible trophic vulnerability of bentophagic fish *Harpagifer antarcticus* (Notothenioidei: Harpagiferidae), in King George Island, Antarctica: A specialist predator threatened**

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Feeding ecology studies are important because they provide insight into the functioning of food webs, helping to infer on the ecological effects product of environmental perturbations. Have been identified a number of threats to the Antarctic ichthyofauna, product of current global warming, such as habitat loss, physiological alterations and trophic vulnerability. In assessing the latter, the bentophagics fishes have been considered less vulnerable regarding fish that feed on plankton, due to trophic generalism that present most fish that feed on the benthos, and the high functional redundancy between benthic prey.

The bentophagic fish *Harpagifer antarcticus*, has been considered as a specialist predator, however, this supposed specialization has been made qualitatively, without using methods that indicate directly its food strategy (generalist/specialist).

For the purpose to know the dietary specialization of *H. antarcticus*, the stomach contents of 45 specimens captured in Fildes Bay, Antarctica, during January 2012 were analyzed. To identify food strategy, the Levin Index ( $B_i$ ) and Costello graphical method modified by Amundsen was used.

Five major groups of prey were found, being the most important item Gammarida (IRI 88.95%). Within gammarid amphipods *Gondogeneia antarctica* was the main item (IRI 76.71%), followed by *Orchomenella* sp. (IRI 19.39%). The rest of amphipods was negligible (<3%). Regarding food strategy, were calculated a  $B_i$  0.051 and 0.149, for major groups and gammarid amphipods respectively. This was supported by the Costello graphical method modified, which indicated a specialist predator.

The specialization of *H. antarcticus*, suggesting higher trophic vulnerability to variations in prey availability for bottom-up effects, regarding the most fish of generalist habits. This becomes relevant, considering the current scenario of the Southern Ocean, affected by the current global warming, which could have consequences on the survival of populations of *H. antarcticus*.

## Lipid diversity and biosynthetic pathways of dominant krill species - a global view of Antarctic via tropical to Arctic euphausiids

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A pronounced seasonal variability in primary productivity is the crucial factor in determining the life strategies of many polar zooplankton species, whereas oligotrophic tropical oceans experience little change at a low productivity level. Lipid accumulation represents an important energetic adaptation in pelagic organisms to cope with the pronounced seasonal productivity in polar oceans. In a global context we compare important krill species from the Arctic via the tropics to the Antarctic, focussing on the genera *Euphausia* and *Thysanoessa*. While the Antarctic krill *Euphausia superba* is the metazoan species with the highest biomass on earth, krill species are clearly less relevant in other oceans. In polar krill species total lipid accumulation is usually very pronounced during the productive season and may be utilised for metabolic maintenance during overwintering or for reproductive processes in spring. Most polar krill species store large amounts of the unusual depot lipid phosphatidylcholine (lecithin), a polar lipid with highly unsaturated fatty acids. However, euphausiids exhibit strong differences in their neutral lipid compounds, which may either consist of wax esters or triacylglycerols, but also of both types of lipid classes. The major end-products of the fatty acid and fatty alcohol biosynthesis are quite different and usually the depot lipids show species-specific chemical characteristics. In contrast, tropical euphausiids do not rely on lipids as energy reserves and exhibit the usual lipid and fatty acid compositions of biomembranes with high amounts of docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA). The ecophysiological implications of these deviating lipid characteristics may determine biogeographical zonation patterns and affect the vulnerability of polar krill species to global warming.

## Embryonic and larval development of Antarctic krill (*Euphausia superba*)

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Antarctic krill (*Euphausia superba*) is a keystone species in Antarctic marine ecosystems, as well as an important species in the Southern Ocean fishery. The survival rate from spawning to late larval stage is essential for recruitment of the species. Despite the significant role of the species, research related to this part of life history of Antarctic krill is scarce. There has been a gap in the life history record due to the technical limitation. Here, we provide the first detailed photographic documentation of embryonic and larval development of Antarctic krill over a 5-month developmental period under controlled laboratory conditions. Developing embryos and larvae were photographed every 3 h and every 5 days, respectively. Our results indicated a developmental time of approximately 6 days for embryos and 138 days for larvae (0.5 °C). This research filled the gap of the record with detailed descriptions and high-resolution photos of a full development process of both embryonic development and larval development. Our results provided baseline biometry information for future investigations of Antarctic krill development under changing environmental conditions.

## The in-situ transcriptome as a means of understanding species-specific responses during initiation of a spring phytoplankton bloom in Antarctica

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The co-existence of many species has long been a central focus and mystery in phytoplankton ecology (Hutchinson's "paradox of the plankton"). While there are usually numerous phytoplankton taxa present in the water column, their relative abundances shift continually, indicating strong differential abilities to respond to changes in the environment and to compete for resources. We are using a functional genomics approach to identify species-specific molecular indicators of diatom success during the dynamic transition from winter to spring in Antarctica, a period of time that mimics predicted warming trends in local climate. For ten weeks (Sept-Nov), the successional pattern of net plankton diatoms (cells  $\geq 20 \mu\text{m}$  in diameter) was studied in neritic waters of the Antarctic Peninsula ( $64^{\circ}49'S$   $64^{\circ}02'W$ ). Species abundances were determined by microscopy and temporal changes in gene expression were quantified using next-generation sequencing technology. The biological data were augmented with a suite of measurements tracking seasonal gradients such as increasing day length and light intensity, the springtime ozone depletion cycle, increasing water temperature and decreasing ice cover. Over 60 diatom taxa were observed in the water column (0-60 m) during the study period. Diatom diversity peaked in mid-Oct; however, in early Nov the *Corethron pennatum* became the dominant species, comprising up to 88% of the net diatom assemblages examined. During this same time period, overall gene expression was highly correlated ( $r^2 = 0.96$ ) to population growth of *Corethron* and the development of the bloom, creating a unique opportunity to evaluate the *in situ* transcriptome from practically a monoculture of cells. Examination of specific mRNA sequences has revealed distinct patterns of co-regulation of gene expression related to 1) basic cellular process (e.g., cellular reproduction and bloom initiation), as well as 2) physiological responses to environmental stress (e.g., seasonal changes in temperature, increased UVB from ozone depletion events). The data generated have the potential to provide significant insights to gauge the effects of current and predicted climate change on Antarctic marine phytoplankton communities.

## Elevated DNA repair enzyme expression in Antarctic sea urchin larvae in response to ozone loss

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Ozone depletion over the Antarctic has resulted in elevated UV-B radiation (290-320 nm) entering the Southern Ocean, while future sea ice loss may also elevate UV-B levels penetrating the water column. Biological responses in Antarctic planktonic organisms to higher UV-B irradiances include increased damage to DNA. We explored further the detrimental effects of UV-B exposure on the planktonic larval stages of the Antarctic sea urchins *Sterechinus neumayeri* by quantifying the expression of the DNA repair enzyme photolyase, after developing and applying an *in situ* hybridisation assay. In the laboratory, we found DNA damage (CPD Mb<sup>-1</sup> DNA) and photolyase expression to be correlated with UV-B exposure. When larvae were out-planted on experimental racks for 5 days during low (166 – 269 DU) and high (233 – 312 DU) overhead column ozone levels, developmental abnormality and photolyase expression was more pronounced during periods when the *Ozone Hole* was present. Photolyase expression significantly increased, indicated by up to 5-fold increases in the number of cells expressing photolyase, while abnormality rates doubled under the ozone hole. In open water conditions, the response was greater at 1 m depth than at 4 m, but was absent at both depths when under a sea ice cover. Expression of photolyase was greatest around important body regions of the embryos and larvae such as the developing gut and the primary and secondary mesenchyme cells. These findings support the notion that polar planktonic organisms may face additional physiological costs, such as repairing DNA, as a result of either on going stratospheric ozone loss or future sea ice loss.

## Long-term monitoring of penguin behaviour, population dynamics and colony structure

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Despite the enormous popularity of penguins, their social behaviour remains poorly understood. Video recordings of penguins and penguin colonies are sporadic, of insufficient resolution and duration, and suffer from camera movements that may be artistically motivated but make them scientifically worthless. Recordings of penguin colonies during the winter months are particularly short in supply. Here we present two different observatories that are able to automatically take time-lapse recording over prolonged time periods under harsh climatic conditions and allow to answer questions on different levels of temporal structure.

i) The *microbs3x* is a very low cost observatory (~600 US\$), capable of recording high-resolution (12 MPix) time-lapse data. It features up to 128GB data storage and can collect with high temporal resolution over the whole season. Time-lapse data can be used to identify penguins or classify pixel color values as penguins, depending on the distance of the animals to the camera. This allows to count single penguins and answer ecological question about arrival and colony size, but it also enables the user to calculate an internal colony turnover, which describes the global rearrangement processes in the colony. Due to its ability to record time-lapse from 1 frame per second to indefinitely long intervals, *microbs3x* can be tuned to meet the requirement of the question. We deployed several *microbs3x* around king and emperor penguin colonies in the Antarctic and Subantarctic islands. We will present recording performance and methods to handle the vast amounts of complex imagery data.

ii) The Single Penguin Observation & Tracking (*SPOT*) observatory is used to track the movements of individual penguins over prolonged time periods and count the present number of individual penguins. The observatory consists of a wide-angle (45°) camera and a high-speed (5 images/s) high resolution (11 MPix) camera equipped with a telephoto lens (400-600mm). By this we measure decision making processes and penguin – penguin interaction, to understand the rules which determine internal colony structure.

We deployed two *SPOT*, one to monitor Adélie penguins and to observe Emperor penguins observatory between 2011-13 respectively, and will present first results alongside with methods to detect and track single penguins.

## Predict changes in polar ecosystems: biological adaptation and technological innovation

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'How biomes (will) respond to ongoing and future rapid environmental changes' is on everyone's lips. To explore how past and current environmental modifications affect ecological processes and population trends, and thus to monitor and predict impacts of global change on Southern Ocean ecosystems, pluridisciplinary and integrative approaches are needed.

The development of new technologies is expanding the scope of the data available to us on wild organisms. Using and developing new techniques in terms of cutting-edge electronics-, computing-, and genome-wide sequencing technologies, our programme aims to explore the ecological processes, from the macromolecule to the population scale, while minimizing human-induced disturbance and therefore scientific bias, that help species cope with environmental constraints.

Our long-term monitoring of top-level predators, i.e. known life history and status king penguins (*Aptenodytes patagonicus*; Crozet archipelago) and Adélie penguins (*Pygoscelis adeliae*; Adélie Land), based on Radio Frequency Identification (RFID) Automatic or Mobile Identification Systems, allow us to gather information on the variability of both life-history and phenotypic traits in these species (age-specific survival rates, recruitment parameters and reproductive performances, behavioural traits).

Powerful analytical and modelling tools, using for instance multi-events and matrix algebra frameworks, are used to assess new insights on demographic parameters and life-history strategies, and to draw up growth trajectories and extinction risks of these populations under projections of warming-climate scenarios forecast by the Intergovernmental Panel on Climate Change.

The genetic monitoring programme we developed to gauge population structure and abundance in space and time (phylogeography, gene flow, demographic history), as well as adaptation to environmental changes, already yields insights into how diversity is maintained in such philopatric colonial species. Genomic data also allow us to investigate potential impact of the last glaciation on their past demography history.

Together, the life-history, demographic and genetic insights in these penguin species offer us the possibility to explore the borderlines and thresholds of the adaptive abilities beyond which these populations would collapse, modifying in turn their ecosystems.

## Pollution and UV resilience in embryos of the Antarctic sea urchin *Sterechinus neumayeri* reflects maternal antioxidant status

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The Antarctic continent is vulnerable to the impacts of anthropogenic pollution, including fuel residues and heavy metals that occur in sediments and seawater. These impacts are particularly evident in sites previously used for waste disposal or currently used for fuel handling around scientific bases. Oxidative stress (OS), which occurs when there is an imbalance between reactive oxygen species production and antioxidant scavenging capacity, is often associated with pollutant-induced toxicity in marine invertebrates. The past decade has seen increasing evidence suggesting that the capacity of organisms to withstand oxidative stress may play a key role in shaping reproductive trade-offs.

We present evidence for non-genetic adaptation and resilience to pollutant and UV-induced OS in the Antarctic sea urchin *Sterechinus neumayeri* via increased maternal loading of protective antioxidants. Our results indicate that *S. neumayeri* sperm have a much simpler antioxidant system than eggs and that the paternal contribution has little influence on whether embryos are more or less susceptible to oxidative damage when exposed to stressors, at least at the early blastula stage of the life cycle. Lastly, we report that abnormal or delayed development in *S. neumayeri* embryos in response to fuel contaminants or UV stress is largely independent of oxidative damage to lipids and proteins, but is highly correlated to oxidative DNA damage. Our findings demonstrate that when dealing with multiple environmental variables, questions regarding the role of oxidative stress as a mediator for resource allocation and stress resilience in natural populations are complex to answer, particularly at the early stages of development.

## Thermal adaptation and gene expression in Antarctic sea spiders (Pycnogonida)

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Current knowledge of the genomic effects of temperatures on Antarctic organisms is limited to vertebrates (antifreeze proteins) or to upper thermal limits. No studies have utilized transcriptomics to directly focus on functional genomic responses of Antarctic benthic marine invertebrates to temperatures approach lowest survivable limits. Technological advances allow molecular genomic studies to investigate functional genomics as they relate to the physiological mechanisms and responses of benthic invertebrate organisms to lower temperature extremes. In this study, we examine the transcriptomes of the widespread Antarctic sea spider *Nymphon australe* to identify candidate genes involved in its ability to persist at low temperatures (i.e., below 0°C). Additionally, we completed a series of experimental trials where the sea spiders were exposed to three different temperature regimes to investigate transcriptomic changes and genomic regulation over short time intervals. These intervals are similar to those shifts the organisms would undergo in natural systems. Due to the rapid pace of climatic change in regions of Antarctica, there is urgency to more fully understand physiological responses of temperature on Antarctic benthic invertebrates. This study tests major dogma about Antarctic benthic invertebrates having novel genetic mechanisms for dealing with freezing temperatures and this study has significant implications for how researchers understand the function of species under adverse conditions.

## Unlocking evolutionary clues about thermal adaptation: evolution of stearyl-CoA-desaturase in Antarctic fish

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What impacts climate change have on biota is due to the capability of an organism to alter gene expression in response to environmental change. Surprisingly, fundamental understanding of mechanisms by which organisms adapt to thermal change is lacking. Antarctic notothenioid fish, operating under narrow thermal tolerance regimes (stenothermal), are an ideal model system to explore thermal adaptation, especially any limitations in gene expression capacity they possess. Embedded within the currently accepted model of thermal limitation are changes in lipid saturation to maintain membrane fluidity and oxygen movement with varying temperatures. Desaturase enzymes are key regulators of membrane lipid composition and exhibit temperature regulation, suggesting they play central roles in thermal adaptation. Delta-9 desaturase (SCD) catalyses an initial, rate limiting step in unsaturated fatty acid formation. As notothenioid fish favour unsaturated fatty acids for metabolism and within membranes, this invokes a key role for SCD. We are testing whether membrane remodelling, a universal response to temperature, occurs at reduced capacity in stenothermal animals, contributing to their narrow thermal tolerance, and limiting adaptive potential. Teleost fish have a complex history of SCD gene loss and duplication of isoforms due to genome duplication events. This has resulted in loss of SCD2 and duplication of SCD1 into SCD1a and 1b. We are determining SCD1a and 1b cDNA sequences in eurythermal and stenothermal notothenioid species as well as in other teleosts. Tissue distribution studies in the notothenioid species so far do not reveal expression differences between SCD from fish of different thermal backgrounds. Our phylogenetic work so far provides strong support for the presence of SCD1a and 1b duplication in Antarctic fish. We are now examining a broader panel of teleosts to provide insight into SCD evolution and refine the timing of the duplication event leading to the two isoforms. Examination of SCD sequences across a range of notothenioid and non-notothenioid fish reveals Antarctic fish have SCD amino acid compositions associated with both an overall increased conformational flexibility as well as reduced hydrophobicity of internal residues, similar to compositions in other proteins from polar species. This 'polar composition' is more prominent in Antarctic fish SCD1b than 1a, suggesting greater cold tolerance of SCD1b. Gene expression studies to evaluate SCD1a and 1b regulation under different environmental conditions using tissues from a thermal acclimation study are being used to test whether stenotherm SCD1a &/or 1b mRNA levels are less thermally responsive than other species. Lipid composition analyses will also be conducted. This research is contributing to our understanding of thermal adaptive and evolutionary theory as well as prognoses of climate change.

## The success of a symbiotic system: Adaptation potentials of lichen photobionts including gene expression

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Lichens dominate biomass production even under most extreme environmental conditions of continental Antarctica. As symbiotic associations of a photosynthetic partner (photobiont) and a fungus (mycobiont), lichen holobionts represent stable systems with autonomous primary carbon acquisition. Due to their photosynthetic activity and also their poikilohydric lifestyle, lichens strictly depend on the environmental water and light regime. The lichen symbiosis can thrive under continental Antarctic conditions by various mechanisms as the colonization of micro niches, the highly stress resistant anhydrobiotic state as well as structural and physiological adaptations of both symbionts. In particular, this study addresses photobionts of the genus *Trebouxia* which are dominant in the macro lichen flora of continental sites. Especially these photobionts exhibit various adaptations to a symbiotic lifestyle in these environments. Photobionts from different sites and different lichen associations are examined in the isolated and in the symbiotic state. Their potential to cope with extreme environmental conditions is tested on the levels of biochemistry, photosynthesis and for the first time on gene expression. Effects of light, temperature and water restriction on the photosynthetic activity as well as the protective role of pigments and other metabolites are included in the study. The physiological findings are completed with the examination of the underlying genetic processes. To assess the effects of drought on photobiont gene expression, next-generation sequencing of two complete photobiont transcriptomes is performed. This approach represents the first transcript analysis of Antarctic lichen photobionts. The results will substantially support the knowledge on these organisms' adaptive potential to harsh environmental conditions. Clarifying the potential of adaptation in the lichen symbiosis will not only reveal new aspects of the current success of Antarctic lichens, it will also increase the knowledge on their prerequisites to cope with future climate change.

## Glacier melting effects on coastal Antarctic phytoplankton ecology and physiology

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Glacier melting, a consequence of air temperature increase in Antarctica, adds freshwater to surface coastal marine waters. During austral summer 2010 the effects of low salinity on Antarctic phytoplankton assemblages' composition as well as on the microbial community production and response to hypo-osmotic stress were studied *in situ* in two coastal environments presenting a different degree of influence from glacier melting in Potter Cove (King George Island/25 de Mayo, South Shetlands). In order to experimentally test the field observations, in both 2010 and 2011 natural plankton was exposed during 8-10 days to a low salinity treatment (LST, 30 PSU) and a control, normal salinity treatment (NST, 34 PSU) in controlled microcosms. Community primary production was measured by means of the oxygen exchange method both in the experiments and in the field. An inhibition of community production was observed in both studies, and of instantaneous growth rate in the microcosms' experiments. However, in this last case growth recovered some days later, becoming significantly higher in LST than in NST at the end of the experiment. Total phytoplankton biomass was lower in LST than in NST and in the low-salinity waters in the field. These results were confirmed by the 2011 experiments. Here, two different phytoplankton assemblages developed: while in the control big centric diatoms (*Odontella weissflogii*, *Porosira glacialis* and chains of *Thalassiosira antarctica*, *Chaetoceros tortissimus* and *C. socialis*) were the most abundant phytoplankton species, comparable to those found in the field under similar conditions, relatively smaller pennate diatoms (*Navicula glaciei*, *N. perminuta*, *Nitzschia cf. lecointei* and *Fragilariopsis cylindrus/nana*) dominated the assemblage in LST. 2-Thiobarbituric acid reactive substances (TBARS) and dichlorofluorescein diacetate (DCF-DA) oxidation (both oxidative stress damage indices), were significantly higher in the low salinity field samples and in LST than in the experimental control on days 4 and 6 of exposure, but later these last values decreases to initial levels. This coincided with a significant increase in the concentrations of lipophilic antioxidants  $\alpha$ -tocopherol ( $\alpha$ T) and  $\beta$  carotene ( $\beta$ C) in LST. Our results suggest the existence of selective protection mechanisms against lipid peroxidation in some diatom species, which in turn could be the driving force to deeply alter the composition of the phytoplankton assemblage and its potential role in carbon fixation under hypo-osmotic stress conditions.

## Overwintering strategies in polar copepods: The role of ammonium accumulation and low hemolymph pH for buoyancy regulation and metabolic depression during diapause

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Herbivorous calanoid copepods such as *Calanoides acutus* in the Antarctic dominate mesozooplankton communities in both polar oceans and play an important link from primary production to upper trophic levels. They overcome starvation periods during the winter season by a combination of ontogenetic seasonal migration and diapause at great depth. Development ceases at the end of summer, and sub-adult copepodite stages C4 or C5 descend to depths below 1.000 m. They stop feeding and severely reduce their metabolic activity, as evident in extremely low respiration rates. They survive the inactive diapause phase at the expense of lipid reserves accumulated during summer. While this general adaptation and life cycle pattern of herbivorous calanoid copepods to the extreme seasonality in food supply in polar regions is well known, the actual triggering mechanisms for the descent and the physiological processes that provide buoyancy without swimming activity during diapause are still enigmatic. Here we present data that *C. acutus* accumulates ammonium ions in its hemolymph and replaces heavier ions by lighter ammonium. Ammonium accumulation and ion replacement apparently assist lipid storage in buoyancy regulation, particularly with regard to the fine-tuning of body density. Of several Antarctic copepod species, only the inactively overwintering species *C. acutus* and, to a lesser extent, *Rhincalanus gigas* accumulate ammonium. By contrast, actively overwintering copepods have an ion composition in their hemolymph similar to seawater. Dependent on the pH, ammonia exists in solutions as both,  $\text{NH}_3$  and  $\text{NH}_4^+$ . Due to the toxicity and the higher diffusibility of  $\text{NH}_3$ , a low hemolymph pH is required to favor the formation of ammonium ions ( $\text{NH}_4^+$ ). With a newly developed method based on fluorescence measurement of pH in extremely small volumes, we could show that the hemolymph of overwintering copepods, which accumulate  $\text{NH}_4^+$ , is indeed characterized by a low pH of ca. 5. In other marine invertebrates, low intracellular pH leads to metabolic depression. Possibly, the low pH in the hemolymph of overwintering copepods contributes to the down-regulation of metabolic activity during diapause. In combination, ion exchange and  $\text{NH}_4^+$  accumulation at lowered hemolymph pH appear to be involved in both, buoyancy regulation and metabolic depression in overwintering polar copepods. This physiological mechanism will affect the response of copepods to climate change and ocean acidification.

## Temperature affects the survival and reproduction of the Antarctic tardigrade, *Acutuncus antarcticus*

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Terrestrial ecosystems in parts of Antarctica currently experiencing sometimes drastic climatic and environmental changes. Understanding how individual species – and hence the populations and communities of which they are part - respond to these changes is recognized as a key research challenge affecting our ability to predict how ecosystem structure and function might alter.

Tardigrades are important members of the simple faunal assemblages found in the extreme terrestrial and freshwater environments of continental Antarctica. In lakes and pools, in particular, they are one of the major community components. The species *Acutuncus antarcticus* is often the most common and dominant species in these communities.

In this study, we set out to clarify aspects of the thermal responses of *A. antarcticus*. Cohorts of 20 juveniles of *A. antarcticus* hatched within a 24 h period were reared at either 20°C, 15°C, 10°C, 5°C in dark on agar plates with Volvic® water and the green alga *Chlorella vulgaris*. Individual tardigrades were inspected daily over 140 d and their survival, egg production and subsequent egg hatching were recorded.

Survival and reproductive performance greatly differed at each temperature. The cohort kept at 10°C showed the best performance, with the longest survival time (average=75.3 d), the largest total egg production (769 eggs), and the highest hatching rate (98.2%) of the eggs laid. Over the same time period, the cohort reared at 5°C laid 250 eggs (30% of the number at 10°C) of which only 42 hatched (16.8% hatching rate, or 5.6% of the number at 10°C).

These data indicate that only a relatively small change in habitat temperature may greatly affect the population growth of *A. antarcticus*. They also suggest possibly rapid changes in the influence of these tardigrades on community structure and function in the terrestrial and freshwater ecosystems of continental Antarctica.

## Acoustic features of display calls may reveal information about breeding status and individual quality in emperor penguins

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Acoustic display calls are important tools for species that live and breed in very dense colonies. Such dense aggregations of individuals occlude and limit the function of visual cues, so many of these species may instead rely on acoustics to mediate behavioural interactions, to select mates, or to establish territories. Thus, within a species or even a population, individual quality or breeding status may be strongly correlated with particular acoustic traits.

In emperor penguins, *Aptenodytes forsteri*, individuals select partners at the beginning of each breeding season through the use of display calls. The calls, which carry features that act as individual fingerprints, are then used to localize mates inside the colony during exchanges for the rest of the breeding season. Moreover, emperor penguins do not breed in a fixed territory, and they constantly shift the location of the colony over the course of a breeding season. Thus, there must be strong selective pressure for display calls to be stable signals to decrease the rate of error in relocating a mate. However, the actual stability of display call features over the course of a breeding season, and the variability of acoustic features associated with physiological constraints are virtually unknown.

Acoustic display calls were analysed from emperor penguins during courtship, incubation, and brooding at the "Pointe Géologie" colony in Adélie Land during the 2011-2013. Display calls were first recorded from both males and females after apparent pair formation, and these individuals were then followed through the rest of a breeding season. Breeding status information on these pairs was noted, and additional display calls were recorded at particular stages of the breeding cycle using playbacks of partner calls. Acoustic features were analysed between groups of individuals to assess how display calls vary over the course of a season. Particular attention was paid to features subject to physiological constraints because of their potential for revealing the effects of stress associated with the long breeding shifts. This study is a first step in determining how variation in call features may be useful to emperor penguins evaluating potential partners or to scientists developing a less invasive measure of assessing individual condition throughout a breeding season. These results will help to develop tools for evaluating the adaptive capacity of individuals and their populations to global changes.

## **S26: IMPACT OF CLIMATE CHANGE ON ANTARCTIC BIOTA**

### **Coastal marine monitoring program at the King Sejong Station (KSS), King George Island (KGI), Antarctica**

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KGI is maritime Antarctica. It is located at the northern tip of the Antarctic Peninsula, one of the most rapidly warming regions on Earth. About 90% of the island is covered by glaciers, and significant glacier retreat has been observed in many coastal areas. KGI is also most crowded region in Antarctic, where 8 countries are operating their stations all year round. All these stations are located on the coastal area. Thus, coastal environment of KGI is likely to be the most sensitive area to climate change and anthropogenic impacts, which warrants a long-term monitoring on coastal marine ecosystem changes. Marine monitoring at KSS consists of largely 2 parts: year-round monitoring (environmental monitoring at a fixed point) and summer-time monitoring (monitoring on glacier retreat impacts on water column properties and planktonic/ benthic communities).

We initiated a year-round long-term monitoring on marine environment in 1996 at KSS, and thereafter we've been collecting environmental data (i.e. water temperature, salinity, nutrient, and Chl.a etc.). We've been also continuously monitoring seasonal & annual variations in species composition and biomass of microalgal populations, relating their changes to the environmental variables measured. We found different diatom species increased towards the tidewater glaciers in Marian Cove (MC), a typical glacial fjord in Maxwell Bay. Sea ice condition and meteorological parameters are being monitored since the operation of KSS in 1988.

Starting lately, we've been monitoring ice retreat and its impacts on marine organisms in Marian Cove. During the last 50 years, the tidewater glacier in MC has been retreated about 2 km. We've been seeing the ice retreat being accelerated in recent years. MC receives a substantial amount of glacier-melt water during austral summer months. In order to understand how glacier-melt water affects sea water properties we're conducting time-series measurement of sea water parameters using CTD casting and tide gauges moored in the cove. We found distinct gradients in water column properties and in concentrations of some terrestrial elements (i.e. SPM, Fe, Al) along the horizontal axis of a varying degree of melt-water influence. We're also assessing the climate-induced impacts on biodiversity and other ecological features of marine benthic communities. Slow-moving or sedentary benthic organisms in shallow (<35m) waters are likely the most vulnerable, which in turn enables them to serve as indicators of climate-induced perturbations.

Finally we propose a future monitoring program in KGI within a frame of international collaboration.

## Assessing impacts on diversity of Antarctic nearshore marine benthic communities by climate-induced processes in a glacial fjord, Maxwell Bay, King George Island (KGI)

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A study on the response of megabenthic epifaunal communities to glacial retreat was conducted in a representative glacial embayment (Marian Cove, MC) in Maxwell Bay, King George Island, KGI. The MC represents Antarctic nearshore (defined in this study as shallow waters of < 35m depth adjacent to shoreline) benthic faunal assemblage. Based on the information from previous investigations, we selected the sites near to glacier (MC4) and far from glacier (MC2), as well as an intermediate site (MC3). We deployed 3 transect lines (25 m each) between 15 to 30 m depth at each site, and total number of taxa at each transect line was determined from hand-picked specimen and from photographs. We determined the communities' difference in terms of their structure (i.e. species richness), taxonomy (i.e. Taxonomic Distinctness index, TD) and function (i.e. Functional Diversity index, FD). We also analyzed the faunal assemblages in relation to environmental characteristics.

The species richness was significantly lower at MC 4 ( $35 \pm 2.51$ ) than at MC 2 ( $64 \pm 11.72$ ), whereas TD values were similar among the sites, indicating all sites were as taxonomically distinct as each other. This study also found out that MC4 had significantly lower FD value (0.33) compared to MC2 (0.90) and MC3 (0.74). Water column properties recorded by CTD showed significant differences down to 30m depths between MC4 and MC2 (t-Test,  $p < 0.05$ ), and distinct gradient by distance from MC 4 to MC 2. In particular, CTD profiles showed very irregular patterns at MC 4, indicating MC 4 undergoing more frequent disturbance by glacier break-up. Massive intrusion of melt-water body was also recorded at 20-30 m depths at MC 4. Difference was also recorded in sediment properties with higher percentages of muddy sediment near to the glacier, indicating higher sedimentation rates at the site.

This study provides early evidence that physical changes in habitat characteristics following glacier retreat and its consequent processes had impacted the benthic communities. In more alarming concern, the event had also reduced the diversity of benthic functions, from which we could infer such impact on the entire ecosystem functions.

## Climate variability and biological nitrogen fixation by soil crusts in Ardley Island, South Shetland Islands, maritime Antarctica

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The evidence on recent climate change in western maritime Antarctica shows a general picture of warming air temperature trend and decreasing precipitation. It is therefore likely that biological processes occurring in those environments are impacted by this climatic forcing. For maritime Antarctica for example it has been reported high bacterial diversity associated with processes of nitrogen transformations such as biological nitrogen fixation, net nitrogen mineralization and denitrification. The present study aims to link key soil biogeochemistry processes with the recent trends on climatic variability of maritime Antarctic environments through field and laboratory assays under different humidity and temperature regimes.

We analyzed annual and monthly meteorological data of the last five decades from the stations Eduardo Frei (62.1°S, 58.92°W) and Bellingshausen (62.2°S, 58.93°W). Both stations are located in the Fildes peninsula, King George Island, South Shetlands. The objective of this analysis was to study if the climatic trends described by literature for western maritime Antarctica are operating in our study area. At the same time we conducted a research that considered three years performing field and laboratory assays to estimate biological nitrogen fixation by soil crusts in a transect that crosses the Ardley Island, distant less than 2 kms from the referred meteorological stations. The objective of this study was to evaluate the effect of moisture and air temperature in biological nitrogen fixation.

Climatic analyses on air temperature and precipitation from Frei and Bellingshausen stations allowed us to confirm the main warming and decreasing precipitation trends described by literature. Local singularities however were clear from more specific analyses. Multiannual and decadal variability and its consequent climatic signals are superimposed on the general trends and determined shorter term climatic oscillations.

Soil biochemistry analyses, on the other hand, performed in consecutive summer seasons allowed to obtained results under contrasting environmental conditions. During February 2012 under dry/warm conditions the addition of water to the assays had significant effects on Nitrogen fixation by biological crusts in almost all the sites. On the contrary, during February 2013, under wet/cold conditions, the addition of water had not effects on Nitrogen fixation. Differences on air temperature were also compared among field and laboratory conditions. Higher temperature had significant effects on biological nitrogen fixation.

The examination of trends/variability of climatic variables at the study area permits to extrapolate the effects of warming trends in air temperature and decreasing precipitation predicting lower diazotrophic activity in biological soil crust in maritime Antarctica.

Project INACH T01-11.

## Responses of moss and lichen vegetation to manipulated warming: Long-term study exploiting OTC approach at James Ross Island, Antarctica

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In 2007, several open top chambers (OTCs) were established in three contrasting habitats: i) moss-dominated coastal vegetation oasis (5 m a.s.l.), (ii) lichen-dominated plateau of a table mountain (350 m a.s.l.), and ice-free forefield of a cap glacier (410 m a.s.l.). The long-term study comprised evaluation of differences in microclimate between the OTCs and outside control plots as well as changes in vegetation cover and selected photosynthetic characteristics. For consecutive 7 years, continuous measurements of air temperature (30 cm above surface), vegetation cover and soil temperatures as well as air humidity have been done at the three habitats in 1 h interval. Vegetation in OTCs and at control plots were photographed each year so that OTCs-induced changes in vegetation cover could be evaluated. To estimate annual courses of photosynthetic activity of *Bryum* sp., a common moss species at the coastal plot, fluorimeters were installed in OTCs and at control plot to measure an effective quantum yield of photosynthetic processes in photosystem II. Additionally, numerous physiological measurements, such as e.g. responses to dehydration, high light and low temperature have been carried out on collected mosses and lichens in a laboratory under controlled conditions. Microclimatological measurements showed that mean annual air temperature increment in OTCs was lower for coastal plot than lichen-dominated table mountain plateau. However, positive vegetation response was found only for coastal plot. Similarly, soil temperature (5 cm depth) was OTC-affected in both habitats which may have consequences for soil microbial activity. Vegetation cover area increased in OTCs located at coast due to OTCs-affected growth of mosses. However, vegetation area was partly affected by episodic depositions of mineral particles transported by a strong wind from ice- and snow-free areas during austral summers. This resulted in a burial of vegetation under several mm-thick layer. Lichen vegetation in OTCs located on a table mountain remained unaffected by elevated temperature. Chlorophyll fluorescence data revealed temperature-induced inhibition of *Bryum* sp. photosynthesis at the beginning of austral winter and several short-term episodes during winter when the moss is physiologically-active due to above-zero temperature. During summer season, data indicated water limitation and resulting inhibition of photosynthesis in *Bryum* sp. sensitively. The authors thank CzechPolar facility.

## Warming in the Antarctic Peninsula: Ecophysiological responses of the two antarctic vascular plants

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The Antarctic Peninsula has one of the fastest rate of warming on earth (IPCC, 2007), with increases about 1-2°C per decade. There is scientific evidence that vascular plant populations are expanding and colonizing new areas that has recently become available after ice retreat. Reports indicate that the recent expansion is particularly evident on *Deschampsia antarctica* populations but not in *Colobanthus quitensis*. There are not clear ecophysiological explanations for this different expansion of the plant populations; hence there is not a good prediction whether this expansion will continue in the near future. For this reason we are addressing the following ecophysiological questions: Is the temperature *per se* the factor that exert an effect upon plant metabolism (photosynthesis and respiration) and promote plant growth and reproduction, or there are indirect effects, such as soil nutrient cycling acceleration and higher availability of limiting nutrients such as nitrogen? Do both antarctic vascular plants will respond similarly to warming? Two different approaches as been used, one is descriptive, in which we are studying and describing how plants have adapted along a natural latitudinal gradient (53° to 67.5° S). On the second approach we are experimentally warming the plants in the field with Open-Top Chambers (OTC) that were installed in December 2012 in three populations of *D. antarctica* and *C. quitensis* in King George Island, near Arctowski Station (62°09' S, 58°28' W). Preliminary results indicate that responses to the increase in temperature in the field, inside OTC, differ among species: while *C. quitensis* increased photosynthesis, photochemical performance ( $\Phi$ PSII, ETR) and growth, *D. antarctica* did not show differences between warmed and control plants. In the laboratory, both species significantly responded to nitrogen fertilization (nitrate and ammonium), which is an important nutrient which availability was modified by the OTC *in situ*. *C. quitensis* from Pta. Arenas (53° S), Arctowski Station (62° S) and Lagotellerie Island (67.5° S) showed distinctive leaf anatomical features: smaller leaves with narrower adaxial surfaces can be distinguished toward southern latitudes. This suggests that the anatomy of this species is plastic enough to respond to higher temperatures. These results suggest that both antarctic vascular plants will respond differentially to the modification of the antarctic environment, and both direct and indirect effects of warming are involved in promoting plant growth. Further research is needed in order to conclude about the likely responses of these species to different warming scenarios.

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## Scenarios of change in the Southern Ocean

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British Antarctic Survey

We present the outcomes of a recent ICED (Integrating Climate and Ecosystem Dynamics in the Southern Ocean programme) workshop on food webs and scenarios of change. The community has made progress with food web research and qualitative assessments of change, and we are now beginning to consider predictive models. Given the knowledge gaps and uncertainties inherent in studying the effects of change on marine ecosystems, scenarios are a useful approach from which to explore the potential responses to and consequences of change. From a Southern Ocean perspective, scenarios need to consider environmental, ecological and fishery-related changes. Collaborations between climate scientists, ecologists, modellers, and fishery scientists and managers were initiated at the workshop towards defining a set of community assessed and agreed scenarios. These include quantitative scenarios of sea ice change and other key environmental parameters, together with qualitative scenarios (including the recovery of key species). We highlight issues involved in the development of these scenarios, explore the associated uncertainty, and provide guidance in applying them (e.g. which regions to focus on with respect to understanding particular drivers of change). These scenarios will provide a basis for exploring potential impacts of change on key species and the whole ecosystem, provide a framework from which to develop projections of future change in the region, and will be used to inform both IPCC and CCAMLR regarding Southern Ocean change and management. This work represents a collaborative effort by participants in the above ICED workshop and the associated community.

## Assessing change in Southern Ocean ecosystems: implementation through the combined activities of the Southern Ocean Observing System and the ICED Southern Ocean Sentinel

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Recent discussions in the IPCC and the Antarctic Treaty System have shown the great importance to policy makers for measuring change in Southern Ocean ecosystems but that there are many gaps in our current knowledge. A capability is being developed to assess dynamics and trends in these ecosystems to understand what has changed as a result of the whaling and sealing eras and what is likely to change as these species recover along with the varying influences of ozone hole recovery, ocean acidification and climate change in the future. This capability is being developed in the Southern Ocean Observing System and in the Southern Ocean Sentinel, which is a signature project in the IMBER Program, Integrating Climate and Ecosystem Dynamics of the Southern Ocean. These two programs complement each other in designing and implementing an observing system to measure change in Southern Ocean ecosystems and in developing statistical and mathematical methods for assessing status and trends in these systems based on the observation system.

This talk will describe the significant progress being made by the Southern Ocean ecological community in building this capability and discuss the future work program that will yield a co-ordinated interdisciplinary, multinational activity equivalent to those programs within SOOS that have been established for the physical sciences. It will describe how the community is assembling a set of ecosystem Essential Ocean Variables, how it is developing a systematic field program for obtaining these measurements in a cost-effective manner and the innovations that are being sought to enhance this capability. The talk will conclude by presenting the timetable over the next 4 years on how these programs can contribute to assessment of status and trends in Southern Ocean ecosystems over the next 4 years.

## Plants and soil microbes respond to recent warming on the Antarctic Peninsula

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The Antarctic Peninsula is one of the most rapidly warming regions on Earth, with air temperature increases of as much as 3°C recorded since the 1950s. However, the longer-term context of this change is limited and existing records, largely relying on ice core data, are not suitably located to be able to trace the spatial signature of change over time. We are working on a project exploiting stable isotope records preserved in moss peat banks spanning 10 degrees of latitude along the Antarctic Peninsula as an archive of late Holocene climate variability.

Here we present a unique time series of past moss growth and soil microbial activity that has been produced from a 150 year old moss bank at Lazarev Bay, Alexander Island (69°S), a site at the southern limit of significant plant growth in the Antarctic Peninsula region. These moss banks are ideal archives for palaeoclimate research as they are well-preserved by freezing, generally monospecific, easily dated by radiocarbon techniques, and have sufficiently high accumulation rates to permit decadal resolution. We use accumulation rates, cellulose  $\delta^{13}\text{C}$  and fossil testate amoebae to show that growth rates, assimilation and microbial productivity rose rapidly in the 1960s, consistent with temperature change, although recently may have stalled, concurrent with other evidence. The increase in biological activity is unprecedented in the last 150 years.

The observed relationships between moss growth, microbial activity and climate at Lazarev Bay suggests that moss bank records have the potential to test the regional expression of temperature variability shown by instrumental data on the Antarctic Peninsula over centennial to millennial timescales, by providing long-term records of summer growth conditions, complementing the more distant and widely dispersed ice core records. We will conclude by placing the records into the wider context of the latest progress of analysis of moss bank cores obtained along the length of the Antarctic Peninsula and Scotia arc.

## Succession of benthic marine algae in newly ice-free areas of Potter Cove, Antarctica: a four years study

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Global warming at the Western Antarctic Peninsula is very high, leading to a massive retreat of the glaciers. In Potter Cove, King George Island, newly ice-free areas appeared due to glacial retreat opening new space for benthic colonization. This study is the first intend to follow the succession of benthic marine algae in two newly ice-free areas (A1 and A2) during four years (2010 to 2014). For this reason a total of 46 artificial tiles were installed in both areas during April 2010 at 5 m depth. Total algal cover and biomass were analyzed in a central square of 16 x 16 cm in five randomly sampled tiles during four summers in each area. Underwater photosynthetically active radiation (PAR, 400-700 nm) was measured weekly around noon during summer months (January to February). A1 was ice free since 1990 and A2 since 2003 approximately. The light attenuation coefficient,  $K_d$  was high during summer indicating strong sediment inflow, and significantly higher in A2 compared to A1. In addition,  $K_d$  in A2 was significantly higher in 2012 compared to the rest of the years and similar for A1 among the studied years. During the first year tiles were colonized by benthic diatoms followed by few macroalgal species such as *Palmaria decipiens* and *Monostroma hariotii*. The following year's tiles were rapidly colonized by the brown algae *Adenocystis utricularis* and red crustose *Corallinaceae* and by *Desmarestia menziesii* and *Urospora penicilliformis* during the last two years of the experiment. Total cover and biomass were not significantly different between areas. Biomass did not increase significantly with time over the four years of the experimental period but the total cover was significantly higher in 2013 compared to the other years. In 2013 temperatures were lower during the summer than in the other years, resulting in a lower inflow of melt water from the glacier into the cove, and consequently a higher light penetration into the water column. The study showed that on the one hand retreating glaciers can open new space for macroalgal colonization, but on the other hand a high sediment run-off from the melting glaciers may affect algal settlement and growth. However, further analysis and comparative studies are needed to understand and predict the possible consequences of rapid environmental changes on algal colonization and succession patterns in Antarctica.

## Warmed and diluted! The stress endocrine axis of *Notothenia rossii* and *N. coriiceps* in response to thermal and osmotic challenges

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Centre of Marine Sciences

Antarctic fishes evolved in a stable thermal and haline environment for roughly 30 million years. Recent climate changes contributed to a significant rise in water temperature and forecast models indicate the rate of such changes will increase in coming years in the coastal areas of maritime Antarctica, possibly leading to ice melting and freshening of shallow waters in enclosed areas.

In experiments run in 2005 and 2012/13 we exposed two species of Notothenidae, *Notothenia coriiceps* and *N. rossii*, to rapid but gradual changes in water temperature or/and salinity to evaluate the response of several physiological processes. Fish collected around the Rothera (UK) and Arctowski (PL) stations using traps or fishing poles were transferred to experimental tanks in cold rooms and acclimated from natural temperatures (0-2°C) to 4-8°C using thermostat-controlled heaters, and from 32‰ to 20-10‰ by addition of freshwater to recirculating tanks, over a period of up to 10 days. The roles of the stress endocrine axis in changing conditions were tested using GR/MR blockers (mifepristone, spironolactone) and agonists (dexamethasone, cortisol), and inhibiting cortisol release (using metyrapone).

No significant mortality or changes in behaviour between the groups were observed. Our preliminary data shows that both cortisol and gene expression of metabolic-related proteins were upregulated, and glucocorticoid- and mineralocorticoid receptors also varied after a heat shock, but that the stress response to handling were reduced in fish exposed to challenging conditions. Additionally, the rise in temperature induced a dependent increase in plasma osmolality while decreasing branchial Na<sup>+</sup>/K<sup>+</sup>-ATPase activity, decreasing osmoregulatory efficiency. These results show that Antarctic fish are reactive to environmental change, but that their ability to accommodate rapid or adaptive responses may be compromised.

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## Climate warming in maritime Antarctica: Expected and unexpected impacts

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Climate warming is expected to change the ranges of terrestrial plants, shifting their suitable habitats towards higher altitudes and latitudes.

The Antarctic Peninsula is one of three regions of the planet that have experienced the highest rates of climate warming over the last 50 years.

Here, based on the most comprehensive and large scale comparison of new and historical surveys yet achieved, we show that the two species of native Antarctic vascular plants (*Deschampsia antarctica* Desv. and *Colobanthus quitensis* (Kunth) Bartl.) have exhibited significant expansions in local range and population numbers since the 1960s.

This has been in response to increases in mean annual and summer air temperatures and in annual and summer precipitation, providing authoritative confirmation of trends reported or hypothesised in smaller scale or shorter term studies elsewhere in the maritime Antarctic.

Our data demonstrate changes in the species' abundances and spatial distributions within their already-colonized elevational range, but provide no evidence of upward (altitudinal) migration.

This unexpected impact could be the consequence of physical disturbance at higher elevations due to the thinner active layer (40 – 185 cm), where the depth of gelifluction, cryoturbation and/or ice segregation in the soil directly involves the root depth zone of the vascular plants.

Our study highlights the importance of including sources of physical disturbance into models of species geographic ranges, in order to improve their explanatory and predictive power, enabling more accurate forecasting of future species ranges under changing conditions.

## Population dynamics at the Prince Edward Islands (Southern Ocean): Forecasting of climate change scenarios through forcing of primary producers

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Potential effects of climate change in an ecosystem can be explored through the bottom up effects reflecting dynamics of the system productivity. Changes in the productivity of the Southern Ocean have been documented through satellite remote sensing, with shifts in frontal positions, periodicity and intensity of seasonal blooms and overall open ocean productivity. Generating an understanding of how these effects will play out in the long term for the Southern Ocean food webs will provide us with insight to better understand the current trends of ecosystem behaviour and future climate change scenarios. For this study we investigated potential ecosystem effects of climate change through changes in primary production on the biota of the Southern Ocean Prince Edward Islands (PEIs). A network ecosystem model of the islands, representing the decade between 2000 to 2010 at the scale of the Economic Exclusive Zone, was constructed with all living biota described by 37 functional groups. Four of these groups were producers: two allochthonous open ocean phytoplankton production groups with a large and a small size fraction delineated at > and <20µm, and two autochthonous production groups representing the island-associated seasonal blooms and the macrophytes. We ran a series of temporal simulations, for duration of 100 years each, and considered the ecosystem effects of increasing and decreasing the four primary producers which resulted in eight scenarios. Of the scenarios, the ecosystem effects were greatest for the open ocean phytoplankton scenarios. Observed changes in productivity in the vicinity of the PEIs from satellite data include a recent (decade long) decline in open ocean production, a decline in observed island associated blooms and increase in macrophytes. A decline in the productivity, particularly the small phytoplankton allochthonous production, resulted in replicating temporal trends documented by survey data in many of the biological groups. Variable trends including declines (e.g. Southern elephant seals, Macaroni Penguins, pelagic fish groups), mixed responses (e.g. King Penguin, Gentoo Penguins, various demersal fish groups) as well as increases (e.g. Macrophytes) were all found. However, not all population trends could be accounted for by a single scenario, and a suite of drivers is needed to complement the climate change scenarios to capture the ecosystem dynamics at the islands.

## Changes in the bryozoan communities throughout the Cenozoic of Antarctica

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Antarctic bryozoans from the marine and glacio-marine sequences stretching back to Paleogene, along with the Neogene represent a transitional time in the Cenozoic evolutionary history coming between the Cretaceous with the K-T boundary which hampers the extinction and survival of many bryozoan taxa, up to the Recent where the cheilostomes dominate.

The earliest Antarctic bryozoan fossil records of the late Early Eocene (Seymour Island) are connected with the major phase of ascophoran cheilostome evolution, clear preponderance of cerioporoid cyclostomes along with numerous anascan microporoideans. Undoubtedly, the occurrence of over 90% of mostly warm-loved taxa with multilamellar colony growth-form of the relatively slow growth-rate represented by cyclostomes and cheilostomes in the lower part of the La Meseta Formation is connected with the short-term episode of a long period of *in situ* evolution. Contrary to that, the impoverished bryozoan biota composed of the scarce anascan macroporoideans, started to radiate ascophoran lepraliomorphs of Smittinidae, and new umbonulomorphs of the family Brydonellidae in the upper part of the La Meseta Formation pointed to the different palaeoenvironmental conditions.

The shallow-marine, pectinid-rich biofacies of the *Pecten* Conglomerate of CIF of Cockburn Island taxonomically shows the mosaic pattern in occurrence of taxa which are known from the Mid- and Late Cretaceous, another that are considered to have originated in the Paleogene (Eocene-Oligocene) then evolved in the Antarctic and becoming widespread through Neogene and Recent, as well as those the most successful and common wholly Neogene such as Microporellidae. Almost exclusively encrusting colony growth-form of the Pliocene biota suggests sedimentation in the a shallow-water environment and indicates an interglacial palaeoenvironment for the deposition of the CIF Formation (Hara & Crame, 2010).

The cold-water geographical distribution of the Recent bryozoans with dominant ascophoran lepraliomorphs of Schizoporelloidea - the most richly represented superfamily as well as umbonulomorphs shows a dynamic history of this highly endemic fauna which evolved over long period of time.

Correlation between the bryozoan's colonial growth-forms and the environmental conditions (substrate, water energy, sedimentation rate, climatic regime) are potential tools in interpretation of the palaeoenvironmental conditions of the changing biota inhabited in different array of ecosystems ranging from greenhouse to icehouse in the Cenozoic of Antarctica.

The evolution of the Antarctic bryozoans is complex and includes faunas which derived from a few centres, mostly associated with the Weddellian Province, where the important place of origin for many taxa is early Paleocene Roca Formation of Patagonia.

## Climate change and Lake Vanda: Past, present and future scenarios

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The 12 m rise in the level of Lake Vanda is the largest documented environmental change in the McMurdo Dry Valleys. The primary driver of this change is meltwater production at the coastal Wright Lower Glacier which feeds the headwaters of the Onyx River. The Onyx River drains into the lake, 32 km inland, and is the principle input. Ablation is the only loss mechanism. In this presentation, we synthesize historic and new information to describe the sensitivity of Lake Vanda to past, present and future climate change.

The earliest measurements of Lake Vanda in the 1960's coincided with a decade of stable level. At that time the lake was comprised of a 29 m thick salinity gradient at the base of the lake, overlain by an isothermal 20 m thick thermohaline convection cell, and a 12 m thick, stepped thermal gradient below the ice. Thermohaline convection was driven by solar heating of the deep saline zone, where high light transmission through ice and lake water allowed temperatures to exceed +25°C. Subsequent lake level rise has inserted a second convection cell, now 19 m thick, above the first. Comparison of modern and 1960 temperature profiles suggest that the upper limit of the lower convection cells marks a previous stable water level, more than 25 m shallower than the current surface, that probably prevailed in the early part of the 20<sup>th</sup> Century.

The stability of the unique mixing regime, within which the ecosystems of the lake are embedded, depends on heat flux. While location of the lower convection cell has remained constant, its temperature has declined since 1960 by 0.03°/y, and with it the flux of heat into the upper cell. In Dec 2013 the upper cell was 4.43 °C, 955 µS/cm, and 1000.404 kg/m<sup>3</sup>, and the lower cell 6.53 °C, 1610 µS/cm, and 1000.736 kg/m<sup>3</sup>. Between 30 Nov and 14 Dec, upper cell convective mixing was dependent on the heat flux across the pycnocline from the lower cell. A fine balance was apparent later in the season when temperatures between 5 and 10 m were highest, indicative of downward heating from solar radiation. This conflict between upward and downward heat flux is critical to maintaining the current lake mixing regime and is threatened by cooling of the lower layer as level rises.

Four future scenarios can be envisioned for Lake Vanda: (1) Continued coastal melting, lake level rise and heat loss in the lower cell. Convection stops and the water column stratification regime changes drastically. (2) The lake reaches a new stable level where ablation from the increased lake surface area balances increased inflow. Solutes increase in the upper cell until both cells mix. (3) Reduced meltwater production, and/or increased aridity inland, causes lake level to fall with similar results to (2). (4) Unstable climate conditions cause cycles of falling and rising lake level, each cycle generating a new convective cell. Implications for the unique biological communities that characterize the cells of the lake are discussed.

## Response of the terrestrial tardigrade *Acutuncus antarcticus* to predicted, climate-driven habitat change

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Low diversity ecosystems such as the McMurdo Dry Valleys are especially important to protect. Their relatively low biodiversity means that each organism plays a disproportionately greater role in ecosystem functioning (compared to places where biodiversity and functional redundancy is high). This means that the survivability of each individual in these low diversity ecosystems is very important to the system as a whole.

Global climate models suggest that future Dry Valley ecosystems will be warmer and wetter. This change is likely accompanied by an increase in temperature fluctuations, meaning that the organisms living in the soil will experience more frequent freeze-thaw cycles than they are accustomed to. This is important because tardigrades that normally were in a dry environment the majority of the year will now be exposed to increased moisture content and also a higher number of freeze-thaw cycles. This has potential to disrupt tardigrade population structure as these conditions may lead to increased mortality.

We carried out a series of laboratory experiments to determine what the effects of changing temperature, humidity, and number of freeze-thaw cycles will have on populations of *Acutuncus antarcticus*.

Our null hypothesis is that increased temperatures, humidity, and number of freeze-thaw cycles will have no effect on tardigrade survivability. Our alternative hypothesis is that these changes lower the survival rates of the tardigrades.

Through our initial experiments we have found evidence to reject part of our null hypothesis by showing that there is a correlation between the humidity at which a tardigrade is desiccated and its survivability. A higher relative humidity leads to a greater percentage of survival. However, we were not able to demonstrate a correlation between temperature and survival rate. Our experiments did show higher average survival at higher temperatures but this difference was not statistically significant. Further experimentation is being conducted to determine the effects that 100% relative humidity and also increased freeze-thaw cycles have on tardigrade survivability. Our hypothesis is that both of these factors will significantly decrease tardigrade mortality.

## Increased bioavailability of iron in frozen environments

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Iron is an essential micronutrient for the growth of living organism on Earth. The bio-availability of iron has been regarded as a crucial limiting factor for the phytoplankton productivity and involved in the sequestration of atmospheric carbon di-oxide(CO<sub>2</sub>), especially in HNLC(High Nutrients Low Chlorophyll) regions such as Southern Ocean. Although the bioavailability and fate of iron in aquatic environments has been intensively investigated, those in frozen environments have rarely studied. In this study, the generation of dissolved iron from particulate iron oxides in ice phase was investigated both in the absence and presence of irradiation. The dissolution of iron oxides in frozen sample was significantly accelerated compared to those in aqueous solution. The outdoor experiments carried out under ambient solar radiation of Ny-lesund (Svalbard, 78 55'N) and King George Island (62°13'S 58°47'W, sea level) also confirmed that the production of bio-available iron species is enhanced when iron oxides are trapped in ice. We speculated that the freeze concentration of iron oxide particles, protons, and organic ligands in ice grain-boundaries could be the plausible reason for the enhanced dissolution of iron oxides in ice phase. These results imply that the iron oxides particles trapped in frozen environments (snow, glacier, ice-cloud particles, permafrost) provide more bio-available iron to the environments when it melt..

## Nematode species distributions, demographics and survival in response to freeze-thaw cycles in soils of the McMurdo Dry Valleys, Antarctica

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Climate changes are likely to result in increased temperatures and water availability in soils of the McMurdo Dry valleys and other terrestrial sites. Importantly, these factors will also result in a shift in the number of freeze thaw cycles which soil organisms are exposed to over time. Freeze survival is an important, but metabolically expensive, component of Antarctic soil fauna physiology. Dry Valley nematodes can survive sub-zero temperatures through freeze tolerance or anhydrobiosis, where organisms survive by almost completely dehydrating. Depending on the environmental conditions (e.g. rate of freezing), Dry Valley nematode species can use either of these mechanisms to survive periods of sub-zero temperatures.

Through lab experiments and field observations of nematode state correlated with soil temperature data, we address the following questions using the three dominant Dry Valley nematode species: *Eudorylaimus antarcticus*, *Plectus murrayi* and *Scottinema lindsayae*. 1) Is there a difference in survival rates among nematode species in response to differing freezing regimes? 2) Does an increased frequency of freeze-thaw cycles alter nematode species abundance, distribution or demographics in nematode samples taken from McMurdo Dry Valley soils? We tested question 1 in the laboratory by extracting nematodes from archived soil samples and exposing each species to different rates (fast vs. slow) and durations (24 hours vs. one week) of freezing as well as the lower limit of soil temperature (0°C to -80°C), and then measuring survival. Question 2 was tested using data collected from several field seasons, by examining abundance, distribution and demography (e.g. juvenile to adult and gender ratios) for nematode species in relation to the number of recorded freezing events.

Our laboratory results show that the species respond differently to the same temperature parameters, providing new information to the strategies used by different species to survive in the Dry Valley soils. Results suggest that nematode species cope with freezing in different ways and with different rates of survival depending on environmental conditions. These results have important implications for future species distributions and ecosystem functioning, e.g. nutrient cycling, given climate change predictions for this region of Antarctica.

## Effects of elevated sea water temperature on the metabolism of Antarctic krill *Euphausia superba*

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Antarctic krill (*Euphausia superba*) hold a central position in the Southern Ocean food web, yet little is known about how they might respond to anthropogenic climate change, in particular the projected rise in temperature in their habitat. Krill's life cycle and metabolism are successfully adapted and timed closely to their highly seasonal environment. An elevation in sea water temperature has the potential to disrupt this delicate interplay, desynchronizing krill physiology with essential cornerstones in the course of the year. The aim of this study was to elucidate the direct effects of rising sea water temperatures on Antarctic krill metabolism. To this end, krill were exposed to gradually increasing temperatures from 0.5°C to 7°C over a period of four months. Over the course of the experiment, respiration and morphometric parameters including growth and maturation were regularly monitored. These observations supplement the analysis of key enzyme activities in a range of metabolic pathways including glycolysis (pyruvate kinase), beta-oxidation (3-hydroxyacyl-CoA-dehydrogenase), Krebs cycle (malate dehydrogenase, citrate synthase) and cellular respiration (cytochrome C oxidase). In combination with the analysis of elemental composition these data add to our understanding of the response mechanisms of krill to a changing environment. The results are discussed in view of possible implications in the context of climate change, such as ecological mis-matches with Antarctic seasonality.

## Response of phytoplankton pigments to varying environmental conditions in coastal Antarctic waters

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Recent warming trends have caused a reduction in surface water salinity around the Antarctic Peninsula as a result of glacial meltwater runoff, which increases the occurrence and abundance of certain phytoplankton groups, such as cryptophytes. The dominance of this particular group over diatoms affects grazers, such as Antarctic krill, which preferentially feed on diatoms. Data from three late summers (February/March 2008, 2009 and 2010) from around the tip of the Antarctic Peninsula showed variations in the dominant phytoplankton pigments determined by High Performance Liquid Chromatography (HPLC). Information on pigments can be used as tracers to elucidate the fate of phytoplankton in the world's oceans and are often associated with important biogeochemical cycles related to carbon dynamics. Three most common marker carotenoids were used for determining distributions of the major phytoplankton taxa: fucoxanthin for diatoms, 19'-hexanoyloxyfucoxanthin for haptophytes (primarily *Phaeocystis antarctica*) and alloxanthin for cryptophytes. A great spatial variability in chlorophyll *a* (Chl *a*) was observed in the study area: highest levels in the vicinity of James Ross Island (exceeding 7 mg m<sup>-3</sup> in 2009), intermediate values (0.5 to 2 mg m<sup>-3</sup>) in the Bransfield Strait, and low concentrations in the Weddell Sea and Drake Passage (below 0.5 mg m<sup>-3</sup>). Results also indicate that the dominance of fucoxanthin, particularly in 2008 and 2009, was associated with a deeper upper mixed layer (UML), higher salinity and warmer sea surface temperature. In contrast, alloxanthin (from cryptophytes), which were dominant in 2010, were associated with a shallower UML, lower salinity and colder sea surface temperatures. The low fucoxanthin concentrations observed in the summer of 2010 was associated with high nutrient concentration, particularly silicate. This study highlights the usefulness of HPLC pigment data as biotic indicators of phytoplankton community responses to environmental conditions and provides new insights about the dynamics of phytoplankton pigments in an undersampled region of the Southern Ocean, highly susceptible to global climate change.

## Skeletal mineralogy patterns of Antarctic Bryozoa

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Ongoing global climate changes including warming of the upper ocean layer and acidification process are currently predicted to be a major factors weakening calcifying organisms including Antarctic bryozoans. It is believed that selection of carbonate polymorphs (calcite, aragonite and mix of the two) incorporated into skeletons is to some extent function of ambient environmental conditions. More soluble aragonite is almost absent in cold Antarctic water, while increasing amount of Mg in calcite enhances dissolution rate of carbonate skeletons.

Presented study provides base knowledge about carbonate composition of Antarctic bryozoans and mineralogical variability at different taxonomic levels. Additionally we examined the influence of external factors (e.g. spatial and temporal changes) on the precipitated carbonate minerals over local scale and in a global context.

Skeletal carbonate mineralogy of 267 specimens belonging to 80 species was investigated with X-Ray Diffraction method. All of the examined species were characterized by calcitic skeletons with wide spectrum of Mg content in the skeleton, ranging from 0.22-10.08 mol% MgCO<sub>3</sub>. Majority of studied skeletons (76%) was composed of calcite with intermediate magnesium content (IMC) (mean: 6.24 ± 1.39 SD; N=202) while remaining 24% incorporated low magnesium calcite - LMC (mean: 2.67 ± 0.91 SD; N=33). Analysis of intraspecific and interspecific differences in carbonate mineralogy indicated that magnesium content was highly variable within population as well as between them. However additional factors such as morphological form or temporal patterns did not show any correlations with mineralogy. Analysis of variance revealed significant differences in the Mg content at a broad regional scale, between bryozoan skeletons from Antarctica and Chile, New Zealand and Mediterranean, respectively. The differences in the Mg content were negligible between bryozoans from both polar zones.

Large differences in the amount of Mg within and among populations prove that mineralogy of bryozoans is species-specific, driven by many factors. Strong latitudinal pattern indicates that the temperature might be a key parameter influencing the type of precipitated mineral over the regional scale.

## **Benthic biodiversity at the Mackellar Inlet, Admiralty Bay, King George Island: Results from five years of surveys**

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It is common knowledge that the Antarctic Peninsula is one of the most vulnerable places affected by global climate change, as it experienced, in the last decades, unprecedented increases in its average temperatures in comparison with the rest of the continent. The implications of this rapid warming on the sessile benthic biota are not yet fully understood since it requires careful monitoring over many consecutive years. During the Antarctic summers of 2008, 2009, 2010, 2012, 2013, the benthic biota and some abiotic factors (Oxygen, salinity, temperature, pH and currents) were sampled at 11 fixed sampling stations set along the Mackellar inlet. Overall results along the years show an increase of around 40% in the number of higher taxa but a decrease of 7% in the number of individuals, with a strong heterogeneity among stations. Concomitantly, the areas near to the glaciers showed a lower number of taxa when compared with those further out in the inlet since ice scouring from the glaciers apparently prevented the benthic communities from fully developing and obtaining the maturity most probably present in the areas further out. Abiotic parameters showed a relative homogeneity within the inlet; nevertheless the importance of the role of salinity in the benthic-pelagic coupling should not be overlooked as increased ice melting might deepen the halocline influence. The colonization of lower latitude individuals and the consequences to the native species will be discussed in the context of the aforementioned warming and increase human activities. This research was funded by the Peruvian Ministry of Foreign Affairs.

## Chronic effect of acclimation at elevated temperature in the metabolism of Antarctic fish *Notothenia rossii* (Richardson, 1844)

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Warming of the Antarctic Peninsula has motivated studies on the thermal tolerance and the adaptation and metabolic plasticity of ectothermic species in this region. The present study assessed the metabolic of the notothenioid *Notothenia rossii* exposed at temperatures at 8°C. Specimens were collected in Admiralty Bay, King George Island, Antarctic Peninsula. In order to evaluating aspects of energy and oxidative metabolism of *N. rossii* bioassays were performed for 90 days at 8°C with the respective control at 0°C. At the end of the bioassays, blood, liver and white muscle samples were collected. The plasma constituents (glucose, cholesterol, tryglicerides, total protein, albumin, hemoglobin, magnesium and calcium), concentrations of energy substrates in the liver and muscle (protein, glycogen and lipid) and the activity of liver enzymes (citrate synthase (CS), glucose-6-phosphatase (G6Pase), lactate dehydrogenase (LDH), malate dehydrogenase (MDH) and superoxide dismutase (SOD)) and muscle enzymes (LDH, MDH and superoxide dismutase (SOD)) were measured. Acclimation of *N. rossii* at 8°C over 90 days induced hyperglycemia, polyglobulia, reduction in cholesterol, triglycerides and blood magnesium. The concentrations of total protein, albumin and calcium were not affected due increasing temperature. Liver and muscle lipid reserves had decreased levels and the glycogen and proteins did not change in both tissues with increasing temperature. For enzymes, only SOD in muscle showed increased activity in 8°C and CS levels doubled in the experimental situation regarding control. The increase in blood glucose observed is a typical response to stress has been associated with the energy demands of tissues, this condition is established when the rate of glucose entry into the blood exceeds the rate of the pathways that remove glucose from the circulation. The reduction in liver and muscle lipid reserves and the maintenance of glycogen levels in both tissues indicate that *N. rossii* mobilized in the long term, the lipid reserves to maintain its activities. The levels of muscle LDH and MDH did not undergo significant variations at 8°C, indicating that neither the anaerobic nor the aerobic ATP-generating potential in the muscle was altered upon heating. The elevated values of CS enzyme indicates an increment in aerobic activity and may be linked to lipid metabolism. The increase in SOD activity, suggests that warming induced an increased production of reactive oxygen species and antioxidant defense system was required to avoid the damage caused by oxidative stress. *Notothenia rossii* realized metabolic adjustments that enable it to tolerate the temperature of 8 ° C for up to 90 days of exposure.

## The metabolic response of the Antarctic fish *Notothenia coriiceps* (Richardson, 1844) to thermal stress

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The region of Antarctic Peninsula have shown an accelerated warming in the past 50 years, having warmed 1,5°C between 1950 and 2006, compared with 0,6°C from the rest of the planet. The Admiralty Bay, site of this study, has wide availability of information on the composition of soils and sediments, as well as on the melting associated with the formation of microenvironments and with fluctuations in salinity, being a suitable environment for studies on the evolutionary adaptations of Antarctic organisms. Antarctic ectothermic organisms are considered extremely stenothermal, since the remarkable temperature stability of its habitat would lead to metabolic compensation that would preclude the maintenance of physiological functions face of an environmental warming. *Notothenia coriiceps* Richardson 1844 (Perciformes: Notothenioidei) is one of the four most common species in Admiralty Bay, King George Island, Antarctic Peninsula, being ecologically important in the food chain of the region, which makes it suitable for studies on the metabolic responses of Antarctic organisms. In order to evaluating aspects of energy and oxidative metabolism of *N. coriiceps* facing the thermal stress at elevated temperatures, bioassays were performed for 1, 4, 15 and 30 days at 4°C and 8°C with the respective control at 0°C. At the end of the bioassays, blood, liver and white muscle samples were collected. We measured plasma constituents and concentrations of energy substrates in the liver and muscle (protein and glycogen). We also measured the activity of liver enzymes citrate synthase (CS), glucose-6-phosphatase (G6Pase), lactate dehydrogenase (LDH), malate dehydrogenase (MDH) and superoxide dismutase (SOD), as well as muscle enzymes LDH, MDH and SOD. We observed that the temperature of 8°C is more stressing than 4°C, since *N. coriiceps* survive 1 and 4 days at 8°C. The muscle MDH and LDH showed no modulation of their levels due to heating (4°C). At 4°C the metabolic response is slow, being evident in 30 days, represented mainly by the increase in hemoglobin concentration and activity of liver LDH. Moreover, the response of the antioxidant system represented by SOD activity occurs in the short term, i.e. at 1 and 4 days. Despite having evolved under temperatures low and stable, *Notothenia coriiceps* has response mechanisms to the increase in temperature of the environment however these responses vary between 4°C and 8°C.

## **Modelling the population dynamics of Antarctic krill: Is krill affected by a mismatch in biological timing?**

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### **Modelling the population dynamics of Antarctic krill: Is krill affected by a mismatch in biological timing?**

Polar regions are characterized by strong seasonal changes in environmental parameters such as light intensity and sea ice coverage. Antarctic krill (*Euphausia superba*) – a key species in the Southern Ocean – has adapted to these extreme changes by synchronizing its metabolism and behavior to the environment. Studies suggest that this synchronization depends on a complex interplay between an internal clock and external environmental cues and thus is very sensitive to changes in the seasonality. In the Atlantic Sector of the Southern Ocean, a trend of later sea ice advance and earlier sea ice retreat can already be observed which could lead to a mismatch in timing between krill and its environment. Most studies on the effects of climate change on krill consider annual mean values and are therefore not suitable to capture this seasonal timing.

We propose a conceptual model describing the population dynamics of Antarctic krill and its functional interactions with the seasonally changing polar environment. The model considers juvenile and adult krill feeding on pelagic and sea ice phytoplankton. The growth of the phytoplankton depends on seasonally changing sea ice coverage, light intensity and nutrient concentrations. Our model is able to reproduce the general course of annual krill dynamics under current environmental conditions. Therewith, it provides a basis for studying the effect of climate induced changes and the associated mismatch in biological timing for Antarctic krill – with profound consequences for the whole Antarctic ecosystem.

## Strategies of light stress tolerance in the brown macroalga *Desmarestia anceps*

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The endemic Antarctic brown macroalga *Desmarestia anceps* colonizes the subtidal between 5 and 30 m in Potter Cove on King George Island (South Shetland Islands, Antarctica). Experiments were conducted to study photosynthetic activities, antioxidative enzymes and UV-tolerance of field-grown individuals with respect to the light histories along different subtidal positions. Individuals collected from the upper (5.5 m) and mid subtidal (9.0 m) are characterized by high maximum electron transport rates (ETR<sub>max</sub>) measured by PAM-fluorometry and high activities of superoxide dismutase (SOD) supported by considerable activities of glutathione reductase (GR). Individuals of this species from the upper subtidal are able to tolerate high irradiances of UV-B radiation because its photosynthetic apparatus is putatively well protected by phlorotannins. In contrast, individuals from lower subtidal positions (13.5 and 15.5 m) showed an opposite trend: lower ETR<sub>max</sub> and SOD activities as well as a lower UV-tolerance of photosynthesis. Moreover, a non-denaturing polyacrylamide gel electrophoresis (native PAGE) of a partially purified crude extract reveals that *D. anceps* has probably six isoforms of SOD. These intra-specific patterns imply a high phenotypical plasticity of *D. anceps* with respect to its photosynthesis and photoprotective mechanisms. Overall, photosynthesis, UV tolerance and antioxidative potential are highly regulated in *D. anceps* corresponding to the respective light regimes along its natural growth sites.

**Is stress tolerance against UV radiation impaired or compensated by higher seawater temperatures in strongly cold-adapted Antarctic macroalgae?**

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The marine ecosystems of the Western Antarctic Peninsula and hence the inhabiting flora and fauna are currently affected by significant environmental changes. Marine macroalgae along the shores are exposed to enhanced UV radiation not only in spring under ozone hole events but also in summer when natural solar radiation is high. Therefore, macroalgae are capable of coping with UV stress by distinct protection mechanisms to sustain their photosynthetic performance and hence, their primary production. However, rising seawater temperatures at the coasts may influence biochemical reactions of macroalgae such that protection against UV radiation is either reduced or enhanced. Particularly strongly cold-adapted macroalgae are thought to respond very sensitive to such temperature shifts with a great impact on their stress tolerance.

Interactive experiments between these two environmental factors were performed to study if and how rising seawater temperatures are able to influence the mechanisms of UV stress tolerance in seven strongly cold-adapted red and brown macroalgal species (e.g. *Trematorcarpus antarcticus*, *Desmarestia anceps*, *D. menziesii*). Stress tolerance at the photosynthetic level was evaluated by PAM-fluorometry. The first results imply that an increase in seawater temperature (7 °C) is able to compensate for an UV-induced inhibition of photosynthesis which was pronounced at 2 °C. By biochemical analyses, it will be tested if this compensation can be attributed to the algae's cellular antioxidant potential and/or the synthesis of UV-absorbing compounds such as phlorotannins and mycosporine-like amino acids (MAAs). Our physiological study may help to understand the potential global change driven ecological changes in the sensitive Antarctic coastal ecosystems, which are dominated by endemic macroalgae..

## Light-driven tipping points in polar ecosystems

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Seasonal snow and ice-cover periodically block sunlight reaching polar ecosystems, but the effect of this on annual light depends critically on the timing of cover within the annual solar cycle. At high latitudes, sunlight is strongly seasonal, and ice-free days around the summer solstice receive orders of magnitude more light than those in winter. Early melt that brings the date of ice-loss closer to midsummer will cause an exponential increase in the amount of sunlight reaching some ecosystems per year. This is likely to drive ecological tipping points in which primary producers (plants and algae) flourish and out-compete dark-adapted communities.

We demonstrate this principle on Antarctic shallow seabed ecosystems, which our data suggest are sensitive to small changes in the timing of sea-ice loss. Algae respond to light thresholds that are easily exceeded by a slight reduction in sea-ice duration. Earlier sea-ice loss is likely to cause extensive regime shifts in which endemic shallow-water invertebrate communities are replaced by algae, reducing coastal biodiversity and fundamentally changing ecosystem functioning. Modeling shows that recent changes in ice and snow cover have already transformed annual light budgets in large areas of the Arctic and Antarctic, and both aquatic and terrestrial ecosystems are likely to experience further significant change in light. The interaction between ice-loss and solar irradiance renders polar ecosystems acutely vulnerable to abrupt ecosystem change, as light-driven tipping points are readily breached by relatively slight shifts in the timing of snow and ice-loss.

## Sliding down the food web: response to ecosystem change on the Western Antarctic Peninsula

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Physical changes occurring within the Western Antarctic Peninsula (WAP) are some of the greatest environmental shifts on the planet. Impacts to the ecology of the WAP are now coming to light. Over the past 30 years the northern WAP ecosystem has shown a suite of sustained biological changes: decreases in primary productivity; changes in phytoplankton community structure and grazer communities; and the disappearance of krill-feeding specialist penguins. Coincident with these changes we document a significant trophic downshift in the 1980s at the top of the food web. Using stable isotope signatures from leopard and crabeater seal specimens collected by Antarctic explorers, and others, we show that the leopard seal, an apex predator has shown a dramatic shift from eating vertebrate prey to krill, unprecedented in the last 140 years. Although over this time there have been profound biological and physical perturbations to the wildlife of the WAP ecosystem, including the removal and then return of krill-eating whales and seals, fin-fish and krill fisheries, as well as recent local warming, the top predators, the leopard seals, show the trophic shift only in recent times, post 1980s. A stability of  $\delta^{15}\text{N}$  values prior to and post the 1980s suggests that dietary composition was stable until the 1980s, and then once the trophic downshift of this top predator occurred it has been sustained over the past ~30 years. Perhaps the trophic downshift of top predators, along with the ecosystem changes lower in the food web in the 1970-80, suggests that this was a time of system transition within the WAP and that the ecosystem today is already an alternate system state.

## Morphophysiological changes of *Colobanthus quitensis* along an antarctic-patagonian latitudinal gradient

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*Colobanthus quitensis* (Kunth) is the only dicot that has successfully colonized the Antarctic. In Chile extends all along the Andes, inhabiting swampy areas at high altitudes, until polar latitudes where it grows at sea level. Along this wide distributional range *C. quitensis* shows considerable morphological variability suggesting a high degree of morphological differentiation in response to changes in the environment. However at what extent these morphological changes help to maintain an appropriate physiological functioning along a latitudinal gradient remains unknown.

In this study, morphological and physiological aspects of *C. quitensis* collected in three different locations within an Antarctic-Patagonian latitudinal gradient were assessed. The selected populations corresponded to the Madre de Dios islands in Punta Arenas (50°16'S, 75°15'W), King George Island, in the vicinity of the Arctowski Station (62°09' S, 58°28' W) and Lagotellerie island in Marguerite Bay (67° 52' S, 68° 42' W).

Leaf anatomy of *C. quitensis* indicates that from sub-antarctic (Pta. Arenas) to polar populations there is a significant decrease in leaf area. This reduction is mainly due to a decrease in leaf length, and a reduced width of the adaxial surface, so that there is a pole ward decreases on the leaf exposed surface, but maintenance of the thickness. Individuals from the polar most populations (Lagotellerie) maintained higher photosynthesis rates at a wider temperature range (10 to 25 °C), than the other populations. Individuals from Arctowski showed their maximum photosynthesis around 15 °C. It is remarkable that at low temperature (5-10°C) plants from the higher latitudes have higher photosynthetic rates. The light energy partition at PSII level showed significant differences in the electrons transport rate (ETR), where plants from Arctowski showed higher ETR compared to Punta Arenas and Lagotellerie. Regarding the photochemical activity (qL) plants from polar populations maintain higher qL than plants from Punta Arenas, which are able to maintain a smaller excitation pressure on PSII (1- qL) as light increases. Finally, at the functional level (photochemical and photoassimilation) no differences along the latitudinal gradient were detected. Thus, differences in the leaf anatomy of *C. quitensis* along a latitudinal gradient help to maintain similar physiological functioning levels despite the important changes in the environmental conditions.

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## Dry valley soil food web structure and complexity is related to decadal trends in climate variation

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Potential climate change impacts on Antarctic soil food webs are poorly understood. We asked: Are climate changes over a temporal scale of 20 years seen in soil food web complexity and structure in the dry valleys? Food webs of the McMurdo Dry Valley soil ecosystems are composed of basal levels of cyanobacterial mats, bacteria, archaea, and fungi, and higher levels of protozoan and metazoan consumers (i.e., two mite, one springtail, two rotifer, two tardigrade, and four nematode species). Previous studies have shown that the physical and chemical composition of dry valley soil habitats is the primary driver of community structure. However, soil invertebrates show mixed responses to interannual trends in temperature and to seasonal pulses of increased moisture, and it is unclear how soil food web complexity changes through time in response to these changes in climate. We hypothesized that climate change (e.g. increased temperature and moisture pulses, and changes in solar radiation) will lead to increased food web complexity belowground. To test our hypothesis, we used ratios of the natural abundance of <sup>15</sup>N and <sup>13</sup>C stable isotopes to determine the position of key taxa in soil food web structure. In addition, we examined changes in soil food web composition and structure from 1994-2013 for the McMurdo LTER's elevational transect study at the south side of Lake Hoare in Taylor Valley. Using link density methods, we analyzed trophic complexity through time for three elevations (83m, 121m, and 183m A.S.L.) and compared these results to long-term climate data. Our results confirmed highest trophic complexity for wetter, lower elevations and less complexity in drier, higher elevations for all years. However, there were changes in trophic complexity through time. In 1994, trophic complexity of the low-elevation site was highest (all groups present) and this continually decreased to two or fewer groups (only algivore and bacterivore nematodes). This decrease in complexity is associated with the climate-cooling trend in the dry valleys. Trophic complexity recovered to 1994 levels for the low site by 2008 (a relatively high temperature and moisture year). Intermediate and high-elevation sites showed no change until 2008 when the intermediate sites also began increasing in complexity. Overall, shifts in Antarctic soil food web complexity were correlated with climate variation over a 20-year period, and areas of greatest initial complexity (low elevation) experienced the largest fluctuations in soil food web structure over time.

## Antarctic sea urchins can acclimate within months to rapid climate change

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The Antarctic Peninsula is subject to rapid warming and will become undersaturated with respect to carbonates as CO<sub>2</sub> continues to increase. Organisms which reside in the shallow Antarctic regions may struggle to maintain homeostatic and biomineralising processes under these conditions. In addition these characteristically slow growing organisms have generational times which almost parallel forecasted climatic change. Therefore persistence in the future of these organisms is debatable with much of the literature to date predicting gross negative response.

Current research needs in this field are those of long term exposures to determine the sustainability of physiological flexibility/acclimation, energy requirements and generational outputs. We address these needs by presenting the responses of an ecologically and carbonate cycling important benthic invertebrate – the Antarctic sea urchin, *Sterechinus neumayeri*. These sea urchins were reared under IPCC forecasted carbonate saturation states and temperatures for long periods of time (several years) and their physiological, energetic and reproductive responses assessed. In addition the next generation of sea urchins were reared under these conditions after short and longer parental exposures demonstrating the importance of widening parental exposure times in laboratory simulated experiments.

The responses of *S. neumayeri* in our research do not demonstrate gross negative responses as predicted by much of the literature. Instead we see acclimation to laboratory conditions within months and this is sustained when exposure is extended to several years. Next generation offspring success improves as adult exposure time is extended to include the whole, rather than only part of, the egg cycle which currently takes two years. These capacities to acclimate do come at a reproductive cost with respect to the eggs. We highlight that different responses can be achieved from short and long term studies. Therefore careful consideration is needed when making predictions on organismal responses based from short term data. This is the first study to assess the long term impacts of predicted climate change conditions on an Antarctic organism and contributes significantly to our current understanding of organismal responses under a future climate.

## Is the reproductive strategy of Antarctic flowering plants changing in response to climate change?

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Increases in air temperature along the Antarctic Peninsula and Scotia arc have been well documented, with the most rapid changes observed along the west coast of the Antarctic Peninsula. Significant increases in local populations of the two native higher plants, *Deschampsia antarctica* and *Colobanthus quitensis*, have been attributed to the regional warming in the maritime Antarctic. Several factors have been proposed to underlie this increase, including changes in the frequency of successful seed maturation, germination and survival. However, no recent field assessments of reproductive strategy of these species have taken place.

Fresh material of *D. antarctica* and *C. quitensis* were obtained from three sites, sub-Antarctic South Georgia, Signy Island (northern maritime Antarctic), and Léonie Island (Marguerite Bay, southern maritime Antarctic) in the 2012/13 season, along with new data from southern South America. For up to 20 individual plants of each species from each location, vegetative and reproductive biomass, seed output and shoot morphology were measured. Reproductive allocation and seed production of newly collected material were then compared with previously published data collected between the 1960s and 1990s. The data are discussed in relation to changing success of different reproductive strategies in response to climate drivers in this region.

## **Climatic variability in the Ross sea region of Antarctica and its potential influences on marine ecosystems**

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NIWA

Climate change will affect marine environments of the Ross Sea region in the coming century. Understanding ecosystem response to climate variability is of fundamental importance to precautionary management in the region, but linkages between the physical environment and ecosystem dynamics remain poorly understood. We describe a research programme which aims to explore likely future changes in the physical environment of the region and potential consequences of these for marine ecosystems. The research has four parts, spanning all aspects of the regional ecosystem from past and present climate and physical oceanography to primary production, export to the benthos, and the dynamics of top predators. Here, we present progress in development of a fine-scale regional ocean model and the use of climate and sea-ice records from the instrumental era to evaluate IPCC AR5 global climate models specifically for the Ross Sea region. We will use projections from the best-performing of these models to understand the timing of change and the rates of change over the next 100 years. From these we will identify keep periods and their respective future environmental envelopes. These will be used to constrain the regional model, allowing us to explore potential future states of the Ross Sea ecosystem.

**Rediscovering the *Discovery Investigations (1925-1951)*: Extending our knowledge into the past to understand the future**

**Johnston N, Murphy E, Silk J, Waluda C, Hill S, Ward P**

British Antarctic Survey

Historical data series that have been generated during the long history of Southern Ocean research represent a valuable resource with which to piece together information about long-term, large-scale ecosystem functioning, variability and change. They also offer a baseline of data against which we can assess current and future dynamics of ecosystems under scenarios of climate and anthropogenic-driven change. Such information can be used to underpin management strategies. As part of a continuing research effort, the British Antarctic Survey has been digitising and uniting the elements of the *Discovery Investigations (1925-1951)* collection into a single open access website for research and education. Here we present our most recent progress including analyses of the regional and circumpolar distribution and abundance of key macro-zooplankton groups which form much of the bases for the food web and an international fishery (Antarctic krill). We examine their relationships to environmental variables (e.g. sea temperature), and develop simple bioclimatic envelope models (or ecological niche models) to enable future projection of geographic ranges. These scientific analyses will contribute to wider international efforts to examine the impacts of past and future change in Southern Ocean ecosystems.

## Developing integrated analyses of Southern Ocean ecosystems: status, change and future projections

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Southern Ocean ecosystems provide globally important ecosystem services: maintaining biodiversity, influencing biogeochemical cycles and in supporting fisheries they affect global food security. They are also being affected by rapid climate driven changes, with impacts being observed at every trophic level in the ecosystem. Understanding the impacts of change in these ecosystems requires integrated (end-to-end) ecosystem analyses at regional and circumpolar scales. Developing those analyses has been the focus of the Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) programme. In this talk we highlight recent progress, particularly in the development of end-to-end analyses and models. An ICED-led assessment of the status of Southern Ocean ecosystems has highlighted the urgent need for better observational data to allow the evidence of change to be rigorously tested. That work led to the development of the ICED-Sentinel programme that aims to generate the observational systems required to monitor change in Southern Ocean ecosystems. A major current ICED activity is the development of scenarios and models for the projection of the impacts of future change, and we highlight developments in that area. Finally we note major priorities for future scientific activities, which include working with CCAMLR scientists to develop analyses that contribute to the sustainable management of Southern Ocean fisheries.

## Effects of environmental change on ecosystem services in the Southern Ocean: the role of pelagic cephalopods in the context of potential future commercial exploitation

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Current and projected climate changes are unprecedented in magnitude, and pose major threats to the structure and functioning of marine ecosystems worldwide. The Antarctic marine environment is regionally warming faster than anywhere on Earth. One of the greatest challenges for research in the region is therefore to develop models, particularly those “ecosystem models” incorporating trophic (food webs) interactions, for assessing the likely ecosystem impacts of climate change. While addressing the question “From the perspective of ecosystem services, what are the effects of environmental change on the structure and functioning of the Antarctic marine ecosystem?”, we review the latest results on the role of cephalopods in Southern Ocean ecosystems, their importance in the diet of top predators and habitat modelling of their present day distributions. We also suggest possible future directions for research on cephalopods and other mesopelagic species, addressing the goals of the SCAR Horizon Scan exercise and reflecting the work carried out by members of the SCAR Expert Group on Birds and Antarctic Marine Mammals, SCAR AnT-ERA and ICED. The difficulty of catching fast pelagic organisms, such as cephalopods, on cruises, limits our knowledge of their roles in food webs and their ability to cope with climate change, and also constrains an assessment of the potential for harvesting cephalopods as a new ecosystem service in the Southern Ocean. Finally, we will discuss the application of future research on cephalopods in terms of conservation, policy making, education and outreach.

## S27: INFLUENCE OF TOP PREDATORS ON ECOSYSTEM DIVERSITY

### Potential cascade effects of global change on penguin health

**Barbosa A**

Natural History Museum, Spanish Research Council

The Western coast of the Antarctic Peninsula is one of the places where the temperature has increased more and faster than any other place in the Earth. The temperature increase has been calculated as 0.5°C per decade in the last 50 years. Some of the consequences of the temperature increase are a reduction of the sea ice extent during winter affecting the phytoplankton production which has been related to the decline of krill stocks. The reduction of some populations of different penguin species such as the Adelie penguin and the Chinstrap penguin has been suggested to be a consequence of the decline of krill but the precise mechanism behind this penguin decline is still unknown. In addition to climate change, increase of human activity in the region can add other factors affecting penguin such as contaminants. Here, it is proposed the potential cascade effects of climate change that could explain such decline based on aspects related to penguin health such as parasite effects, the effects on immune function and the interaction with contaminants. In this context, climate change could affect penguins in different ways. First, due to direct effects of climate change in the distribution, abundance of parasites/pathogens and second through the effects of krill stocks decline. One the consequences are the diet change to fish or squid which could expose penguin to new parasites which can compromise the immune response. Moreover, considering that krill is a rich source of carotenoids which have an immunoestimulant function, a reduction in krill intake will likely produce an immunodepression and then a reduction of the immunocompetence. Due to the antioxidant properties of the carotenoids, another effect of the reduction of krill intake could affect the ability of free radical eradication increasing the effects of pollutants. In some species with carotenoid-based ornamental traits as the Gentoo penguin, the reduction of krill could produce changes in the coloration that could affect processes of mate selection. Finally, the presence of contaminants which is dependent of human activity can produce immunodepression.

## Tidal variability in nearshore Antarctic krill distribution patterns in an Adélie penguin foraging hotspot

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A recent analysis of a 10-year dataset of foraging trips for Adélie penguins (*Pygoscelis adeliae*) breeding near Palmer Station, West Antarctic Peninsula, found that foraging distance varied with tidal phase. In this region during summer, tides switch between diurnal and semi-diurnal phases roughly on a weekly basis. Foraging distances were consistently shorter during diurnal tides, doubling when the tides switched to the semi-diurnal phase. Antarctic krill (*Euphausia superba*) are the primary food source for Adélie penguins breeding on the islands near Palmer Station. During the summer months, Adélies are central place foragers, returning to their nests to feed their chicks each day. The distribution patterns, densities and aggregation structure of krill determine the penguins' abilities to optimize their foraging.

During the austral summers of 2011-2012 and 2012-2013, we acoustically mapped distribution patterns, estimated biomass, and investigated the aggregation structure of Antarctic krill in the nearshore waters off Palmer Station. Biomass was integrated over the depth of the water column or to 250 m, whichever was shallowest. Aggregation parameters included mean depth within the water column, an estimate of aggregation size (determined as the product of length and height), estimates of mean volumetric biomass of krill, biomass encounter rates (determined as the product of aggregation-specific integrated biomass and aggregation length), and nearest neighbor distance. We found tidal phase to be a significant predictor of krill biomass, distribution patterns and aggregation structure. During diurnal tides, krill were distributed through much of the nearshore study area, while during semi-diurnal tides the distribution of krill was limited. Integrated biomass of krill was significantly higher during diurnal tides (mean=406 g m<sup>-2</sup>) compared with semi-diurnal tides (mean=152 g m<sup>-2</sup>). Aggregations encountered during diurnal tides were significantly larger in size (mean=702 m<sup>-2</sup>) than those observed during semi-diurnal tides (mean=319 m<sup>-2</sup>). Semi-diurnal aggregations were more densely packed with krill than diurnal aggregations (i.e. had greater volumetric biomass), but due to the larger size of diurnal aggregations, biomass encounter rate was significantly higher during diurnal tides (mean=78 kg m<sup>-1</sup>) than during semi-diurnal tides (mean=43 kg m<sup>-1</sup>).

The aggregation structure of krill during diurnal tides favors the optimization of Adélie penguin foraging. On the whole, Adélie penguin foraging distances recorded during the same time period corresponded to changes in nearshore krill distribution patterns. Understanding local spatial and temporal variability of krill as a key prey item will assist in the analysis of changes in the population of its predators over time.

## Summer foraging hot spots of post-breeding southern elephant seal males from King George Island / Isla 25 de Mayo

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Deployments of ARGOS satellite transmitters on 19 post-breeding adult southern elephant seal males at King George Island / Isla 25 de Mayo in November 2013 represent a follow-up study of earlier projects on post-moulting adult males satellite tagged in 2000 and 2010. These previous deployments were constrained by the fact that only a small fraction of the satellite tagged seals could be unequivocally attributed to the local breeding population of the Antarctic Specially Protected Area (ASP) 132 on King George Island / Isla 25 de Mayo due to earlier permanent marking procedures. As a result, a number of the previous tracks ended at South Georgia towards the breeding season, implying that the tagged seals originated from that breeding colony. The recent tracks represent the first deployments on post-breeding males at the ASPA 132 and they include about 50% of the population of adult males that were present during the breeding period either as harem bulls ( $n = 3$ ), challengers ( $n = 7$ ), or isolated males ( $n = 9$ ) between October and December 2013. Of the 19 transmitters, two failed within the first two weeks after deployment and were disregarded for further analyses. The post-breeding long-distance foraging tracks of the remaining 17 males were primarily oriented along the continental shelf margin towards the Bellingshausen and even Amundsen Seas ( $n = 12$ ), and shorter tracks along the Bransfield Strait / Mar de la Flota to the North ( $n = 4$ ) and around the tip of the Antarctic Peninsula ( $n = 1$ ). This suggests far more south-westerly oriented foraging movements of mature males of the ASPA 132 elephant seal colony than previously assumed. All seals showed extended residence times at specific circumscribed at-sea locations, considered as foraging hot spots. These spots were widely distributed within the aforementioned marine areas and coincide with bathymetric features, such as slopes, bays and troughs.

## A perfect match? Toothfish (*Dissostichus mawsoni*) and Type-C killer whales (*Orcinus orca*) in the Ross Sea

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The Type-C killer whale (TCKW: *Orcinus orca*), one of four ecotypes proposed for the Southern Ocean, is thought to have a specialised fish diet based on stomach content data from Soviet whaling and anecdotal observations of predation on Antarctic toothfish (*Dissostichus mawsoni*: toothfish) in McMurdo Sound, Antarctica. However, the importance of Antarctic toothfish as prey of TCKW is currently unknown, as is the potential contribution of avian, mammalian, or other fish prey.

During a pilot project in late January 2014 to determine the summer diet of TCKW in McMurdo Sound, we recorded and photographed three incidents of TCKW with toothfish prey. These observations were made during late summer break-up of the fast ice over shallow coastal waters and reinforce the hypothesis that toothfish are a prey for TCKW, at least during the summer season. To further test this hypothesis, we are analysing stable isotope enrichment of skin samples collected from TCKW during our and previous expeditions to the Ross Sea (IWC cruises in 2003/04), to determine diet and potential shifts in trophic level through time.

Most avian or mammalian prey items taken by Antarctic killer whales (penguins, seals, minke whales) are larger and more energy-dense than available fish prey. We therefore investigated whether a dietary specialisation of TCKW on fish is feasible, given that killer whales have (a) exceptionally high energy expenditures and (b) a very large brain: body mass ratio. Large-brained, strictly predatory mammals (hypercarnivores) need a source of glucose to meet cerebral substrate requirements, and glucose is also required for successful reproduction to support pregnancy and milk synthesis. High-fat prey is not only energy-dense, it also supplies glycerol, an efficient precursor of glucose.

Based on estimated TCKW metabolic rates, toothfish stands out as the only fish prey of sufficient size, energy density, and fat content in the Ross Sea suitable for supporting reproduction and calf growth. We propose that a dietary specialisation on fish and the establishment of a separate ecotype of killer whale in the Southern Ocean is predicated on the availability of Antarctic toothfish. By contrast, current stock models for Ross Sea toothfish do not include significant predation by killer whales. Given the potential trophic dependency of TCKW on toothfish, there is an urgent need to determine the importance of toothfish to the diet of TCKW in the Ross Sea.

## Breaking the ice: The foraging behavior and kinematic patterns of Antarctic minke whales

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Minke whales are among the most abundant and widely distributed balaenopterid cetaceans, yet we know little of their underwater behavior. For example, the diving, foraging, and kinematic patterns of Antarctic minke whales (*Balaenoptera bonaerensis*) are completely unknown. To understand these aspects of their biology, we deployed multi-sensor suction cup tags on two Antarctic minke whales in Wilhelmina Bay, Western Antarctica Peninsula, in February 2013. These whales fed almost constantly and at an average depth of 19 meters (max. = 106) on 1.5-minute dives (max = 9.4). Water filtered per unit time was 219 m<sup>3</sup>/hr, 18x less than a blue whale feeding at a similar depth. Average lunge rate was 112/hour, four times higher than reported for baleen whales, including 40 dives with >15 lunges (max = 24). A significant relationship existed between feeding depth and lunge frequency overall, but k-means clustering suggests that several dive types exist, with differing combinations of depth, duration, and feeding rates. Feeding rate increased with depth in only the shallowest and shortest feeding dives. Our results provide the first direct observations of the subsurface behavior of Antarctic minke whales, including feeding under sea ice. These observations allow comparisons with other balaenopterid whales with respect to anatomical scaling and the energetic costs of lunge feeding. With these data in hand, we can begin to examine ecological relationships among krill predators in this region and determine how these species partition resources. This knowledge is important given the rapid warming and diminishing sea ice conditions driving ecological change around the Antarctic Peninsula. Future efforts combining fine-scale kinematic information with broad-scale information from satellite-linked dive recording tags will provide a greater understanding of the movement patterns and ecology of these whales, and inform efforts to manage their populations around Antarctica, while minimizing the need for lethal sampling.

## **Location, location, location: Seasonal habitat preference and foraging behavior of Weddell seals in the Ross Sea, Antarctica**

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Weddell seals are the only mammal to live in Antarctic waters year-round, surviving through the cold, dark winter when heavy ice cover prevails. Despite being a top predator in the Southern Ocean, little information exists on their seasonal movement and foraging ecology. To gain insight into Weddell seal behavior, we satellite tagged 63 animals (11M, 42F) around Ross Island and up the Victorialand coast. To date, these tags have recorded over 335,000 dives. We used generalized linear mixed models to identify the importance of environmental variables in structuring habitat use of Weddell seal. Comparing Weddell seal tracks to correlated random walks, we found that sea ice concentration, modified circumpolar deep water, bathymetry, distance to coast, and distance to the shelf break were significant in predicting Weddell seal presence across seasons. In addition to examining habitat, we used physical variables (bathymetry, bathymetric slope, distance to shelf, distance to coast, sea ice concentration, and distance from the 10% sea ice concentration contour) in conjunction with time of day (dawn, day, dusk, night), dive metrics (max dive depth, dive duration, bottom time) and oceanographic variables (mixed layer depth and modified circumpolar deep water) to predict Weddell seal seasonal foraging areas. Both habitat use and high intensity foraging areas varied seasonally. Gaining insight into Weddell seal habitat preference and the subset of habitat where high intensity foraging occurs is especially important in light of recent fishing pressures on Weddell seal prey species. This information may provide valuable information on how the interaction between Weddell seals and fishing activities may impact the future foraging behavior of a predator that exploits vast regions of Antarctic waters.

## Fatty acid composition suggests leopard seals are no longer apex predators in the WAP ecosystem

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The leopard seal, *Hydrurga leptonyx*, is an apex predator that has a key role as consumer within the Antarctic ecosystem. Due to the constraints of traditional methods for studying feeding ecology fatty acids (FAs) analysis of blubber has become a useful tool for determining diet since it provides an indication of long-term dietary histories. FAs however, are not distributed uniformly within the blubber so understanding the degree of stratification is important in order to obtain accurate results. The FA stratification in blubber has not been examined for the leopard seal. We used whole blubber core samples from 24 individual leopard seals captured in the Danco Coast region off the Western Antarctic Peninsula (WAP). The cores were sub-sectioned into: outer, middle and inner layers and the FA compositions were compared with potential prey species (krill, fish and penguins). We found 17 FAs present at greater than trace amounts (>0.5%) across all samples. The most abundant FAs were: C18:1 $\omega$ 9, C16:1, C22:6 $\omega$ 3, C16:0 and C18:1 $\omega$ 7 which accounted for approximately 70% of the total. This composition of blubber is similar to other marine mammals, although some differences do exist. Principal Component Analysis confirmed clear separation between inner and outer layers where most of the FAs were present in significantly different amounts between these layers. Monounsaturated FAs (MUFA) dominated the three layers being more abundant in the outer layer. The higher presence of MUFAs, which have comparatively low melting points, in the outer layer, may suggest that this section has a thermoregulatory function. On the other hand, polyunsaturated (PUFA) and saturated FAs (SFA) were more abundant in the inner layer. PUFAs are known to be of dietary origin and SFAs are inert chemically so they can be used as long-term reserve suggesting this layer is associated with dietary intake. Moreover, the FA composition of the inner blubber layer resembles those of the prey more closely than the outer layer. Detailed analysis of the inner layer and the prey species revealed that although they did not overlap completely, inner layer FAs resembled krill FAs more closely than any of the other prey types. This would suggest that seals are eating a combination of prey types, but are using krill more heavily. FAs analysis indicates that this top predator is feeding predominantly at lower trophic levels than anticipated; so that, within the WAP food web, the leopard seal is behaving more like a mesopredator rather than an apex predator.

## From high-resolution to low-resolution dive datasets: a new index to quantify the foraging effort of marine predators

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In the last decade thousands of Satellite Relayed data Loggers (SRDLs) have been deployed, providing large datasets on marine predator's movement patterns at sea and diving behaviour. The main objective of this study was to develop a simple but accurate tool to: (i) detect intensive foraging occurrences and (ii) quantify the overall foraging effort, in low resolution dives when no concurrent information on prey encounters are available. Two southern elephant seals were fitted with a head mounted TDR and an accelerometer from which prey capture attempts were estimated (PrCA). A Weddell seal was fitted with TDR. For both species, TDRs recorded depth at 1Hz. High-resolution dives were used to: (i) calculate an accurate index of foraging effort based on the detection of vertical sinuosity switches (i.e. hunting<sub>highres</sub> time), (ii) produce a SRDL equivalent low-resolution dataset using a broken stick algorithm. Then, a set of potential foraging effort indexes were calculated for each low-resolution dive: the time spent below 80, 65 and 60% of the maximum dive depth, descent and ascent rates, time allocation at depth index (TAD index) and the hunting<sub>lowres</sub> time. Hunting<sub>lowres</sub> time, which is the total time spent in decreased vertical velocity segments of the dive, was the best correlated with hunting<sub>highres</sub> time. 77% of PrCA in SES occurred in hunting<sub>highres</sub> mode (highly sinuous parts of high-resolution dives) and 71% of the PrCA in SES occurred in the hunting<sub>lowres</sub> segments which were also associated with four times more PrCA than transit<sub>lowres</sub> segments. We found a low-resolution index, that as the high-resolution one, encapsulates all foraging activity within a dive and identified most PrCA, despite degraded information. Used in combination with other measurements of the *in situ* environment, the hunting<sub>lowres</sub> index could be used in more integrated ecological studies.

## Circumpolar habitat use in a deep-diving Southern Ocean predator: implications for foraging success and population trajectories

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In the Southern Ocean, wide-ranging predators offer an opportunity to quantify how animals respond to differences in the environment because their behaviour and population trends are the integrated signal of prevailing conditions across multiple marine habitats. Southern elephant seals in particular, can provide useful insights due to their circumpolar distribution, their long and distant migrations, continuous deep diving and varying population growth rates. In this study, we present a dataset from Marine Mammal Exploring the Oceans Pole to Pole (MEOP) for southern elephant seals, which combined a large sample size of (290 individuals), a global geographic extent, *in situ* ocean data and at-sea foraging metrics to explicitly link foraging behaviour and habitat structure in time and space. Broadly speaking, the seals used two habitats, the relatively shallow waters of the Antarctic continental shelf (and also the Kerguelen Plateau) and deeper open water regions. Deep ocean waters were used the most overall (79% vs 21% of all area restricted search (ARS) locations). It seems that while Antarctic shelf waters are prime habitat for both sexes, females seals generally moved northwards with the advancing sea-ice. The water masses used by the seals also influenced their behavioural mode, with ARS behaviour being most likely in waters where there are high mixing rates such as Antarctic Bottom Water, Circumpolar Deep Water and modified CDW. The combined effects of these differing habitat qualities, differing responses to encroaching ice as the winter progresses and differing distances between breeding and haul-out sites and high quality habitats may explain the differing population trends observed in elephant seals. Seals from Macquarie Island are showing ongoing declines, while seals from Iles Kerguelen (which have declined substantially in the past but have recently stabilized) made the least use of the high quality Antarctic continental shelf, particularly later in the winter, and the shelf was most distant from the breeding sites. In contrast, seals breeding on South Georgia, which have been stable from many decades, and made the most use of the shelf habitat which was relatively close to the breeding island. Although relatively small, the population of seals that breed on the islands of the Antarctic Peninsula are currently increasing, and do not have to travel at all to reach shelf habitats.

## Habitat utilization of Weddell and crabeater seals throughout their entire distributions as obtained from satellite telemetry

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Identifying habitat requirements of Antarctic predators is fundamental to understanding how they will respond to the human-induced challenges of commercial fisheries and climate change. We compiled, for the first time, all of the available tracking data for Weddell (*Leptonychotes weddellii*) and crabeater seals (*Lobodon carcinophaga*) throughout their ranges in the Southern Ocean in order to analyze these species' patterns of habitat utilization using a consistent analytical approach. A total of 132 individual tracks and 107 were obtained for Weddell and crabeater seals respectively, collected during a span of three decades (1990s, 200s and 2010s). Raw Argos tracks were filtered using a Switching State Space Model, and individual kernel home ranges were calculated (95% Utilization Distribution). The distributional patterns of both species was analyzed for three major areas, which were defined for the Antarctic continent based on the width of the continental shelf and sea ice coverage: a) exposed continental shelf (western Antarctica Peninsula), b) wide shelf covered by sea ice (Ross and Weddell seas) and c) narrow shelf covered by sea ice (East Antarctica). Home ranges of Weddell seals were rather restricted in their spatial extent, ranging between . There was a clear difference among the areas defined, with Weddell seals utilizing significantly larger areas in both the Ross and the Weddell seas, sometimes beyond the limit of the shelf break, whereas individuals from exposed shelf environments, and narrow shelf environments were rather limited to coastal waters. Crabeater seals' home ranges varied widely in size from 161 to 269,824 km<sup>2</sup> (57,870 ± 64,782 km<sup>2</sup>, mean ± SD) and were largely associated with the continental shelf break throughout their distribution. Yet, the home ranges of crabeater seals did not differ in size across the different environments. This difference in habitat utilization patterns between these species opens up interesting questions regarding their ability to cope with environmental changes. Crabeater seals, in accordance with their high ecological specialization, presented no clear difference in their patterns of habitat utilization across their ranges, while Weddell seals displayed adjusted their distributional patterns in response to local environmental conditions. Further research will focus on discerning what environmental variables drive the local distributional patterns of both species, and how changes in these variables will impact the distribution of these species.

## A synoptic comparison of the foraging behaviour of Weddell and crabeater seals

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The Expert Group on Birds and Marine Mammals (EG-BAMM) has initiated the "Retrospective Analysis of Antarctic Tracking Data" (RAATD) program. This project aims to create a predator community-wide assessment of habitat use in the entire the Southern Ocean. Identifying the basic habitat requirements of Antarctic predators is fundamental to understanding how they will respond to the human-induced challenges of commercial fisheries and climate change. This understanding can only be achieved if the underlying linkages to physical processes are related to animal movements. As part of this effort we are collating and synthesizing the available data on the foraging and movement patterns of Weddell and crabeater seals.

While Weddell seals are one of the best studied top predators of the Southern Ocean, significantly less is known about crabeater seals, which are one of the most numerous mammals on the planet. We have synthesized the available tracks on these two seal species for comparison. We compare tracks from a 113 Weddell seals from the Weddell sea, the Antarctic Peninsula, East Antarctica and the Ross Sea and 53 crabeater seals from the Antarctic Peninsula and the Weddell Sea.

The foraging behaviour of Weddell seals is surprising similar across the different regions, with dive durations ranging from 8.6 to 12.6 minutes with average ranging between 43 to 69 meters. Weddell seals tended to remain on the continental shelf and had similar movement patterns covering 7 to 13 km/day. In contrast crabeater seals moved greater absolute distances and greater distances per day ranging between 19.2 and 33.6 km/day. Further, their use of the continental shelf habitat varied with 85% of the crabeater seals on the wAP remaining on the shelf while only 24% remained on the shelf in the Weddell Sea.

## **Bouvetøya: The forgotten island of seals, penguins and a fortuitous oceanographic mooring**

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Bouvetøya is a subantarctic island in the Atlantic Sector of the Southern Ocean which hosts the world's second largest breeding colony of Antarctic fur seals and provides suitable breeding habitat for various bird species as well as southern elephant seals. The island shelf is narrow and the sea floor rapidly drops to great depths. It is thus likely that top predators in this region must depend more heavily on transient ocean features to find concentrated prey, compared to conspecifics in other areas, and they might deplete near-shore prey densities more completely than at islands that have more extensive shelves. These hypotheses lead us to explore the role of eddies, fronts, convergence zones and filaments in the foraging ecology of the region's krill predators. These ocean features are typically associated with elevated levels of primary productivity at both meso- (>100's km) and submeso- scales (10's km). Although the spatially and temporally transient nature of these features may limit their usefulness during the breeding season, these productive patches of ocean likely attract marine predators during periods when they can travel far enough to exploit them. In this study we quantify oceanographic variability in the area around Bouvetøya using a combination of remotely-sensed data and a serendipitous 9 month in-situ conductivity, temperature and depth (CTD) dataset (collected via a CTD-SRDL instrument borne by a female elephant seal) and present the at-sea movement behaviour of three sympatrically-breeding, centrally-foraging marine predators throughout a breeding episode. Remotely-sensed data showed a reasonably strong ( $>0.15 \text{ d}^{-1}$  FSLE) submesoscale filament ~40 km west of the Nyrøysa breeding colony, which persisted from January through until late March, along a prominent shelf-break. This feature was consistently exploited by all three predator species during the breeding season. Late-breeding season movements by individuals from all species were characterised by increased residency time at convergence zones (regions of positive mean sea level anomaly gradients) and filaments at both mesoscale and submesoscale levels. The fact that these animals travel great distances to track such zones suggests that this strategy is likely more profitable than remaining in the shelf waters late in the breeding season. Longer-term studies assessing interannual shifts in behaviour under different environmental conditions are needed to determine whether the predators consistently rely on these oceanographic features, but the occurrence of three species of centrally-foraging predators with different life history constraints at this very isolated island provides a fascinating opportunity to examine foraging dynamics between individuals and species at multiple temporal scales in relation to oceanographic conditions.

## New censuses of a breeding population of Emperor penguin *Aptenodytes forsteri* at Snow Hill Island by ground and aerial photography techniques

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During the last hundred years have been discovered new breeding colonies of emperor penguins. Snow Hill Emperor's colony was discovered in the mid-nineties through an over flight at the area. Even today, new colonies are added to the already known, reaching a total of 46. Breeding colonies of *A. forsteri* are distributed around the Antarctic coastline between 64°S and 78°S during the winter season. This colony was located by GPS at 64° 30'S, 57° 26'W at the south coast of Snow Hill Island, a similar position reported by others authors in the past. This is the northernmost known Emperor penguin colony in the whole Antarctica.

Snow Hill colony, as most other emperor breeding colonies, is placed on the sea-ice pack about 40-50 m from the low ice cliffs. Although in general the colonies are found protected from prevailing strong winds by natural barriers like icebergs, but, when we visited this colony, in the winter of 2013, we did not find any significant icebergs circling the colony.

There is growing concern about the future of some Antarctic species in view of the changes observed in recent years regarding the extent and thickness of the sea ice pack related to global warming. The Emperor penguin depends on sea-ice pack as a breeding platform during the winter-spring months also it is the molting habitat and the foraging environment. Actual climate models predict a decrease in this Antarctic penguin population as the result of the decline in sea-ice distribution. In the Antarctic Peninsula, where warming has been pronounced during last decades, the colony of emperor penguin at Dion Islands, Marguerite Bay, West of Antarctic Peninsula, became the first colony recorded as lost in the recent period of Antarctic regional warming. Meanwhile the colony counts performed on Snow Hill Island, located at a similar latitude, on the east side of the Antarctic Peninsula, resulted in 7012 and 7952 breeding pairs during the winter seasons of 2005 and 2013 respectively.

Studies involving regular monitoring allow a determination of the fluctuation in Emperor's breeding populations and obtaining long-term demographic dataset.

Our objective was to verify the location of the colony, to census the breeding population by aerial photography, to conduct a ground census of chicks and to obtain other useful information for the long term research project that we started at this colony.

## Seasonal variation between biomass distribution and foraging behaviour of southern elephant seals north of the Ross Sea

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The temporal and spatial variability in marine resources influences foraging behaviour and success of top marine predators. However, little is known about the links between these animals and ocean productivity. The southern elephant seal (*Mirounga leonina*) exhibits two annual foraging trips: a two month post-breeding foraging trip (Nov – Jan) that coincides with elevated summer productivity; and an eight month post-moulting foraging trip (Feb – Oct) over the winter period when productivity is low. Physical parameters are often used to describe inter-annual habitat targeted by elephant seals, but lack biological information.

We used electronic tags deployed on elephant seals during both trips to record their movement and foraging behaviour. These tags also recorded light, which was used to measure the bio-optical properties of the water column to estimate its biomass density. We investigated the relationship between biomass density and seal foraging behaviour, and compared trends between post-breeding and post-moulting trips.

Our results showed the relationship between biomass density and seal behaviour varied seasonally. Post-breeding seal foraging behaviour responded strongly to biomass density, while post-moulting seal foraging behaviour responded less to biomass density. We propose that seal prey tend to aggregate at sites of elevated productivity during post-breeding trips when peak phytoplankton blooms occur. In contrast, seal prey may be more dispersed during post-moulting trips when phytoplankton density is considerably lower and more variable in space and time. We suspect physical conditions may be a greater driving force behind seal prey distribution during the winter months, rather than biological conditions, as they are in summer.

These results show how the use of light data as a bio-optical proxy for biomass provides insight into the foraging behaviour of an apex marine predator and their association with seasonal productivity. This has important implications for our understanding of predator habitat use in the Southern Ocean.

## Improved processing methods for light-based geolocation tags with the SGAT package

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For many marine and high latitude species, information about the large scale movements of the species can only be obtained through electronic tagging. Light-based geolocation tags are lighter and smaller than other technology types, and so are the preferred tag type for many applications. The TripEstimation package is a widely-used tool for deriving location estimates from the raw data collected by these tags. This package has the advantages that (i) it can deal with both satellite and light-based geolocation data, (ii) sensible constraints can be imposed on the estimated movement of animals, (iii) auxiliary information (e.g. sea surface temperature or other environmental data) can be incorporated into location-estimation models, and (iv) it provides a natural estimate of the spatial uncertainty associated with each position.

As technology has advanced, light-based geolocation tags have become even smaller, extending the range of species that can be instrumented. However, the light curve methods used by TripEstimation are not suited to the data collected by some of these newer tags, and so we have developed new threshold based techniques for this purpose. A new R package entitled SGAT (Solar/Satellite Geolocation for Animal Tracking) implements both the new threshold techniques and the older light curve methods. It allows users to seamlessly transition from simpler to increasingly sophisticated models, building up analyses in a layered fashion. The package also contains improvements to better cope with high latitude species that move in and out of the Antarctic/Arctic circles, and facilities for parallel calculation to better exploit modern computer architectures. The output data are structured so that users can easily extend their analyses with other popular R tools and export results to standard formats.

This presentation will illustrate the features of SGAT with a number of worked examples. Future developments will also be discussed, including the implementation of regime-switching movement models capable of identifying changes in animal behaviour over time, and improvements to the algorithms for extremely high latitude species.

## Breeding and post-breeding foraging locations of Adélie penguins at Hope Bay/Esperanza, Antarctic Peninsula

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Adélie penguins (*Pygoscelis adeliae*) are important predators that act as central place foragers during the breeding season. Along the West Antarctic Peninsula (WAP), Antarctic krill (*Euphausia superba*) constitutes their main prey. Recently, it has been widely reported that Adélie populations are decreasing throughout the WAP, a region where rapid climate warming has been recorded and where a large commercial fishery for krill currently operates.

Adélie penguins are believed to respond to changes in the availability of species which may be targeted by a fishery, such as krill. They are therefore considered by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) as an indicator of the state of the ecosystem. If information from monitoring programs indicates that these populations are decreasing in the area, possibly related to climate change and/or commercial fishing activity, CCAMLR may consider the introduction of new fishery management measures which could include changes to the spatial and temporal operations of the fishery, to mitigate the impact of the fishery on Adélie penguin populations. However, new management actions require knowledge of Adélie penguin summer and winter distributions throughout the WAP region.

Here, we present for the first time, tracking data from Adélie penguins during two breeding seasons (2012-13 and 2013-14) from the Hope Bay/Esperanza breeding population together with data on the distribution of the krill fishery. During summer the birds foraged less than 100 km from the colony. During the pre-moulting period, preliminary results suggest that Adélie penguins continue to feed close to their colonies, which contrasts with the movement patterns of Adélie penguins from the South Orkney Islands. These birds exhibited large-scale southern movements to areas remote from their colony before moult and subsequent dispersal even further afield.

This work highlights the need to understand the distribution of predators, such as the Adélie penguin, during breeding and during their post-breeding dispersal in relation to fisheries activities in the WAP. Furthermore, another aim was to emphasize the benefits of collaboration amongst different countries and CCAMLR, as a constructive way to help manage the living resources in the Southern Ocean.

## Carbon and nitrogen stable isotope compositions in fin and humpback whales near the Antarctic Peninsula

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Stable isotopes are being increasingly used to address questions on diet and trophic interactions among top predators as well as for studying ecosystems subjected to different oceanographic conditions. In this context, the main objective of this study was to assess the existence of species-specific and small-scale geographical variations in carbon and nitrogen compositions in skin of whales feeding near the Antarctic Peninsula. Skin was obtained by biopsy sampling humpback whales in the Gerlache strait (GS, n=11) and fin whales from the Bransfield strait (BS, n=5) and the Powell basin (PB, n=11) during the 2013 austral summer (February). Stable carbon and nitrogen isotope ratios were obtained, and expressed in delta ( $\delta$ ) notation, while the relative variations of stable isotope ratios were expressed as permil (‰) deviations from the predefined international standards ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ , respectively). Relatively high  $\delta^{15}\text{N}$  values were found in humpbacks from GS (8.74‰; SD =0.68) and fin whales from BS(8.66‰; SD = 1.24). Mean  $\delta^{15}\text{N}$  in fin whales from the PB (7.80 ‰; SD =0.35) were significantly lower than humpbacks from GS ( $p<0.05$ ). Differences in  $\delta^{15}\text{N}$  between fin whales from BS and PB were not significant ( $p=0.46$ ). Carbon isotope values were not significantly different among areas ( $p>0.05$ )( $\delta^{13}\text{C} =-24.76$ ‰; SD =1.01 in GS, -23.61‰; SD =1.16 in BS, -24.96‰; SD =1.07 in PB). Differences found in nitrogen isotope compositions between GS and BP could be interpreted as (i) a difference in diet composition among humpbacks and fin whales from the sampled areas; (ii) a change in krill isotopic composition due to differences at the base of trophic chains among regions (i.e. different phytoplankton composition resulting in differences in isotope values); (iii) differences in nitrogen sources due to different oceanographic conditions that cascade up through the food web. In order to clarify this issue, isotopic composition analyses of particulate organic matter (POM) and krill samples are needed and are underway so whales' diet can be inferred through isotopic mixing models. This sort of information will help to clarify whether variation between fin and humpback whales isotopic composition is related to differences in prey (e.g. different krill species or size) or oceanographic characteristics (i.e. location) that lead to different POM isotopic values.

## Can we use land-based marine predators as honest indicators of ecosystem status?

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British Antarctic Survey

Using some of the longest datasets currently available for the Scotia Sea, we explore the trophic interactions between Antarctic krill (*Euphausia superba*) and a guild of land-based marine predators that feed upon krill. Based upon almost two decades of consistently collected acoustic data and contemporaneous predator monitoring data from Bird Island, South Georgia, we highlight that complex relationships exist between krill abundance and predator population size and breeding performance. We explore how these relationships differ between species, showing that when krill abundance is low in some years, predator performance can still be above average, indicating that they are still able to forage successfully and find food. Previous studies have made the link between predator performance and variability in sea surface temperature, linked with regional scale environmental indices such as the Southern Annular Mode and the El Niño Southern Oscillation, postulating that temperature is a good proxy for prey availability. Here we show that such relationships are also complex. Long term monitoring data for both krill abundance and predator performance are perceived to be fundamental tools for helping to manage the commercial fishery for Antarctic krill in the Scotia Sea and potentially more widely across the Southern Ocean. Our results demonstrate that the use of such monitoring data in a management context may be feasible, but that fundamental studies of predator/prey relationships are also urgently required.

## An Optimality Approach for Estimating the Physiology of Humpback Whales (*Megaptera novaeangliae*)

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The physiology of diving marine predators can be difficult to measure due to the inherent difficulties associated with studying these animals. Thus, physiological studies of diving predators regularly rely on the use of allometric relationships originally developed using estimates of terrestrial or captured mammals' physiology to estimate parameters such as metabolic rates ( $m$ ), total oxygen capacities ( $K$ ), and oxygen replenishment rates ( $\alpha$ ). These parameters are often subsequently used to model foraging behaviours of these species to evaluate their response to current environmental conditions and/or to predict their response to future environmental changes. Thus, a large degree of error may be present in these subsequent models if the physiological parameters used in the original foraging models were inaccurate. We implemented a Bayesian statistical approach to estimate posterior values of  $m$ ,  $K$ , and  $\alpha$  for humpback whales foraging along the Western Antarctic Peninsula to assess if observed diving behaviours of whales and optimal foraging theory could provide insights into their physiology. We implemented a Markov Chain Monte Carlo simulation with a Gibbs sampler and a Metropolis sampling algorithm to estimate posterior values of  $m$ ,  $K$ , and  $\alpha$  based on the likelihood that whales were allocating their time 'optimally' during foraging dives (i.e., that they were maximizing their foraging durations during a dive cycle). Whale dive behaviours were recorded in the austral autumn of 2009 and 2010 with high-resolution, multi-sensor digital acoustic recording tags ( $N = 13$  whales). Foraging dives were detected by the presence of feeding lunges and the travel, forage, and surface durations of each whale's dives were logged for use in the simulated model. The mean posterior estimate (CI: 2.5%, 97.5%) of total oxygen capacities ( $K = 1253$  L (1234, 1272)) was consistent with the estimate obtained from commonly used allometric relationships ( $K = 1226$  L). Mean posterior estimates of metabolic rates while traveling and foraging ( $m_1 = 1.003$  L O<sub>2</sub> s<sup>-1</sup> (1.000, 1.011);  $m_2 = 3.576$  L O<sub>2</sub> s<sup>-1</sup> (3.294, 3.878), respectively) and of oxygen replenishment rates ( $\alpha = 0.024$  s<sup>-1</sup> (0.021, 0.028)), however, varied considerably from the estimates obtained from commonly used relationships ( $m_1 = 1.623$  L O<sub>2</sub> s<sup>-1</sup>;  $m_2 = 10.280$  L O<sub>2</sub> s<sup>-1</sup>;  $\alpha = 0.006$  s<sup>-1</sup>). These findings will further our understanding of the physiology of large whales and help to direct future research priorities.

## Aerial and ship-based distance sampling surveys for cetacean density estimation in selected areas of the Southern Ocean

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Dedicated line-transect distance sampling surveys for cetaceans were conducted during five expeditions in the Southern Ocean since 2006, using the German research icebreaker Polarstern as a platform of opportunity. In addition to ship-based observations, helicopter surveys were used to achieve spatial coverage independent of the ship's track. We modeled separate detection functions for humpback whales (*Megaptera novaeangliae*), fin whales (*Balaenoptera physalus*) and Antarctic minke whales (*Balaenoptera bonaerensis*) and estimated local densities for these species for sub-strata of the survey area, encompassing the Atlantic sector of the Southern Ocean as well as the Western Antarctic Peninsula. We identified highest densities for large whales on the western side of the Antarctic Peninsula, for Antarctic minke whales in the Weddell Sea. We further used the results for a comparison of methods between aerial and ship-based surveys to a.o. assess differences in obtained density estimates, typically observed between the two methods, with aerial surveys revealing lower densities than ship based surveys. We found these differences not to be statistically significant. Aerial surveys generally provided estimates with lower CVs, led to wider coverage of the survey area, allowed for survey design independent of the ship, enabled better species identification and allowed for density estimates in shorter effort time than ship-based surveys. Here we present minimal density and abundance estimates for cetaceans in selected areas of the Southern Ocean based on aerial as well as ship-based distance sampling surveys and discuss further application of the data in a density surface modeling context.

## Where do they go? Does year-round movements of Southern Giant Petrels from Antarctica reveals a migration pattern?

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While migration is a common behavior for many seabird species, Subantarctic populations of Southern Giant Petrels seem to be more or less gregarious, only increasing their home range during winter, but without changing the center of dispersion. Nonetheless, recent researches with stable isotopes suggested that Antarctic Populations should probably use both Antarctic and Subantarctic waters along the year. Our study evaluated the year round movements of a Southern Giant Petrel population from Maritime Antarctic Peninsula by geolocation methods, and also evaluated the breeding and non-breeding home range habitats. We found a clear spatial shift, with petrels foraging in cold mid-productive waters south the 60°S parallel during breeding, and then using preferentially the productive, shallow and temperate waters near Argentina and Falkland Islands during non-breeding, but always taking incursions to the ice edge. This behavior generated a bimodal home range and habitat use during winter. It confirms the previous hypothesis of Antarctic population movements, and also contributes to understand why the Southern Giant Petrels have a large niche during non-breeding as consequence of the exploration of distinct habitat features. Further analysis should contribute to a deep understand of the Antarctic populations ecology regarding trophic niche, relations with fisheries and climatic changes.

## Oceanographic characteristics to explain sexual segregation in foraging habitats by Giant Petrels

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Oceanographic factors are important in explaining the organization of seabird communities, but how genders use foraging habitats and reduce competition is still poorly understood. We evaluated the influence of Chlorophyll-a concentration (Chl-a) and sea surface temperature (SST) on the differential habitat use by male and female Giant Petrels *Macronectes giganteus* during the austral summer. We tagged 7 females and 11 males in Stinker Point at Elephant Island, Maritime Antarctic Peninsula, with Lotek geolocators. There were no differences in latitude and longitude of sites used by both sexes, but Kernel Densities (KD) showed a significant difference in the core areas used by males and females. There was a tendency of females to avoid the core areas used by males, corroborated by a significant negative relationship between the KD of males and females. There were no differences in Chl-a and SST used by both sexes, but we detected that females KD was negatively associated with SST while male KD was positively associated with Chl-a. The potential avoidance of male core areas by females could be attributed to marine productivity, because the greater the concentration of Chl-a the lower was the avoidance. It means that in areas with high marine productivity, the female and male KD overlap was enhanced. This is a species whose active interference between sexes is possible. Males assume a coastal foraging strategy and, as they are more aggressive and more efficient in foraging on coastal carrions, females assume a pelagic foraging strategy. Nonetheless, both sexes can use a dual coastal-pelagic foraging mode. At Stinker point, it seems that differences are not that clear and both sexes overlapped in foraging distribution, but detailed habitat use was characterized by different oceanographic characteristics. We suggest that females adapted by following different environmental cues than that followed by males to avoid competition with them. As expected, our data suggests that competition between males and females is lower in areas with higher marine productivity.

## S28: HUMAN BIOLOGY AND MEDICINE

### Happy wintering design in Antarctica

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Since establishing the King Sejong Station at King George Island, Antarctica in 1988, Korea has dispatched a wintering party for 26 years. While staying in Antarctica and conducting duties of research and station management for 13 months, wintering members get to experience physical suffering and an existential crisis under direct and indirect influence of nature. So, it's required to understand their difficulties and analyze their unsatisfied needs as a subject of wintering.

According to the theory of Maslow, deficiency needs and difficulties of wintering members were analyzed. In Antarctica, with the environment-specific property, physiological and safety needs come to be stronger in terms of an individual and needs for belongingness and respect in terms of a group. Difficulties accompanied by the set routine were encoded and ideas for solution were suggested.

Human being achieves perfection through continual interaction with the external. Various stimuli coming from a sensory organ make human behavior and feeling abundant. For human being as a creature to be adapted to the natural world and finally to evolve, diversity and symbiosis took an important role. Finding clues for solution from such an idea, Antarctica University Program was designed to provide wintering members with a variety of stimuli and experiences.

This design takes a role of making an exit for stress in order for members not to be controlled helplessly by negative feelings, or feeling bored, oppressed or heavy in addition to yearning during wintering. It aims at training of body and mind, increasing of capability, pursuing of interest and enhancing of cultural diversity. Beyond one-time solution for frustration, it'll give an opportunity for self-actualization through providing a continuous driving force for growth during wintering.

This will also be helpful for people who live away from the general civilized world such as an army, prison, ISS, long-term voyage ship and a deep submersible vehicle including a disastrous situation.

## Surviving in extremes: anthropological aspects of polar medicine in Brazilian Antarctic Program

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Over these 30 years of Antarctic research the visibility of environmental, climatic, geophysical and geopolitical issues emerges consistently and continuously from Brazilian research groups (PROANTAR) who excel in their contributions to the field of natural sciences and humanities. However research groups in Polar Medicine did not materialize as a reality in the Brazilian scenario. In fact medical and health issues in the Antarctic territory are addressed in individual topics and produce scarce science, usually very specific. We developed a Brazilian pioneer project aiming to investigate and reflect on medical and anthropological aspects of medicine and its features in polar context of Antarctic territory multidisciplinary initiative. In recent decades the scientific interest in Antarctica is unprecedented. The current scenario of human activity in Antarctica fields involve bodily exposure to extreme environment generating specific risks of accidents and events that affect health, or at least determine adaptive physiological phenomena of medical interest. However there is a lack of comprehensive review on the participation of medical scientists and their training for acquisition of medical knowledge in the Antarctic medicine. The physiological adaptations to cold has increased, innovations in the area of food technology to ensure the power and thermal protection in extreme environments has been the subject of exploration and industrial research, and research in the area of technological support and as application of telemedicine in polar conditions is considered strategic for the autonomy of nations in the occupation and exploitation of the territory. The question of isolation, depressive states or violence affecting people living in Antarctic stations is also a problem to be addressed. Worldwide companies and specialist rescue teams and medical assistance for major expeditions have aroused. In Brazil, this type of medical concern had its beginnings in a very modest way, at the time of the expeditions of colonial Brazil. A few Centuries later medical personnel accompanied military activities in several wars. Sports, and adventure expedition activities in remote areas, gave rise to what is known today as Wilderness Medicine. This medical field is now widespread in Europe, United States and Canada. In Brazil scarce resources are available mostly related by teams from the Fire Department, Military Police and Armed Forces. In some areas of Brazil there are small groups of people, usually volunteers, who try to meet rescue situations in some parks and environmental groups that are organized to promote attendance at sporting events outdoors and in areas of difficult access. However, a permanent operation such as the Antarctic Program claims for largest investments in planning and staff, in addition to greater international integration. Addressing such issues are the objectives of this project.

## Tracking the psychosocial health of ICE teams

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**BACKGROUND:** This research is part of a project funded by NASA that investigates how people react and adjust to the conditions associated with isolated, confined, and extreme (ICE) environments such as the Antarctic. Such environments represent “analogs” of the conditions that astronauts face on long-duration space missions. This research is designed to help us understand how people react, cope, and adjust to working together in ICE environments. Our participants, much like astronauts, work collaboratively with others in an ICE environment to accomplish a mission that requires interdependence and teamwork.

**SAMPLE:** We have collected data from multiple US-based ICE teams. All teams were composed of scientists living in the ice fields of Antarctica for approximately six weeks at a time. Each team followed one of two missions: (1) seeking out new locations in the ice fields for sample collection; or (2) collecting samples from already-known/established locations. We surveyed participants daily to learn about the ebb and flow of their perceptions, thoughts, and reactions throughout their missions. Targeted Likert-scale items tap key team processes related to psychosocial health; open-ended responses are used to gather additional team- or task-related information.

**RESULTS:** In our presentation, we will focus on answering the following question: Why do some teams show relatively stable psychosocial health throughout the mission, while others’ show more volatile patterns? To address this issue, we will first discuss results from lagged analyses to highlight potential predictors of team psychosocial health. Additionally, we will identify “peaks” and “lulls” in each team’s psychosocial health and will use qualitative data to help explain why those “peaks” and “lulls” occur.

**IMPLICATIONS:** One key finding from our work to-date is that the particular indicators important for psychosocial health depend on the personal characteristics of team members, the types of work they are doing, and the level of frustration or discomfort induced by the ICE environment. This leads us to believe that each team functions as a complex dynamic system wherein a number of events, feelings, and personal reactions continuously and uniquely affect its members’ tendencies toward cohesion. Qualifying the dynamics of these teams is an important step toward enhancing the psychosocial health of future ICE teams.

## Understanding team affect, cohesion and performance dynamics in long duration Antarctic missions

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**BACKGROUND:** Through a grant from NASA and an international collaboration, we have investigated the psychosocial health of individuals in an isolated, confined and extreme environment over long duration missions (8 to 12 months). Although researchers have investigated such factors in longitudinal designs, analyses do not typically examine the dynamic relationships of these variables over time. Our research extends our understanding of changes in team processes and affect over time, as well as their dynamic relationships with performance and well-being.

**SAMPLE:** We collected daily surveys from 22 Australians clustered into three distinct teams (i.e., stations) over the course of their one-year mission in the Antarctic. They provided 2,445 reports of their daily perceptions of team behavior (e.g., performance, cohesion) and personal experiences (e.g., affect). In addition, individuals were asked to complete an initial survey gathering ratings on a variety of individual characteristics and a final survey about their mission experience.

**RESULTS:** We found four distinct individual-level dynamic patterns, displaying that some individuals show no change, some change only in one variable, others are variable across time in many respects, and some vary initially but stabilize over time. Differences in these dynamics may reflect variations in the mental health or emotional stability of an individual, providing unique insight that most research designs are not able to capture. Through investigating team level dynamics, team cohesion shows variability that might be associated with individual members' ratings of their positive and negative affect. Teams that experienced higher and more consistent social cohesion (i.e., commitment to maintaining interpersonal relationships) had higher levels of positive emotions, suggesting better mental health.

**IMPLICATIONS:** These data not only provide unique insight into the lives of individuals that are in isolated, confined, and extreme environments, but also indicate that positive and negative affect, team cohesion and performance are dynamic phenomena that occur differently across individuals, teams, and time. By examining each of these dynamics in turn, we are able to gain insight into the impact of time on individual well-being, and the effect of individual fluctuations on team behavior. Understanding these dynamics is a critical step in the science of psychosocial health in teams, whether in extreme settings or otherwise.

## Alterations in circadian rhythm, sleep and psychological state of winter-over members of the 27th Chinese Antarctic Expedition

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**Background** There are summer (Dec-Feb) and winter (Mar-Nov) at Zhongshan Station (69°22'24"S, 76°22'40"E) with 2-month polar nights and 2-month polar days respectively. The unique light-dark cycle may increase risks of sleep disturbances and circadian desynchrony. A comprehensive study was undertaken to investigate changes in circadian rhythm, sleep and psychology of winter-over members.

**Methods** The 10-month study was carried on 17 male winter-over members (36.8±10.3y) from Shanghai in Nov 2010, throughout winter from Mar to Oct 2011 at Zhongshan Station and returning Shanghai in Apr 2012. Sleep parameters were derived from wrist actigraphy and sleep diaries. The melatonin metabolite aMT6s and cortisol in 48-h sequential urine samples were assessed by ELISA. The aMT6s circadian rhythm was analyzed by a cosine curve-fitting method. The psychology were evaluated via questionnaires.

**Results** The acrophase of aMT6s rhythm was delayed by 1.94 h, 1.69h ( $p < 0.05$ ) in Mar, Apr 2011, by 2.31h, 3.17h ( $p < 0.001$ ) in Jun, Jul, by 2.70h in Sep, and by 2.42h ( $p < 0.05$ ) in Mar 2012. The sleep start time and end time were delayed ( $p < 0.05$ ) from Mar to Sep in 2011. Sleep duration, efficiency and latency showed no significant change. The subjects had greater evening phase preference from May to Jul ( $p < 0.05$ ). Urinary cortisol increased in Apr, May ( $p < 0.05$ ). Stress increased in Apr ( $p < 0.05$ ). Depression increased in Apr ( $p < 0.05$ ), while confusion increased in Apr, May, Jun ( $p < 0.05$ ). The Global Seasonality Score peaked in Jul ( $p < 0.05$ ), while the prevalence of subsyndromal SAD is 2-5 during winter. Team-member exchange quality decreased in Oct ( $p < 0.05$ ). The trust in team did not change.

**Conclusion** Wintering-over in Antarctica caused problems as follows: desynchronized circadian rhythm, sleep disturbances, increasing incidence of S-SAD, occurring of negative affect and less exchange in team. The results provide data for establishing monitoring, assessing, prevention and treatment system.

**Key words** Antarctica; winter-over; sleep; circadian rhythm; psychology

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## Stress and immune research in Antarctica (CHOICE project): An international and interdisciplinary study at Concordia and Neumayer III

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Adapting to hostile and unnatural conditions is often accompanied by adverse physiological and psychological effects. Major questions remain: What are the principle and most prominent environmental and social threats to physical and mental health during either long-duration space flight missions, overwintering in a hostile and exposed spot and how can we prevent and mitigate the adverse effects from these threats and ensure adequate adaptation?

The steps involved in the adaption process to extreme environmental conditions are gradual and the biological system either builds up resistance to the stress and maintains a healthy physiological and psychological equilibrium, or succumbs to the stress, resulting in disequilibrium, cognitive or emotional dysfunction with a negative impact on performance and immunity, disease or even death. In general, stressful conditions, of either a psychological or physical nature, can activate and/or paralyze specific immune responses - a finding which has been shown in manifold laboratory, clinical and epidemiologic studies on Earth and in Space and Space analogues. Recent studies point to (epi-)genetic factors which are related to immune dysfunctional states which can activate and/or paralyze specific immune responses through the action of stress hormones. Studies have confirmed the stress-induced permissive roles of the catecholaminergic and glucocorticoid systems involved in the control of the host's immune response, immunosuppression and e.g. herpes reactivation.

However, despite the current understanding of stress-dependent, neuroendocrine – immune interactions - it is still not clear under what conditions (e.g. duration) these changes remain physiological and adaptive and when they become maladaptive resulting in pathology, which is either critical for an expeditioner in Antarctica or in Space, as well as in the patients on Earth.

These questions have been addressed in the project CHOICE and the experiment has been implemented at Concordia and Neumayer III accordingly. The background, design and first outcome and conclusions of the study are reported and the next potential steps described.

**Acknowledgement:** Supported by the European Space Agency (ESA), the French (IPEV), Italian (PNRA) and German (AWI) polar institutes, the German National Space Program (DLR, 50WB0719/WB0919/WB1317), by BELSPO/PROEDEX/ESA, by NASA, the ESA Topical Team *Stress and Immunity*.

## Monitoring cellular immune reactions in overwintering crews and the role of hypoxia: new implications for space travelers and Antarctic crews?

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Concordia Station is located inside Antarctica about 1000km from the coast at an altitude of 3200m (Dome C) while Neumayer III is a costal base at sea-level. Hence, individuals living in this harsh environment are either exposed to hypobaric hypoxia (Concordia) and normobaric (Neumayer II) conditions, while confinement and extreme isolation is in effect for both station. Both hypoxia and confinement can affect human immunity and health, and these effects are to be taken into consideration for care at the Antarctic bases, but also for planning exploration class space missions or treating patients.

This report is focusing on some key immune alterations as by an in vitro delayed type hypersensitivity test, at the bases and during the overwintering. All procedures followed a standardized *study protocol and methodology*. After informed written consent 14 healthy subjects were included to the CHOICE- study (Consequences-of-longterm-Confinement-and-Hypobaric-HypOxia-on-Immunity-in-the Antarctic-Environment) at Concordia and at the Neumayer base (nine could be analyzed at the time of abstract submission, from other nine samples were not received yet). Data collection occurred during two winter-over periods lasting each one year. Blood was drawn monthly and incubated for 48h with various bacterial, viral and fungal antigens or direct immune cell stimulation followed by an analysis of plasma cytokine levels (TNF- $\alpha$ , IL2, INF- $\gamma$ , IL10). As a control, blood was incubated without stimulation ("resting condition").

Initial *results* indicate that under resting conditions the in vitro DTH-like test showed low cytokine levels which remained almost unchanged during the entire observation period. With incrementing months of confinement DTH-like response tended to show an "overshooting" immune reaction after stimulation which was not visible at Neumayer III. Only responses to fungal antigens were similar in both conditions and increased in the Concordia as well as in the Neumayer crews. We conclude from these yet not completed and therefor preliminary data that the differential answers to the in-vitro DTH-like test direct to a dysregulation of cellular immune responses upon stimulation, but not the resting state. This is indicating either a) priming of immune answers and/or b) an uncoupled or dis-regulated control of cellular immune answers by auto-, para- and endocrine pathways. Further analyses and correlations are warranted and the relation to bacterial/fungal colonization need to addressed

**Acknowledgement:** Supported by the European Space Agency (ESA), the French (IPEV), Italian (PNRA) and German (AWI) polar institutes, the German National Space Program (DLR, 50WB0719/WB0919), by BELSPO/PROEDEX/ESA, by NASA, the ESA Topical Team on Stress and Immunity and, especially by the Concordia and Neumayer III crews who have participated with great enthusiasm

## Antibacterial and cytotoxic activity of secondary compounds produced by an Antarctic *Streptomyces* strain (INACH3013)

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The indiscriminate and inappropriate use of antibiotics in clinical practice, the treatment of infections caused by resistant organisms, and the agricultural antibiotic use is a single factor that contribute to global rise of drug resistant bacteria. The rapid transference and dissemination of resistance genes among different microbial populations and the spread of multidrug-resistant bacterial pathogens necessitates the search for novel or alternative antibacterial agents. Microorganisms are a prolific source of diverse bioactive metabolites, which provide the majority of the most important products and antibiotics in use today in the pharmaceutical industry. Among these, 45% are produced by actinomycetes, 38% by fungi and 17% by unicellular bacteria. Thus, diversity of actinomycetes secondary metabolites is unrivaled and unmatched in making remarkable contributions to human life. The cosmopolitan occurrence of a lot of antibiotics and other bioactive compounds among Actinomycetes (such as *Streptomyces*) reduces the chances of finding novel compounds. Therefore, the exploration of microorganisms in poorly explored areas with unusual environments, like Antarctica, would avoid redundancy in isolation of compounds and strains. A new strain of *Streptomyces* identified as INACH3013, closely related to *Streptomyces griseus* by 16S DNA, was isolated from the soil of King George Island, South Shetland Islands – Antarctica. This strain was initially screened for its ability to inhibit the growth of *Staphylococcus aureus* (ATCC6538P). The present study aims at evaluating antibacterial and cytotoxic activity of secondary compounds extracted by ethyl acetate solvent from the culture filtrate of this strain. Inhibitory was carried out against 7 multi-resistant bacteria isolated from Chilean Hospitals, 4 ATCC strains and one from Public Health Institute of Chile (ISP): *Escherichia coli* (Ec241), *Pseudomonas aeruginosa* (P145), *Acinetobacter baumannii* (Ab1), *Klebsiella pneumoniae* (Kb 494), *Klebsiella pneumoniae* (KB503), *Serratia marcescens* (S32), *Serratia marcescens* (S41), *Salmonella Typhimurium* (ATCC14028), *Escherichia coli* (ATCC25922), *Pseudomonas aeruginosa* (ATCC27853), *Staphylococcus aureus* (ATCC25923), *Listeria monocytogenes* (ISP). The extract showed significant antibacterial activity against *S. aureus* (ATCC6538P) and *L. monocytogenes* (ISP). Minimum inhibitory concentrations of the ethyl acetate extract were found to be 1 and 10 µg/ml, respectively. Cytotoxic activity of extract against OKF6-TERT2 epithelial cells was found at lowers concentrations (5 µg/ml). From the ethyl acetate extract 11 compound was separated by TLC chromatography where 3 of them have activity against *L. monocytogenes* (ISP). The crude extract had a good activity and low preparation cost, and may be useful in topical applications to combat microbial infections.

## The study of environmental factors on lower urinary tract symptoms

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Backgrounds and purpose: Lower urinary tract symptom is one of the common symptoms for urological diseases and leads to decrease of quality of life. Lower urinary tract symptom is generally related with various factors including age, psychiatric status, urological disease (benign prostatic hypertrophy (BPH), overactive bladder syndrome (OAB), etc), environmental factors and etc. However, there were few studies about relationship between disorder of urinary symptoms and working environments. My interest is to elucidate the influences of working environments on urinary symptoms. In this study, we will study the status of urinary symptoms of workers in polar environment as a preliminary study.

Methods: We carried out questionnaires survey about urination among the 54th Japanese Antarctic Research Expedition from December, 2012 to March 2014. 13 people were part of this study. We used three kinds of questionnaires; International prostate symptom score - Quality of life due to urinary symptoms (IPSS-QOL), Overactive bladder symptom score (OABSS) and Pittsburg sleep questionnaires. And also we checked frequency volume charts to compare the answers of questionnaires and real data of urinations. They were conducted before departure from Japan, regularly at Showa station and after returning to Japan. We also investigated the presence or absence of complications and medication.

The expected results and its value; This study will be the first report to reveal more about the presence of change in urination by working in polar environment. We undertake a statistical analysis of the presence or absence of change over time on the date of questionnaires of each item and the pattern of frequency volume charts. In addition, we have studied among shift-workers by using the date of the periodical health examination. It may become apparent the effect of sunshine hours or seasonal variations on urination through comparison of these studies.

## Over, than under-consumption is the nutritional challenge for Antarctic expeditioners in the modern age

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### Background

Early expeditions to Antarctica were plagued with nutrient deficiencies and starvation, often due to the inability to consume fresh produce, so were reliant on nutritionally poor preserved foods. Modern expeditioners also require provisions to be shipped in, and have limited access to fresh produce, but improved knowledge of dietary requirements ensures foods provided are nutritionally sound. Despite sufficient energy intake, nutritional imbalances are still observed.

### Objective

To determine the adequacy of dietary intake of Antarctic expeditioners wintering at Australian stations.

### Design

Dietary intake was determined on 228 expeditioners (16% female) from 2004 - 2010 at the four Australian Antarctic and sub-Antarctic stations (Maswon, Casey, Davis, Macquarie Island) using 3-day food records. Nutrient intake were analysed using FoodWorks (XYRIS, Australia). Foods were divided into the 5-food groups based on the Australian Dietary Guidelines.

### Outcomes

Women were younger ( $35.1 \pm 8.1$  v  $42.8 \pm 10.8$  yrs,  $p < 0.0001$ ) and had a lower BMI ( $25.3 \pm 3.8$  v  $27.5 \pm 3.6$ ,  $p < 0.01$ ) than men, and had mean intakes of micro- and macro-nutrients more in line with recommended intake levels. Men consumed below the recommended intake for dietary fibre ( $75 \pm 30\%$  of RDI,  $p < 0.001$ ), calcium ( $79 \pm 42\%$  of RDI,  $p < 0.001$ ), magnesium ( $83 \pm 34\%$  of RDI,  $p < 0.001$ ), potassium ( $86 \pm 29\%$  of AI,  $p < 0.001$ ) and above the upper limit for sodium ( $125 \pm 48\%$  of UL  $p < 0.001$ ), while women consumed below recommended levels for calcium ( $68 \pm 21\%$  of RDI,  $p < 0.001$ ) and iron ( $73 \pm 37\%$  of RDI,  $p < 0.001$ ). Men consumed more alcohol than women ( $18 \pm 24$ g v  $10 \pm 13$ g,  $p < 0.05$ ), which is near the recommended maximum daily intake of two standard drinks per day (20g/d). On average both males and females consumed only 1 serve of dairy food per day, and required 2 more serves of vegetables to achieve recommended intake levels.

### Conclusion

Improving the consumption of calcium rich (dairy) foods and moderating salt and alcohol intakes are dietary changes that support better bone health, which can be compromised during prolonged periods of sunlight deprivation. Increasing vegetable intake to recommended levels will increase fibre intake. The challenge is the logistics of providing these foods throughout the wintering season.

## Changes over time of mood and mental health during five Japanese Antarctic Research Expeditions

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This study investigates the changes over time of mood and mental health of the wintering party. Data have been collected for five consecutive years by questionnaire (positive affect negative affect scale (PANAS) and subjective health complaints (SHC)). PANAS asks about the participant's mood; SHC asks about physical and mental disorder. The participants were 174 members of the wintering party at the Syowa Station during the Japanese Antarctic Research Expedition in 2003-2009 (JARE45-49).

The following things became clear as a result of the investigation. 1) About half of the members had sleeping problems during the polar night and on the return ship. 2) About half of the members suffered from fatigue before departure and during the summer period. 3) Most of the members were not troubled with anxiety and depression. However, about ten percent of the members were conscious of anxiety and depression. It was suggested that they needed mental health care. 4) The positive mood score kept high during a winter in Antarctica. On the other hand, the positive mood had decreased before departure and on the return ship. 5) The negative mood score had increased in the latter half of their stay. This supports the 'third-quarter phenomenon' to some extent. However, this phenomenon sometimes happens and sometimes does not. Climate conditions, member's individual differences, and human relations may determine whether this phenomenon will occur.

The mental state of the members of the wintering party with respect to time was investigated. Therefore, stress management at the time might be able to be performed, and it was suggested that mental education related to stress would be effective.

## Relation between positive (and negative) affects and coping with stress experienced by Japanese wintering parties in Antarctica

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Successive Japanese wintering parties were placed in an isolated environment in Antarctica for about one year. There were few visitors there because there were no other permanent research stations near that of Japan. The main purpose of this research was to investigate the relation between positive (and negative) affects and coping with stress in a long term isolated environment.

Questionnaires were conducted and 101 people in Japanese wintering parties (from 2003 to 2009) completed them. The results were that high positive affect groups used 'planning', 'positive reinterpretation & growth', 'suppression of competing activities', and 'active coping' more than low groups, and high negative affect groups used 'mental disengagement', 'focus on & venting of emotions', 'denial', and 'behavioral disengagement' more than low groups.

These results indicated that positive affects prompted wintering members to actively cope with stress, and negative affects prompted them to disengage themselves from stressful events. Not only coping actively but disengagement could be regarded as an adaptive coping strategy in long term isolated environments.

## Predictors of positive and negative psychological change in expeditioners post-Antarctic employment

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Extreme weather conditions and geographical isolation are among many factors that render Antarctica a challenging environment for employees to sustain optimum levels of physical, psychological and social functioning. However, the challenges associated with Antarctic employment can extend beyond their time “on the ice” to influence post-Antarctic adjustment. The current study investigated predictors of positive and negative psychological change reported by Antarctic expeditioners 2 and 12 months post-return from “the ice” in an effort to identify factors that influence adjustment following Antarctic employment. The sample comprised 383 (277 male, 106 female) single and partnered expeditioners, recruited by Australian Antarctic programs between 2005 and 2010. Scores on the Changes in Outlook Questionnaire (CiOQ) were examined at two time periods; 2 and 12 months post-return. Results indicated that positive and negative psychological change at both 2 and 12-months post-return was predicted by pre-departure and post-return factors, and not by experiences whilst “on the ice”. It was also identified that the predictors of positive and negative change differed as a function of relationship status, such that the predictive factors for single expeditioners differed from those of partnered expeditioners despite no differences in the overall magnitude of positive and negative change in each group. These findings have important implications as they indicate that expeditioners would benefit from proactive prevention and intervention strategies prior to departure and upon return from their employment, not simply whilst working in Antarctica. In addition, the nature of such interventions needs to consider relationship status as a factor that can influence post-return adaptation and functioning. By utilising timely intervention strategies based on identified predictive factors associated with relationship status, retention rates of expeditioners and hence long-term efficiency of Antarctic programs could be maximised.

## Comparing the effects of sea versus air-based transportation on the psychological wellbeing of expeditioners

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The introduction of air-based personnel transportation within the Australian Antarctic program to complement the existing ship-based transportation arrangements provided a unique opportunity to examine the impact of differing transportation methods on expeditioner health and well-being. This research investigated the response profiles of 88 expeditioners who returned to Australia via ship following Antarctic employment, and 88 expeditioners who returned to Australia via plane during the first and subsequent years of implementation. Results indicate that expeditioners who returned by plane reported significantly higher distress two months post-return than those who returned by ship. There were no significant differences in expeditioner response profiles at 12 months post-return based on method of transportation. Implications of these findings for expeditioner training and support needs are discussed.

## A report of Legionella spp. survey at Antarctic stations

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Back Ground : Gene of Legionella spp. was detected from the 24-hour bathwater at Antarctic winter-over station in 2000. The result pointed two subjects. The first one was to prevent of an outbreak of Legionellosis. Once a bather inhales this bacillus, he might contract the pneumonia. Legionella pneumonia requires special antibiotics and respirator treatment and has a high lethality. The second was to reveal the derivation of Legionella spp. or if the microbe were indigenous or from outside. The natural environment of the Antarctic Region was considered not suitable for habitation of Legionella.

Method: We have been observing *Legionella* spp. in the hot-water supplying system for the bath during 15 years in our Antarctic wintering bases. To prevent the Legionellosis, we have adopted of bathtub water disinfection systems such as chlorine sterilization, ultraviolet irradiation and silver ion sterile system. To detect Legionella spp, bathtub facilities and soil have been brought back to culture and PCR.

Result: We detect DNA gene of Legionella spp. was detected from the bathwater of our coast station in 1999 and from the bathing facilities of a inner land base Until 2006, DNA gene from *Legionella* spp. had been detected in the bathing facilities (shower heads, ultrafiltre, biofilms etc.) of the coast station and also inner land base. The same examination was done in delivery ship in 2007. Since 2008, the RNA of *Legionella* spp. or host Ameba was detected from soils or pebbles around station, and also of the Antarctic field, that is located 50 km away from the station. Separation culture has been negative for Legionella. After introducing precautionary measure, no DNA nor RNA was found from bath system of station.

Conclusion: We have been observing *Legionella* spp. in the hot-water supplying system for the bath during 15 years in our Antarctic wintering bases for the medical purpose of participant's health in Antarctica. We have controlled Legionellosis successfully. The survey also brings up subject of Antarctic Legionella spp.. It is expected to accomplish the separation culture.

## Sleep in Antarctica: an update on the big eye

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Sleep complaints are consistently cited as the most prominent health problem in Arctic and Antarctic expeditions. Continuous bright light exposure in the summer, and continuous darkness in the winter suggest a fundamental disturbance of circadian sleep-wake regulation in this environment. However, there is no clear evidence to date of a consistent disruption, nor of the relationship between different circadian rhythms. Furthermore, the circadian disruption has not, so far, been related to the sleep complaints. Apart from the loss of photoperiodicity due to seasonality, other features of Antarctic campaigns can be responsible for sleep disturbances, such as mood disturbances due to long duration isolation and confinement, or exposure to chronic hypobaric hypoxia for the altitude stations.

The current presentation will summarize the findings of our experiments investigating sleep, circadian rhythms, mood and performance conducted for the past 3 years in several Antarctic stations. These include the ASMo project (Antarctic Sleep Monitoring) at Princess Elizabeth station (N=21); the Neuropole (N=13) and the HASTE (N= 10) ESA projects at Concordia; and the Duopole project comparing Concordia (N=8) and the Dumont d'Urville station (N=18). The main findings of these different studies, depending on seasons and populations, were:

- A dissociation of melatonin and cortisol secretion profile, with melatonin showing to be mainly driven by light exposure, and cortisol by the behavioural schedule.
- An association of the occurrence of deep sleep with melatonin secretion.
- A potential protective effect of the sleep environment with regard to sleep quality.
- A severe sleep-disordered breathing due to the chronic exposure to hypobaric hypoxia, which does not show acclimatization over a period of 9 months, and which effect is far more detrimental than the seasonality effect.
- The effect of hypoxia being highly dependent on interindividual variability, suggesting the existence of responders and non-responders.
- A detrimental effect of exercise on acclimatization to long-duration hypobaric hypoxia.
- A consistent decrement of psychomotor speed and vigilance associated with the sleep disturbance.
- A correlation between the amount of deep sleep and the stability of performance.
- An absence of mood disturbances, which emphasizes the positive effect of the Antarctic experience.

These findings will be discussed in terms of their implications for the physiology of sleep-wake regulation, as well as with regard to operational recommendations to alleviate sleep complaints during Antarctic expeditions/campaigns.

## Dynamics of neurotrophin 3 in Romanian Antarctic expeditioners in relation to immune response to extreme environment

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Implication of neurotrophin 3 (NT-3), depending on interleukine 1 beta, in adaptation response of Romanian expeditioners to Greenland environment was previously shown by us.(1). This study aim was to evaluate serum levels of NT-3 in Romanian expeditioners in Antarctica as compared with cold and physical effort exposed volunteers and to investigate their relationship to immunological data previously reported (2,3).

Our subjects were the Romanian expeditioners in Antarctica A\_2006 (January-February), n=3 (S1\*, S2, S3\*\*) and A\_2007 (February-March), n=1 (S1\*), and the volunteers continuously exposed to winter cold weather (February) in Romanian Bugegi Mountains (B\_2005), n=5 (S1\*, S3\*\*, S4, S5, S6). The NT-3 serum levels were determined by ELISA (Abcam kit) before (RO\_2), during (AU/JO\_3, SO\_4, Ant\_5, Ant\_6, Ant\_7, SO\_8) and after (RO\_9) the expedition, and before, during and after the voluntary tests.

NT-3 level increase as effect of the rapid transition (flight) from Boreal winter to Austral summer in Australia (A\_2006) and SA Johannesburg (A\_2007), was recorded in S1\* [pg/mL: 18 (AU\_3) vs <4,12 (RO\_2, RO\_9); 75 (JO\_3) vs 20 (RO\_2) and 7 (RO\_9)], and in S2 [pg/mL: 21 (AU\_3) vs <4,12 (RO\_2, RO\_9)]. On the contrary, NT-3 level in S1\* and S2 decreased below 4,12 pg/mL during the Southern Ocean travel (SO\_4, SO\_8). Interesting, on Antarctic Continent (Ant\_6), reactivation of Herpes simplex virus infection (associated with a decrease of ceruloplasmin (CP) and IgG levels) in S1\* corresponded to a NT-3 level <4,12 pg/mL, while the good state of mind (associated with an increase of CP and IgG) in S2 corresponded to a NT-3 increase to 71 pg/mL. The NT-3 level in subjects B\_2005 increased 5 times (pg/mL: 293 vs 57) in the (S4, S5, S6) acute cold stress group (associated with an increase of levels of IgA by 20,9% and IgG by 16,75%), and decreased to <4,12 pg/mL in the (S1\*, S3\*\*) transitory hypothermia group (associated with a decrease of levels of IgA by 21,2% and IgG by 17,39%). Surprisingly, subject S3\*\*, which passed the cold test in Bucegi but presented an adaptation incapacity to Antarctic environment, constantly shown exacerbated NT-3 levels (2002-2977 pg/mL).

Our results show that NT-3 test is an efficient marker for the selection of Antarctic expeditioners and their health state monitoring on the Antarctic Continent.

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## 100+ years of polar psychology: looking back, looking ahead

**Steel G**

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Interest in the psychological adaptation and adjustment of human beings to the often harsh conditions of life in the polar regions has had a long history. Documentation of psychological effects connected to wintering in the Antarctic exists in various source well before the so-called 'heroic age' of polar exploration, although the first known instance of the use of the term "polar psychology" occurred in Cherry-Garrard's (1922/1965) well-known book, *The Worst Journey in the World*. From the early focus on selection and resilience to the current fascination with positive effects, there have been several distinct phases and levels of activity of research during this time. Each of these phases is characterized by its own particular influences; some from outside the field, others from within. Notably, there have been very few long-term, international, and large-scale programs of research. This stands in stark contrast to other areas of Antarctic science. This talk will describe the major themes and findings of polar psychologists, or similar researchers, in each epoch. Current and potential influences on research will then be described and analyzed in order to show likely paths for research topics and programs in the next decade.

## Research on application of artificial lighting to curb seasonal affective disorder in Antarctica research stations

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Due to sunlight shortage in polar night period, people in Antarctica stations are likely bedeviled by Seasonal Affective Disorder (SAD) which includes symptoms of depressed mood, anxiety, irritability, fatigue and weight gain or loss.

SAD began to arouse people's attention in mid-1980s base on researches in high latitude areas such as north America and Europe. A study made by Dr. Rosenthal found that SAD was related to high latitude and shortage of sunlight.

Compared with people in north America and Europe, people in Antarctica stations are more likely to suffer SAD because of longer time without sunlight, worse climate, duller work and life with limited social communication.

Light therapy, cognitive-behavior therapy (CBT) and antidepressant are common treatment to SAD. Among them, light therapy has been proven to be more secure and effective way to cure SAD.

Artificial light environment influences the physical and psychological health of people in Antarctic scientific stations based on author's analysis of current light environment of several Antarctic scientific stations.

In order to alleviate SAD, the light design in Antarctica stations was improved in three ways below:

1. Higher illuminance standard, less uncomfortable glare and higher color rendering index light source are selected in lighting design.
2. Cold white (4000K) light sources which simulate dawn sunlight are installed to stimulate pineal gland and restrain melatonin during daytime in polar night period.
3. As auxiliary lighting, a set of banded multi-module LED with wavelength of 670nm, 580nm and 490nm is designed to embed to the ceiling. This system simulates dawn and mid-day light automatically or manually via a controller.

The first two ways have been adopted in the reconstructions of the Great Wall and Zhongshan Antarctica stations. In the Great Wall station, the satisfaction rate increased from 43% to 65% as showed in a questionnaire regarding new adopted light environment compare with previous light environment.

As for application of LED, a series of in-depth experiments are going to be carried out in 2014. The research on application of artificial lighting to curb seasonal affective disorder in Antarctica research stations will continue.

## Dietary surveys of the 22th and 24th Chinese winter-over expeditioners at Zhongshan Station during prolonged Antarctic residence

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**Background** There are nearly 2-month polar nights and polar days respectively at Zhongshan Station (69°22'24"S, 76°22'40"E) with the average temperature of -23°C in winter. And food supplement is once a year in summer by Xuelong Ship, resulting in a short of fresh vegetables and fruit in winter-over period (March- November). The unique environmental conditions call for higher demand of dietary and nutrition for winter-over expeditioners in their 15-month stay at Zhongshan Station. Through investigation of the dietary of the expeditioners, we can obtain their nutrients intakes, evaluate the dietary pattern and provide advices and guidance to administrators and expeditioners to improve their dietary quality and promote health.

**Methods** The 3/4-day food intakes of the 22th and 24th winter-over expeditioners were investigated with weighing methods in March, July and November in the year of 2006 and 2008 respectively. The average daily intakes of food and nutrients were calculated. Dietary status was evaluated according to Chinese Dietary Reference Intakes (DRIs).

**Results** The average energy intake was in the range of those of people with moderate and heavy physical labor (2700- 3200 kcal). Among the obtained 17 nutrients, the intakes of Calcium, Vit A, Vit C, Selenium were below the recommended daily intakes (RDI), while the intake of sodium exceeded the RDI. Oil and salt intakes were excessive. Energy supplied by fat and protein exceeded the recommended proportion of the total kilocalories by 20%-30% and 12%-14% respectively, while the ratio supplied by carbohydrates was less than the recommended.

**Conclusions** The dietary status of the expeditioners showed the features of high fat, high protein, low carbohydrates, excessive intakes of oil and dietary sodium, and insufficient intakes of Calcium, Vit A, Vit C and Selenium. It should be adjusted by balancing the proportions of the three major nutrients, reducing intakes of oil and dietary sodium, and increasing supplement of vitamins, Calcium and Selenium.

**Key words** Zhongshan Station, winter-over expeditioner, dietary survey, nutrition

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## The Physio-psychological Changes of the 29th Chinese Antarctica Inland Expeditioners at Dome-A Environment of Hypoxia and Extreme Cold

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**Background** Kunlun Station is located in Dome-A (80°25'01"S, 77°06'58"E) with an altitude of 4087m, air pressure of 558-584hPa (Jan-Apr) and an average temperature of -58.4°C. The effect of hypoxia and extreme cold may trigger or aggravate acute mountain sickness (AMS). The physio-psychological Changes were obtained to explore the adaption, compensation and injury patterns of human body in Dome-A environment.

**Methods** The subjects were 22 male inland expeditioners(35.2±8.6y). Blood samples were collected and analyzed, cardiovascular functions were examined by portable devices, mood states and AMS scores were evaluated via questionnaires from Shanghai on Oct, 2012, staying at Kunlun Station on Jan 5-23, 2013, returning Shanghai on Apr, 2013.

**Results** At Kunlun Station (1) the prevalence of AMS evaluated by Lake Louise Scoring System is 9-13 per 25 (2) cardiovascular function: SBP, DBP and HR increased while SpO<sub>2</sub> decreased; ECG changed; cardiac contractility and pump function reduced while peripheral vascular resistance increased (3) the immune-neural-endocrine network system: for the blood hormone level of hypothalamus-pituitary-thyroid axis, FT4 increased and TT4, FT3, TT3, TSH didnot change; the hormone level of hypothalamic-pituitary-gonadal axis(GnRH, FSH, LH, Testo), HPA axis (CRF, ACTH, cortisol), sympathetic-adrenal medulla system(NE, E, DA) didnot change; IgA, IgM increased and IgG, TNF- $\alpha$ , IFN- $\gamma$ , hsCRP didnot change; Grhelin increased, and GH, leptin, adiponectin, insulin, EPO, ANG $\square$ , BNP, ANP, ET-1, 5-HT didnot change (4) mood states: anxiety and stress peaked in the 10<sup>th</sup> day at Kunlun Station, the total mood disorder score peaked in the 16<sup>th</sup> day. After returning, most parameters recovered except a few: TSH and DA increased and TT4 and E decreased. TSH of 5 subjects exceeded the upper limit of clinical reference value.

**Conclusion** The physiology and psychology changed greatly at Kunlun station to compensate the effect of hypoxic and extreme cold environment on human body. A few parameters didnot recover after returning, which implies the corresponding dysfunction. The results provide data for prevention and medical treatment.

**Key words** Dome-A, hypoxia, physio-psychology, expeditioners

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## S29: BIOPHYSICAL LINKAGES MESOSCALE PROCESSES AND LARGE-SCALE COUPLING OF ANTARCTIC CONTINENT SHELF AND SLOPE WATERS

### Bipolar snow UV albedo research in Sodankylä and Marambio

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#### Bipolar snow UV albedo research in Sodankylä and Marambio

Our bipolar snow ultraviolet (UV) albedo research started within the International Polar Year (IPY) 2007-2008, cluster-project "Ozone layer and UV radiation in a changing climate evaluated during IPY" (ORACLE-O3). In 2007, the continuous Sodankylä snow UV albedo measurements were installed in Sodankylä, in the operational albedo field of the Finnish Meteorological Institute Arctic Research Center (FMI-ARC).

These Sodankylä data were soon compared with the German Antarctic Neumayer Station UV albedo data (Meinander et al. 2009). We found an up to 10 % decrease in albedo as a function of time within a day, ranging from 0.77 to 0.67 in the Arctic, and from 0.96 to 0.86 in the Antarctic. Physical explanations to asymmetry were: high relative humidity and low surface temperature during the previous night, favorable to frost and higher albedo on the next morning; new snow on the previous night; snow melting during day time and refreezing during night. A more comprehensive analysis of Sodankylä data is in Meinander et al. (2008). In the Arctic Ocean ASCOS-expedition (Finnish contribution to the Arctic Summer Cloud Ocean Study), we measured  $A = 0.91-0.92$  for UV and PAR at 87 deg N (Paatero et al. 2009).

The black carbon (BC) has been estimated to be the second most important human emission after carbon dioxide, in terms of its climate forcing in the present-day atmosphere. The effect on reflectance of BC deposited on snow surface is the bigger the smaller the wavelength, i.e. the albedo effect of BC is the biggest at UV (e.g., Fig. 10 in Meinander et al. 2013). In Sodankylä, albedo may be affected by high concentrations of carbon due to air masses originating from the Kola Peninsula, Russia, where mining and refining industries are located (Fig. 9 in Meinander et al. 2013).

In the beginning of 2013, new continuous snow UV albedo measurements were installed in Marambio. In our presentation, we will show the first Marambio UV albedo results, and compare the Arctic and Antarctic snow UV albedo.

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## Bipolar AOD research activities in Marambio, Antarctic and Sodankylä, Finland

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Finnish Meteorological Institute (FMI) started bipolar aerosol optical depth (AOD) measurements in summer 2004 in Sodankylä, Finland and 2005 in Argentinian Antarctic Marambio station. Instrument type is Precision Filter Radiometer (PFR) attached on Kipp&Zonen 2AP-GD suntracker. In 2013, we extended the measurements in Sodankylä with an AERONET Cimel sunphotometer running in cloud mode to get the cloud optical depth in addition to its basic AOD and aerosol inversion products.

The main focus of the measurements is to get a picture of the bipolar difference of the mean level of the AOD as well as its seasonal and diurnal variation. Total average of AOD at 500 nm observed in Marambio is 0.04 whereas that in Sodankylä is 0.08. No systematic seasonal variation is seen in Marambio whereas in Sodankylä the AOD has its maximum in spring and late summer, when the long transported aerosol particles mostly originating from eastern Europe and Russia are prevailing (Aaltonen et al., 2012). These spring and summer maxima are enhanced by aerosol plumes arisen from Russian wildfires. In Marambio, the diurnal variation of the AOD is strongly depending on the local meteorological conditions, wind speed, dust from permafrost snowless surface and sea salt abundant at this coastal station.

Measuring at polar conditions, especially in Marambio, is demanding due to the extremely low AODs (as low as 0.01 at 500nm), near the detection limit of the instrument, making the instrument stability and quality control crucial. However, intercomparison campaigns carried out within POLAR-AOD network in Ny-Ålesund, Spitzbergen and Izaña, Tenerife, have shown that our instruments are in good agreement with other sunphotometer used at polar areas (Mazzola et al., 2012).

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## **Bipolar Finnish research activities in Marambio and Sodankylä since the first Marambio ozone-soundings in 1988**

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<sup>1</sup> Finnish Meteorological Institute FMI, Helsinki, <sup>2</sup> Arctic Research Center of FMI, Sodankylä

The bipolar research activities of the Finnish Meteorological Institute (FMI) started in 1988, when the first ozonesonde observations in the Argentinian Antarctic station of Marambio were carried out in November 1988 as Argentinian-Finnish co-operation. A few months earlier, March 1988, the FMI Arctic ozone sonde program was already started at Sodankylä, Northern Finland. The Marambio station soundings have covered all seasons with an emphasis on the ozone depletion season. We have observed severe ozone depletion during each spring since the start of regular ozonesonde observations. Currently Marambio station is participating in an ozonesonde data quality assessment activity. The aim of this activity is to establish an homogenized ozonesonde data set, taking into account changes in instrumentation and operational practices that have occurred during the more than 20 years of ozonesonde measurements at Marambio. Long term observations of ozone profiles do not yet suggest signatures of ozone recovery in the lower stratosphere. Ozone soundings are used together with chemistry-transport model simulations of the stratosphere in order to study the variability and trends of ozone in the polar regions. Marambio and Sodankylä ozone sounding measurements have also been extensively used for satellite validation, in particular for Envisat/GOMOS (2002 - 2012) and EOS Aura/OMI (2004 onwards).

FMI has experience of high-quality UV measurements in harsh environmental conditions in high northern latitudes since 1990. This has played an important role in establishing the quality control and quality assurance of the NILU-UV Antarctic network, established in 1999. Using a traveling reference instrument, the selected irradiance scale is transferred from the Arctic stations to Antarctic stations, so that measurements made at the Arctic and Antarctic are comparable with each other.

Since 2005, FMI has measured aerosol optical depth (AOD) in Antarctic Marambio station with Precision Filter Radiometer (PFR). Same instrument type has been used since 2004 in Arctic Sodankylä, where the measurements were extended with AERONET Cimel in 2013. Extremely low AODs (down to 0.015 at 500nm) at Marambio are near the detection limit of the instrument which makes the quality control crucial. Pb-210 activity concentration is measured both in Arctic and Antarctic by filter sampling and later analyzed in Finland. Antarctic measurements also include a dose rate meter.

In the beginning of 2013, new measurements were installed in Marambio to measure the amount, chemical contents and optical properties of aerosols, and the atmospheric concentrations of carbon dioxide and methane, as well as incoming solar radiation and reflected UV radiation. The same methods had been applied in Pallas-Sodankylä.

In our presentation we will show our bipolar results and give examples on our understanding of the similarities and differences of the Arctic and the Antarctic.

## A generalized bioenergetic model for pinnipeds: a toolkit for testing hypotheses about impacts of environmental change on top predators

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Pupping, molting and foraging are key components of the delicate balance between energy influx and efflux in individual mammals. Changes in timing of these life history events can impact population health by causing temporal mismatches between predator behavior and prey abundance, thus decreasing foraging success and increasing both baseline and reproductive costs in predators. Bioenergetic modeling approaches have been used to estimate the gross energy requirements of several marine mammal species; however, models are rarely used to address the sensitivity of these energetic demands to changing environmental conditions. Here, we present a standardized bioenergetics model that estimates baseline energy requirements as a function of age category, sex and reproductive state for both Arctic and Antarctic seals (family *Phocidae*). Input parameters were taken from the literature and include both physiological parameters as well as population-wide ranges for the typical duration and phenology of seasonal life history events. We then used the model to predict changes in energy requirements resulting from simulated changes in breeding and molt timing relative to varying environmental conditions.

Our bioenergetic model provides a theoretical construct into which measurements for a variety of species can be incorporated. As expected, it replicated the large fluctuations in total energetic requirements known to result from seasonal life history events such as reproduction and molt. Additionally, the model allowed us to test sensitivity of energy budgets to environmental perturbations. In the future, the comparative nature of our predictive model will allow us to determine which parameters are species-specific and which are environmental- or region-specific. Further, the model can identify critical times of the year when species are particularly vulnerable, which can then inform management decisions in polar regions.

## **Biogeochemical modifications of water masses on the Ross Sea shelf**

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The shelf systems of Antarctica play important roles in the modification of major water masses, primarily in the formation of Antarctic Bottom Water. One such system is the Ross Sea, which lies on a biologically productive shelf where water mass modification is seasonal and tied to extensive polynyas. Though the hydrography of the Ross Sea has been well researched, as it is key to global ocean overturning circulation, the biogeochemical modifications of its water masses have not been carefully studied. It is important to understand the biogeochemical fate of these water masses due to the substantial impacts of changing climate on polar shelf ecosystems. Some of these impacts, such as freshening of shelf waters due to increased precipitation and ice melt, have already been observed in the Ross Sea.

In this study, we use data obtained from oceanographic expeditions in the Ross Sea (NBP 1302) and Southern Ocean (CLIVAR S4P). The biogeochemical components of interest from these data include dissolved oxygen, carbon, and nutrients, introduced into the system via their fluxes associated with the biological pump (the main force behind sequestration of carbon from the atmosphere to the deep ocean). Using these data paired with hydrological data, we investigate and quantify the transformations of biogeochemical components of the water masses found in the Ross Sea and determine whether these modifications are seen in Antarctic Bottom Water formation at the continental shelf break.

## Seaglider observations of iceberg-induced biological productivity in the northwest Weddell Sea

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During the GENTOO project, carried out in the northwestern Weddell Sea in early 2012, a large iceberg (C19C; 39 km x 22 km in area) was advected by the Antarctic Slope Current along the continental slope through a region being monitored by two Seagliders. The high spatial and temporal resolution of the data from the two gliders reveal a pronounced effect of the iceberg on physical, chemical and biological ocean properties. Increased oxygen concentrations of  $>15\mu\text{mol/kg}$  than background levels indicate that biological production occurred before the Seaglider sampled the water. This response, 17 days after the iceberg had passed through, was confined to a small portion of water ( $<14\text{ km}^2$ ) in the direct vicinity of the iceberg track, and occurred at around 15 metres depth. These findings suggest that icebergs can have a significant local impact on Antarctic continental shelf productivity rates through micronutrient deposition, which may not always be apparent through satellite ocean colour observations.

## **Glider observations of subsurface Antarctic circumpolar current water along the West Antarctic Peninsula**

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Winter temperatures in the western Antarctic Peninsula (WAP) region are among the fastest warming on Earth however, understanding the heat sources driving the rise in temperatures remains an open research question. Recent observations from Slocum Webb autonomous underwater vehicles, with unparalleled sampling resolution in this area, are used to quantify the distribution and heat content of eddies located on the continental shelf. The gliders reveal that warm Upper Circumpolar Deep Water intrudes onto the shelf more often than can be resolved by traditional shipboard sampling. The sizes and frequency of the warm water intrusions are consistent with predictions based on mooring data and regional models. These high-resolution observations may fill the gap in our understanding of the heat budget of this important region.

## Thermal responses of polar soil microfungal enzyme activity

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Soil microfungi were isolated from Arctic (Hornsund, Svalbard) and Antarctic (King Geoege Island, South Shetland Islands) locations during the boreal summer in August 2010 and the austral summer in February 2007, respectively. Antarctic soil samples were collected from a penguin rookery, ornithogenic, pristine and human-impacted soils, and Arctic samples were collected from vegetated, ornithogenic, pristine and animal-impacted sites. From these soils we (i) describe the diversity of soil microfungi based on molecular approaches; (ii) classify them according their thermal characteristics; (iii) screen for extracellular amylase and cellulase production; and (iv) assess the effect of temperature change on enzyme production. Soil samples were cultured using the Warcup soil plating technique and incubated at 4°C and 25°C to permit thermal classification of the isolates obtained. All psychrophilic, psychrotolerant and mesophilic isolates were then screened at culture temperatures of 4°C or 25°C in order to detect the presence of extracellular hydrolase enzyme activity. Relative enzyme activity (RA) provides a simple measure of the strength of enzyme activity. The three best enzyme producing isolates for each enzyme from each incubating temperature (4°C and 25°C) were then selected and screened in culture at five different temperatures - 4°C, 10°C, 15°C, 20°C and 25°C. Cultures were run for 10 days and RAs were calculated. In total, 74 isolates were screened for enzyme activities from the Antarctic, with 3 isolates of *Geomyces* sp., a member from Onygenales and two unidentified species had significant activity for amylase while two isolates of *Pseudeurotium* sp., a *Geomyces* sp., a *Glomerella* sp., and 2 unidentified isolates had the best activity for cellulase. Amongst these, Onygenales had an optimum temperature of 15°C, an unidentified isolate was optimal at 20°C and the remainder showed highest activity at 25°C. Seventeen isolates from the Arctic were screened for both enzyme activities, but only one isolate showed significant activity, in this case for both amylase and cellulase.

## Hot shapes in cold places: Plant heating in the Arctic and Subantarctic

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Adaptations to absorb or retain heat energy within floral structures have evolved in many cold-climate environments. Floral density, shape and size are all important factors influencing heat retention in regions of the Arctic and Subantarctic. Heating of the flower is thought to be of benefit in environments where the climate is consistently cool, or where the angle of the sun remains low throughout the growing season. Maximising heating in these circumstances can significantly add to the number of growing degree days experienced by the flower, and can contribute to successful reproduction.

Although flower colour is generally assumed to play a less important role in insect attraction in high latitude regions, the colours present can play a vital part in heating the flower and, when combined with shape and size, can play a significant role in warming the flower thus enabling reproductive processes to occur.

The degree of warming achieved in selected flowering species in the Subantarctic and Arctic were measured using thermal imaging and thermal probe techniques during the respective austral and boreal summers of 2010 and 2011. Simultaneously, relevant environmental data were collected. Megaherb species, with giant, herbaceous growth forms, including *Pleurophyllum speciosum* (Asteraceae) and *Stilbocarpa polaris* (Apiaceae) were sampled on Campbell Island (52°S) as were common species *Papaver dahlianum* (Papaveraceae) and *Saxifraga oppositifolia* (Saxifragaceae) on the High Arctic archipelago of Svalbard.

Our data demonstrate that in arctic and subantarctic regions, solar radiation is the influential factor in floral and leaf heating, and the efficiency and intensity of heating that occurs after brief moments of sunshine is vital to successful reproduction. The giant rosette growth form with deeply coloured, densely packed flowers, typical of the New Zealand Subantarctic, provides a thermal benefit which may be beneficial to reproductive output. In the High Arctic, floral shape seems to be of similar significance. It is concluded that through convergent evolution of unique floral adaptations, characteristic cold temperature effects on plant reproduction in polar regions can be mitigated.

## The Third Pole Environment (TPE) under global changes

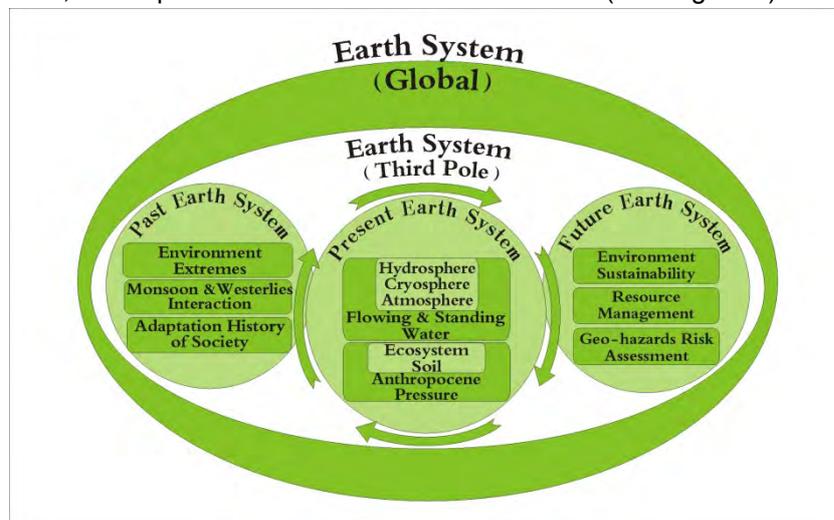
YAO T<sup>1</sup>, Thompson L<sup>2</sup>, Mosbrugger V<sup>3</sup>, Liu X<sup>1</sup>, Zhang F<sup>1</sup>, Yang X<sup>1</sup>, Joswiak D<sup>1</sup>, Wang W<sup>1</sup>, Liu Z<sup>1</sup>, Ping F<sup>1</sup>

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Like the Arctic and Antarctica, the Third Pole is one of the most sensitive areas responding to global climate change due to its high altitude and the presence of permafrost and glaciers. The unique interactions among the atmosphere, cryosphere, hydrosphere, biosphere and lithosphere on the Third Pole significantly influence social and economic development of China, India, Nepal, Tajikistan, Pakistan, Afghanistan and Bhutan.

The Third Pole Environment program endorsed by the UNESCO, SCOPE, and UNEP focuses on six key scientific questions: (1) Environmental and ecological changes having occurred on different time scales in the past, and driving mechanisms; (2) Characteristics of water and energy cycles, their main components, and relationship to the Indian monsoon and westerlies; (3) Responses of ecosystems changes to global warming, especially at high elevations; (4) The glacial status of the Third Pole, and the response of glacial retreat and mass balance changes to the water and energy cycle and its components, in addition to their environmental impacts; (5) The impact of anthropogenic activities; and (6) the more appropriate way to adapt to global change and more efficient way to sustain future environment sustainability.

TPE (<http://www.tpe.ac.cn/>) pays special attention to the earth system of the past, present and future, in which multi-phase water transformation at present is of high significance on the Third Pole, in comparison with the Arctic and Antarctica (See Figure 1).



## Observations of dissolved oxygen dynamics during a phytoplankton bloom in the Ross Sea polynya

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The Ross Sea polynya is one of the most productive regions in the Southern Ocean; however high spatial and temporal variability of both physical and biological processes and limited access as the polynya opens prevent the use of conventional oceanographic methods to precisely measure primary productivity early in the season. High-resolution observations from two autonomous gliders provide new insights into the timing of a bloom observed in the southern Ross Sea polynya in December 2010. Changes in chlorophyll *a* and dissolved oxygen concentrations are used to identify the vertical and temporal variability of the bloom. The timing of the bloom is shown to be strongly tied to wind speeds; strong winds delayed the onset of the bloom and its demise was accelerated through wind-induced mixing. Using a ratio of apparent oxygen utilisation to particulate organic carbon (AOU/C), net primary production is estimated over the duration of the bloom. Estimates of production determined from changes in dissolved oxygen suggest a sensitive balance between net community autotrophy and heterotrophy. Both gliders observing spatially distinct regions during the same time period found net community production rates of  $-0.670$  and  $0.362 \text{ g m}^{-2} \text{ d}^{-1}$  of carbon. The challenge of obtaining accurate estimates highlights the need for increased observational efforts, particularly focusing on sub-surface processes, which are not resolved using surface or remote observations, and *in situ* sampling to determine Redfield ratios and production rates. Without such knowledge, it is not possible to correctly determine the net balance of the Ross Sea polynya during the growing season and quantify the shelf's importance in carbon export.

## The role of large amplitude internal waves on benthic-pelagic processes of the Weddell Sea shelf

**Richter C**

Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research

Current and temperature records sampled at 1-minute resolution reveal powerful internal waves on the Weddell Sea continental shelf. Packets of up to six solitary waves with leading soliton amplitudes  $>200$  m and vertical velocities  $> 0.15$  m/s were observed at tidal frequencies, causing large vertical displacements of sound scattering layers. Breaking of large amplitude internal waves in the shallower portions of the eastern Antarctic Peninsula and eastern Weddell Sea shelf may be an important up to now overlooked source of mixing with important repercussions on pelagic production and coupling with the filter-feeding benthos, explaining recent observations of rapid sponge growth.

**A decade of efforts on measuring the air-sea interaction processes at the Brazil-Malvinas Confluence Region: why the region is a key region for understanding the Antarctica-South America tele-connections?**

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National Institute for Space Research - INPE

The Brazil-Malvinas Confluence (BMC) region is considered one of the most dynamical regions of the World's Ocean and pairs with the Agulhas Current retroflexion region in the South Atlantic for its intense sea surface temperature (SST) gradients and intermittent eddy formation. The opposing warm Brazil (BC) and cold Malvinas (MC) currents meet at the BMC region which is also at the path of frequent transient atmospheric systems like cold fronts and atmospheric cyclones reaching South America. Observations of both the Oceanic Boundary Layer (OBL) and the Marine Atmospheric Boundary Layer (MABL) were taken by Brazil from 2004 to the present at the BMC region, usually during October and/or November onboard the Brazilian Antarctic Program (PROANTAR) research vessels. Our data reveal heat fluxes ranging from over  $200 \text{ W.m}^{-2}$  down to  $0 \text{ W.m}^{-2}$  or even negative. The higher (lower) heat fluxes are associated with relatively strong (weak) near-surface winds. On the absence of large-scale atmospheric synoptic systems, the MABL is modulated by the local SST gradients being stable (unstable) over cold (warm) waters. The frequent passage of cold fronts imprint changes in the MABL with distinct responses for situations of cold (pre-frontal) and warm (post-frontal) advection.  $\text{CO}_2$  fluxes measured directly at the study region indicate that they are not only modulated by the SST gradients and the chlorophyll concentration, but also by the front passages. Our data indicate that the study region in the ocean is a key region for modulating the MABL and modifying the original (sub polar to polar) cold front's characteristics. Once modified, the cold fronts usually reach South America bringing a new signature carried from the BMC region.

## Circulation scheme and current oscillations in the southern Weddell Sea

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The coldest and most oxygen-rich bottom waters in the Southern Ocean have their origin in the Weddell Sea. Cold, dense shelf waters interact with off-shelf water masses at the continental shelf break and contribute to the formation of Antarctic Bottom Water, which feeds the global thermohaline circulation.

Even though a number of instrumented moorings have been deployed in the southern Weddell Sea from 1968 to present, little data were available for the Filchner depression, where the current scheme for the circulation had to be derived from hydrographic observations. Based on recent in situ measurements - including data from newly recovered moorings in the depression - and numerical modeling we propose a new circulation scheme with outflow along the eastern flank of the Filchner depression.

Data from the moored instruments at the shelf break show anomalously large diurnal tidal currents. It has been suggested that continental shelf waves (CSWs) are responsible for this amplification. Continental shelf waves are coastally trapped waves on a continental shelf, which enhance mixing and facilitate the exchange of different water masses across the shelf break. Here we present time series of tidal currents and ellipses, focusing on their seasonality. Furthermore, we show results from numerical models which indicate a seasonal presence of resonant diurnal shelf waves on the continental slope.

## **A panorama of sea ice-polynya-ice shelf- ocean system in Prydz Bay**

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<sup>1</sup> Ocean University of China, <sup>2</sup> Chinese Marine Environmental Forecasting Center

Temperature and salinity data obtained in the last decade, as well as remote sensing sea ice concentration and reanalysis meteorological data are used to analyze the impacts of sea ice, polynya and ice shelf on water masses in Prydz Bay.

In melting season, sea ice in the region of Prydz Bay not only retreats southward from the out edge in deep basin, but also decreases in the near shore area of the bay. Two ice tongues are left in Fram Bank and Four Ladies Bank, between which exists a low concentration ice region. This region is also the canyon where upwelling warm deep water enter the bay, which might contribute heat to the polynya at south flank of the Four Ladies Bank. The surface water in this sensible heat polynya is heated by solar radiation in early summer, and then flows south with the cyclonic gyre in the bay, resulting the extremely warm surface water observed in the region north to the east end of Amery Ice Shelf (AIS) front. The Mackenzie Polynya near the west end of AIS front is a latent heat polynya, where intense cooling and brine release modify the shelf water in the bay. This location is also the major outflow area of sea water in the cavity under AIS, where both ice shelf water and super-cooled water were observed. Above understandings preliminarily established a panorama of sea ice-polynya-ice shelf- ocean system in Prydz Bay.

## Links between Weddell Gyre variability and surface winds: process models and surface drifter data

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The circulation of the northwestern Weddell Sea influences the ventilation of deep water into the global overturning circulation as well as the injection of nutrient-rich shelf waters into the Scotia Sea. The physical processes that govern variability in these different exchange processes are explored using both an idealized model of the gyre circulation and observations from a pair of drifter deployments carried out in 2007 and 2012.

Forty surface drifters were released along Joinville Ridge in 2007 and 2012 as part of the ADELIE and GENTOO cruises respectively; the trajectories describe the Lagrangian transport pathways between the eastern Antarctic Peninsula and sites of elevated chlorophyll in the Scotia Sea. The export of the drifters from the Weddell Sea occurs more rapidly in 2012, suggesting that the deployments captured two different modes of the gyre circulation. This is confirmed through the advection of many virtual surface drifters between 2003 and 2013 using the remotely-sensed OSCAR surface velocity product. Variations in the circulation are correlated with both the strength of the Southern Annular Mode (SAM) and remotely-sensed chlorophyll levels in the South Scotia Sea, suggesting a link between wind forcing distributions, the northwestern Weddell Sea surface circulation and broad patterns of biological productivity.

We also develop a simple two layer model of a bowl-shaped, circular basin to explore the importance of mesoscale variability on gyre properties. Spatial variations in the strength of the cyclonic wind stress generate lateral variations in the depth of the layer interface. Adjustment of the layer interface may occur through Rossby wave propagation, however, recent observations indicate that this time scale is at least an order of magnitude too slow. Through the introduction of a mesoscale eddy diffusivity, baroclinic instability may extract available potential energy stored in the interface tilt. This process produces a more rapid response of the isopycnals to temporal changes in the wind strength, and can produce fluctuations in the layer interface depth that reach 50 m near the boundary. This result is consistent with seasonal fluctuations in isotherms recorded in moored instruments south of the Orkney Plateau.

## What controls algal production in the coastal zone of the WAP?

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The Western Antarctic Peninsula (WAP) is the fastest warming oceanic region on earth, with a recorded increase in winter temperature of 6° C since 1950. Coinciding with the warming of shelf water the amount of sea ice that is formed over winter shows a general declining trend. In recent studies, it was found that the decrease in sea ice has consequences for the stability of the water column, with a deepening of the wind mixed layer far into summer. The consequences for algal productivity were subject of a two-year study in Ryder Bay, an extension of Marguerite Bay (67° S, 68° W).

Ryder Bay is a highly productive area, with large fluctuations in biomass over the course of the season. To determine what controls these fluctuations, adaptation to prevailing light conditions by microalgae was studied based on algal pigment signatures (HPLC-analysis) and fluorescence characteristics (PAM-kinetics). We will present data on photoacclimation of the resident algal community in relation to the water column stability. Preliminary data suggest that algae were well adapted to prevailing light conditions. Biomass accumulation in Ryder Bay appeared to be not only controlled by in-situ production but also by input from sea ice and associated algal communities from outer Marguerite Bay. We predict that with on-going climate change, algal production in Ryder Bay will decline because of the decline in sea-ice cover along the WAP.

## Poles apart: Inter-hemispheric contrasts in lacustrine diatom community structure and diversity

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In the past decade, the field of microbial biogeography has witnessed a paradigm shift due to the culminating evidence that microorganisms can be dispersal limited and are therefore expected to display biogeographic patterns similar to those observed in plants and animals. Despite this, surprisingly little is known about intercontinental patterns in the macroecology and biogeography of microbes. Here we assessed whether differences in the climate and tectonic history and the contemporary connectivity and distribution of landmasses between the Arctic and Antarctica impacted on the composition and diversity of lacustrine diatom communities. To achieve this we developed the first taxonomic consistent bipolar diatom dataset. We showed that patterns of biodiversity and endemism in the diatom floras of Arctic and Antarctic lakes with comparable limnological properties are strongly divergent. The Arctic flora is dominated by globally successful genera and characterized by a relatively low incidence of endemism. By contrast, Antarctic communities are impoverished and imbalanced relative to their Arctic counterparts and possess a high level of endemism, the absence of key functional groups such as planktonic taxa, and an overrepresentation of terrestrial lineages. Our findings point to high rates of local extinction among lacustrine taxa during ice ages in Antarctica, in combination with radiations through allopatric speciation and the selective survival of terrestrial lineages in glacial refugia on the continent. Our findings also underscore the pressing need for more stringent measures to prevent the introduction and spread of non-native microbes into Antarctic terrestrial environments.

## S30: OBSERVING ANTARCTICA AND THE SOUTHERN OCEAN

### **Ocean2ice: Processes and variability of ocean heat transport toward ice shelves and the resulting meltwater pathways in the Amundsen Sea Embayment**

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Here we present the first results of the Ocean2ice field campaign in the Amundsen Sea in January-March 2014. The Amundsen Sea hosts some of the most rapidly retreating ice shelves in Antarctica, such as Pine Island Glacier. This field campaign is designed to understand the processes by which ocean heat is delivered from the open ocean to the continental shelf, and by which that heat is then modified across the continental shelf en route for the Amundsen Sea ice shelves. The processes to be studied include the Antarctic Slope Undercurrent, coastally trapped waves, wind-driven upwelling, bottom Ekman layers, diapycnal mixing and topographic steering. The influence of mixing of inflowing warm Circumpolar Deep Water with glacial meltwater, and of atmosphere-ocean-ice interaction, are of particular interest.

We will present the hydrographic sections (temperature, salinity, dissolved oxygen, current velocity and microstructure) at the Amundsen Sea shelf break and along and across troughs towards the ice shelves from a variety of ship-based and autonomous platforms. Initial calculations of quasi-heat fluxes will be discussed, as well as the modifications of water masses across the slope and shelf using their temperature, salinity, and dissolved oxygen characteristics. We will compare the observations with historical hydrographic sections from the region since 1994, and with our understanding of the circulation from numerical modelling.

Hydrographic properties (dissolved oxygen, salinity and temperature) are used along with Gade lines and the melting/freezing line to identify meltwater in the Amundsen Sea, with the aim to understand meltwater pathways. A simple mixed layer model (PWP) is adapted to understand the effect of biogeochemical processes on the dissolved oxygen in these different locations. The results of this model help to locate the areas on the continental shelf where the use of dissolved oxygen characteristics to identify meltwater is reliable.

## Using end-to-end ecosystem models to design marine observing systems to deliver robust advice on ecosystem change

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Statements on structure, function, dynamics and change in ecosystems are derived from the synthesis of field data and models. The recent imperative to better document change and the drivers of change in order to better manage marine ecosystems now and into the future has exposed a number of difficulties with existing datasets for assessing ecosystem change. Many of these difficulties relate to a mismatch between sampling (distribution, frequency and physical/biological coverage) and the spatial and temporal requirements for making robust conclusions of change. A particular difficulty is with the different spatial and temporal scales of the biological cycles, processes and drivers of different trophic levels, along with the different scales of feedbacks that might arise within foodwebs. A number of initiatives to observe marine ecosystems (Southern Ocean Observing System, Global Ocean Observing System and the like) and to estimate change from available data (Southern Ocean Sentinel, IndiSeas and the like) are grappling with how to design ecosystem observing systems in order to estimate change. This talk will discuss developments in establishing ecosystem Essential Ocean Variables (eEOVs) as a standardised set of ecosystem measurements. In particular, this presentation will show how end-to-end ecosystem models can be used to help design field programs and to assess the efficacy and cost-effectiveness of potential eEOVs.

## Geodetic observations in and around Syowa Station

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Many geodetic observations have been conducted in Syowa Station. Space geodetic observations including VLBI, GNSS and DORIS have been continued for more than fifteen years there (Shibuya et al. 2003). Observations of temporal gravity variation have also been conducted using three SGs since 1993 as well as AG measurements using absolute gravimeter FG-5 at 5 times at IAGBN(A) site in Gravity Hut (Higashi et al. 2013). In addition, ocean tide observation at Nisinoura Cove has been made since 1966 using bottom pressure gauge (Odamaki et al. 1991).

In addition to the continuous observations in the station, we conducted campaign GNSS measurements on several outcrops (Ozono et al. 2006), sea ice and ice stream as well as absolute and relative gravity measurements on outcrops (Kazama et al. 2013, Doi et al. 2013) around Syowa Station.

We will show recent topics on observations in Syowa Station and campaign observations in the field around Syowa Station in the presentation.

## Interannual changes in the Bransfield Strait water masses

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The Bransfield Strait is an important region of the Southern Ocean given its complex ocean dynamics and biological importance. It is located at the tip of the western Antarctic Peninsula – a region that is suffering great warming in the last decades. Here, we show the changes in the hydrographic properties (potential temperature, salinity and dissolved oxygen) of the Bransfield Strait water masses. We used data from two summer cruises (2004 and 2013) from the Brazilian High Latitudes Oceanographic Group (GOAL; [www.goal.furg.br](http://www.goal.furg.br)) database (2003-2005, 2008-2011, and 2013) sampled in a high-resolution grid. The water column is distinct in upper (< 800 m) and deep (> 800 m) layers.

In summary, during 2013 the water masses had higher temperatures than 2004 in both layers and basins (Central and East Basins). The upper layer temperature in both basins were greater than  $\sim 0.35^{\circ}\text{C}$ , while in deep layer the East Basin showed warmer temperatures ( $\sim 0.2^{\circ}\text{C}$ ) than the central one ( $\sim 0.01^{\circ}\text{C}$ ). The year of 2013 showed higher values of salinity than 2004. The differences in this field were  $\sim 0.039$  in upper layer and  $0.03$  for deep layer of East Basin and  $0.006$  for deep layer of the Central Basin. The waters of East Basin were more ventilated in 2013 than 2004 by  $\sim 0.15$  mL/L. On the other hand, in the Central Basin, the upper layer of 2013 showed lower values of dissolved oxygen than 2004 (by  $\sim 0.032$  mL/L), while in the deep layer, the year of 2013 was more ventilated than 2004 by  $\sim 0.4$  mL/L.

Despite these discrepancies between 2013-2004, long-term observations spanning from 1960 and 2013 showed freshening and cooling trends of the deep waters in the Central Basin, while in the East Basin warming and freshening trend were observed for the deep layer.

Since the Bransfield Strait is influenced by water masses coming from both the Weddell and Bellingshausen Seas, those changes will be further investigated through the analysis of the source water masses contribution to the mixture of the water column in the Bransfield Strait.

## Controlled Meteorological Balloon experiments in Queen Maud Land, Antarctica

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The Controlled Meteorological (CMET) balloons are unique in that their altitude can be changed at any time during flight by operators on the ground. They are controlled via the Iridium network and use GPS for positioning. They have been operated at altitudes from sea-level to six kilometers and have flown for periods as long as five days. Campaigns have been carried out from the Amazon via Mexico City to polar regions. CMET balloons can perform repeated soundings in order to probe evolving thermal and chemical structure, measure wind shear, and track atmospheric layers. Typical ascent/descent rate is 1 m/s and the data sampling rate is 10 sec.

The standard CMET balloon consists of zero-pressure balloon (~300-500 liters at sea level) which itself contains a much smaller (~100 liter) superpressure balloon. Transferring helium between the super pressure balloon and the zero-pressure balloon regulates the volume (and density) of the system, leading to controlled ascent and descent. The CMET design is ideally suited for long-duration flights because the helium released from the high pressure balloon is retained. The CMET measures standard meteorological parameters but can also be equipped with chemical sensors and camera. Due to the rarity of meteorological observations from the Antarctic, especially from inland and over the sea, CMET balloons have a great potential to provide strongly needed data for evaluation of numerical weather prediction and climate models.

Here, we present data from a CMET campaign carried out at the Finnish Aboa station in Antarctica (73° 03' S, 13° 25' W) in January 2013. The campaign was unique in that three CMET balloons were shipped to the station and launched by the local team. After the launch, they were controlled by scientists located in MA, USA and Norway. One balloon, Bravo, was particularly successful and cruised for more than 100 hours over the coastal slopes of Queen Maud Land and nearby sea ice, covering the Princess Martha Coast, the Luitpold Coast and the Caird Coast, with a total trajectory length of over 3000 km. It also passed nearby the UK Halley station. The altitude was generally kept at about 3000-3500 masl, but 8 controlled soundings down to 400-500 masl were carried out. The balloon data were compared with the Weather Research and Forecasting model (WRF) simulations using one domain with 2km horizontal resolution.

## Thermohaline variability of AAIW in the Atlantic sector of the Southern Ocean investigated using an Altimetry Gravest Empirical Mode

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The southeast Atlantic sector of the Southern Ocean connects the Atlantic with the Indian Ocean and the Antarctic Circumpolar Current, thereby acting as a major conduit within global ocean circulation. Thermohaline transports in this region are widely thought to have a critical influence on global climate. Yet magnitudes of the associated heat and salt content variations are poorly understood due to a lack of hydrographic observations and model limitations. An improved Gravest Empirical Mode (GEM) is set up for the Southern Ocean south of Africa using the updated store of hydrographic measurements obtained from CTD transects for the area, combined with the available Argo profiles sampled in the region. Satellite altimetry is combined with the GEM relationships to create an Altimetry GEM (AGEM), thereby generating 20 years of temperature and salinity fields. These thermohaline sections for the region of the ocean south of Africa are found to be proficient at reproducing observations, with associated RMS errors being two orders of magnitude smaller than those reported by other comparable Southern Ocean GEM studies. Confident in the accuracy of the AGEM produced fields, an examination of the temporal evolution of Antarctic Intermediate Water (AAIW) is undertaken. The fluctuation and trends in heat and salt content anomalies and budgets is presented for each Southern Ocean frontal zone, along with the examination of the change in position of the isopycnal limits and resultant water mass thickness. So as to better understand one of the factors that may be influencing some of the changes detected within AAIW, property alterations of eddies identified in the region from 1992 to 2010 are investigated. A general decrease in magnitude and frequency of cyclones, coupled with an increase in absolute dynamic topography (ADT) of anticyclones, designates elevated injection of warm, saline water into the area. The connection identified between eddy property variations and AAIW modification in the region of the ocean south of Africa indicates that the water mass experiences ventilation with the mixed layer at latitudes further north than previously thought to occur. Obtaining an improved image of the magnitudes and variability of AAIW thermohaline properties in the Atlantic sector of the Southern Ocean greatly improves our understanding of its role in the ocean-climate system.

## Changes of phytoplankton composition in the Indian Ocean Sector of Southern Ocean using long-term monitoring datasets

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Long-term changes in phytoplankton biomass and community composition are important in the ecosystem and biogeochemical cycle in the Southern Ocean. We aim to evaluate changes in phytoplankton assemblages in this region on a decadal scale. However, yearly continuous data are lacking, and long-term datasets often include seasonal variability.

First, we evaluated the seasonal changes in phytoplankton abundance/composition across latitudes in the Indian Ocean sector of the Southern Ocean via multi-ship observations along the 110°E meridian from 2011 to 2013. The chlorophyll a concentration was 0.3–0.5 mg m<sup>-3</sup> in the subantarctic zone (40–50°S) and 0.4–0.6 mg m<sup>-3</sup> in the polar frontal zone (50–60°S); pico-sized phytoplankton (< 10 μm), mainly haptophytes, were dominant in both zones. In the Antarctic divergence area (60–65°S), the chlorophyll a concentration was 0.6–0.8 mg m<sup>-3</sup>, and nano-sized phytoplankton (>10 μm), mainly diatoms, dominated. Chlorophyll a concentrations and phytoplankton community compositions were the same within a latitudinal zone at different times, except during a small but distinct spring bloom that occurred north of 45°S and south of 60°S. This small seasonal variation means that this part of the Southern Ocean is an ideal site to monitor the long-term effects of climate change.

Second, we analyze the long-term plankton dataset derived by Japanese Antarctic Research Expedition (JARE) program. JARE have been conducted plankton monitoring along 110°E meridian from 1985 to present. We found the increasing trends of chlorophyll a and the spreading of higher chl-a area with 3-7 year cycles. In addition, chlorophyll a was rapidly increased in 1998/1999, and the copepods decreasing dramatically in the same time. Recently westerly wind intensification has been reported. The strong westerly wind would be enhancement upwelling of iron from deep ocean. Furthermore, southern annular mode (SAM) are strongly affected to westerly wind, positive SAM index indicate strongly westerly wind in the Indian Ocean sector of the Southern Ocean. We found that the positive correlation between SAM index and chlorophyll a, and negative correlation between SAM and zooplankton biomass and in early summer. The long-term changes of plankton would be influenced by the strength of westerly wind in the Indian Sector of the Southern Ocean.

## Antarctic moss beds exhibit dynamic changes over a decade of observation

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Global climate change is causing widespread changes in ecosystems across the planet. In order to examine Antarctic ecosystem responses to climate change, long-term monitoring of Antarctic species abundance and biodiversity is required (IPCC 2007, ATME 2010, CEP XV 2012). Such monitoring of continental Antarctic flora can be difficult due to climatic extremes and logistics issues, however it is vital to establish plant growth trends along with associated meteorological and microclimate data, particularly given the slow vegetation growth rates on the continent (< 4 mm/y).

Some of the most well-developed and extensive continental Antarctic flora can be found in the Windmill Islands, East Antarctica. These communities have been the subject of a long-term vegetation monitoring program established in 2003, informing the only Australian Antarctic State of the Environment indicator for terrestrial vegetation (SOE 72: [http://data.aad.gov.au/aadc/soe/display\\_indicator.cfm?soe\\_id=72](http://data.aad.gov.au/aadc/soe/display_indicator.cfm?soe_id=72)). Sampling has occurred at 2 sites in the region, Antarctic Specially Protected Area 135 and Robinson Ridge, at a set of 25 cm x 25 cm permanent quadrat locations established along a water gradient, where a relatively small change in water availability has significant impacts on community composition and species abundance.

The sampling methods used have been designed to comply with the Antarctic Treaty System principle of minimal destructive sampling, due to the slow growth and regenerative capacity of continental Antarctic vegetation. Change in bryophyte percent cover over a period of 10 years was assessed using object based image analysis of very high resolution digital ground photography, a non-destructive method requiring considerably reduced time spent in the field than other species abundance measures.

Evidence of both rapid and reversible change, and longer lasting stress, has been observed over the past decade. Bryophytes exhibited a green to red colour change between 2003 and 2008, known to be an indicator of stress in these species, with a subsequent return to green between 2008 and 2013. A significant increase in moribund bryophytes was, however, found between 2008 and 2013, suggesting that some of the most exposed, stressed bryophytes were not able to recover even when conditions improved. Decreased water availability and increased wind speeds have been observed, potentially resulting in a drying trend for the region. Changes in the abundance and species composition of bryophytes in these extensive continental Antarctic communities are thus much more dynamic than previously thought.

## The Southern Ocean Animal-Borne sensor program of the Integrate Marine Observing System

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Longitudinal observations of the physical world provide the context for quantifying how the environment is changing and how these changes affect the underlying biota. The Integrated Marine Observing System (IMOS) has at its core, long-term monitoring of the seas around Australia and the Southern Ocean. IMOS animals (123 seals from 2010 to 2013) carrying oceanographic sensors have provided globally important information on (i) the movements and habitat usage of the animals, (ii) the physical ocean structure (62 000 CTD casts in East Antarctic since 2010), and (iii) inter-annual variation in both of these. Here we describe IMOS's contribution to bio-physical research and oceanographic monitoring in the Southern Ocean to illustrate how IMOS can be a model for a coordinated global animal borne observing program in SOOS. We demonstrate how animal-borne sensors in the Southern Ocean have vastly enhanced our capacity to measure and monitor longitudinally oceanographic sampling in one of the World's least understood ocean realms, have identified novel zones of bottom water formation, how marine mammals behaviour has change in response to shifts in ocean structure and how this may affect population viability.

## Towards and integrated sea ice information for the Southern Ocean for the International Science Community

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Information about sea ice plays a critically important role in many aspects of Antarctic science and operations. Reliable archives of historical data and easy access to current information support both scientific studies and ship operations.

In recent years the Antarctic Polar View programme has developed and provided access to a wide range of integrated near-real-time sea ice information services ([www.polarview.aq](http://www.polarview.aq)). This includes operational delivery of sea ice concentration information from passive microwave data, more detailed tactical information from high-resolution SAR satellite imagery and derived products such as ice charts, iceberg occurrence and sea ice motion. New developments currently being investigated aim to bring sea ice thickness, pressure and forecasting information to the Antarctic.

NASA has funded the two other complimentary projects. RapidIce aggregates historical imagery from over 15 sensors for specific areas of interest around the continent. Users can quickly see change at outlet glaciers and along ice shelves back to the initiation of the sensor. Also, the WorldView application that provides seamless access to MODIS continent wide. The time series will soon stretch back to the launch of the sensors.

These information products rely on delivery of data from a significant number of satellites, including the new European Sentinel series and the US MODIS and LANDSAT sensors and satellites. Access to these data is also greatly enhanced by open access data policies and interoperable data standards which allow easy distribution to a wide audience. This is all augmented with commercial imagery from DigitalGlobe, MDA and other vendors.

This poster will present the range of sea ice information data available and highlight examples of its uses. We will also focus on the integrated approach to data distribution and how users access information now and in the future.

## **The influence of marine scape morphology of West Antarctic Ice Sheet response to climate forcing**

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The primary controls on Antarctic Ice Sheet volume and extent include changes in water temperature, precipitation, atmospheric temperature and sea level. We evaluate the influence of a 5<sup>th</sup> factor, the depth of the shelf. Shelf depth and morphology affect ice sheet mass balance in the marine environment in three key ways because it controls 1) the flux of ice that can be exported to the marine environment, 2) the area of the ice sheet in contact with the ocean, and 3) the flux of warm water that can intrude onto the shelf. The latter two items are important because ocean temperature is the dominant control on heat exchange between the ocean and ice sheet at its marine termination. Preliminary modeling experiments have suggested that ice sheet retreat from the marine environment is most rapid on overdeepened and foredeepened shelves. Our ongoing experiments use geologically realistic configurations of the marine scape (i.e., water depth and morphology) to see how the WAIS responds to the same forcing. We hypothesize that the larger area of the WAIS in contact with warm water on an overdeepened and foredeepened continental shelf triggers a significant negative mass balance response.

## Long-term observing system for the oceanic regime of Filchner-Ronne Ice Shelf, Antarctica

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Long term observations of the flow of dense waters from their area of formation to the abyss of the World Ocean, and the return flow of warm waters, are central to climate research. For the Weddell Sea an important component of such a system entails monitoring the formation of High Salinity Shelf Water (HSSW) on the continental shelf north of Ronne Ice Front, the transformation to Ice Shelf Water (ISW) beneath the floating Filchner-Ronne ice shelf, and the flux of ISW overflowing the shelf break to the deep Weddell Sea. Equally important is the return flow of warm water toward the Filchner-Ronne Ice Shelf system.

We operate a number of monitoring stations in the southern Weddell Sea. The systems build upon techniques and methods developed over several decades and have a proven record of high data return. Here we present plans for extending, integrating and operating the existing long term observatories to increase our knowledge of the natural variability of the ocean-ice shelf system, and to allow early identification of possible changes of regional or global importance.

The S2 observatory at the Filchner sill was established in 1977 and continues to deliver the longest existing marine time series from Antarctica. The existing S2 observatory consists of a sub-surface mooring carrying sensors for current velocity, temperature, salinity and dissolved oxygen measurements.

Observations at the Filchner sill also show a seasonal inflow of relatively warm water that is able to reach Filchner Ice Front. New model results indicate that this flow of water might increase in the future and we have deployed a number of instrumented moorings in the Filchner Depression to estimate the heat flux towards the ice shelf.

In 1999 we established Site 5 on Ronne Ice Shelf using a hot-water drill to access the 402 m of water underlying the 763-m thick ice. Results from the multiyear time series show the sensitivity of the sub-ice shelf circulation to changes in conditions over the continental shelf and highlight the importance of monitoring the ice shelf cavity. We will reoccupy Site 5 in the 2014/15 to deploy a suite of observing systems for long time monitoring of the circulation below Ronne Ice Shelf. The systems will consist of sub-ice shelf oceanographic moorings instrumented with high quality sensors. They will transmit in real-time and are designed to operate for more than 10 years. In 2015/16 we will extend the observing network by deploying observatories on Filchner Ice Shelf.

The Filchner-Ronne Ice Shelf and S2 observatories will provide the first ever concurrent observations from the ice-shelf cavity where ISW is formed, and the sill where it starts its descent towards the deep Weddell Sea, and will provide a unique dataset allowing us to link processes and variability within the cavity directly to overflow properties and deep water formation.

## **Innovative Autonomous Underwater Vehicle (AUV) for the recording of main environmental parameters in polar conditions**

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The use of Autonomic Underwater Vehicles (AUV) continuously recording the basic environmental parameters in marine polar regions are extremely difficult. This study provides a summary and a description of the existing solutions for the AUV, their use, construction, actuators and transmitters. Based on the actual knowledge a new vehicle equipped with innovative solutions and components was designed. The underwater robot is dedicated to be working in harsh environmental conditions requiring resistance to high pressure, low temperatures and strong currents, which are typical for the polar regions.

The first stage of the design process consist of selection miniature sensors, vision systems to collect information about the environment. The next step was to develop a method for processing and storing data from the measurements. There has been elaborated a special communication and data transfer for this system. An important aspect of this design is a proprietary control system, which includes selecting an appropriate drive with the control program according to the external conditions. Another part of the research was the review of the existing navigation systems and subsequently implementation to the designed vehicle. Then, the power system with automatic charging was elaborated, which is possible to use natural energy sources. The last part was to design the shape of the mobile robot, taking into account the environmental conditions and the possibility of mechanical and electronic devices to be installed.

## Tidal gauge stations at Deception and Livingston Islands 2007-2014: records, analysis and georeference

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In order to establish an approximate value of the mean sea level in the South Shetland, in 2007 the first gauges in Livingston and Deception islands was installed. Due to the harsh conditions of the area, with sea ice for long periods of the year, pressure sensors were installed near the coast but deep enough to not be affected by ice.

Two tidal records of more than six years duration were obtained at Livingston and Deception islands since December 2007 to February 2014. DECMAR tide gauge station is located at Deception Island and LIVMAR tidal station at Livingston Island. Data were obtained using two moorings with a SAIV TD304 bottom pressure sensor at points near the coast. Additional data of temperature and salinity of seawater were obtained simultaneously with the tidal records. Harmonic analysis has been used to obtain the amplitudes and phase lags of the most energetic tidal constituents. The instruments were anchored near the coast, to minimize errors in the subsequent referencing to the benchmark. For tidal observations, a land benchmark was used as the primary reference point. These tidal gauge benchmarks (TGBM) were well-marked points located on an exposed rock, and linked to GPS benchmarks (GPSBM) near the gauges. The analysis of the time series has enabled to study the contribution due to tidal. Sea level have been correlated with meteorological and oceanographic variables.

By referencing the bottom pressure sensors to the benchmarks, it was possible to calculate MSL relative to a precise levelling network for the period analysed. The sensor reference levels were linked to the TGBM by linear fitting of the instantaneous measurements of the sea level observed by tide staff to the data obtained from the pressure sensors. In order to correlate the two measures, data from the meteorological station were used.

A more accurate mean sea level was obtained in the geodetic reference benchmarks. The orthometric heights may be calculated, from the ellipsoid height, obtained from the GPS measures, absolute gravity measures and geometric levelling differences.

## Monitoring temporal and spatial change in Antarctic terrestrial communities

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Antarctica has experienced major changes in temperature, wind speed and stratospheric ozone levels over the last 50 years. Whilst West Antarctica and the peninsula have shown rapid warming and consequent ecosystem change, East Antarctica appeared to be little impacted by climate warming, thus biological changes were predicted to be relatively slow. Detecting the biological effects of Antarctic climate change has been hindered by the paucity of long-term data sets, particularly for organisms that have been exposed to these changes throughout their lives. We have shown that radiocarbon signals preserved along shoots of the dominant Antarctic moss flora can be used to determine accurate growth rates over a period of several decades, allowing us to explore the influence of environmental variables on growth and providing a dramatic demonstration of the effects of the recent climate change. This work has revealed evidence of a drying trend in several of the extensive moss beds in the Windmill Islands region of East Antarctica. Free water is critical for moss growth and the length of the summer growing season is predominantly influenced by the length of time that water is available (a function of both snow bank inputs and the extent and severity of seasonal melt). Developing methodologies to monitor key environmental drivers such as water availability and moss health parameters as well as species composition across larger spatial scales is a key aim of our research. Long-term monitoring of vegetation communities along a moisture gradient at two sites in East Antarctica commenced in 2003 using three complementary sampling regimes; turf water content, digitally determined broad scale percent cover of vegetation and finer scale relative abundance of species, but these methodologies are labour intensive and limited to relatively small-scale plots. Recently we have also incorporated the use of unmanned aerial vehicles and high spatial resolution imaging spectroscopy to develop efficient methodologies to monitor Antarctic vegetation health and composition at a larger scale. These technologies could be invaluable in the development of an Antarctic terrestrial and near shore observing network.

## Correction of hydrographic data collected by southern elephant seals in the Bransfield Strait, Antarctica

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Oceanographic data collected by mini-CTDs (conductivity, temperature, depth) deployed on marine animals have recently been appointed as a viable alternative for widening the area and sampling period of conventional environmental data collection programs such as the Global Ocean Observing System (GOOS). Recent data collected by the MEOP-BR project in the Southern Ocean have demonstrated the potential of this technique for assessing near real time oceanographic conditions of the Western Antarctic Peninsula and its vicinity as well as other areas never sampled by ships before. However, given the unique characteristics of the new sensors and their independence from human manipulation at sea, their accuracy may be different from the more conventional sensors often applied in oceanography. In this work we compare data collected by four Southern elephant seals (*Mirounga leonina*) equipped with SMRU data-loggers (SRDL) in 2008 to data collected by conventional CTD onboard Brazilian research vessels in the Bransfield Strait region. The data used for evaluation was collected between February 21 and March 03 of 2008 and the data corrected in this work was collected between 07 February and 17 August 2008. Temperature and salinity data collected by the SRDLs were corrected by  $-0.12^{\circ}\text{C}$  and  $+0.11$ , respectively, to match conventional CTD data. Corrected range of potential temperature ( $\Theta$ ) and salinity ( $S$ ) of the Bransfield Strait water masses were between  $-1.96^{\circ}\text{C}$  and  $1.85^{\circ}\text{C}$ ,  $34.22$  and  $35.01$ , respectively. As observed in previous studies, the Bransfield Strait Water ( $0 > \Theta$  and  $34.45 < S < 34.6$ ) is dominant at depths greater than 100 m. The Circumpolar Deep Water is observed only for a short period at the end of July, probably due to intrusions between Livingston and Greenwich Islands, where the presence of southern elephant seals was also recorded. Surface waters (0 – 150 m) had a reduction in  $\Theta$  of about  $3^{\circ}\text{C}$  between the beginning and end of the sampling period, mainly due to seasonal changes, while  $S$  exhibited an increase due to the release of salt during the sea ice formation. We believe that any future work performed in SOOS using animal-borne CTDs should consider intercalibration with independent (conventional) sensors for better and more accurate results.

## Rate of sea ice formation and temporal variation of hydrographic parameters in the vicinity of Wilkins ice shelf depicted by southern elephant seals

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The use of marine mammals (MM) as autonomous platforms for collecting oceanographic data has revolutionized the understanding of physical properties of low or non-sampled regions of the polar oceans. The use of these animals became possible due to the development of new, cheaper and lighter electronic devices, sensors and batteries to be carried by MM. Oceanographic data collected by two Southern elephant seals (*Mirounga leonina*) during the Fall of 2008 were used to infer the sea-ice formation rate in the region adjacent to the Wilkins Ice Shelf, west of the Antarctic Peninsula from February to June 2008. The sea-ice formation rate was estimated from the salt balance equation for the upper (100 m) ocean at a daily frequency for the period between Feb. 13th and June 20th. Animal borne oceanographic data were also used to describe the temporal variation of the water temperature and salinity from surface to 300 m depth in the study area. Sea ice formation rates ranged between 0,087 m/day in early April and 0,008 m/day in late June while temperature and salinity ranged from -1.84 °C to 1.60 °C and 32.85 to 34.85, respectively. Estimations of sea-ice formation rate do not consider the water advection, only the temporal changes of the vertical profile of salinity. This may cause underestimation of the real sea-ice formation rate. The intense reduction of sea ice rate formation from April to June 2008 may be related to the intrusion of the Circumpolar Depth Water (CDW) into the study region. As a consequence we believe that this process can be partly responsible for the disintegration of the Wilkins Ice Shelf during the winter of 2008. The data presented here represent a new frontier in physical and biological oceanography thus providing a new approach for monitoring sea ice changes and oceanographic conditions in polar oceans. This is particularly important for regions covered by sea ice where traditional instruments deployed by research vessels cannot be used.

## Multi-frequency observations of seawater pH, alkalinity, and carbonate chemistry of coastal western Antarctic Peninsula

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Assessments of benthic coastal seawater pH, alkalinity, and carbonate chemistry for the western Antarctic Peninsula are rare and have generally been of short duration during the austral spring/summer under sea-ice or in offshore open water. Herein we present multi-frequency measurements of these seawater parameters collected from the benthos on a diel schedule over five weeks (March – April 2013), once daily over three months (March – May 2013), and weekly over one year (May 2012 – May 2013). We detected moderate variations in median diel seawater pH with a maximum variation of 0.13 pH units and values generally lower in the morning than evening. Similarly, daily measurements of seawater over a longer three-month period revealed moderate variability in seawater pH. Weekly sampling over a year revealed a stable median annual seawater pH of 8.09 throughout the majority of the year. However, a notable pH increase (max pH = 8.62) occurred in the late austral spring/summer (November - December 2012) coincident with the break-up of the sea ice. Based on diel, daily, and weekly total alkalinity (TA) and salinity normalized TA (nTA) measurements it appears that biological activity has a greater direct effect on TA than the presence or absence of sea ice. Estimates of weekly calcite ( $\Omega_{\text{cal}}$ ) and aragonite ( $\Omega_{\text{arg}}$ ) saturation states over a year were  $\geq 1$ . Collectively, these findings are important in informing seawater carbonate chemistry parameters utilized in OA experiments to evaluate vulnerability of coastal benthic Antarctic marine organisms. Supported by NSF grant ANT-1041022 provided to CDA, JMB, RAA.

**Mornings design for dense water formation diagnosed iceberg keel and monitored the Diel Vertical Migration in the vicinity of the Mertz Glacier Polynya**

**Sultan E**

MNHN

Since 2008 in the frame work of the Adélie Land Bottom water and sea ice Interaction project, up looking ADCPs are moored offshore the GeorgeV-Adelie Land Coast. This long term monitoring has been designed initially to document the dense water formation in the Mertz Glacier Polynya.

The echo sounder of the ADCPs registered the Mertz calving and the keel of Icebergs from 3 different glacier overriding the mooring lines. In addition in the period of the ice floe, the echo sounder measurements show a diel vertical migration that seems to be correlated to krill activity. We then discuss the process involved in this behavior.

This study illustrate how a well design monitoring system can be efficient for long-term multidisciplinary observations in order to accurately detect, assess and interpret how Antarctica will respond to change and at what rate.

## Biogeochemical properties of Antarctic multi-year fast ice and underlying seawater near Syowa Station

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The Southern Ocean plays an important role in modulating the global carbon cycle by transporting and storing anthropogenic carbon dioxide. This region is predicted to be greatly influenced by global change, given that polar marine ecosystems are particularly sensitive to carbonate change. Sea ice influences the global carbon cycle through biotic and abiotic transformations that occur within the ice. For biotic example, 10-28% of primary production within the seasonally ice-covered regions of the Southern Ocean takes place within sea ice (Arrigo et al., 1997, 1998; Arrigo and Thomas, 2004). Sea ice algae are also important to seed spring phytoplankton blooms and lead remarkably low concentration of dissolved inorganic carbon in the seawater. In this work, we analyzed biogeochemical properties of multi-year fast ice and underlying seawater around Syowa Station. Sea ice core and seawater samples were taken at St.A(69.0023S, 39.6022E) and St.B(68.9974S, 39.6146E) northeast of Syowa Station from January 15 2013 to January 29 2013. Sea ice core were taken twice during the period and seawater samples were taken once a day in principle from each station. Sea ice thickness was more than 4 m and snow depth was more than 45 cm throughout the period in both station. Top of the sea ice core in both station shows nearly zero salinity, very low concentration of nutrients and nearly snow value of  $\delta^{18}O$  suggest that upper part of ice core is originally snow.  $\delta^{18}O$  and phosphate were gradually increased, approach to the value of underlying seawater with depth. However, nitrate and silicate show very low concentration at the bottom of the core. Very high concentration of chlorophyll a were observed in deeper part (>3m) of sea ice, despite to low (<1%) light condition. Pigment analysis suggested that diatom must be a dominant species. Our study suggests that, even in 4m thick multi-year fast ice, sea ice melting or breaking could seed phytoplankton blooms.

## The Southern Ocean Network of Acoustics - a circumpolar database of acoustic observations of the mid-trophic level in the Southern Ocean

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Understanding and predicting how the Southern Ocean responds to change is a globally relevant issue requiring circumpolar scale analyses. Sustained multidisciplinary observations are required to detect, interpret and respond to change. Syntheses of global observations have been undertaken for hydrographic properties (e.g. temperature, World Ocean Circulation Experiment). However, despite their wide spatio-temporal distribution, huge abundance, and crucial importance within Southern Ocean ecosystems, information on the large scale distribution of mid-trophic level organisms has lagged behind.

These organisms typically include euphausiids and mesopelagic fish and play a key role by transferring biomass and energy through the foodweb. Acoustic methods offer a means to collect high resolution data of the mid-trophic level over small to large spatio-temporal scales. However, acoustic measurements cannot be used without standardisation of systems, appropriate validation and quantification of basic relationships between biological variables of interest and acoustic energy. To that end a systematic and long-term strategy to implement standards and protocols in acoustic sampling programmes for basin-scale ecosystem comparisons, co-ordinated through international organisations and programmes is required. The Southern Ocean Network of Acoustics (SONA) aims to address this.

The increasing importance of ecosystem assessment has resulted in most scientific vessels (and additionally now, fishing vessels) having calibrated acoustic capabilities. SONA represents partners from national research programmes (Australia, France, New Zealand, Norway and the UK) and the fishing industry (Aker, Olympic, Sanford Ltd, New Zealand Longline Ltd, Seaview Ltd). It is guided by strong links with other research and policy networks which value the collection and processing of calibrated acoustic data on common principles (e.g. Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), International Council for Exploration of the Seas (ICES)). SONA will utilize this existing infrastructure and collaboration to develop a database of circumpolar acoustic observations of the mid-trophic level in the Southern Ocean, with a web-based interface to allow data discovery.

## Observational evidence of an eddy overturning circulation at the Antarctic margins

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Recent observations and numerical simulations emphasize the key role of mesoscale variability in enabling transport across the shelf break around much of Antarctica. From January to March 2012, three ocean gliders were deployed in the northwestern Weddell Sea as part of the GENTOO project, resulting in more than 700 profiles, corresponding to roughly 20 hydrographic sections across the shelf break. The glider data reveals frequent eddy shedding of warm Circumpolar Deep Water onto the continental shelf within a narrow range of density classes. We interpret this exchange through an analysis of the potential vorticity (PV) structure, which encodes information about eddy mass transport via thickness fluxes. The continental shelf break is a source of high PV where dense water is present. This PV intrudes into the interior and establishes isopycnal PV gradients that can support down gradient eddy fluxes. Without dense shelf water, PV is more variable, but isopycnal PV gradients remain. These results suggest a complicated cross-shelf exchange of water properties in intermediate/deep density classes, as opposed to a simple export into bottom waters.

## S31: MAPPING ANTARCTICA AND THE SOUTHERN OCEAN

### The International Bathymetric Chart of the Southern Ocean (IBCSO)

**Arndt J**<sup>1</sup>, Schenke H<sup>1</sup>, Jakobsson M<sup>2</sup>, Nitsche F<sup>3</sup>, Buys G<sup>4</sup>, Goleby B<sup>5</sup>, Rebesco M<sup>6</sup>, Bohoyo F<sup>7</sup>, Hong J<sup>8</sup>, Black J<sup>9</sup>, Greku R<sup>10</sup>, Udintsev G<sup>11</sup>, Barrios F<sup>14</sup>, Wigley R<sup>15</sup>

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The SCAR expert group on the International Bathymetric Chart of the Southern Ocean (IBCSO) was inaugurated in 2004. IBCSO is a regional mapping project of the General Bathymetric Chart of the Ocean (GEBCO) under the joint auspices of the Intergovernmental Oceanographic Commission (IOC) (of UNESCO) and the International Hydrographic Organization (IHO). The project aim was to create the first seamless bathymetric compilation for the entire Southern Ocean south of 60°S. In 2013, finally the first Version of IBCSO was published in the Journal Geophysical Research Letters (Arndt et al., 2013).

IBCSO Version 1.0 is a prime example for an international collaboration in Antarctic Science. Over 30 institutions from 15 countries contributed data and shared their expertise to generate the, so far, largest database of bathymetric data of the Southern Ocean. From this database a digital bathymetric model (DBM) was produced. The DBM covers the entire Antarctic Treaty area in a resolution of 500 m. It is available in several formats and projections. In addition, a new map has been created of the Southern Ocean and Antarctica and now is also available to the SCAR community. Both, the DBM and the map, can be downloaded free of charge from the IBCSO web site ([www.ibcso.org](http://www.ibcso.org)).

In my poster presentation I will present the map product of the IBCSO project and give information about its included data sets, its distribution and its design.

## IBCSO V1.0 - new bathymetry for the SCAR community

**Arndt J**<sup>1</sup>, Schenke H<sup>1</sup>, Jakobsson M<sup>2</sup>, Nitshe F<sup>3</sup>, Buys G<sup>4</sup>, Goleby B<sup>5</sup>, Rebesco M<sup>6</sup>, Bohoyo F<sup>7</sup>, Hong J<sup>8</sup>, Black J<sup>9</sup>, Greku R<sup>10</sup>, Udintsev G<sup>11</sup>, Barrios F<sup>12</sup>, Reynoso-Peralta W<sup>13</sup>, Taisei M<sup>14</sup>, Wigley R<sup>15</sup>

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In my presentation I will give an overview of the IBCSO V1.0 compilation methods and highlight the improvements of the IBCSO DBM compared to global datasets. Furthermore, some tips and hints for the usage of IBCSO including the use of the Source Identifier grid (SID) will be given.

## **Multibeam acquisition for characterizing post-LGM Antarctic Ice Sheet retreat from the continental shelf - an assessment of data acquisition needs and recommendations of best procedures**

**Bart P**<sup>1</sup>, **Nitsche F**<sup>2</sup>

<sup>1</sup> Louisiana State University, <sup>2</sup> Lamont Doherty Earth Observatory of Columbia University

Geological and geophysical evidence demonstrates that the Antarctic Ice Sheet (AIS) advanced to the outer shelf during the Last Glacial Maximum (LGM). Reconstructing the pattern and timing of the post LGM retreat history from the shelf is important because it provides the information needed to understand cause and effect relationships that control ice sheet stability/instability and sea-level change. Details of the recent retreat history also provides perspective on the stability of the current grounding positions in the marine environment as might be influenced by continued global warming.

Since the 1990s, multibeam survey data have begun to reveal detailed views of grounding zone wedge (GZW) morphology that was previously known from coarsely spaced 2D seismic transects. In many cases, AIS retreat involved several pauses during which the location of grounded ice temporarily stabilized and GZWs formed. Studies of different paleo ice stream systems have found variable numbers of GZWs in adjacent paleo-troughs, which strongly suggest that retreat history differed from place to place. The location, shape and timing of these grounding and liftoff events are essential for detailed reconstructions of the retreat of individual ice streams.

Here we report on work done by a SCAR Action Group formed to 1) consider whether the currently available multibeam data are adequate to describe the pattern with which the AISs retreated from the outer shelf since the LGM and 2) recommend potential strategies to acquire additional multibeam data. The currently available multibeam data are inadequate to describe the continental-scale pattern with which the AISs retreated from the outer shelf. More than 30 ice streams may have drained the AIS during the LGM and of these, only Marguerite Trough on the Pacific margin of the Antarctic Peninsula is well surveyed. Given the enormous area of the Antarctic margin, a long-term international collaborative effort involving many multibeam equipped research vessels presents the best opportunity to obtain the data needed to make a continent-wide reconstruction of AIS retreat. If the currently active research vessels were available, surveying a subset of paleotrough axes along their entire lengths could be accomplished in two to three seasons. The existing data should be shared so that a minimum duplicity of new data coverage is acquired.

## **New Zealand mapping and place naming in Antarctica**

**Blick G, Shaw W**

Land Information New Zealand

Land Information New Zealand and its predecessor agencies have operated topographic mapping programmes in the Ross Sea Region of Antarctica, as well as place naming administration for over 50 years.

During this period there have been significant changes in the ways mapping has been carried and on its focus. Much of this mapping has been carried out in collaboration with the US Geological Survey. Recently the large scale maps (1:50k) in the area has been updated to ensure they are consistent new formats and are consistent with a new datum and projection in the region. .

Through the New Zealand Geographic Board's sub-committee on Place Naming, LINZ has operated a shared arrangement with the US for place naming in the Ross Sea Region to ensure agreement on the adoption of place names and no duplication of names. The arrangement continues to operate very well.

This presentation will detail the history of New Zealand's topographic mapping and place naming activities in the Ross Sea Region of Antarctica.

## Insights about the structure and evolution of the Scotia Arc from a new magnetic data compilation

Martos Y<sup>1</sup>, Catalán M<sup>2</sup>, Galindo-Zaldívar J<sup>1,3</sup>, Maldonado A<sup>1</sup>, **Bohoyo F**<sup>4</sup>

<sup>1</sup> Instituto Andaluz de Ciencias de la Tierra (CSIC/UGR), <sup>2</sup> Real Instituto y Observatorio de la Armada, <sup>3</sup> Departamento de Geodinámica. Universidad de Granada, <sup>4</sup> Instituto Geológico y Minero de España

The analysis of a new regional compilation of magnetic anomalies from marine, aeromagnetic and satellite data reveals the main structural/tectonic elements of the Scotia Arc. The most relevant magnetic anomaly in the continental crust, the Pacific Margin Anomaly (PMA), is related to a basic to intermediate elongated batholith. It was emplaced by subduction processes along the Pacific continental margin of the Antarctic Peninsula and can be followed within the continental blocks of the South Scotia Ridge and South America. Four representative magnetic profiles also show the structure in depth, and allow us to characterize the main crustal elements of the region. The PMA is seen to have a roughly W-E orientation, decreasing in intensity eastwards from the Pacific Margin of the Antarctic Peninsula and extending towards the South Scotia Ridge to Discovery Bank and even to Herdman Bank. However, the identification of the PMA in the North Scotia Ridge is uncertain, since the magnetic anomalies and the modeled profiles do not support the presence of an important batholithic body. This setting can be attributed to the kinematics of subduction, almost orthogonal to the Pacific margin of the Antarctic Peninsula and oblique along the South American margin. We propose a reconstruction of the initial distribution of the main continental blocks in the initial stages during the Cretaceous, taking into account the continuity of the PMA along the Antarctic Peninsula and South Scotia Ridge. The anomalies identified in the northern Scotia Sea are probably related to local basic rocks intruded in pull-apart basins that developed in the South America-Antarctica plate boundary deformation zone during the initial stages of South Atlantic Ocean spreading.

## Mass transport deposits along the southern Scotia Sea (Antarctica) and its relation to the Scotia-Antarctic plate boundary

Pérez L<sup>1</sup>, **Bohoyo F**<sup>2</sup>, Hernández-Molina F<sup>3</sup>, Galindo-Zaldívar J<sup>4</sup>, Maldonado A<sup>1</sup>, Casas D<sup>2</sup>, Ruano P<sup>4</sup>

<sup>1</sup> IACT(CSIC-UGR), <sup>2</sup> IGME, <sup>3</sup> Royal Holloway University of London, <sup>4</sup> University of Granada

The South Scotia Ridge (SSR) constitutes a left lateral strike-slip boundary between the Scotia and Antarctic plates. The deformation and stretching of continental blocks occurred during the Scotia Sea evolution has been particularly relevant along this boundary that at present shows restraining and releasing bends structures compatible with the recent stress field. Northern of the SSR the southern Scotia Sea is formed by deep intra-oceanic sedimentary basins developed since Oligocene between stretched continental morpho-structural highs, from west to east: Ona, Protector, Dove and Scan basins. The sedimentary record covering these oceanic domains presents highly variable thickness even been locally absent. Generally, deposits present a stratified pattern. They have been divided in two main sequences limited by a regional chronostratigraphic limit attributed to the middle Miocene.

Main objective of this study is identify and map the Mass Transport Deposits (MTDs), and their stratigraphic position within the sedimentary record of the southern Scotia Sea basins. Potential triggers and their relationship with the main regional tectonic processes is also discussed. This work is based on the stratigraphic analysis of multichannel seismic profiles where MTDs are characterised by a lenticular to irregular morphology, of internal transparent or semitransparent chaotic seismic facies. Their size, considering apparent length and thickness, is highly variable even though the greater are located in the Scan Basin. MTDs are commonly related to the eastern continental margin of the basins, implying here greater sediment instability from the middle Miocene to the present-day. In older deposits MTDs are less frequent and can be recognized particularly in the Ona and Scan basins denoting the evolution of slope instability. Onset and location of MTDs could be related to events in the tectonic evolution of the Antarctica, the behavior of the adjacent segment of the Scotia-Antarctic plate boundary; the higher occurrence of volcanic buildings toward the east and the own basins infill and tectonic development.

## **BATDRAKE V1.0: Multibeam bathymetry map of the Drake Passage (Antarctica-South America)**

**Bohoyo F**<sup>1</sup>, Larter R<sup>2</sup>, Galindo-Zaldivar J<sup>3,4</sup>, Leat P<sup>2</sup>, Maldonado A<sup>4</sup>, Tate A<sup>2</sup>, Flexas M<sup>5</sup>, Gowland E<sup>2</sup>, Kim Y<sup>6</sup>, Hong J<sup>6</sup>, **Lopez Martinez J**<sup>7</sup>, Maestro Gonzalez A<sup>1</sup>, Bermudez O<sup>1</sup>, BATDRAKE team

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The opening of the main southern oceanic gateways, mainly Drake Passage and the Tasman Strait, permitted the modern pattern of global ocean circulation to be established. This allowed extensive exchange of water between the main ocean basins and led to the development of the Antarctic Circumpolar Current (ACC), which caused the thermal isolation of Antarctica, and was partially responsible for global cooling at the Eocene-Oligocene boundary. These gateway openings were important tectonic events involving complex geological processes such as continental fragmentation, development of oceanic basins and rifting of continental blocks. As a consequence of this and the subsequent submarine processes, these areas show a varied physiography, in particular the Drake Passage which is the object of this work.

This first version of the map constitutes an international cooperative effort coordinated by the Spanish Geological Survey (IGME), the British Antarctic Survey (BAS) and the Korean Polar Research Institute (KOPRI). A compilation of precise multibeam bathymetric data obtained on cruises from the period between 1992 and 2014 in the Drake Passage region has been carried out. The map covers the area between parallels 52°S and 63°S and meridians 70°W and 50°W. This new detailed mapping with a 200 m cell resolution of the sea floor in Drake Passage permits identification of the main physiographic features, which can be related to dynamic processes of deep oceanic currents. Sea-floor topography in the region is an important boundary condition for high-resolution ocean circulation models and also provides constraints on stress field models for the initiation of Drake Passage opening. Sea-floor digital elevation models are also very important in scientific areas such as physical oceanography and marine biology. Future developments of this work will be sea-floor feature cartography and digital elevation models.

This initiative is part of IBCSO (International Bathymetric Chart of Southern Ocean), under the SCAR umbrella, which recognises the importance of regional data compilations in areas of particular scientific interest in the Antarctic, such as the Ross Sea, Drake Passage and the southern margin of Weddell Sea.

## The Antarctic geological 1:250000 map series of the GIGAMAP project: the Freyberg Mountains Quadrangle (Victoria Land)

**Capponi G**<sup>1</sup>, Meccheri M<sup>2</sup>, Pertusati P<sup>3</sup>, Carosi R<sup>4</sup>, Crispini L<sup>1</sup>, Musumeci G<sup>3</sup>, Oggiano G<sup>5</sup>, Roland N<sup>6</sup>, Tessenshon F<sup>6</sup>

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Here we present a new printed geological map from the northern Victoria Land area (NVL): the 1:250000 "Freyberg Mountains" quadrangle, realized within the framework of the GIGAMAP (German-Italian Geological Antarctic Mapping Programme) and based on data collected during different Antarctic Expeditions. The GIGAMAP was born in 1995, from a German-Italian collaboration on geological mapping in NVL. The project planned the production of the eighteen, 1:250000 USGS quadrangles of the NVL from the Pacific coast southwards up to the David Glacier area. This part of NVL was systematically surveyed only starting from the sixties, by several New Zealand field parties, that established the overall framework of the regional geology. In 1987 the Ganovex Team III published a 1:500000 geological map of the NVL.

The geology of the "Freyberg Mountains" quadrangle is characterised by an early Paleozoic metamorphic basement (Ross Orogen) and a mostly flat-lying cover, spanning in age from Carboniferous-Permian to Quaternary, with large stratigraphic gaps. The basement consists of three main terranes: (1) the Wilson Terrane (WT) that includes low to high grade metamorphic rocks, intruded by large bodies of late Cambrian Granite. (2) The Bower Terrane (BT) consisting of three low-grade metamorphic sequences, showing primary sedimentary contacts and regressive trend from marine to fluvial - deltaic continental environment; the age spans from Middle Cambrian or older to Late Cambrian. (3) The Robertson Bay Terrane (RBT) a very thick monotonous, low-grade metamorphic sequence of quartzose turbidite greywacke, alternating with silty mudstone; the age is Cambrian to Lower Ordovician (Tremadocian). A minor belt, the Millen Schist, intervenes at the boundary between BT and RBT. The Devonian Admiralty intrusive and Gallipoli volcanic rocks were emplaced in the three terranes and supply an upper time constraint for the docking of the WT, BT and RBT. After the Admiralty - Gallipoli magmatic event, the area was uplifted and eroded. On the resulting peneplain surface, the deposition of a Carboniferous-Permian moraine occurred (Neall Massif Tillite). Both the basement and the tillite were covered by the sedimentation of the Takrouna sandstone, that was in turn covered by large flows of Jurassic Kirkpatrick Basalt; the coeval Ferrar Dolerite formed sills chiefly along the basal sandstone horizon. The youngest event was the emplacement of the Cenozoic Melbourne alkali-volcanic suite.

## Towards improved geological maps of the Transantarctic Mountains: datasets for studies of glacial dynamics and climate change

Cox S<sup>1</sup>, Rattenbury M<sup>1</sup>, Salvatore M<sup>2</sup>, Morin P<sup>3</sup>, Townsend D<sup>1</sup>, Niebuhr S<sup>3</sup>

<sup>1</sup> GNS Science, <sup>2</sup> Arizona State University, <sup>3</sup> Polar Geospatial Center, University of Minnesota

A new geological map of southern Victoria Land (QMAP-SVL) has integrated and summarised all previous work in the largest ice-free area of Antarctica. Limited new fieldwork, satellite and aerial photograph interpretation were completed in areas that were poorly known or contentious, but elsewhere has been compiled from existing maps. Data covering 76°30'-78°45'S, 158°-178°E have been captured and stored in an ArcGIS® database, now delivered via web-server (<http://maps.gns.cri.nz/geology/web/>), OneGeology (<http://portal.onegeology.org>) and published as a hard-copy 1:250,000 scale geological map (Cox et al. 2012).

As in many areas of Antarctica, the previous geological maps of southern Victoria Land were principally focused towards description of bedrock geology. Most provide little information on the source, age and composition of glacial deposits, typically showing only one or two 'Quaternary' units. Till is an important on-land indicator of major climatic and glacial events. Much can be achieved with the aid of aerial photographs and remote sensing: tills can be grouped on geomorphological criteria using dating, elevation and composition information to distinguish them from colluvium, scree, lake and delta deposits, dunes, beach deposits, fan gravel and alluvium. QMAP-SVL differentiated >70 units of surficial deposits on the basis of mode of formation, source, and inferred age to provide a systematic overview. It highlighted targets worthy of specialist future research, and provides holistic context for biological and ecological studies.

Spanning 20 degrees of latitude, the Transantarctic Mountains are a grand target for yielding information on the waxing and waning of Antarctica's ice masses during the late Cenozoic Era. There are numerous bedrock outcrops against which are draped sequences of surficial deposits, but for the most-part these are poorly defined and described by the existing, hard-copy, geological maps. The latest high-resolution satellite data offers a rapid way to collect wide swaths of detailed spectral information that can significantly improve glacial deposit mapping (e.g. Salvatore et al. 2013, doi:10.1017/S0954102013000254). Drawing on experience gained in southern Victoria Land, we aim to facilitate a multinational collaborative effort towards reducing this knowledge gap, with a view to building a comprehensive geological dataset that can highlight records of past climate change preserved in the Antarctic landscape.

## High resolution aeromagnetic glimpses of Cenozoic arc magmatism on the Antarctic Peninsula

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<sup>1</sup> British Antarctic Survey, <sup>2</sup> University of Leeds, School of Earth and Environment: Now at ION GX Technology,, <sup>3</sup> British Antarctic Survey: Now at University of Leicester, Department of Geology, <sup>4</sup> British Antarctic Survey: Now at Midland Valley, Glasgow., <sup>5</sup> British Antarctic Survey: Now at University of Cambridge, CASP, <sup>6</sup> Swedish Museum of Natural History

The magmatic arc along the Antarctic Peninsula (AP) once formed part of the tectonically active circum Pacific 'ring of fire'. Cessation of subduction due to Cenozoic ridge-trench collision along the AP has uniquely preserved an intact arc/forearc system. The broad tectonic structure of the AP arc is well understood. However, magmatic processes occurring along the arc are only constrained by regional geophysical and sparse geological data. Key questions therefore remain about the timing, volume, and structural controls on magma emplacement. Here we present two new high resolution aeromagnetic surveys across Adelaide Island, on the western margin of the AP. Our new data for the first time reveal the complex structure of the AP arc/forearc boundary. Using digital enhancement, 2D modelling and 3D inversion we constrain the form of the magnetic sources at the arc/forearc boundary. Our interpretation of this magnetic data, guided by geological evidence and new zircon U-Pb dating, suggests significant Paleogene to Neogene magmatism formed ~25% of the upper crust in this region. Significant structural control on Neogene magma emplacement along the arc/forearc boundary is revealed. We hypothesize that this phase of magmatism reflects mantle return flow through a slab window generated by the cessation of subduction south of Adelaide Island. This mantle process may have affected the final stages of arc magmatism along ~200 km of the AP margin, in part accounting for the apparent split of the positive magnetic Pacific Margin Anomaly.

## The Lanterman Fault-Exiles Thrust connection in East Antarctica in light of enhanced aeromagnetic imaging

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Three fault bounded terranes of Cambrian – Ordovician age are generally recognized in Northern Victoria Land (NVL): the Wilson Terrane, the Bowers Terrane and the Robertson Bay Terrane. These terranes are part of the Paleo- Pacific active margin of Gondwana that gave rise to the Ross Orogen. The Lanterman Fault is the main suture zone that separates the Wilson and the Bowers Terrane, while within the Wilson Terrane there are two major intra-terrane thrust faults, the Wilson and Exiles thrusts.

Here we present new enhanced aeromagnetic images that reveal the subglacial extent of a major inferred fault that lies on strike with the Lanterman Fault and appears to link to the Exiles Thrust system beneath the Rennick Graben. The broad similarity between the Matusевич anomaly in the Exiles Thrust region and the anomalies over the northern Bowers Terrane along the eastern flank of the Rennick Graben is particularly intriguing, as it may imply a tighter tectonic linkage between the Wilson and Bowers terranes than currently assumed.

To explain these aeromagnetic observations we propose a new tectonic model that involves significant strike-slip motion along both the terrane bounding and intra-terrane faults. Three alternative scenarios can be put forward: 1) Strike-slip faulting occurred in an early stage of the Ross Orogen, as has been identified much further south over the Transantarctic Mountains; 2) Strike-slip faulting occurred as part of a late-stage, and dominantly transpressional stage of the Ross-Orogen, which was responsible for both the development of major intra-terrane thrusting and reactivation of the older terrane bounding faults; 3) Strike-slip faulting occurred much later, during the Cenozoic, and led to both transpressional and transtensional structures, the latter represented primarily by the Rennick Graben. Superposition of all three scenarios is a further, and arguably perhaps the most likely possibility. Regardless of which alternative scenario holds true, it is clear that the aeromagnetically proposed connection between the Lanterman Fault and the Exiles Thrust has major potential implications for the debate on Ross age tectonics and terrane accretion, as well as Cenozoic reactivation of these inherited tectonic structures in NVL.

## Unveiling subglacial geology beneath major ice streams flowing in the Weddell Sea Embayment with aerogeophysical observations

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Subglacial geology provides important controls on the onset and maintenance of fast glacial flow associated with the West Antarctic Ice Sheet (WAIS). Widespread subglacial sediments deposited within deep rift basins, thinner drapes of marine sediments within the West Antarctic Rift System (WARS) and high geothermal heat flux associated with Cenozoic rift-related magmatism have been previously identified as the main geological controls that can modulate ice sheet dynamics.

Here, we compile a suite of new and vintage aerogeophysical observations over the catchments of several major ice streams flowing into the Weddell Sea Embayment to examine their large-scale geological setting and assess the role of regional geological controls on subglacial topography and WAIS flow regimes. Specifically, we examine the subglacial geology beneath the catchments of the Institute and Moeller ice streams, the Rutford ice stream and the Evans ice stream using a combination of airborne radar, aeromagnetic and airborne gravity imaging. We show that the Moeller ice stream is underlain by a major strike-slip fault system along the tectonic boundary between East and West Antarctica. A set of en-echelon subglacial basins formed along the strike-slip fault and these basins appear to steer enhanced flow further inland. We find no evidence, however, for deep sedimentary basins along this fault system, suggesting that subglacial sediments are not necessarily a geological template for the onset of fast glacial flow. However, the newly identified Robin Subglacial Basin that underlies the fast flowing coastal region of the Institute ice stream contains 1-3 km of sedimentary infill and remarkably smooth bedrock topography. Enhanced flow in the tributaries of the Institute ice stream cuts across the Ellsworth Mountains and is controlled by basement faults in metasedimentary and metavolcanic rocks.

Prominent magnetic anomalies overlie outcrops of Jurassic granitic intrusions and enable us to trace their subglacial extent beneath the catchments of Institute, Moeller and Rutford ice streams. These large granitoid bodies form the topographic highs that also exert significant controls on ice flow. Magnetic anomalies also delineate the extent of Precambrian basement that underlies a significant part of the Evans ice stream catchment. Narrow rifts may have formed along the edges of this Precambrian block and appear to be a significant control on fast flow for both the Evans and Rutford ice streams.

## New aerogeophysical survey targets the recovery frontier in East Antarctica

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East Antarctica is the least known continent on Earth, despite being regarded as a keystone in Gondwana, Rodinia and perhaps Columbia supercontinents. Significant progress has however been made in recent years in the exploration of East Antarctica using airborne geophysical techniques. Major collaborative aerogeophysical campaigns have been performed over the Wilkes Subglacial Basin, the Aurora Subglacial Basin and the Gamburtsev Subglacial Mountains. Analyses of these recent datasets is providing fundamental glimpses into the crustal architecture in interior East Antarctica, as well as several new interpretations regarding its linkages with tectonic and geodynamic evolution from the Precambrian to Mesozoic and Cenozoic times.

Here we present the first results of a major reconnaissance aerogeophysical survey over the largely unexplored Recovery ice stream frontier in East Antarctica, flown during the IceGRAV 2012-13 field season, as part of a new international Danish, Norwegian, UK and Argentine collaboration. Over 29,000 line km of new radio-echo sounding, laser altimetry, gravity and magnetic data were acquired using a British Antarctic Survey Twin Otter. We focus primarily on presenting the new potential field datasets and discuss the anomaly patterns seen in the new aeromagnetic anomaly, free air, Bouguer and isostatic residual maps.

These aerogeophysical datasets provide a new foundation to address a cascade of open questions in this part of East Antarctica, including: i) Where are and what is the nature of the major tectonic boundaries separating the Coast block, the Shackleton Range and the Dronning Maud Land crustal provinces? Specifically, is there new geophysical evidence in support of a Pan-African age suture zone in the Shackleton Range linked to Gondwana assembly?; ii) can an older Grenvillian-age orogenic belt, extending across the interior of East Antarctica be traced?; Or, is there a continuation of a collage of Precambrian provinces recognised further in the interior of East Antarctica, including the Gamburtsev, South Pole and Recovery provinces (Ferraccioli et al., 2011, *Nature*)?; iii) are there major subglacial rift structures and sedimentary basins beneath the Recovery catchment, e.g. similar to those identified in the adjacent Weddell Sea Rift, or in the East Antarctic Rift System?; and finally, iv) how significant are geological controls on the subglacial topography, hydrology and ice sheet dynamics in this part of East Antarctica?

## **Bathymetry data, end-to-end, at the British Antarctic Survey**

Gowland E, **Fretwell P**, Gutierrez De Gracia M

British Antarctic Survey

This poster describes the lifecycle of marine multibeam bathymetric data within the British Antarctic Survey (BAS). An overview of the end-to-end process of collection, processing, storage, access and usage of these data are shown, including detail of procedures used both on ship and in the office.

This poster shows both the current coverage and the variety of products produced, from high resolution bedforms, through regional bathymetric grids to international collaborative projects. Information on a recent project to capture the metadata, enhance data sharing and provide access through a single web portal are also specified.

## Tectonic evolution and magmatism of the Dove Basin: new insights in the South Scotia Arc

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The Dove Basin was formed during the development of the Scotia Arc and has oceanic character. The basin is located in the south-central Scotia Sea and has a roughly elongated shape, with a prominent NNE–SSW Dove Ridge located in its central part, which is considered as the spreading centre. A NE-SW elongated tectonic seamount is located in the north-eastern region of the basin, bounded by a late normal fault dipping to the southeast. Igneous rocks along the Dove Ridge are mainly tholeiitic basalts, derived from asthenospheric upper mantle within an extensional supra-subduction back-arc tectonic setting, which evolved over time from back-arc basin basalts toward Mid Oceanic Ridge Basalts (MORB). Most altered olivine-bearing doleritic and basaltic rocks were also dredged from Dove Ridge and the seamount, together with minor oceanic island arc basalts and basaltic andesites. The mantle source was affected by a subducted oceanic floor slab that originated, up to early Miocene times, a back-arc at the Dove Basin related to an eastward arc. Later, minor alkaline oceanic island basalts dredged at the seamount might represent a final extensional stage which gave rise to an incipient volcanism deriving from a deeper mantle source.

<sup>40</sup>Ar/<sup>39</sup>Ar dating of MORB samples dredged from the Dove Ridge provided ages of  $20.4 \pm 2.6$  to  $22.8 \pm 3.1$  Ma. These outcrops were later coated by Fe–Mn crusts with Co-Chronometer ages ranging from at least 12.6 Ma and probably up to 18 Ma. Analysis of magnetic anomaly profiles shows the best fit in the central profile, corresponding to chrons C6B (21.7 Ma) to C7 (24.5 Ma), although alternative ages may be proposed due to the short length. This interpretation supports the <sup>40</sup>Ar/<sup>39</sup>Ar dating of a late Oligocene to early Miocene age. The spreading was asymmetrical, the asynchronous age of extinction of spreading in the basin being confirmed by the variable character of magnetic anomalies. The western part extended faster than the eastern part, suggesting an eastward location for the subduction zone. In this setting, the Dove Basin was originated from an Oligocene to Early Miocene arc-back-arc spreading system, which would contribute to the eastward general development of the Scotia Arc.

## **Magnetic and field tectonic observations in the Greenwich, Robert, Dee and Barrientos islands: new insights on the South Shetland Block crustal structure**

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The Greenwich and Robert islands together with other nearby small islands are located in the central part of South Shetland archipelago. This is a key region for understanding the recent continental fragmentation processes corresponding to the final stages of the opening of the Drake Passage, that have affected the Antarctic Peninsula and Bransfield Basin. During February 2014 field season, new magnetic surveys including total field measurements by a GSM8 proton precession magnetometer, rock magnetic susceptibility and field tectonic researches developed in Pedro Vicente Maldonado Ecuadorian Antarctic Station contribute to constrain the crustal structure and the recent tectonic evolution. Most of the structures are related to volcanic edifices, including domes and pythons feeding volcanic cones, mainly basaltic in composition. Layering is generally determined by alternating lava flows and pyroclastic levels.

The northern part of the Pacific Margin Anomaly belt is identified in this region, which was fragmented during the opening of the Bransfield Basin into two main branches. The previous magnetic data are scarce. A single aeromagnetic line crosses the Greenwich Island. Magnetic susceptibility measurements are comprised between  $11 \times 10^{-3}$  (SI) and  $195 \times 10^{-3}$  (SI) with a mean value of  $38.6 \times 10^{-3}$  (SI). These high magnetic susceptibility values fit clearly with the nature of the basic volcanic rocks on surface (basalts and pyroclastic levels). The interpretation of the total magnetic field intensity measurements suggests that there is an overprinting of very shallow anomalies related to the mafic volcanic edifices and other regional anomalies of deeper crustal bodies. The integration of ground and aeromagnetic total field magnetic anomalies contributes to characterize in more detail the crustal structure and nature of the central part of this archipelago.

In addition, geological observations show that the fracture system is formed by interacting cooling volcanic and tectonic joints. Preliminary observations have not yet found evidence of major faults previously reported affecting the area. Anyway, calcite filled joints and basic dikes are common and have been formed during late stages of NE-SW extension and NW-SE compression. These structures may be associated with the activity of the oceanic subduction of the former Phoenix Plate that was located towards the NW of the SSB along the South Shetland trench from Mesozoic up to Present.

## **ADMAP-2: the next-generation magnetic anomaly map of the Antarctic**

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<sup>1</sup> VNIIOkeangeologia, <sup>2</sup> BGR, <sup>3</sup> BAS, <sup>4</sup> DNA/IAnt-Arg, <sup>5</sup> KOPRI, <sup>6</sup> Kongju Nat. Univ., <sup>7</sup> BPRC/OSU

Given the extensive ice, snow and marine cover of the Antarctic region south of 60°S, magnetic surveying is a most effective tool for characterizing and expanding our knowledge of the underlying geology. The initial magnetic anomaly map of the Antarctic (Golynsky et al., 2001) revealed terranes of varying ages, including Proterozoic-Archaeon cratons, Proterozoic-Palaeozoic mobile belts, Palaeozoic-Cenozoic magmatic arc systems and other important crustal features. Since the production of the initial magnetic anomaly map, the international community has acquired more than 1.5 million line-km of additional air- and shipborne data, nearly doubling the amount of near-surface magnetic survey data in Antarctica. To facilitate integrating the new survey data into the ADMAP database and to initiate the production of the next generation magnetic anomaly map for the Antarctic, an ADMAP-2 steering committee was formed which met at the Korean Polar Research Institute (KOPRI), in Incheon, Republic of Korea. The August'13 meeting established milestones for completing the project, reviewed the new magnetic survey data for the ADMAP-2 compilation, and developed enhanced formats for digitally archiving the airborne and marine survey data and metadata. ADMAP-2 will significantly enhance the geological utility of the magnetic surveys in the database and also make substantial contributions to the World Digital Magnetic Anomaly Map.

Golynsky, A., Chiappini, M. Damaske, D., Ferraccioli, F., Ferris, J., Finn, C., Ghidella, M., Ishihara, T., Johnson, A., Kim, H. R., Kovacs, L., LaBrecque, J., Masolov, V., Nogi, Y., Puruker, M., Taylor, P., and Torta, M. 2001. ADMAP – Magnetic anomaly map of the Antarctic, 1: 10 000 000 scale map. Morris, P., von Frese, R.R.B., eds., BAS (Misc) 10. Cambridge, British Antarctic Survey.

## Geological and geomorphological mapping of Hope Bay (Antarctic Peninsula)

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Geological mapping in a broad sense, is a powerful tool for geological research and usually represents the first and most valuable stage of geologic reconnaissance for a region.

In this contribution we present the geological and geomorphological maps of Hop Bay (Antarctic Peninsula). These maps were done by Spain Geological Survey (IGME) with the scientific collaboration and logistic support of the Argentine Antarctic Institute (IAA), in the framework of the collaboration of both institutions, and they are published by IGME with the support of within the new Antarctic Geoscientific Cartography Series as part of the Spanish Polar Research effort. Fieldwork was conducted during the austral summer seasons of 2004, 2005 and 2008. The editing scale of both maps is 1:10.000, with a new topographic base produced by the IAA and IGME. The legends, symbols and map contents, follow the IGME standard for geological and geomorphological maps.

The geological map contains fifteen geological units, which are part of three formations: Hope Bay Fm (Carboniferous-Triassic), Mount Flora Fm (Early Jurassic), and Kenney Glacier Fm (Early-Middle Jurassic). Quaternary and recent sedimentary deposit were mapped in six separate units.

The geological mapping coupled with the stratigraphic analysis allows the separation of mappable allostratigraphic units. As a result of this work, the Hope Bay Fm is now interpreted as shallow siliciclastic platform deposits, and new outcrops of the Mount Flora Fm have been discovered. The map contains a legend showing the relationship between units, symbols, four geological cross-sections, ten stratigraphic columns with a correlation panel, and sketch maps with the geographical and geological context.

The geomorphological map shows two types of elements: landforms and superficial deposits. These elements are represented with different components (coloured enclosures, symbols and frames) organized in groups according to their morphogenesis. Each group is identified by its specific colour. The map has illustrates a relative morphochronological organization, since the late Pleistocene, age attributed to the Last Glacial Maximum (LGM) by an absolute age (5,550 BP) in the Boeckella lake sediments (Zalle, 1994).

The geomorphological features shown in the map are grouped in six morphogenetic processes: structural, fluvio-glacial, glacial, periglacial, coastal, and anthropic. Most of these Quaternary landforms and deposits are a glacial origin, reflecting the generalized glacier retreat in the region. Also, the map contains: symbols, geographical and geological settings, and some panoramic photos showing the different landscapes.

## Geological and geomorphological mapping of Seymour (Marambio) island (Weddell Sea)

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Geological mapping in a broad sense, is a powerful tool for geological research and usually represents the first and most valuable stage of geologic reconnaissance of a region.

In this contribution we present the geological and geomorphological maps of Seymour (Marambio) island (Weddell Sea). These maps were done by Spain Geological Survey (IGME) with the scientific collaboration and logistic support of the Argentine Antarctic Institute (IAA), in the framework of the collaboration of both institutions, and they are published by IGME with the support of within the new Antarctic Geoscientific Cartography Series as part of the Spanish Polar Research effort. Fieldwork was conducted during the austral summer seasons of 2006 to 2011. The editing scale of both maps is 1:20.000, while the work scale was 1:10.000 based on the topographic map produced by the USGS and IAA. The legends, symbols and map contents, follow the IGME standard for geological and geomorphological maps.

The geological map contains forty one geological units which are part of eight formations: Snow Hill Island Fm. (Maastrichtian), Lopez de Bertodano Fm. (Maastrichtian-Danian); Sobral Fm. (lower-middle Paleocene); Cross Valley and Wiman Fms. (upper Paleocene); La Meseta Fm. (early-middle Eocene); Submeseta Fm. (upper Eocene-earliest Oligocene?); Hobbs Glacier Fm. (Miocene), and Weddell Fm (Pliocene-Quaternary).

Some conclusions of the cartographic and stratigraphic analysis are: the subdivision in cartographic units whose contacts are limits of stratigraphic sequences (allostratigraphic units): the correlation between the Cross Valley and Wiman Fms, and magnetostratigraphic absolute dating. The map contains a legend showing the relationship between units, symbols, two geological cross-sections, stratigraphic columns with a correlation panel, a DEM, and sketch maps with the geographical and geological context.

The geomorphological map shows two types of elements: landforms and superficial deposits. These elements are represented with different components (coloured enclosures, symbols and frames) organized in groups according to their morphogenesis. Each group is identified by its specific colour. The map has illustrates a relative morphochronological organization, since upper lower Pliocene, age attributed to the glaciomarine deposit in top of stratigraphic serie

The geomorphological features are grouped in four morphogenetic types: structural; fluvial; snow and periglacial; and coastal. There are another six genetic types of lesser importance: volcanic, hillslopes, glacial, eolian, lacustrine and anthropic landforms. In addition the map contains: symbols, geographical and geological settings, a DEM, a slope sketch and some panoramic photos showing the different landscapes.

## **An effort to digitize and preserve the SCAR paper map collection**

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The United States Antarctic Program has undertaken an effort to preserve the entire 6000+ maps in the SCAR Map collection at the US Geological Survey and the Polar Geospatial Center. The purpose is to enhance and ensure the collection and to bring it to the widest possible audience.

The maps are being scanned at with an archive quality scanner at the University of Minnesota Libraries. The scans are rectified by the Polar Geospatial Center so that they can be used in GIS software, web applications and services. Metadata is added from the SCAR Antarctic Map Catalog hosted by AAD and the final digital files will be distributed whenever possible to the public. When complete, the maps will go into a dark archive at the USGS in Reston, Virginia for long term storage.

<http://www.pgc.umn.edu/maps/antarctic>

## Imaging and creating digital elevation models of Antarctica using sub-meter commercial imagery

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Polar Geospatial Center

The NSF funded Polar Geospatial Center (PGC) is 5 years into a project to repeatedly image the Antarctic with DigitalGlobe, Inc.'s sub-meter satellite constellation. All imagery is available to US federally funded researchers at no cost and is available by the rest of the Antarctic community for licensing by DigitalGlobe.

Two generic products are now available. First, PGC hosts a web viewer and service that contains 0.5m panchromatic orthorectified and mosaiced imagery for more than 90% of the continent. This imagery is produced by orthorectifying individual panchromatic imagery strips using a best available digital elevation model. Imagery is scored using parameters such as high sun angle, low cloud cover, and low off-nadir angle. To access the viewer's commercial imagery content, users must demonstrate United States federal funding and register for an account.

The second product is a collection of digital elevation models (DEMs) derived from in-line stereoscopic commercial imagery. Currently the Antarctic is being imaged in stereo down to 84 south approximately once per austral season. 2-4m posting elevation models can be produced using open source software from NASA Ames and the Ohio State University. Preliminary accuracy assessment shows the DEMs have a vertical error up to 6m without ground control. If reference points are used, the error drops to less than 1m. This data will be distributed in two forms, 1) a mosaiced 2m posting DEM and 2) a series of time stamped DEMs. Since DEMs are highly derived products from commercial imagery they can be distributed free of copyright.

## Southern Ocean compilation of the Global Multi Resolution Topography

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Lamont-Doherty Earth Observatory of Columbia University

Detailed bathymetry data provide high value information for studies of oceanographic and biological processes, sediment transport, mass wasting, and paleo-ice flow reconstructions. Although an increasing number of research ships are collecting high-resolution swath bathymetry in the Southern Ocean, existing bathymetry data cover only a fraction of the seafloor. Large bathymetry compilations interpolate where no data exist and usually are limited in the maximum resolution they can provide. The Global Multi Resolution Topography (GMRT) synthesis preserves swath bathymetry detail by creating high-resolution tiles only where data exist. Providing data at the highest feasible level of resolution allows the visualization and analysis of detailed features critical to morphology and other fields.

The core of the GMRT in the Southern Ocean is swath bathymetry data collected by US research ships, especially the NB Palmer, but also includes selected available data from other vessels and high-resolution grids. It is updated regularly as new data become publically available. New data are added after a basic quality control and cleaning process. The majority of the current data holding is located in the Scotia Sea, Drake Passage, Antarctic Peninsula, Amundsen Sea, and Ross Sea.

Bathymetry tiles of the GMRT can be accessed through web services such as WMS and clients such as GeoMapApp, Virtual Ocean, and Earth Observer. In addition, the highest-resolution tiles are also integrated into GoogleEarth and incorporated in the International Bathymetric Chart of the Southern Ocean (IBCSO).

## Bedgap - where next for Antarctic subglacial mapping?

**Pritchard H**

British Antarctic Survey

The recently-published Bedmap2 datasets mark the culmination of several decades of sub-ice and sub-ocean Antarctic topographic surveying by many nations, but maps of the topographic data distribution show that in the global context, the Antarctic bed still remains very poorly sampled. Most of the large unmapped areas on Earth lie under Antarctic ice and polar surveying is still difficult and expensive, so it is important to identify where future efforts should be concentrated. A survey of 75 experts in various aspects of polar science shows that a lack of adequate topographic data is an important constraint in several themes, but the data gaps and the data needs do not tend to coincide. There is strong demand for yet higher-resolution surveying in previously visited areas, particularly in the most dynamic, and most rapidly changing regions as identified by glaciologists, oceanographers, hydrologists, biologists and geomorphologists, while geologists and ice-core scientists focus on the most important areas for understanding Antarctica over deeper time. The data requirements identified here could be addressed for most areas given sufficient time and funding, but the technology needed to survey the interiors of the large ice shelf cavities has only just been developed.

## Digital soil mapping of soil attributes driving microbial habitats

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Despite extreme conditions, bacteria are distributed throughout soils of Antarctica and represent a major part of the biodiversity. The spatial distribution of these communities is not random. Aislabie *et al.* (2012) found that the microbial composition of soils is strongly influenced by soil attributes such as water content, salinity, organic carbon and pH. A prerequisite to monitoring these microbial communities, to quantify the potential impacts of climate change, is to locate where the different communities occur. A major hurdle for microbiologists to do so is the sparse coverage of environmental data.

This study investigates the potential for digital soil mapping techniques to map the soil attributes driving microbial habitats distribution in the Dry Valleys of the Ross Sea region. Digital soil mapping (DSM) creates spatial soil information by combining field and laboratory observations with environmental proxies in quantitative models.

515 soil samples have been collected in the Wright Valley and analysed for pH, salinity and organic carbon. Additionally, terrain derivatives have been derived from a digital elevation model (DEM): elevation, slope, aspect, compound topographic index (CTI), and wetness index. A data-mining method has been used to model soil organic carbon, salinity, and pH at two depths (desert pavement and next underlying soil layer) from the available environmental covariates.

The results of this preliminary study demonstrate the technical feasibility of mapping a set of key soil attributes in the Dry Valleys using DSM. Such maps can support microbiologists to understand where soil biota is more likely located, and hence allow target sampling to reduce the need for time-consuming and costly lab analysis. Such spatial data can also help explain the relationship between abiotic factors and soil microbiological abundance and biodiversity.

## **New mappings of ice sheet properties for Antarctica: Roughness, thickness, velocity, and change from visible - near-infrared sensors**

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We describe 3 separate efforts: a 3rd MODIS Mosaic of Antarctica (MOA) and the change detection that is enabled by that; a MISR mapping of (primarily) sastrugi roughness; and an ice velocity mapping of the Antarctic ice sheet grounding line (+/- 200 km) using Landsat 8.

A third continent-wide mosaic of surface morphology and snow grain size is being produced from Moderate-resolution Imaging Spectroradiometer (MODIS) data. Past mosaic images have provided cloud-cleared continent-wide mappings at 125 m gridding for the 2003-2004 ('MOA-2004') and 2008-2009 ('MOA-2009') austral summers. We are now assembling a third mosaic, identically processed, for 2013-2014 ('MOA-2014'). The series supports ice sheet surface change detection of all kinds, including ice edge calving, grounding line migration, ice velocity mapping over ice shelves (to  $\pm 15$  m yr<sup>-1</sup> accuracy over 5 years), and snow grain size changes. MOA has also been used for mapping rifts and streaklines, blue ice and wind glaze extent, and megadune orientation. More recently, spatial fourier analysis of the mosaics has yielded derivative products that correlate quantitatively with ice thickness and bedrock structure. They can provide an interpolation guide for future BEDMAP compilations.

We are also mapping snow surface roughness of the ice sheet based on surface scattering of visible light. The sensor, Multi- angle Imaging Spectroradiometer (MISR) observes the surface with fore- and aft- pointing imaging sensors. An atmosphere- and bi-directional reflectance -corrected normalized ratio of the data (specifically the C camera, at 60° incidence) provides surface roughness at scales below 275 m (the scale of a MISR pixel). Strong roughness characteristics are seen in megadune – wind glaze – blue ice areas, crevassed regions, and coastal accumulation areas.

The Landsat 8 satellite sensor, launched in February 2013, provides ~monthly coverage of the Antarctic coastline over the summer season. Image-to-image cross-correlation software using the high radiometric (12-bit) and moderate spatial resolution (15 m) of Landsat 8's panchromatic band, and its exceptional (3 m) geolocation accuracy, is being used to map ice velocity. Accurate maps can be produced over short intervals, i.e., low multiples of the satellite repeat imaging frequency (16, 32, 48, and 64 days). The velocity data include areas of very subtle surface features, including un-crevassed sastrugi regions, and an improved sub-pixel correlation fit provides smooth and accurate velocity fields to ~0.2 pixel-equivalent movement (~0.2 m/day at 16-day repeat; 0.05 m/day, or ~20 m yr<sup>-1</sup>, for 64-day repeat). Combining this capability with a rapid data processing and management system will permit seasonal ice flow mapping for the perimeter of Antarctica. Ice elevation data from CryoSat-2 near the ice grounding line will yield a net ice flux determination on an annual basis.

## Insights under ice shelves: Mapping bathymetry under floating ice from Operation IceBridge aerogravity surveys

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Mapping the bathymetry under ice shelves remains one of the outstanding problems in understanding ice-ocean interactions around Antarctica. The access route and circulation of warm ocean waters to the grounding line of major glaciers must be known in order to predict the future stability of the Antarctic ice sheets. Knowledge of the bed geometry in front of the grounding line in turn aids models of past behavior of the ice sheet. Direct measurement of the bathymetry in these environments is logistically intensive, and so limited data coverage is available even in areas where direct measurements have been possible.

Since 2010 NASA Operation IceBridge (OIB) has been flying a multi-sensor instrument suite, including the Sander Geophysics AIRGrav, in surveys over Antarctica. The measured gravity anomalies from these surveys have been inverted in order to model the bathymetry beneath the floating ice where radar surveys cannot penetrate. These surveys allow extensive coverage of ice shelves around the coast of West Antarctica and the Filchner-Ronne Ice Shelf. In 2013 for the first time Operation IceBridge conducted surveys over the Ross Ice Shelf. Over large regions, gravity inversion has been shown to produce bathymetry models accurate up to  $\pm 60$  m, with uncertainty varying with geological complexity.

We present results from these inversions, including detailed surveys over the ice shelves of the Amundsen Sea where bathymetry models improve our understanding of the circulation of warm ocean water towards the grounding line of the West Antarctic Ice Sheet. The bathymetry of these ice shelves is marked by the tectonic fabric of the region, which provides elongate troughs under Pine Island Glacier and Crosson ice shelf, and ridges parallel to the grounding line of Thwaites Glacier and calving front of Dotson ice shelf. By combining these surveys into a single self-consistent bathymetric model we investigate the influence of bathymetry on glaciological changes in the region.

We also show results from sparser, exploratory lines over the large ice shelves of the Filchner-Ronne and Ross ice shelves, highlighting regions where more detailed surveys are required.

## **Aerogeophysical site selection for the Rapid Access Ice Drill**

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The Rapid Access Ice Drill (RAID) project will focus on retrieving a diverse suite of samples by drilling to bedrock through the deep ice sheet. The primary target will be the southern plateau of East Antarctica, between the Gamburtsev Subglacial Mountains, the South Pole, and the Transantarctic Mountains, which is geologically poorly known; this region is critical for understanding the assembly of the Antarctic continent, the climate record of the Antarctic ice sheet, feedbacks between geology and deep glacial ice, and the long-term potential contribution of the ice sheet to sea-level change. In particular, RAID will search for a potential site for a future 1.5 million year ice old ice core. Key for the RAID project will be locating regions of the bed that are frozen, to prevent contamination of the subglacial environment.

We describe a proposed new survey of this region (SPICECAP), focused on RAID site selection, using proven aerogeophysical methods. Targeting deep drilling sites for this exciting new technology will similarly require a new paradigm for acquiring geophysical knowledge of the ice sheet and bedrock geology in the proposed RAID study region. We will characterize upstream ice-sheet mass balance through time, detect the presence or absence of water at the bed, and determine regional and detailed ice-sheet geometry and basement geology trends. Our approach to this task has been refined over the course of five field seasons and 150,000 km of surveying for the just concluded ICECAP project. Combined radar, gravimetry and aeromagnetism will allow imaging of geological trends and architecture and, in particular, inversion for geological composition.

SPICECAP will comprise two field seasons. The first will focus on two reconnaissance corridors - one linking Titan Dome to Dome A, and one linking Beardmore Glacier to the Gamburtsev Subglacial Mountains. During the second season, we will target sites within these corridors at high resolution to fully characterize the subglacial water system to find regions of frozen bed appropriate for drilling, as well as map the geology and englacial stratigraphy in detail.

## S32: DATA ACCESS AND SHARING FOR CUTTING-EDGE SCIENCE

### Novel ways of integrating and presenting polar space science data to enhance understanding and application

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The diversity of polar space science data presents formidable challenges for optimal use in today's and tomorrow's interdisciplinary science. The South African National Antarctic Programme manages an array of Space Science instruments at SANAE in Antarctica and on the high latitude islands, Marion Island and Gough Island. The instruments include the SuperDARN Radar, Riometers, VLF receivers, Magnetometers, Aurora cameras, GPS receivers and ionospheric scintillation monitors. The integration of the data from these instruments play a key role in the space weather monitoring and predictions of the Regional Space Weather Warning Center for Africa at SANSa Space Science in Hermanus South Africa and other members of the International Space Environment service.

This paper presents some novel ways of presenting real-time and historical data from the instruments managed by the SANAP programme which facilitates the following key data management issues:

1. Detection of space weather events through the correlation of data from different instruments
2. Identification of spurious and anomalous data from particular instruments which do not match data from co-located instruments
3. Estimation of the nature of the terrestrial impact of the space weather event i.e. whether it manifests primarily as a radio storm, a geomagnetic storm, or both.
4. Identification of the altitude and spatial distribution of the event.

SANSa is currently working on the development of a data portal which will integrate and provide access to the data and metadata from its array of instruments in Antarctica and present it in a coherent way with the data from its other Space Weather monitors in Southern Africa for example the real-time display of the data from all the INTERMAGNET and Plasmon magnetometers in the network of instruments managed by SANSa Space Science.

One of the ways in which events are easily discerned to be different from the normal daily variation in a particular parameter, and correlated with related observations from other instruments is to superimpose the current data on plots of similar data and that of other instruments for the previous days. An example of a novel display of a combination of real-time and historical solar flare data from the X-ray monitor on the geostationary GOES satellite on the same time-scale as the geomagnetic data from the total magnetic field monitor at SANAE can be seen on <http://chingchongciao.com/spwx/>

The paper will present other useful ways of integrating and comparing data from different instruments in order to derive useful information for modelling, monitoring and prediction of space weather events.

## Metadata management at the Polar Data Center of the National Institute of Polar Research, Japan

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National Institute of Polar Research

The Polar Data Center (PDC) of the National Institute of Polar Research (NIPR) has a responsibility to manage the data for Japan as a National Antarctic Data Center (NADC) in the last two decades. During the International Polar Year (IPY2007-2008), a significant number of multidisciplinary metadata have been compiled mainly from the IPY- endorsed projects involving Japanese activities. The amalgamated metadata have a tight collaboration with the Global Change Master Directory (GCMD), the Polar Information Commons (PIC), as well as the ICSU World Data System (WDS). The PDC has the significant task to archive and deliver the digital data obtained from the polar region. Summary information of all the archived data (metadata) is available to the polar science community, together with more general interests. The compiled metadata describe all kinds of science disciplines (space and upper atmospheric science, meteorology and glaciology, geoscience and bioscience) from both long- and short-term projects in the Arctic and Antarctic, particularly data collected by the Japanese Antarctic Research Expedition (JARE). In science meta-database provided by PDC, a total of 300 records had been accumulated as of February 2014 including the metadata from IPY endorsed projects (<http://scidbase.nipr.ac.jp/>). In order to promote inter-operability between NIPR database and other metadata portals developing by other polar communities and countries, moreover, such the database system by using the "Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) should be developed in near future. The science database provided by PDC has also a tight connection with the Antarctic and Arctic Master Directories (AMDs) in GCMD. In addition to the IPY data, the data from Japanese national and other international projects have been compiled. Moreover, almost 300 metadata records have been amalgamated at moment inside the Japanese Antarctic portal in GCMD. The PDC stores its metadata by the original format, but this includes the main items listed in the GCMD Directory Interchange Format (DIF). There are tight cross-linkages between corresponding metadata in both the AMDs and PDC.

## The Integrated Climate Data Center at the Center for Earth System Research and Sustainability (CEN), University of Hamburg

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Easy access to easy-to-use data is an important pre-requisite for Earth System research. To monitor, better understand and predict the future climate observational data are an asset. These should have undergone a vigorous quality assessment. Usefulness and scientific value of such data increase once these are stored in a self-explanatory, easy-to-use format, and once these can be obtained from a data center which provides easy data access and expert support for users and data providers.

The Integrated Climate Data Center (ICDC) at the Center for Earth System Research and Sustainability (CEN) at the University of Hamburg provides several types of Earth observation data via the web-portal <http://icdc.zmaw.de>. Each data set has an own web-page on this web portal. The web-page gives the data access point(s), a short description of the data, i.e. which algorithm and which sensors are used to create which parameters, about spatial-temporal coverage and resolution, and about data quality. Each web-page closes with reference documents to the data set, contact information and information about how to correctly cite the data. Data access is realized via FTP, HTTP or OPeNDAP. The ICDC Team supports and consults users and data providers, e.g., regarding selection of dataset and format. The preferred data format at ICDC is ASCII or netCDF. Data products are visualized using a Live Access Server. This server also allows analyzing datasets and parts of them along transects and profiles, zooming into key regions, and creating time series. ICDC is closely linked to the CERA data base at the German Scientific Computing Center (DKRZ). This ensures long-term data storage and provision of digital object identifiers. In addition, ICDC has the mandate to contribute to data product quality assessment and improvement on international level, and to enhancement of ease of use.

ICDC offers a number of world-wide unique data sets. One example of these is the bias-corrected data set of temperature profiles from MBT and XBT instrument measurements. Other examples are the thickness of thin sea ice derived from brightness temperatures of the SMOS sensor or the melt pond cover fraction on Arctic sea ice derived from MODIS. The Easy INIT project is an important link between hydrographic observations and ocean modeling. ICDC hosts the Easy INIT Ocean Synthesis Directory and provides access to over 10 different ocean re-analyses data products.

## Forming a National Antarctic Data Centre for Canada

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Research in Antarctica is conducted pursuant to the international Antarctic Treaty and various related instruments (e.g., the Protocol on Environmental Protection), and science is carried out under the Scientific Committee on Antarctic Research (SCAR). Under the Treaty, all countries which are parties and which conduct scientific research in Antarctica are expected to properly manage and share the resulting data via a National Antarctic Data Centre (NADC). Although Canada is a non-consultative party to the Treaty and an associate member of SCAR, there is currently no officially-recognized NADC for Canadian research data from Antarctica. Although Canada has actively participated in the activities of the SCAR Standing Committee on Antarctic Data Management, to better meet its Treaty obligations, recent discussions within the Canadian polar research community have identified a possible path for formalization of a Canadian NADC.

Recognizing that the Polar Data Catalogue (PDC, <http://www.polardata.ca>) has a bi-polar mandate and manages Antarctic data and metadata, and conforms to international standards of interoperability it is being proposed that the PDC be formally established as the NADC for Canada. Should PDC be recognized as the Canadian NADC, it would serve as the focal point for Antarctic research datasets and provide data management services and support to Canada's Antarctic scientists. Current efforts involve a formal proposal to the Canadian Polar Commission (CPC), the SCAR adhering body for Canada, and the Canadian Committee on Antarctic Research (CCAR). The scope of development required to make DIF-formatted metadata available to the Antarctic Master Directory is currently under consideration as is funding availability for support of NADC-related data management activities at the Polar Data Catalogue.

Recognition of PDC as Canada's NADC would expand the visibility and accessibility of Antarctic data online as well as the support that would be available to Canada's Antarctic researchers, increasing the profile of Antarctic research in Canada and broadening discussions of strategies for supporting polar data management within Canada. Creation of a Canadian NADC would also support the creation and expansion of a Canadian Antarctic Research Program, providing an opportunity for this potential new program to apply the substantial experience of the international Antarctic research community to planning Antarctic data management in Canada.

## Environmental data and cloud service management

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The CNR coordinates the research activities in the Antarctica, in the frame of Italian Antarctic Research National Programme (PNRA), and in the Arctic. In this context the CNR is in charge of managing the data and disseminate the scientific results of the activities carried out in the polar regions. The data collected refer to projects carried out at Antarctic stations of Concordia (Dome C), Mario Zucchelli (Terra Nova Bay) and at Arctic station Dirigibile Italia in Ny - Alesund (Svalbard Islands). Many of these data sets are not yet interoperable and accessible because they do not accomplish to international standard formats. To have an organized and distributed information system to store, record information (metadata), validate and view the captured data becomes now very important, as the continuous increasing of data amount. Moreover, historical catalog must be updated to the international standards and federated in the same system.

CNR is establishing the information infrastructure (Environmental Data and Cloud Service Management - EDCSM) to provide also the polar scientific community, through the Polar Metadata Infrastructure, to easily manage with historical and real-time data and metadata. The infrastructure will ensure transparent data discovery through the interconnection of the system with the most common ones for discovery and broker access to environmental data, integration with the global environmental observation network of GEOSS, and contribute to increase the entire GEO community. The EDCSM system is conceived to support the scientist, who may want to use it, through simple and intuitive interfaces to create a customized work environment. The infrastructure is provided with SOS service to allow real time updates on data and metadata directly from remote sensors.

The architecture that applies the "System of Systems" principles will increment the existing systems by supplementing but not supplanting their mandates and governance arrangements. This allows to keep the existing capacities as autonomous as possible. This infrastructure implements multi-disciplinary interoperability following a Brokering approach, supporting SCAR data policy and in accordance with European and international standards, including GEO/GEOSS, INSPIRE.

The functionality of the infrastructure will be validated using the data acquired at Italian Arctic Station in Ny Alesund - Svalbard. The data collected in the Arctic represent a peculiar dataset because of different type of sensors and measurements as well as different acquisition system. The full operability of the system will be tested off line using all the data stored and on line accessing directly to the sensors during the measurements.

## **Design of a geospatial decision-support tool for biological conservation and management in Antarctica: A call for stakeholder input**

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Remote sensing imagery has radically expanded the amount of data available on the abundance and distribution of seabirds breeding in the Antarctic. At the same time, long-term studies and other direct field measurements, remote camera installations, and citizen science efforts continue to supply a wealth of relevant data. A major challenge is thus turning these data into meaningful policy-relevant information; in other words, we have yet to develop a 'knowledge management framework' that makes these new streams of data accessible to Antarctic stakeholders or integrates them with more traditional data streams. In this poster, we will describe an interactive browser-based geospatial decision-support application currently in development that is designed to address precisely this challenge. This application will allow Antarctic stakeholders to access spatially-explicit and policy-appropriate information on Adélie penguin distribution and abundance with associated uncertainties for user-defined spatial areas of interest. We will present the basic schematic elements of our decision-support tool and several potential designs for a graphical-user interface. Stakeholder input is essential to ensuring that the design of our software is user-friendly and provides the functionality desired by its users. Feedback received on the application and the alternative graphical user interfaces will be integrated into the final design concept.

**"Quantarctica": new standalone GIS package for Antarctic research, operation and education using open-source software**

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We gathered Antarctic geographic data from data centers worldwide and developed a GIS project file that works on Quantum GIS, a free, open-source software (GNU licensed). This GIS package was named Quantarctica with playful mind (i.e. Quantum GIS + Antarctica). Quantarctica works locally so no internet access is required. In the past two years, we have used previous versions to examine geographical data at a range of scales (continental to local views), prepare maps for publications, examine various project data together with the continental datasets included in Quantarctica, and plot the GPS-provided positions together with satellite images real time basis during field campaigns. It should also be useful to teach Antarctica in classrooms. We wish that researchers will contribute their field and remote sensing data as well as model outputs to improve Quantarctica; in particular, we solicit contributions from biologists, oceanographers, geologists, and atmospheric scientists. Norwegian Polar Institute will play a key role to regularly update and improve the package by integrating such community contributions into future Quantarctica. More details and project files are available at [www.quantarctica.org](http://www.quantarctica.org).

## **NSF Antarctic and Arctic Data Consortium: Scientific research support & data services for the polar community**

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The U.S. National Science Foundation Antarctic & Arctic Data Consortium (a2dc) is a collaboration of research centers and support organizations that provide polar scientists with data and tools to complete their research objectives. From searching historical weather observations to submitting geologic samples, polar researchers utilize the a2dc to search and contribute to the wealth of polar scientific and geospatial data.

The goals of the Antarctic & Arctic Data Consortium are to increase visibility in the research community of the services provided by resource and support facilities. Closer integration of individual facilities into a “one stop shop” will make it easier for researchers to take advantage of services and products provided by consortium members. The a2dc provides a common web portal where investigators can go to access data and samples needed to build research projects, develop student projects, or to do virtual field reconnaissance without having to utilize expensive logistics to go into the field.

Participation by the international community is crucial for the success of a2dc. There are 48 nations that are signatories of the Antarctic Treaty, and 8 sovereign nations in the Arctic. Many of these organizations have unique capabilities and data that would benefit US-funded polar science and vice versa.

We'll present an overview of the Antarctic & Arctic Data Consortium, current participating organizations, challenges & opportunities, and plans to better coordinate data through a geospatial strategy and infrastructure.

## Enhancing the accessibility of Antarctic geoscience spatial information through web map and web feature services

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GNS Science

Geological maps of Antarctica reside in many institutions throughout the world. They may be in printed paper form only, or also available as digital scanned images, and in some cases available in digital GIS vector formats. Improved metadata has streamlined the discovery opportunity for these geological maps but obtaining Antarctic geological maps in a usable form for research purposes is not always straightforward.

Internet web services are a technological solution that improves the accessibility of geological map information. This is exemplified in the OneGeology project concept [www.onegeology.org](http://www.onegeology.org) where geological survey organisations around the world serve their chosen maps as web map services (WMS) and/or web feature services (WFS). These map data services are consumed through the purpose-built OneGeology web portal <http://portal.onegeology.org> but can also be consumed by other clients, for example GNS Science's <http://data.gns.cri.nz/geology> geological webmap application and by mainstream GIS software.

The Antarctic region is an ideal application of the OneGeology concept. To date the OneGeology portal consumes two Antarctic geological WMS; a Geoscience Australia's 1:10M geological map of the entire continent served by the British Geological Survey, and the new 1:250 000 geological map of southern Victoria Land published and served by GNS Science. The latter service contains geological map units, their boundaries, faults, folds, dikes, lineaments and data sources as layers within the WMS. The rich attribute information attached to these geological features is returned with GetInfo requests onscreen. The One Geology portal has recently added alternative projections for displaying high latitude maps and some high-end GIS software can consume WMS into Antarctic Polar Stereographic projection. Through GIS software the WMS layers can be integrated with local or other WMS/WFS data in multidisciplinary studies, for example, integrating observations of the geosphere with that of the biosphere. The first step though is turning many more geological maps into attribute-rich, web-accessible datasets.

**IDIPOS project: is a multidisciplinary data infrastructure for polar observation sciences feasible?**

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IDIPOS (Italian Database Infrastructure for Polar Observation Sciences) is a project supported by the Italian Antarctic Program (PNRA). The main aim of IDIPOS is to realize a feasibility study of a hardware and software data infrastructure that would allow the creation of relational databases of digital acquisitions from past and current experimental measurements in polar areas performed by Italian observatories.

The project proposes a modern and high-tech infrastructure dedicated to the data treatment, accessibility and archiving, accordingly to the international standards. Such infrastructure would allow a modern, fast and reliable treatment of the acquired data.

In this paper, the feasibility study results will be reported related to the different scientific sectors "Geodesy and observatories", "Glaciology", "Atmosphere physics and chemistry", "Sun-Earth Relations and Astrophysics", "Technology". Potential use of the infrastructure will be also demonstrated by case studies: geomagnetic and ionospheric scintillation data acquired by means of different instruments and available on different web services to characterized geomagnetic events over Antarctica.

The implementation on cloud of the infrastructure will ensure that the infrastructure will be very flexible and scalable in terms of virtual hardware and software specifications.

IDIPOS is willing to be a step toward a next level of data sharing and integration maturity for Polar Sciences, first at Italian national level, which is the data management culture and governance.

## Development of a Sensor Observation Service (SOS) Javascript library

Breen P, **Tate A**

British Antarctic Survey

This paper discusses the development of a client-side Javascript library to provide an Application Programming Interface (API) to the Open Geospatial Consortium (OGC) Sensor Observation Service (SOS). The library is modular and layered, consisting of a Core module, and a User Interface (UI) module. The Core module encapsulates key concepts of the SOS, such as the connection parameters, the service's Capabilities document, methods to access the service's Features Of Interest (FOI), Offerings, Observed Properties etc. It also provides various utility functions. The UI module provides a number of User Interface components, such as SOS.Plot and SOS.Table for presenting the data acquired from the service, and SOS.Menu and SOS.Map for allowing navigation of the available Offerings of the service.

We then go on to discuss how this library was used to build a web application, to enable discovery, browsing, and access, to British Antarctic Survey (BAS) meteorological data.

## Unlocking the potential of marine data collected by the British Antarctic Survey

**Tate A**, Bazeley-White E, Chapman S, Connor D, Doemel J, Gaikwad S, Gowland E, Gutierrez M, Peat H, Ross L, Thomas J

British Antarctic Survey

This presentation will describe a recent project within the Polar Data Centre at the British Antarctic Survey (BAS) to create a publically-available database of marine cruise metadata. Over the last few decades BAS ships have collected a large number of multi-disciplinary marine datasets in both polar regions. However, until this project, there was no single comprehensive account of where and when scientific cruises occurred, nor was there information on who participated in cruises, why the cruise was undertaken and crucially what went on in terms of scientific deployments (the events). Instead this information was spread across an array of primary and secondary sources such as cruise summary reports, equipment logsheets, existing scientific databases and raw underway data.

The project has created a single quality controlled source for cruise metadata and associated events. The information is now available to internal and external users through a web-based interface. The data model and controlled vocabularies used were based on work done by the British Oceanographic Data Centre and international efforts such as SeaDataNet. The geospatial interface was developed using open-source web mapping standards and was built to support the breadth of queries that marine scientists will pose.

The interface can be accessed at <http://data.antarctica.ac.uk/marine/>

## The data behind the Biogeographic Atlas of the Southern Ocean

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The multi-author Biogeographic Atlas of the Southern Ocean represents a concise synopsis of the current knowledge on the distributional patterns of all the major Antarctic benthic and pelagic taxa and of key communities. For this purpose an unprecedented amount, diversity and quality of biogeographic data, was gathered, covering phyto- and zooplankton, macroalgae and zoobenthos, nekton, birds and seals south of 40°S.

Before we can undertake analyses of biogeographical or macroecological patterns, we need to ascertain how comprehensive our sampling is. The critical factors here are the extent to which the fauna has been described, and how extensive the sample coverage has been.

Here we want to quantify, visualise and explore the data used to create this atlas. This will allow us to ascertain how evenly and well-sampled our study region is and how the distribution of this sampling influences our understanding of the biogeography.

Most of the data that was used to make the Atlas have been made freely and openly available through digital taxonomic and biogeographic databases of Antarctic marine life such as the Register of Antarctic Marine Species (RAMS) and the SCAR Marine Biogeographic Information Network (SCAR-MarBIN) and the Antarctic Biodiversity Facility (AntaBIF).

## Access to the polar scientific resource sharing of CHINARE

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<sup>1</sup> Polar Research Institute of China, <sup>2</sup> Chinese National Antarctic & Arctic Data Center

Polar scientific data and Information sharing is an effective resolution to global system and polar science problems and to interdisciplinary and sustainable study, as well as an important means to deal with polar scientific heritages and achieve Chinese Antarctic and Arctic expedition (CHINARE) program goals. Corresponding to the CHINARE Data-Sharing policies and the Antarctic Treaty System, the polar scientific data and information sharing platform of CHINARE with Chinese & English editions have been set up for providing data and information service to polar community. This paper will give a brief introduction of platform background, main content, developing plan and so on. Chinese National Antarctic & Arctic Data Center (CN-NADC) of Polar Research institute of china (PRIC) is responsible for developing and maintaining the platform.

### **S33: REMOTE SENSING OF THE ANTARCTIC ENVIRONMENT**

#### **Detection and Identification of an anomalously large granite block on Anchorage Island using airborne LWIR hyperspectral imaging and ground validation**

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<sup>1</sup> ITRES Research Limited, <sup>2</sup> British Antarctic Survey, <sup>3</sup> Defence Research and Development Canada Valcartier

In February 2011, airborne LWIR hyperspectral data (32 spectral bands spanning 8.0 to 11.5 microns at 1.0m/pixel) were acquired of Anchorage Island located approximately 4km south of Rothera Research Station. Analysis of the data revealed an unusually large rectangular spectrally anomalous feature (27m by 25m) with very well defined boundaries situated in the northern part of Anchorage Island. The anomaly's spectral emissivity between 8.4 and 9.6 microns was significantly lower than the surrounding area; implying higher quartz content. In January 2014, a ground campaign identified the anomaly as a large block of strongly weathered megacrystic granite dominated by pink potassium feldspar and quartz. The area surrounding the anomaly consisted of strongly weathered diorite-granodiorite with no intrusive or mingling contact at the anomaly's boundaries.

The anomaly is uniform, large, geologically stable, slightly north-facing and is snow-free for most of the Antarctic Summer. It's also easily accessible from Rothera Research Station. These factors combine to make the anomaly an ideal Antarctic high-latitude site for testing and calibrating broadband, multispectral and hyperspectral LWIR polar-orbiting satellites.

## **Snowpack characteristics at Union Glacier, Ellsworth Mountains, as estimated by field measurements and Cosmo-SkyMed imagery**

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High-resolution information on the spatial distribution of snow accumulation on the West Antarctic Ice Sheet (WAIS) is scarce. Satellite based studies are among the most appropriate ways to estimate accurately these mass balance parameter. In order to evaluate the potential of COSMO-SkyMed X-band Synthetic Aperture Radar (SAR) to identify spatial patterns of snowpack characteristics related to snow accumulation (e.g., snow stratigraphy, snow density, crystal size and morphology), a remote sensing survey was carried out at Union Glacier (79°46'S, 83°16'W) during the austral summer 2011/2012, simultaneously with measurements on the glacier surface. COSMO-SkyMed data acquired consisted of 04 Spotlight-2, 07 Stripmap Himage, 02 Stripmap PingPong, and 02 ScanSAR Wide Region images. Seven snow pits were dug in Union Glacier areas with different backscattering patterns observed in COSMO-SkyMed images acquired in July 2011. Snow stratigraphic data were then used to test five empirical and five physical based models of snow backscattering at X-band. In general, physically based models showed better results than that obtained by empirical models. Furthermore, X-band backscattering on the Union Glacier surface is affected by surface roughness and snowpack characteristics, giving important information on the spatial patterns of snow accumulation related parameters (i.e., snow stratigraphy and snow density). Additional studies are planned to investigate the relationship between small-scale snow stratigraphy variations as detected by GPR surveys and the signal measured by X-band SAR sensors.

## **IcePod: Next generation modular airborne remote sensing capability**

**Bell R**, Frearson N, Tinto K, Zappa C, Das I, DeTemple J

Lamont-Doherty/Columbia University

Understanding key processes in the Polar Regions requires high resolution imaging of the environment at many scales. The IcePod is a modular ice/ocean imaging system installed on New York Air National Guard LC-130s to image the surface and subsurface of polar ice sheets and oceans. Lamont-Doherty Earth Observatory of Columbia University has developed the IcePod system. It has been developed with support from the US National Science Foundation, Columbia University and the Tinker Foundation. The Icepod system currently includes a scanning laser, a visual camera, an infrared camera, a shallow-ice radar and a deep-ice radar. These instruments provide observations on the elevation of the ice sheet, the freeboard of floating ice, the surface temperature of the ice and ocean, estimates of the ice surface velocity and constraints on the supra and sub-glacial hydrology. The IcePod system will enable major science efforts in the next decade focusing on ice sheet mass balance, subglacial hydrology, locating the oldest ice, Antarctic tectonics, surface mass balance, dynamics of the marginal ice zone, formation of polynyas and ice-ocean interactions. Integrated into routine NYANG operations, Icepod can provide estimates of the surface mass balance, constraints on the glacial hydrology and insights into the fjord stratification. Dedicated missions flown with the IcePod system can provide important new insights into the evolution of the West Antarctic Rift system, the stability of the Ross Ice Shelf and linkages between subglacial lakes and ice streams. The fundamental data sets produced by the IcePod system are necessary for the development of accurate ice sheet models to predict sea level rise. The modular pod also enables new research proposals and adding new instruments for expanded use of IcePod as a long-term research facility. Additionally, this NSF-sponsored project leverages the unique experience of the NYANG operating in Greenland and Antarctica in support of NSF scientific research as well as for infrastructure and logistics.

## Recent changes in ice dynamics of Antarctic Peninsula glaciers revealed from multi-mission SAR data

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The physical conditions along the Antarctic Peninsula have undergone considerable changes during the last 50 to 60 years. A pronounced period of air temperature rise, increasing ocean temperatures as well as changes in the precipitation pattern have been reported by various authors. The glacial systems also have shown changes including widespread retreat, surface lowering or frontal areas as well as changes in flow speeds. Latter are attributed to dynamic adjustments. We analyse time series of various SAR satellite sensors (ERS-1/2 SAR, ENVISAT ASAR, ALOS PALSAR, TerraSAR-X/TanDEM-X) in regard to changes in surface velocities. Where possible we integrate the ice dynamic information with data on ice thickness for ice discharge estimates as well as with data on glacier retreat.

## Surface elevation and ice shelf thickness estimation from TanDEM-X and altimeter data - an example from Wilkins Ice Shelf

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Radar altimeters have proved to provide accurate surface elevation over large ice sheets and ice shelves including the estimation of elevation and thickness changes. However, the analysis of altimeter data is often limited by the revisit times and by the spacing of the satellite tracks. On the other hand, new satellite missions like TanDEM-X provide the possibility of bi-static SAR acquisitions that enable to derive precise elevation models over the entire swath, in particular over not too steep terrain. The bi-static acquisitions are not affected by temporal decorrelation, but may be affected by volume decorrelation. Limitations in the analysis of the data are the absolute reference and the variable penetration depth of the SAR signal in dependence of surface conditions. In this case study for Wilkins Ice Shelf, we demonstrate the combination of different satellite sensors to obtain surface topography and ice thickness estimates. We integrate overpasses of the German TanDEM-X satellite and altimetry data from the NASA IceBridge as well as ESA CryoSat-2 mission in order to determine accurate surface elevation and to provide error bars of the product. Freeboard surface elevation is converted to ice thickness using a mean density of ice of 0.9 kg/m<sup>3</sup>, assuming brine saturation of the firn below sea level. The product reveals details of elevation and thickness variations due to different flow units and effects of ice rises.

## **Preliminary results of the superficial and sub-glacier topography survey using Radio Echo Sounding at the La Claveré Plateau, Antarctic Peninsula**

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The northern Antarctic Peninsula (AP) is a key area to understand recent local and global climate variability. This area is especially sensitive to temperature increase. Intensification of ice-mass loss due to increasing summer melt events has been reported, as result of strengthened heat transport, for the last decades for almost all coastal regions from the AP. However the north-west coast still represents a big gap of information, since less investigation has been carried out in this area.

This work presents the preliminary results of the information collected by Radio Eco – Sounding (RES) and Global Positioning System (GPS), conducted in January 2014 on Plateau La Claveré (63 ° 22'09" S, 57 ° 39 '33" W) at the northern of the AP. The objectives is obtain by analyzing the captured information; the identification of an optimal site for extracting for a >200m ice core, whit a drilling campaign planned for the up-coming season and then the depth will be determined according to the results obtained. These measurements were performed using two types of the RES, first a pulse radar system, for the subglacial topography and a second system Frequency Modulated Continuous Wave (FMCW) to analyze the internal structure of the glacier. Information by both radars were supplemented with data from GPS 's mode differential to determine the surface topography and the geographical position of each radar measurement. The impulse radar with a mobile GPS receiver was installed on two sleighs and was transported by hand on the glacier surface. The FMCW is also installed with the GPS receiver on a single structure, and was transported by hand. As one second GPS receiver was installed as fixed station near the base camp to make the post differential process.

To obtain the superficial and sub-glacier topography a 1 square kilometer grid with several transverses was measured. The captured information was displayed for both radar and the captured data by GPS's were processed together with radar information to obtain a 3D model of the measured grid, which shows the physical characteristics of the area, where several shallow firn cores were extracted in 2008-2010 and 2014 by our team, successfully demonstrating the potential of this area to recover relevant climate information for this region.

Preliminary results show the general characteristics of the area on the La Claveré Plateau, surface and subglacial topography and an approximate maximum depth of 350 meters, as well as some glacial features to determine that there is not the presence of crevasses in this sector.

Using a simple Nye thinning model combined with geochemical information from the firn cores, we conclude that at a depth of 300m more than 200 years of accumulation are stored on the ice cap, reaching beyond the end of the pre-industrial era in the past, making this area an interesting region for more intensive glaciological research.

## Trapped Snow Dragon broke free from Antarctic ice guided by remote sensing

Cheng X

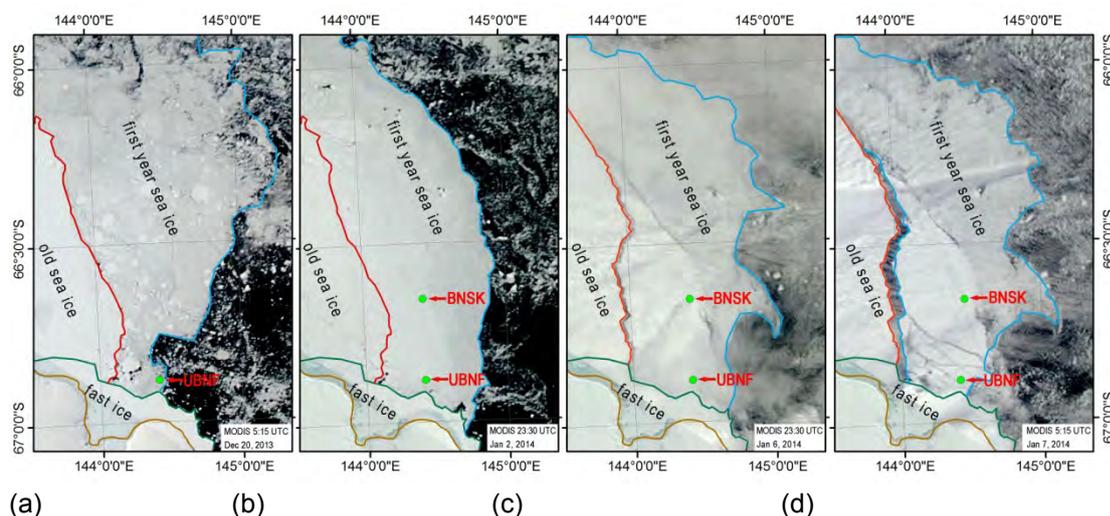
Beijing Normal University

On Jan 7, 2014, both the Chinese Xue Long ship and the Russian Akademik Shokalskiy broke free from the Antarctic ice. The shifted west wind loosened the ice packs and the timely remote sensing images helped the vessels to break out.

On Christmas Eve, Russian ship became trapped in Antarctica's Commonwealth Bay west of Mertz glacier. Xue Long arrived on late Dec 26. After the multiple tries to get close to the stranded ship fail, a spot of clear weather on Jan 2 gave a chance to use Chinese helicopter to airlift scores of passengers to Australian ship, though Xue Long finally itself stuck in the ice.

During the rescuing process to Xue Long, satellite remote sensing played an important role. Radarsat-2 SAR images acquired on Dec 31, 2013 and Jan 1, 2014 show that under the influence of the persistent strong southeasterly wind over just one day, the eastern sea ice edge has compacted and retreated westward up to five nautical miles. The Chinese SAR images from Jan 2 to Jan 5 show that the eastern sea ice edge was compacted further by winds, and thousands of small ponds appeared over the eastern sea ice area.

MODIS images acquired on Dec 20, 2013, Jan 2, 6 and 7, 2014 shows clearly the dramatic change of sea ice in this area. Pervasive southeasterly winds blew the loose sea ice west against the coastal fast-ice and formed into compacted ice body, while west winds from Jan 7 to 8 loosen the compacted sea ice and help the rescue. Timely MODIS image acquired on Jan 6 and Jan 7, showed that several large cracks appeared on the south part of the ice where the Russian ship was located, and the whole ice pack flow away about 4km from the fast ice, and most importantly is that the open water area are much larger than that six-hour ago despite the area being under heavy cloud or fogs. These findings finally led to the decision at 5 pm that Xue Long made all efforts to turn around and force its way out toward southeast. Satellite remote sensing helped to make the final decision, showing its strong ability in handling emergency.



(a) (b) (c) (d)  
Figure. Sequential satellite images showing the fast change of sea ice trapping the two vessels (BNSK: MV Xue Long, UBNF: MV Akademik Shokalskiy). The background images are NASA MODIS images acquired on Dec. 20 2013, Jan 2, 6 and 7, 2014 respectively. From (c) and (d), Xue Long was suggested to break towards southeast it took just one hour to get free. UBNF fortunately fell into an ice crack to get released (d).

## Oceanographic features observed in the northwestern Weddell Sea and in the Bransfield Strait (Antarctica), from relationships between the SAR backscattering and sea-ice thickness measurements

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In 2006, in the transition from winter to spring, a researcher team performed sea-ice thickness profiles in the northwestern of the Weddell Sea, aboard the R.V. Polarstern, utilizing a Helicopter-borne Electromagnetic system (HEM) composed by an electromagnetic sensor, laser altimeter, and a DGPS. Simultaneously, the European Space Agency acquired ENVISAT ASAR WSM images from the same research area. Our main objective was to determine a relationship between the Synthetic Aperture Radar backscattering and the HEM's sea-ice thickness measurements using the data listed above. We projected the flights trajectories on the images obtained on the same dates, extracting the pixels pertaining to places where the sea-ice thicknesses were determined. We ascribed ice thickness values for each area covered by the pixel. A statistical analysis determined that the best ice thickness parameter within a pixel area is its mean. Linear regression is the best way to adjust the relationship between the pixel backscatter value and the sea-ice thickness contained within the pixel area. The Pearson linear correlation coefficient, resulting from parametric analysis, indicates a strong correlation (0.75) between backscatter and sea-ice thickness. However, the nonparametric Spearman analysis resulted in a low correlation coefficient (0.06), which may indicate that the analysed data consist of two distinct populations (e.g. first-year and multi-year ice). However, the Kolmogorov-Smirnov nonparametric analysis brought up the possibility that we might have not sampled the entire population. This could explain the no existence of sea-ice thicknesses values on the interval from -9.21dB to -1.35dB, which could lead to the low correlation coefficient in the Spearman analysis. We applied the linear **equation  $y = 0.6345x + 12.015$**  to the images, separating them into twelve classes: one for water and eleven to sea-ice, the latter in one-meter thickness intervals. The results enabled us to observe important oceanographic features such as open water channels, pressure ridges, sea-ice decay, icebergs motion (as indicators of currents, tides and winds), glaciers discharge, ice shelves disintegration, wakes and oceanic eddies. Based on the foregoing, we can say that, statistically, our results are robust and significantly, with a confidence level from 95% to 99%. The proposed equation is a first step to inferring sea-ice thickness from SAR backscatter coefficients.

## Results from atmospheric correction and geological mapping using airborne hyperspectral data in Antarctica

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As part of a collaborative project between the British Antarctic Survey, DRDC Suffield (Canada) and ITRES Research Ltd., (Canada) the first known airborne hyperspectral dataset was acquired over the Antarctic in February 2011. Multiple sensors were simultaneously deployed covering the visible-near infrared, shortwave infrared and thermal spectral ranges. Additional data was generated during a field campaign in January 2014, with the deployment of multiple ground spectrometers.

To enable quantitative analysis of surface properties using imaging spectrometry data the removal of atmospheric absorption and scattering effects is an essential pre-processing step. The implementation of a sufficiently accurate and robust atmospheric correction methodology is of critical importance in ensuring that the results from spectral and spatial analysis algorithms are as accurate as possible. However, whilst methodologies are well established for most environments, there is currently no published methodology for correcting airborne hyperspectral data in the Antarctic region.

Firstly, this study presents results from an investigation into the applicability of the standard atmospheric correction methodology. This methodology has been well researched but was developed in temperate regions; for the first time it has been applied to Antarctic airborne hyperspectral data. Secondly, following atmospheric correction, preliminary results from geological mapping algorithms using the unique Antarctic hyperspectral data will be presented.

## Counting baleen whales by satellite; problems and possibilities

Fretwell P, Staniland I, Forcada J

British Antarctic Survey

We describe a method of identifying and counting whales using very high resolution (VHR) satellite imagery in three case studies at South Georgia, Auckland Island and Península Valdés. The studies highlight the potential and the problems of counting marine mammals using satellite imagery. The most successful study was counting southern right whales in the Golfo Nuevo, Península Valdés. This species proved ideal as in the breeding season it spends a high percentage of its time near the surface in calm coastal waters. Here we found that automated methodologies could be applied in order to count the whales over large areas. Using WorldView2 VHR imagery we tested several methods of automatic detection and found that thresholding the “coastal band” ( a sensor that collects light from the far-blue part of the spectrum which allows us to see deeper into the water column) was the most successful technique. The main confounding factor in our attempts was sea surface roughness, which scatters light, prevents light penetration and the detection of underwater features. In essence, the technique requires the right conditions, in the right location, at the right time of year searching for the right whale. The use of satellite imagery to effectively count whales, and the future availability of even higher resolution satellites, if combined with synoptic ground truthing, could provide efficient, cost effective and accurate population estimates for southern right, and potentially several other species of baleen whales.

## The impact of early summer snow properties on land-fast sea-ice X-band backscatter

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Snow cover on sea ice and its impact on radar backscatter, particularly after the onset of freeze-thaw processes requires increased understanding. In this study, we present a data set that comprises in-situ measured snow properties from the land-fast sea ice of the Atka Bay, Antarctica, in combination with high-resolution TerraSAR-X backscatter data. Both data sets are discussed for the transition period from austral winter to summer (November 2012 - January 2013). The changes in the seasonal snow cover are reflected in the evolution of TerraSAR-X backscatter. We are able to explain between 62 % and 80 % of the spatio-temporal variations of the TerraSAR-X backscatter signal with up to three snow-pack parameters by using a simple linear model. Especially after the onset of melt processes, the majority of the TerraSAR-X backscatter variations are influenced by snow depth and snow-pack grain size and thereby imply the potential to also retrieve snow physical properties from X-Band backscatter.

## Facilitating quantification of vegetation cover in Antarctic Specially Protected Areas using satellite and hyperspectral remote sensing methods

Fleming A, Hughes K, Ireland L, Fretwell P

British Antarctic Survey

Regional climate change in the Antarctic may have impacts upon population size and distribution of biological species and the extent of natural ecological systems, including those protected as Antarctic Specially Protected Areas (ASPAs). Increasing temperatures accompanied by retreat of coastal ice and loss of snow cover will provide new habitats for expanding and invading flora. This so called 'greening of Antarctica' has a high profile in public and political arenas, but monitoring of changes is not widely implemented and is currently based on limited and inconsistent observations. No consistent monitoring data are available against which to measure change and assess predictions.

Previous work has established the ability of satellite remote sensing vegetation indices (e.g. NDVI) to detect sparse vegetation on the Antarctic Peninsula (Fretwell et al, 2011, Polar Biology). In order to establish monitoring data and provide the required level of detail necessary to monitor small changes in vegetation extent likely to be associated with progressive change from year to year, we analysed high spatial resolution multispectral satellite imagery for each ASPA that contains terrestrial habitat.

The resulting vegetation data is compared with airborne hyperspectral data and ground survey observations acquired during a campaign in 2011. The high spectral and spatial resolution of the hyperspectral data allows determination of the vegetation types detected and development of new indices that highlight other types of vegetation, including cryptogams, which critically are not identified by current vegetation indices.

This presentation will summarise the results of the ASPA vegetation survey and on going work using the airborne hyperspectral data and field spectroscopy to refine these techniques to ensure robust calculation of vegetation cover for all species. Developing these new methods for the vegetated parts of the Antarctic will support future wide application of new satellite sensors planned for launch this decade that will provide imagery with the required spatial and spectral resolution.

## **A novel set of normalized difference snow/ice index ratios for extraction of snow cover from the Antarctic environment using very high resolution satellite data**

**Jawak S, Luis A**

Earth System Sciences Organization (ESSO), National Centre for Antarctic and Oce

An array of novel set of normalized difference snow/ice index (NDSII) ratios are proposed using multispectral (MS) and panchromatic (PAN) images from WorldView-2 (WV-2) satellite data, for extraction of snow/ice surface area in Larsemann Hills, east Antarctica. The performance of various NDSIIs is evaluated qualitatively as well as quantitatively using reference ground truth data. Two most widely used pansharpening algorithms: Gram-Schmidt (GS) and Hyperspherical Colour Sharpening (HCS), were implemented for fusing MS and PAN images. Pansharpening algorithms were compared for NDSII-based snow/ice cover extraction to evaluate the consequent effect of fusion on spectral quality of sharpened images and on possible effect on information extraction. Our study provides an interactive method to determine the optimum combination of MS bands that enhances discrimination of snow/ice from the non-snow class by using the eight bands of WV-2. The error associated with NDSII customization were calculated by using root mean square error (RMSE) in extracted and reference snow cover area. Our quantitative evaluation of extracted snow/ice-covered area using NDSII showed that the HCS (RMSE: 1637.30 m<sup>2</sup>) performed better than the GS (RMSE: 1838.16 m<sup>2</sup>) pansharpening method. The study also revealed that band 3 (Green), 4 (Yellow), 7 (near-infrared-1), and 8 (near-infrared-2) provided a decisive tool for generating novel NDSII. Our research provides new facets to polar remote sensing research using very high resolution multispectral data, which is expected to contribute to our enhanced understanding of snow-covered regions.

## **Spectral bands of WorldView-2 satellite remote sensing data for semiautomatic land cover extraction in the Antarctic environment**

**Jawak S, Luis A**

Earth System Sciences Organization (ESSO), National Centre for Antarctic and Ocean Research (NCAOR), Ministry of Earth Sciences, Govt. of India.

This study evaluates the potential of very high resolution WorldView-2 (WV-2) satellite data for mapping the land cover classes present in the Schirmacher oasis, eastern Antarctica. The main purpose of this study is to investigate the popular supervised classifiers for the 8-band WV-2 data to extract the Antarctic land cover and compare their performance with the manually digitized land cover map as a reference data. After initial data preprocessing and pansharpening, the supervised classification using five classifiers -Parallelepiped, Mahalanobis Distance, Maximum Likelihood, Minimum Distance, and Spectral Angle Mapper- was conducted. An accuracy evaluation was carried out by estimating the bias and root mean square error (RMSE) values in classified area by comparison with the reference data. Results indicate that Parallelepiped classifier (bias: 48.92 m<sup>2</sup> and RMSE: 18.98 m<sup>2</sup>) and Minimum distance (bias: 40.13 m<sup>2</sup> and RMSE: 28.62 m<sup>2</sup>) were superior than the rest of the classifiers used in this experiment. The study also revealed that 8-band image data provides a decisive tool for satellite image classification and consequent land cover mapping in Antarctic environment. Despite the availability of the limited data, this experimental research provides new facets to image processing research in Antarctic environment which is expected to contribute to our better understanding of polar regions in near future.

## New insights into snow depth on Antarctic sea ice from satellite remote sensing

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Snow is an important component of the Antarctic marine cryosphere. Snow on sea ice increases the sea ice albedo, isolates the sea ice from the atmosphere and contributes to the Antarctic sea ice volume via snow-ice formation. Growth and melt of Antarctic sea ice is closely linked to the snow cover and its properties, mainly its depth. The physical properties of snow on Antarctic sea ice are much more variable horizontally, vertically and temporally than those of its Arctic counterpart. Relevant physical properties are depth, grain size, density, wetness, salinity, and temperature. These properties change in the complex interplay between atmosphere, sea ice and the underlying ocean. In contrast to the Arctic, Antarctic sea ice has a tendency for a close to zero or even negative sea ice freeboard. Therefore, sea water can infiltrate the snow basal layers or the ice-snow interface even can become flooded with sea water. This has immediate and also later consequences for the snow properties and also for the vertical structure of the sea ice.

These highly variable physical snow properties make retrieval of the snow depth from satellite measurements a difficult task. Satellite remote sensing of snow depth is possible using microwave radiometry using Special Sensor Microwave / Imager (SSM/I) and/or Advanced Microwave Scanning Radiometer (AMSR-E) data. By exploiting the difference in snow volume scattering at two different frequencies snow depths can be obtained up to about 45 cm. Several studies have underlined potential biases in snow depth derived this way. Recently it was demonstrated that an empirical relationship between snow freeboard and snow depth obtained from in situ drillings can be used to derive the snow depth on sea ice from satellite laser altimetry in the Weddell Sea.

In the present paper, this approach to retrieve snow depth is extended to the sea ice cover of the entire Antarctic. Snow depths around Antarctica for all ICESat measurement periods are calculated. Comparisons are carried out between the snow depth results and: 1) snow depth derived from AMSR-E and SSM/I data, 2) in-situ observations of snow depth from field expeditions, and 3) visual estimations of the snow depth from aboard ships according to the ASPeCt protocol.

## **Applications of high-resolution imagery for sustainable resource use and conservation in the Southern Ocean**

**LaRue M**

University of Minnesota

Population projections suggest continued decline of seal and penguin populations in Antarctica due to losses in sea ice extent and duration, coupled with impacts from commercial fishing for krill and ice fishes. Assessing population distribution, abundance, and change is therefore critical to sustainable resource management of the Southern Ocean. However, current methods to estimate populations are limited primarily by proximity to research stations; this means that most populations of krill and fish predators in the Southern Ocean are largely unknown with regards to distribution, abundance, and population trends. Remote sensing, via very high resolution (VHR) satellite imagery, of krill and fish predators is currently the only method by which regional- to global scale population data can be obtained. Because of the influx of recent research using VHR imagery to assess populations of predators in polar regions, the goal for this talk is to review the literature and discuss the implications for conservation and sustainable resource use in the Southern Ocean. I will review direct and indirect methods of estimating abundance from imagery, discuss results and lessons learned, and provide ideas for discussion of new directions using this “disruptive technology” as an important tool for sustainable resource management of the Southern Ocean.

## Characterization of surface features within ice-free areas of the northern Antarctic Peninsula region using RADARSAT-2 data

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The ice-free areas in the northern Antarctic Peninsula region are dominated by periglacial processes under the influence of maritime climate conditions, being this one of the fastest warming areas of Antarctica. Depending on the parent material, the effects of freeze-thaw cycles will influence the form and spatial distribution of surface features that will result in a mosaicked land surface cover. Satellite-borne Synthetic Aperture Radar data are ideal for characterizing and mapping remote areas with persistent harsh weather conditions and limited access. The objective of this work is to characterize surface formations within selected ice-free areas on Deception, Livingston and King George islands, using polarimetric RADARSAT-2 data. These data are combined with topographic cartography to include a detailed digital elevation model (DEM) to carry out spatial analyses of the ice-free areas and the distribution of the identified surface features. Polarimetric C-band data was acquired through the Canadian Space Agency for the different study areas. Pre-processing of these data included terrain correction with a DEM and geocoding as well as the application of speckle filters. Selected processing techniques were applied such as edge enhancement filter and texture analysis. Furthermore, polarization signatures were extracted for different regions of interest to distinguish surface covers according to the backscattering characteristics and for applying training sites in a supervised classification using the support vector machine algorithm. Field data and observations were obtained during several campaigns to acquire detailed surface cover data information as well as collecting soil and sediment samples. The field information was also implemented for validating the results obtained with the polarimetric data. The results show that a number of surface features were well identified according to backscattering properties and these could be associated to specific polarization signatures. Initial classification results show a complex spatial distribution of surface features occupying varying surface areas. The incorporation of DEMs for the different study areas greatly helps to separate the different features and associated classes according to topographic characteristics. These results could be useful for comparing changes with past results and future monitoring of geomorphological features affected by ongoing processes in ice-free areas of the northern Antarctic Peninsula region.

## Data fusion modeling approaches for tracking Adélie penguin abundance and distribution

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The Adélie penguin (*Pygoscelis adeliae*) has been identified as a key indicator species of the health and status of the Antarctic and Southern Ocean ecosystem, which is currently threatened by commercial fishing, a growing tourism industry, and the effects of climate change. Despite its central role in the decision-making process for conservation and management in Antarctica, data on Adélie penguin populations has been limited by logistical constraints and has been largely focused on the tiny fraction of its breeding population situated near permanent research stations. This situation is poised for change as the use of remote sensing technology radically transforms Antarctic ecology and management from a data poor situation to a data rich situation. At the same time, traditional streams of data from remote cameras and direct field survey continue to provide important information on the occupancy and abundance of Adélie penguins. I will discuss advances in data fusion through hierarchical Bayesian modeling that allow us to integrate multiple streams of data in a spatial explicit way that is easily scaled from individual breeding populations to biologically-relevant meta-populations to areas of interest for the management of Southern Ocean fisheries. Direct field measurements will neither be replaced by, nor relegated to validation of, remote sensing measurements. My talk will emphasize that these two approaches can and should be integrated in a synthetic model of population abundance and distribution that exploits the strengths of each and provides real-time information relevant to both basic research on penguin dynamics and applied questions important for resource management.

## Surface and sub-surface response of soils in the Antarctic Dry Valleys derived from full-polarisation Radarsat-2 imagery

McNeill S, Belliss S, McLeod M

Landcare Research

Current soil mapping around the Wright Valley (1, 2) uses high resolution satellite imagery to assist with field planning and investigations. Here, we consider the use of full-polarisation radar data to reveal characteristics of surface and sub-surface features. Radar can detect these in hot dry desert areas (3,4,5) and should be similarly useful in the cold hyperarid Dry Valleys where sub-surface soils are typically dry or frozen to depths of one metre or more. Without the typical strong sensitivity of radar to soil moisture in temperate and tropical soils (6) the backscatter characteristics should be useful for retrieving information concerning the surface roughness, the depth to ice-cemented permafrost (ICP) (7), subsurface density and, possibly, depth to halide layer and sub-surface soil moisture.

Radasat-2 fine beam SLC full polarisation data of part of the Wright Valley were collected on 7 April 2011. The ESA NEST software, combined with PolSAR-Pro, was used (8) to orthorectify to map space using both SRTM and a lidar-derived terrain model. A number of standard polarimetric decomposition products were formed from the imagery, in order to understand the types of scattering on the valley floor. Examples of such decompositions are the set of indices proposed by Cloude from the covariance and coherency matrix for incoherent target decomposition (10). Although a useful starting point for visual interpretation, we use them with caution since the Dry Valley soils are quite different to the temperate and tropical vegetation and soil environments for which they were developed. The primary questions are whether the radar scattering is a single-bounce, or whether a second scattering is evident from the ICP layer, and whether the sub-surface soil layer between the surface and ICP layer exhibits any significant effect.

The decomposition indices were investigated for a number of well-defined targets known from previous field surveys. Backscatter shows considerable variation spatially, associated with surface geomorphological features. Eroded slopes on the sides of the Wright Valley are darker than their surroundings; Pauli decomposition suggests single-bounce scattering from these areas. Within the valley floor, there is evidence of double-bounce scattering, suggesting that at least some is coming from the deep ICP layer. Flat areas suggest single-bounce scattering from a rough surface layer. In addition, backscatter from these flat areas shows some evidence of azimuthal orientational dependence; this is consistent with the orientational smoothness of surface rocks in this region as a result of the erosion effect of the dry katabatic winds.

These visual interpretations form the basis of a simple model for backscatter in the principal targets within the Wright Valley area. Results will be reported at SCAR-2014 meeting.

## Intersensor calibration between F17 SSM/IS and F13 SSM/I EASE-Grid data for the Antarctic continent

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We investigated snowmelt spatiotemporal variations in Antarctica, from October 1978 to February 2008, using microwave brightness temperature (Tb) data series recorded by the Scanning Multichannel Microwave Radiometer (SMMR) and the Special Sensor Microwave Imager (SSM/I). For time series analysis, the Tb from these two sensors must be recalibrated. So, we converted the SMMR, F11 SSM/I and F13 SSM/I data into F8 SSM/I equivalent values using the regression coefficients derived by Jezek et al. (1991) and Abdalati et al. (1995). In this process we used the F8 SSM/I data as a baseline. The F13 SSM/I data series ended in April 2009, so we used the Tb data recorded by the Special Sensor Microwave Imager/Sounder (SSM/IS) to monitor the snowmelt from December 2006 to the present. However, the F17 SSM/IS calibration regression coefficients were not previously calculated. So, we determined these calibration parameters for channels 19H, 19V, 37H and 37V, by inter-calibrating the F17 SSM/IS data with F13 SSM/I ones, and by overlapping observations between these sensors during the 2007-year (341 days), covering the Antarctic continental area. This investigation methodology followed these steps: a) a spatial random sampling approach; b) ordinary least squares (OLS) analysis for the four channels; c) transformation of SSM/IS data using the regression coefficients in the OLS equation. We used a spatially balanced random sampling algorithm (Theobald et al., 2007) implemented in ArcGIS to avoid spatial autocorrelation issues. We sampled pixels located only in the continental area, by using the Antarctic Digital Database (ADD) coastline as mask. The OLS models are based on the formula  $Y = \beta_0 + \beta_1 X$ , where Y is the F13 Tb in the channel,  $\beta_0$  is the intercept,  $\beta_1$  is the regression coefficient and X is the F17 Tb in the same channel, and were performed using R scripts. The resulting OLS models presented high performance ( $R^2$  higher than 0.98). The model parameters (intercept and regression coefficient) were respectively -0.394 and 1.015 (19H), -1.269 and 1.016 (19V), 3.446 and 0.979 (37H) and 1.185 and 0.989 (37V). All model coefficients were statistically significant (p-value lower than 0.0001).

## Snowmelt spatiotemporal variations in the Antarctic Peninsula in the 2008-2009 austral summer as derived from subpixel mixture analysis of F13 SSM/I EASE-Grid data

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We analyzed spatiotemporal variations in the Wet Snow Zone (WSZ) of the Antarctic Peninsula during the 2008-2009 austral summer. For this, we carried out a subpixel mixture analysis of the Special Sensor Microwave Imager (SSM/I) data, using F13 SSM/I EASE-Grid data (25 km) of microwave brightness temperature (T<sub>b</sub>) products for channels 19H, 19V, 37H and 37V. In the study area, we used a Spectral Linear Mixing Model (SLMM) of three endmembers, which were called as WSZ, Dry Snow Zone (DSZ) and rock outcrops. In this SLMM, the T<sub>b</sub> of each pixel (R<sub>k</sub>) in a given channel k is a result of a linear combination of each endmember (r<sub>k</sub>) spectral signature in this channel, weighted by the percentual coverage area (or fraction area F) of this component at each pixel of EASE-Grid images. This linear model can be expressed in matrix notation by:  $R_k = F \cdot r_k + E_k$ , where E<sub>k</sub> is the vector of the channel k residuals. The calibrated SSM/I F13 data (19 and 37 GHz channels) were compared to the components' proportion (fraction images) of the study area endmembers, derived from classified ASAR images on wide-swath mode (150 m). Sixteen endmembers ASAR fraction images and 16 registered F13 SSM/I images at the same acquisition period (2006–2007) were used in the SLMM to estimate the unknown spectral signatures. These spectral signatures were estimated based on the least squares solution determined by Haertel and Shimabukuro (2005):  $r_k = (F^T F)^{-1} F^T R_k$ .

The estimated T<sub>b</sub> in channels 19H, 19V, 37H and 37V were, respectively: WSZ (256.122; 269.679; 239.865; 251.192), DSZ (200.256; 227.464; 204.568; 224.161); rock outcrops (261.514; 287.697; 215.217; 227.824). The r<sup>2</sup> are higher than 0.98 and p-values lower than 0.00001 for all channels. The estimated WSZ summer fraction images were compared with correspondent ASAR fraction ones, and the average overall accuracy was 73% for class ranges of 0.2 (*i.e.*, each class represents 20% of one pixel). In the austral summer of 2008–2009, snowmelt areas covered more than 50,000 km<sup>2</sup> (about 9% of the Antarctic Peninsula) in late December and became lower than this value by the end of January. Pixels with higher and more persistent melting were observed in the Larsen C and Wilkins ice shelves. In the former, the WSZ fraction images showed values higher than 0.8 (*i.e.*, more than 80% of each pixel is a snowmelt area) during 20% to 40% of the 2008-2009 summer period, while the latter presented values of 0.8, reaching 57% in the same season.

## **Analysis of oceanographic and meteorological parameters as triggers to relevant break-up and calving events in the Wilkins ice shelf**

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Laboratory of Cryosphere Monitoring - FURG

This study aims to analyze the variability of oceanographic and meteorological parameters, sea ice concentration, superficial runoff and wet snow zone area, in order to understand their influence on major calving and break-up events in the Wilkins ice shelf between 1980 and 2011. The amount of water runoff from this ice shelf to the adjacent ocean, based on a surface discharge model, totalized 17,35 Gt over the 32 years analyzed. The wet snow zone reached the largest extension during the summer 1997/1998, when melt had occurred about 57 % of the Wilkins ice shelf, possibly contributing for the break-up event in the 1998/1999 summer. A wavelet analysis of oceanographic and meteorological parameters revealed variability periods of 2 and 4-5 years, indicating that events of basal melting caused by ocean warming may be triggering some of the break-up events of Wilkins ice shelf.

## Fully-automated high-resolution digital elevation model generation over glaciated regions from WorldView stereo pairs

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The monitoring of surface change in glaciated regions such as Alaska, Greenland and Antarctica is an important pursuit in climate-related Earth Science. Repeat Digital Elevation Models (DEM) created by photogrammetric surface extraction from a time-series of stereo pairs provide an efficient and low cost means for analyzing surface change over large, remote areas. Stereo-photogrammetric DEM extraction over glaciated regions is challenging due to typically low-contrast surfaces such as ice, snow, mountain shadows and steep slopes, resulting in large feature search areas and matching failures. A method for reducing the feature search area is critical for successful and efficient DEM extraction in this terrain.

The SETSM (Surface Extraction with TIN-based Search-space Minimization) algorithm is developed for overcoming these problems and performs surface extraction fully-automatically, without any user-defined or a-priori information, such as seed DEMs, using only the sensor Rational Polynomial Coefficients (RPCs) for geometric constraints. Rotation-invariant, multi-patch Normalized Cross Correlation (NCC) is used as its basic similarity measurement. SETSM constructs a TIN (Triangular Irregular Network) in the object-space domain in order to minimize the necessary search space. It employs a pyramiding strategy that uses iteratively finer resolution TIN's to minimize the search space and uses a vertical line locus to provide precise geometric constraints for reducing the search area. As a major benefit, SETSM relatively adjusts the Rational Function Model (RFM) between stereo pairs to reduce the offset between corresponding points projected by the vertical line locus caused by RPC errors, dramatically reducing the number of matching failures. In SETSM, this offset is iteratively removed with a parabolic adjustment of the NCC solution.

As a demonstration, Worldview stereo pairs for a variety of test areas in Alaska, Greenland and Antarctica are selected for creating 2m grid-spacing DEMs and validating the SETSM algorithm. Each DEM granule was mosaicked to a master grid by a simple height co-registration and split into 20 x 20 km tiles. Qualitatively, most surfaces in snow and ice-covered areas, mountain shadows and steep slopes are exactly reconstructed by SETSM. In addition, SETSM resolves edges and height of discrete features, such as icebergs, crevasses, rocks and streams at high detail. For analyzing DEM accuracy quantitatively, Operation IceBridge data is utilized for validating the height accuracy in Kangerlussuaq and Unmmannaq, Greenland. The RMSE mean and standard deviation without co-registration are 2.21 m and 1.47 m, and 1.75m and 1.82 m in rock area, respectively.

## Mapping of *Pygoscelis penguins* by using an UAV in the vicinity of southwestern King George Island

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At SCAR XXXII Delegates' Meeting in Portland the action group 'Development of a satellite-based, Antarctic-wide, remote sensing approach to monitor bird and animal populations' was established. The present study focuses on the enhancement of the methodological basement of such a monitoring approach.

A satellite based monitoring of changes in penguin colonies requires high-quality ground-truthing data to calibrate satellite images. Several scientists have provided such data since many years for colonies of small or medium size (<10.000 breeding pairs) by on-site counting or GPS-based mapping. However, for larger colonies (up to 150.000 breeding pairs) ground-truthing data can only be obtained by helicopter/airplane overflights, by panorama photography or by extrapolation of partial counting.

The use of UAVs could provide a precise and efficient method to carry out local population assessments by mapping penguin colonies even those of larger size. To proof and develop this method three colonies in the vicinity of southwestern King George Island were mapped in the 2013/14 Antarctic season by using an UAV. A visual and a thermal camera were used as sensors. At Ardley Island the detected nest groups of gentoo, Adelie and chinstrap penguins covered an area of 11,993 m<sup>2</sup>. Nestgroups of gentoo and chinstrap penguins at Narebsky Point have been found at 8,454 m<sup>2</sup>, while at Withem Island solely chinstrap penguins were breeding at 9,350 m<sup>2</sup>. Beside the collecting of ground-truthing data, using UAVs also provides the possibility to generate high resolution Digital Surface Models (DSM) which allow, a more precise orthorectification of satellite images. The results of these surveys will be shown; advantages, limitations and further applications will be discussed.

## **Orbital mapping of compositional variability in the Shackleton Glacier region, Central Transantarctic Mountains, Antarctica**

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The ability to remotely characterize spectral and compositional variations of ice-free Antarctic landscapes was recently demonstrated in the McMurdo Dry Valleys (Salvatore et al., 2013). In this study, we apply similar techniques to the Shackleton Glacier region of the Central Transantarctic Mountains (CTAM), where currently available geologic maps preclude detailed planning and scientific investigations. These efforts directly support the proposed 2015-2016 Shackleton Glacier deep field logistics hub that will serve detailed in situ scientific investigations throughout the region.

Ice-free rock outcrops in the Transantarctic Mountains provide the only accessible windows into the interior of the ice-covered Antarctic continent. These exposures, however, are remote and difficult to access. Geologic mapping completed during the 1960s identified major lithologic unit boundaries, but were unable to capture small-scale stratigraphic and compositional variability. Alternatively, the high spatial resolution, eight multispectral channels, and off-nadir pointing capabilities of the WorldView-2 satellite allows for detailed compositional investigations to be conducted remotely for ice-free regions throughout the Transantarctic Mountains.

Relative spectral variability (RSV) has been mapped from Amundsen Glacier to Beardmore Glacier, and the derived data products were made available to the scientific community in Q2 of 2014. The RSV product consists of three spectral parameters, combined in to a single color composite. The 908 nm absorption depth, the 546 nm absorption depth, and the 478 nm shoulder heights are rendered in the red, green, and blue channels, respectively. These parameters successfully highlighted major lithological variability throughout the McMurdo Dry Valleys, and their application to the CTAM region has shown similar scales of variability.

Ongoing efforts include (1) filling local and regional data gaps, (2) the development and testing of atmospheric correction techniques, and (3) the acquisition of laboratory spectra of samples collected throughout the CTAM region and currently stored in the Polar Rock Repository at The Ohio State University. The goal is to provide calibrated surface reflectance data throughout this region that can be verified and ground-truthed with in situ investigations.

## The thickness of sea ice derived from satellite altimetry in the vicinity of Antarctic ice shelves

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Sea ice freeboard and thickness in the vicinity of Antarctic ice shelves is modified by ice shelf water. Here we attempt to quantify the influence of the sub-ice platelet layer on satellite measurements of total freeboard and their conversion to sea ice thickness. The sub-ice platelet layer forms as a result of the seaward advection of supercooled ice shelf water from beneath ice shelves. This ice shelf water provides an oceanic heat sink promoting the formation of platelet crystals which accumulate at the sea ice-ocean interface. The build-up of this porous layer increases sea ice freeboard, and if not accounted for, leads to overestimates of sea ice thickness from surface elevation measurements. In order to quantify this buoyant effect, the solid fraction of the sub-ice platelet layer must be estimated.

An extensive in situ data set was measured in 2011 and 2013 in McMurdo Sound in the southwestern Ross. From the freeboard to thickness relationship we estimate a mean value for the solid fraction of the sub-ice platelet layer of 0.16. We test this value with independent Global Navigation Satellite System (GNSS) surface elevation data to estimate sea ice thickness. We find that sea ice thickness can be overestimated by up to 19 %, with a mean deviation of 12 % as a result of the influence of the sub-ice platelet layer. It is concluded that in close proximity to ice shelves this influence should be considered universally when undertaking sea ice thickness investigations using remote sensing surface elevation measurements. Though its influence is predominantly local to ice shelf margins, its effects have been noted up to 100 km offshore.

Given this information we further investigate the ability of the European Space Agency's CryoSat-2 radar altimeter to accurately record the freeboard of Antarctic sea ice using different processing techniques. For this purpose surface validation data have been acquired along satellite tracks. We report the accuracies of the techniques, the influence of variable snow cover, and the relationship of freeboard to total thickness conversion.

## Characteristics of ice shelf and sea ice in the McMurdo Sound assessed by ground validated helicopter EM measurements

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Ice Shelves, sea ice, and snow are the most susceptible components of the polar cryosphere with respect to climate change. Interpretation and prediction of change require better understanding of how floating ice interacts with the ocean and the atmosphere. Most importantly, the thickness and consequently the volume of very thin ice are largely unknown, which still limits the interpretation of satellite data restricting conclusions as to why overall sea ice cover in Antarctica is expanding.

We investigate thickness, freeboard, and density of sea ice and ice shelf in McMurdo Sound and the western Ross Sea for the validation of satellite altimeter measurements like CryoSat-2. In this area ice shelf processes are known to significantly favour sea ice growth. Between 2009 and 2013 we used a helicopter-borne electromagnetic induction sounder (EM bird) to measure thickness and freeboard profiles across the ice shelf and the sea ice. Airborne data were validated with field measurements for ice thickness, snow depth and density, and thickness of the sub-ice platelet layer.

It is found that the EM sounder detects the presence of the sub-ice platelet layer, which is observed in areas of outflow of super-cooled ice shelf water. Using freeboard and thickness, the bulk density is calculated assuming hydrostatic equilibrium. Significant density steps are detected between first-year and multiyear sea ice, with higher values for the younger sea ice. On the ice shelf, mean bulk ice density in some areas is significantly higher than that of pure ice. Mean values of up to  $975 \text{ kgm}^{-3}$  can be explained by a combination of accreted marine ice, inclusion of glacial sediments, and subice platelets. Our investigation draws a picture of areas of basal freezing and supercooled Ice Shelf Water emerging from below the central ice shelf cavity. The implications for the interpretation of ice thickness retrieved from satellite measured ice freeboard are discussed.

## Retrieval of Adélie penguin distribution and abundance from Landsat imagery

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Distribution and abundance of the Adélie penguin, *Pygoscelis adeliae*, was mapped over the entire continent of Antarctica. To perform this task, an automated algorithm was developed to ingest Landsat-7 Enhanced Thematic Mapper Plus (ETM+) data, transform it as needed for analysis, and classify Adélie occupancy based on the spectral signature of guano. The classification algorithm was based on a training dataset covering Adélie penguin colonies plus other ground targets used as controls. The classifier was built specifically for the purpose of retrieving Adélie colonies from their surrounding environment, taking into account the unique physics and biology of the task.

Overall, 234 ETM+ scenes collected during the era from 1999 to 2003 were processed for a continent-wide retrieval. Excluding the Antarctic Peninsula, which was not included in the initial phase of development and testing, the Landsat retrievals successfully located Adélie penguin colonies that accounted for 96 to 97% of the population used as ground truth, with very low errors of commission (<1%) and omission (3-4%). Landsat retrievals indicate several populations that are significantly larger than published estimates, and Adélie penguin colonies were found that were previously unreported in the literature, including several on the Antarctic Peninsula. A strong linear correlation was found between retrieved colony area and population, with coefficients of determination  $r^2 > 0.8$ , and sometimes much higher, depending on the population dataset. This relationship was used to estimate Adélie populations in the newly discovered colonies.

Landsat Thematic Mapper observations over Antarctica began in 1984, and there is a good data record from the mid-1980s to the early 1990s, with the data record picking up again in 1999 and running to the present. Thus, the Landsat retrievals provide a promising approach for generating decadal population estimates of Adélie abundance on a regional and continent-wide basis for the past 40 years.

### 3D Antartida - Mapping and monitoring the ice-free areas of the Antarctic Peninsula region: from crowdfunding to data acquisition

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The Polar Research Group of the University of Lisbon has been studying the ice-free areas of the Antarctic Peninsula region for several years and conducting both field data collection with multiple techniques and also remote sensing imagery analysis. The recent technological developments of Unmanned Aerial Vehicles, allowing for fully automatic aerial surveying (photography and terrain modelling) and operation in moderate wind conditions allow for very significant advances in mapping and monitoring the fast changing ice-free areas of the Antarctic Peninsula.

3D Antartida is a crowdfunding project that aimed at the acquisition of an UAV in order to use it in the various research projects that our group is conducting in the Antarctic and the Arctic, as well as in the Portuguese mountains (Permantar-3, HiSurf-2, Contantarc-3, Holoantar). The aim was to obtain 20,000 euro for buying the UAV, while offering the funders a number of small prizes depending on the contribution, as well as a close link with the research group. The call for crowdfunding was initiated in December 2013 for a period of 40 days and we have been able to gather 21,800 euro supported by c. 300 people, including two main sponsors (Agencia Ciencia Viva and IGOT). The UAV was bought in early February and immediately integrated in the Antarctic campaign at Barton Peninsula (King George Island), with field testing and surveying taking place in late February and early March. The project also involves an educational component, including a blog with daily inputs from Antarctica, field trials in Portugal and visits to science centers.

The poster presents the overall organization of the project, the structure of the crowdfunding and also the preliminary results from the field surveys in Antarctica. It aims essentially at showing the SCAR community how such a crowdfunding initiative was implemented allowing for a boost in technology to be used in remote sensing field surveys by our group.

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## Modeling the distribution of *Usnea* sp in Hurd Peninsula, Livingston Island, Antarctic

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A strong control of winter snow cover on the spatial distribution of *Usnea* sp lichens has been reported in previous studies in King George Island (Antarctica): dense covers of this species occur mainly in convex relief sectors, such as rock outcrops or moraine ridges, where snow is swept away during the cold season. This suggests that a good mapping of *Usnea* sp lichens can be used as a proxy for winter snow cover maps, therefore using this lichen species as a bio indicator. Winter snow cover distribution is one of the key variables controlling ground thermal regime and consequently permafrost distribution.

This research conducted in Hurd Peninsula (Livingston Island, Antarctica) aims at mapping *Usnea* sp lichens distribution in order to derive snow cover information for use in the permafrost modelling that is being undertaken by the Climate Change and Environmental Dynamics Research Group at IGOT - University of Lisbon. Ground truthing georeferenced data was collected for various surface types, focusing on differentiating patches with lichens predominance versus surfaces with moss, debris, rock outcrops or sandy sediments. A QuickBird satellite scene with a ground resolution of 2.4 meters and RGB+NIR bands has been used to map the types of surface cover. Ground truth data was used to train the classifiers with different supervised classification algorithms. Maximum likelihood algorithm showed the highest accuracies with over 90% of overall accuracy. A map of the spatial distribution of *Usnea* sp. and a map of snow during the cold season are presented.

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## **S34: PRESENCE OF THE PAST & METHODS AND INNOVATIONS IN POLAR SOCIAL SCIENCES**

### **Listening in on Antarctic history: the verbatim records and sound recordings of Treaty diplomacy**

**Antonello A**

Australian National University

This paper is about listening in on Antarctic diplomacy. It is about two bodies of evidence. The first is a collection of documents created by the Conference on Antarctica in Washington, DC, in October and November 1959. Among other documents, this collection is composed of verbatim records of the words spoken by the delegates in the two committees that conducted the conference's work. The second is a collection of sound recordings made during the Canberra sessions (in 1978 and 1980) of the special consultative meetings to negotiate CCAMLR. Both of these sources have recently been released by the national archives of the US and Australia, respectively. This paper considers whether these verbatim records and sound recordings change the way we understand the history of Antarctic Treaty diplomacy. My argument is that these sources should make us reconsider the place of at least three issues in both Antarctic and diplomatic historiography. First, these sources emphasise the centrality of translation. Translation here has two registers: one is about translation between the four Treaty languages and the attendant issue of cross-cultural communication; and the other is the translation between science and scientists and the legal and formal language of international diplomacy. The second main issue these sources raise relates to rhetoric and the physical presence of the diplomat. How do these sources contribute to our understanding of the physical encounter and cultural forms of diplomacy? And the final issue is that these verbatim and sound records make us consider, once again, the specificity of language. Why were certain words and phrases chosen and not others? Both these sources offer new insights about the ways in which the national policies of each of the Treaty parties was articulated in the context of the conference room and the ways in which the divergent party views were negotiated into one text.

## The presence of the past: Antarctica in China's national narrative

**Brady A**

University of Canterbury

National narratives have an important role in state-building and creating national identities. They also have a flow on effect to foreign policy. China's predominant historical national narrative on Antarctica is one of being initially excluded and having experienced inferior status in Antarctic affairs; tropes that resonate with the wider national narrative on China's modern history of foreign exploitation and victimisation. The logical response to such a historical narrative is Beijing's present-day emphasis on the "right to speak up" (huayu quan) on Antarctica affairs and assertion of China's "rights and interests" (quanyi) in Antarctica. China is rapidly expanding its Antarctic capacity and assessing the opportunities it can derive from increased Antarctic engagement. In the process, as many other leading Antarctic players such as the United States, United Kingdom, Russia, and Australia have done (and continue to do); China is now incorporating Antarctica into its meta narrative on national identity, national interests, and the nation's global rise as an economic and political power. As a state where the media, culture, education, and historiography are under strict control from the ruling political party, this process is relatively obvious to observe in China compared to societies with a more open political environment. This paper explores "the presence of the past" in China's current Antarctic policy and overall foreign policy; locating this enquiry within a consideration of the part historical narratives have played, and are playing, in other leading states' Antarctic engagement.

## Antarctic value study: Making use of existing data in a framework of multidisciplinary theories and methods

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Many polar scientists have emphasised the significant role of Antarctica in Earth's ecosystem, thus underscoring its value to the human race. However, the values underpinning activities in Antarctica are not uniform. Growing commercial interests – such as tourism or fishery – are observed with great concern by some individuals, organizations, and governments. Recently, the question of the possibility of Antarctic mineral resource exploitation has returned to the forefront of certain discourses resulting in a scenario in which values clash. A study is currently underway to examine these conflicting values. The investigation uses a novel – for Antarctic research – set of data and form of analysis. The Antarctic Treaty Secretariat maintains an extensive collection of all papers and reports ever produced for Antarctic Treaty Consultative Meetings (ATCM) since 1961, as well as additional special and expert meetings to the ATCM, and meetings of the Committee for Environmental Protection (CEP) since its establishment in 1998. Papers submitted to any of these meetings, which may be authored by a single party or a coalition of multiple parties, provide indications of existing problems at a certain time, or bear witness to arguments for or against an issue at stake. Meetings' final reports, in turn, give a summary of the discussions and decisions made during the meetings. Together, the documents provide a rich source of political discourse in Antarctic affairs. Efforts to digitize the documents are making them now easily accessible online to the general public. Based on a framework of value and value-related theories borrowed from various disciplines within the social sciences and humanities, we will show how the existing data can be very fruitful for an Antarctic value study using political discourse analysis. In this presentation we will argue that an interdisciplinary approach presents the versatility necessary for the unique conditions of Antarctica – particularly due to its lack of a human indigenous population and single sovereign. We conclude that Antarctica is in fact an exceptionally good case for a value study that examines the relationship of human beings to the environment in general.

## Importance of contemporary historical perspectives for legal analysis of territorial claims in Antarctica

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In the legal study of state claims to Antarctica, the analysis and interpretation of historical expeditions and events are an important element of establishing 'effective occupation' of territory.

From a legal perspective, the work that historians partake in to interpret activities on the continent assist in building a hypothetical legal case for effective occupation of territory. While not a decisive element, the types of activities and the way in which they were undertaken are important to analyse the 'who, what, where, why and how' of activity in Antarctica, which assists in evaluating the legal validity of territorial claims.

As theories and principles of international law shift, so too does the emphasis upon historical research. This necessitates a revision and deeper insight into human activities in and around Antarctica. The information to be analysed includes, but is not limited to, accounts of multi-national scientific expeditions into the 'hinterland' of Antarctica, the building and location of old and new research stations, scientific exploration, industrial activities, and political statements made in relation to these activities.

This type of research requires the unique expertise offered by historians in order to present material in an accessible form, to answer legal questions of effective control, recognition, acquiescence and other elements. Like science communication, historical communication is also an area of importance to Antarctic affairs.

This presentation will address:

- the types of historical information required in a legal analysis of territorial sovereignty and why they are important,
- the ways in which legal interpretation of historical documents shift as principles and theories of international law change, and
- will suggest the ways in which historians can assist in presenting materials to make them accessible to multi-disciplinary researchers.

## Seven paths to cooperation on the ice

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International and interdisciplinary cooperation has been shown to be key for successfully tackling a range of environmental, social, cultural and economic issues. However, whilst all Antarctic Treaty System (ATS) signatories may agree on the value of scientific research, peaceful purposes and the protection of the Antarctic environment, plurality of stakeholder values can lead to alternative interpretations of agreed terms and diverse courses of action. In fact, environmental management has been deliberately fragmented by policy, national interests, and territorial sovereignty across the continent.

Cooperation in Antarctica may be of particular importance because of cross-continent weather systems, currents, common pool resources, features considered public goods, and the high mobility of some threatened species. To maximise successful research and implementation across the continent, decisions need to be made in the interests of all parties, working towards common goals in cooperative consensus.

Game theory can be used to demonstrate how actors (be they individuals, organisations or nations) may choose not to cooperate with each other in strategic interactions, even when it appears in their best interests to do so. Where there is no consensus or there is uncertainty over whether others will cooperate in return, actors may choose to act in their own self-interest and not cooperate, so as not to risk any act of cooperation not being reciprocated.

To tackle challenges in the unique environmental, physical and social conditions of Antarctica, we need to increase cooperation on and around the continent. The poster demonstrates seven paths to enhance cooperation on the Ice; repetition, reputation, network reciprocity, group selection, kin selection, laws and prohibitions, and incentives.

## How to implement the precautionary principle in Antarctic environmental protection

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The Precautionary Principle is an important legal principle in International Environmental Law, being accepted into many international legal instruments. However, there is no explicit article concerning this principle in the Protocol on Environmental Protection to the Antarctic Treaty (the Protocol), which has impeded the effective protection of the Antarctic environment. Some scholars noticed this gap but they did not put forward any systematic responses, beyond those focused on tourism activities.

The absence of this principle in the Protocol caused adverse effects in Antarctic management, of which, the most urgent, is the inability of managing cumulative effects. According to the Protocol, if an activity will have less than a minor impact, this activity may proceed forthwith without carrying out environmental evaluation. But if there were a series of minor activities that may accumulate to cause a more than minor effect, then the available regulations could not cope. It is uncertain that these minor effects will cause a more than minor or transitory effect immediately or in the future. Furthermore, this would raise a question of liabilities if these minor activities are carried out by different countries.

Different criteria of, and cognition to, environmental risks in different countries may also set back the effective application of the Precautionary Principle in Antarctica. Even in other areas, such as in North Sea, when the signatory states incorporated the Second North Sea Conference Ministerial Declaration into their domestic legislations, different states, including Germany, France, Belgium and the UK, made different regulations regarding the extent of scientific uncertainty. It is more obvious in Antarctica. In 2007, at XXX Antarctic Treaty Consultative Meeting, Italy put forward two Initial Environmental Evaluations for construction of an ice runway and restructuring work on a pier, some states declared Comprehensive Environmental Evaluation should be used to assess these activities.

Therefore, this paper discusses, firstly, whether the Protocol needs the Precautionary Principle to be made explicit, then rebuilds the current framework of the Precautionary Principle to make it more suitable for Antarctic environmental protection, and explores the possibility of setting up common criteria of environmental risks in Antarctica.

## China's biological prospecting activities in Antarctica and its management

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Biological prospecting has been one of the most important subjects in the Antarctic Treaty Consultative Meeting (ATCM) since 2002, considering both its abundant benefits for science and commerce and its adverse influence on the Antarctic environment. Compared with some developed countries, the intensity of China's biological prospecting activities in Antarctica is weaker and the amount of the patents applied by Chinese is fewer. There are no laws or regulations in China directly regarding biological prospecting in Antarctica. This essay analyzed China's current administrative management system and available laws, regulations and orders in China that would impose potential influence on biological prospecting activities in Antarctica, such as Patent Law of the People's Republic of China, Management Plan for Sample and Data of China's Polar Scientific Research (by State Oceanic Administration), concluded that these legal instruments had some problems in effectively and reasonably managing biological prospecting activities in Antarctica. In the end, some measures were put forward to help China administrative authority to improve its management of biological prospecting in Antarctic, especially by registration and records.

## The Macquarie Island penguin-harvesting controversy: Science, celebrity and media in a subantarctic wildlife campaign

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In 1901, Edward Wilson visited some abandoned sealers' huts at Lusitania Bay, Macquarie Island, while en route to the Ross Sea as a member of the British National Antarctic Expedition led by Robert F. Scott. In both his personal diary and his ornithological notes, Wilson expressed horror at what he saw: "the putrid remains of penguins ... the refuse of poor birds which had been boiled down for their oil." Railing against the "havoc made by these Penguin butchers," on his return he set about alerting scientists to this issue, addressing the 1905 International Ornithological Congress and the Royal Society for the Protection of Birds.

Over the next fifteen years, the cause was taken up by a diverse group of internationally famous men, including the explorers Douglas Mawson, Frank Hurley, and Apsley Cherry-Garrard; the wealthy and eccentric zoological collector Walter Rothschild; and the novelist H.G. Wells. Largely through their efforts, penguin-harvesting ceased in 1920, and the island was declared a wildlife sanctuary in 1933. While disquiet about commercial activities on the island had been expressed locally since the 1890s, it took a global media campaign to put an official stop to the subantarctic "Penguin butchers."

Drawing on diaries, published accounts and media reports, this paper looks at the factors leading to the banning of penguin-harvesting on Macquarie at a time when whales were being uncontroversially slaughtered in great numbers in the subantarctic. While arguments presented to scientific societies focused on ecological concerns, they were combined with claims of animal cruelty, and it was the latter that seem to have mobilized action. Many of the media campaigns focused on what we would now term animal rights, using highly emotive language to arouse readers' indignation at the treatment of the birds. The penguin-harvesting campaign might be seen as an early case of the celebrity animal rights activism, enacted through print media and public addresses. We show how difficult it is to disentangle science and emotion in this controversy.

## Gaussberg - An island in ice

Lüdecke C

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At the beginning of the 20<sup>th</sup> century, four expeditions joined an international meteorological and magnetic cooperation (1901-1903) to solve the question whether Antarctica is a continent or a frozen ocean. The first German South Polar Expedition was in good hope to make discoveries in the Southern Indian Ocean at 90° W south of Kerguelen, a starting point promoted by Georg von Neumayer since the 1870es. Oceanographer Otto Krümmel even proposed the possibility that in this area a ship frozen in like the “Fram” in the Arctic Ocean might drift to the South Pole pulled along

by an underlying ocean current and then reach open water in the Weddell Sea. However, instead of the wishful thinking of highly recognized German scholars, Erich von Drygalski's ship “Gauss” was beset by ice at the Polar Circle and did not move for a whole year. The only discovery within the white desert was an extinct volcano of 366 m height sitting exactly at the border where sea ice met inland ice 80 km south of the overwintering station aboard “Gauss”. This island surrounded by ice called Gaussberg was representing Antarctica for the German expedition. A base station was established at the foothill of the volcano for meteorological and magnetic observations and a detailed geological and photogrammetric survey was performed. Besides, the movement of the inland ice towards the coast was measured also. The paper explains the meaning of the discovery of Gaussberg at the time of imperialism. Today the mountain waits for being used as marker to investigate the actual height of the inland ice cap as indicator for climate change within more than 110 years.

**Southern Ocean and Antarctic; Law of the Sea Convention and Antarctic Treaty System:  
Conflict or consistency within the legal regime on the Antarctic Security**

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The legal regime of the Antarctic can be deemed as a unique one. That legal regime also covers to some extent the surrounding waters of the continent. No doubt that the Antarctic Treaty is to be considered as the start point of the formation of the above-mentioned legal regime, just as the Antarctic Treaty System to be taken into account as the means to strengthen and develop the evolving process of the Antarctic legal regime. One of the most significant dimensions of the Antarctic and the Southern Ocean legal regime, on the one hand, is the International as well as the internal security, of which has become even more important given the increasing development of the concept of the security in the recent years, and also has become more influential on other dimensions of the Antarctic legal regime. On the other hand, considerable parts of the Southern Ocean are still covered by the Law of the Sea Convention international legal regime upon which states are under obligation to comply with the relevant regulations on various subjects and rights and obligations vis-à-vis each other as well as relevant international organizations in certain areas of the continent. The Antarctic legal regime regulates the security aspects of certain areas of the Southern Ocean, however at some points it may not seem to be fully consistent with the Antarctic Treaty regulations and other instrument known as Antarctic Treaty System from the security perspective. Examining the security aspects of Antarctic and the Southern Ocean, this paper intends to illustrate a clear picture of the existing legal regime therein which will highlight the seemingly conflicting points of the two legal regimes, trying to introduce interpretations in order for the seemingly existing conflicts to be solved.

## Extreme environments and the shaping of scientific knowledge: The Royal Society expedition to Halley Bay

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During the 1957-58 International Geophysical Year, Antarctic research exploded at an international level. Throughout this period, many countries constructed research stations around the continent, most of which remain active today. However, the extreme, hostile, and alien environment of Antarctica greatly impacted the way that research scientists made observations, conducted their research, or even lived their daily lives. One of these research stations, at Halley Bay, was established by the Royal Society Expedition in 1956. Over the course of the next four years, this base produced a wealth of knowledge in the geophysical sciences, despite near constant interruptions from the physical environment. However, according to both a published memoir by meteorologist Joseph MacDowall as well as the scientific papers produced by the Expedition, the scientists and support staff at this station constantly devised novel solutions and adaptations to their methods and equipment in order to continue their research despite the extreme conditions. This led to a culture of scientific improvisation where rather than following standardized methodology, they were free to devise technological and pragmatic solutions that could allow them to complete their work. In addition, they were forced to coordinate together in many of their tasks, polishing their own observational skills and adapting them to the environment. Though one could argue that equipment could break down and need repair in field research in any part of the world, I will focus on not basic repairs to broken technology, but rather technological adaptations and behavioural readjustments forced by the extreme environment of the Antarctic. In this paper, I use methods from science and technology studies (STS) and the history of science and the environment to show how the material environment of Antarctica contributed to the production of scientific knowledge, as well as the unique ways that scientists negotiated with these environmental factors.

## From Shelter to Showpiece: The Evolution of Antarctic Base Design

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Gateway Antarctica

Habitation is a fundamental requirement for all other activities that take place on the Antarctic continent: without adequate shelter, scientists and support staff would simply not survive. Examining how Antarctic base design has developed from 1957 to the present can provide an insight into both the needs (material and social) of those who have lived on “the Ice”, and the ways humans have interacted with the Antarctic environment itself.

Many existing Antarctic bases were founded during the International Geophysical Year (IGY) of 1957-8 (49 bases). By the International Polar Year (IPY) of 2007-9, the number of bases had grown to over 60 and there had been marked developments in the design and build of habitation structures in Antarctica. While it is a misconception that the number of Antarctic bases has dramatically increased since 1957, what has changed is the technology available for building those bases and the design principles that are used to overcome the difficulties of erecting a human shelter in the hostile Antarctic conditions. As Sandra Ross points out in her introduction to the ‘Ice Lab’ Antarctic architecture exhibition, ‘it was only until recently that the mainstay of Antarctic Architecture was based purely on function; now, however, the region is a forum for design, technology and innovation.’<sup>1</sup>

This technology and innovation tells the story of how we think about, inhabit and interact with the southern continent. This project focuses on the changes in base design that occurred over the past 50 years, using scientific bases that have been newly built, rebuilt or substantially altered as examples, and asks what motivated each of these transformations. Whether bases were rebuilt, renovated or newly built, their design has responded to the challenges at hand. This paper presents a survey of the challenges encountered when dealing with human habitation in the Antarctic, including the physical environment and social, political and financial drivers, and examines how those challenges have been overcome in a range of ways.

<sup>1</sup> Ross, *Ice Lab*, Introduction.

## From the shortest day to the longest night: lessons in human behaviour and performance training from spaceflight

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Antarctica is a well-known analogue for spaceflight with regard to life sciences. Indeed, spaceflight stressors are commonly classified into four categories: environment, habitat, mission and social situation. Whereas the specificity of these stressors differs, this categorization also applies to long duration Antarctic missions. From our experience in the field, we noticed a discrepancy between Human Behaviour and Performance (HBP) training for space (even for short duration missions), and HBP training for overwintering in Antarctica. This is striking because, from our own experience and based on previous research on teams in extreme environments, psychological and socio-cultural factors are critical for individual and group success. There are many examples of exploration, including space exploration, that have failed due to human factors (Bishop, 2013). The aim of the present investigation was thus to compare the HBP training approaches from the National Antarctic Programs and the space agencies, in order to foster further collaboration and synergies between these different partners on the topic of Human Behaviour and Performance Training by making a state of the art available to all parties.

For the data collection on the Antarctic part, an exploratory qualitative questionnaire survey was conducted on voluntary basis amongst the national delegates to the Joint Expert Group on Human Biology and Medicine from the Scientific Committee on Antarctic research, for the nations with stations operating all year. The delegates from the following nations provided the requested information: France, Germany, New Zealand, UK and Ukraine. Data collection for the Space part included formal documents with regard to international collaboration among International Space Station partners and the communications of the Interagency Working Group on Human Behavior and Performance Training material, as well as personal interviews with national experts in the field.

There is a clear cultural impact on the HBP approach, ranging from an experience based, informal German strategy applying selection and training in the same environment, to a formalized and outsourced to an accountable external partner NZ strategy for the psychological selection. With regard to psychological training, some nations do not include any formalized approach to it, whereas Ukraine uses both classroom teachings and a psychophysiological approach. As such, we find a far less “unified” view on HBP in the different national Antarctic programs than in space agencies, where the common work environment (ISS) has pushed the international partners towards collaboration. Unlike these standardization and collaboration efforts undertaken by space agencies, no international initiatives exist so far to pool resources to cope with these phenomena in Antarctica. The similarity between the challenges of long duration spaceflight and overwintering warrant that similar approaches may be needed in the psychological preparation of both.

## **The influence of Soviet Antarctic expeditions on the future of Russia's Southern Polar interests**

### **Prior S**

#### Prior Group

Russian interest in Antarctica is usually dated from the discovery of the continent by the expedition of Bellingshausen and Lazarev (27 January 1820). Russian involvement in Antarctic activities began over a century later. From the beginning Russia consistently opposed territorial division of the continent and argued for management by special international regime. A foundation supporter of the 1959 Antarctic Treaty, Russia has hewed to this policy since.

Pursuit of Russian national interests evolved over the decades, covering the continent and the surrounding Southern Ocean – through whaling and fisheries, and, under the Antarctic Treaty regime, through fisheries (fish and krill), science, and environmental management. These activities can be grouped into three distinct phases, which can be characterised as: reconnaissance, exploration and familiarisation (1955-1969); studying and mastering the resource potential of the continent and the Southern Ocean (1970-1991); and, the refocusing of Russian Antarctic efforts aimed at returning Russia to the status of a leading Southern Polar power, following the collapse of the Soviet Union (1991 to the present).

The Soviet intellectual, policy and practical Antarctic and Southern Ocean heritage underpins Moscow's approach today. This paper examines how Russia's regional policy towards the Southern Polar region is developed in parallel to, but is distinct from, its policy towards its Northern Polar interests. Its aim is to demonstrate Russia's status as a global power with a right to be intimately involved in addressing the most important challenges faced by the global community. Russia's Antarctic policy programme is seen as one of a trio of programmes – the others are nuclear and space – which demonstrate to the global community Russia's ability, and right, to address matters of global importance which cannot be limited by territorial boundaries.

## Cold comforts: Balancing the needs of Antarctic stations inhabitants

### Rack U

Gateway Antarctica, University of Canterbury

In the early days of Antarctic exploration, accommodation on the continent was by no means luxury but rather an extreme version of housing. While rough circumstances were acceptable, expedition members tried to make their accommodation as 'homey' as possible (furnishings included pianos for example, libraries were included, and customizing one's own space was often undertaken by the men).

Today's Antarctic stations are still working environments in a remote location. But, it has become important for the comforts of the inhabitants of the stations to be recognized and implemented into design and build. There continues to be a balance between "too comfortable" and "too rough". The balancing act has meant that many different concepts have been tried.

Our expectation on living space has changed since the Heroic Age; however, some perceptions are consistent (perception of security for example). The demands of workspace has also changed and therefore it has to be taken into consideration when planning and fitting a station today. The separation of working space and private areas is now usually considered in the station plans. The shape of rooms, colours and the practicality of interior is also an important issue today. For long term station stays, stimulation of inhabitants is important because daily routine can have effects on personnel psychological and physical wellbeing.

This poster will examine a few examples of how the needs of Antarctic station inhabitants influence the creation of the living environment and how that creation can have an impact on the individual in such extreme locations. It complements the work of 'From Shelter to Showpiece: The Evolution of Antarctic Station Design'.

**"Blizzard blowing again and considerable discomfort on board as usual." Personal accounts of weather as scientific data, and the weather's influence on expedition members during the Heroic Age**

**Rack U**

Gateway Antarctica, University of Canterbury

Diaries and logbooks are a valuable source of scientific and historical data on weather phenomena and the weather's impact on members of the early Antarctic expeditions. Dr Edward Wilson (Discovery Expedition, 20<sup>th</sup> August 1902) noted in his diary "Blizzard blowing again and considerable discomfort on board as usual." Wilson's observations, as a naturalist and medical doctor, were both astute and analytical and are recorded in his diaries, scientific records, and in numerous watercolours and drawings. In addition to the officers and scientists, there is also documentary evidence available from ordinary crew members.

This paper presents preliminary results from an investigation of the relationship between ambient weather conditions and elements of the social climate such as inter-personal interactions between members, variations in group dynamics, and individual physical and mental wellbeing. A range of personal accounts have been compared with the recorded temperature and pressure measurements published in official reports from the same time. Preliminary analysis of the official expedition accounts demonstrates a distinct correlation between the perception of temperature and wind as recorded in the diary entries and the actual weather phenomena as reported. However, further examination of other published and unpublished diaries - to get a more representative account - reveals the different ways in which the weather influenced individual expedition members and even affected the expedition itself. One example is the account from Hartley Ferrar (geologist of the Discovery Expedition 1901-1903) who often mentioned headache when there was a strong wind recorded.

The source information comes in two main formats: tables and charts, and written accounts such as diaries and letters, many of which are handwritten. Transcribing, and in many cases translating diaries and letters requires time, patience and expertise. However, this process can sometimes be assisted with e.g. optical character recognition (OCR) software, albeit that an expert review is still required to confirm the programme's results. The resulting digitised and edited information can then be used by a wider community of researchers that will have their own methodologies and research questions concerning the material. How this can be done in an accurate, efficient and practical way will be outlined and discussed at the workshop "Connecting the past – present – future: studies and methods in history for Antarctic research and science".

## Archaeology and the master narratives of Antarctic History

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The aim of this paper is to present material culture studies and historical archaeology research on 19th century sealers and whalers in the South Shetland Islands as a point of rupture for the thought schemes that are implicit in the master narratives of Antarctic History.

The Antarctica was the last continent to be incorporated to the space dominated by modernity. Its official discovery, at the beginning of the 19th century, marks the beginning of a history that presents certain particularities, not only in its content, but also in the way that it is usually told. Some versions of this history are more extensively distributed and known than others, as well as being more widely accepted. The recurrences – in form and in content – construct and structure the master narratives of Antarctica. The master narratives produce and reproduce the visible history of Antarctica. This way of looking at the past has been accepted as the truth and assumed as representative of everything and everyone. The master narratives of Antarctic past present a conceptualization of Antarctic History, in terms of exploration vs exploitation. These narratives are discursive formations that represent a specific version of the continent's history, which operate in written and material dimensions. Written and material dimensions of the master narratives offer the same version of the past. The stories related to scientific exploration are "preserved", by celebrating specific events, dates, personalities, and specific locations; whereas stories associated with the exploitation of Antarctic resources have been, and are still, silenced and forgotten. It is worth mentioning that many of the stories of sealers and whalers of 19th century carry no specific protagonists, exact dates, or apparent "historical relevance" to be commemorated. Even if there are numerous material remains widely dispersed, they are scarcely considered in the conservation agenda for Antarctic Heritage.

Historical archaeology research on sealers and whalers in the South Shetland Island during 19th century is seen here as a different standpoint, focused on the study of processes, working with the material remains of ordinary people and their everyday life, incorporating new characters and invisible stories into the history of Antarctica

**Can the transects followed by the different voyage to Wilkes/Adélie Land Coast document the rhythm of the Mertz Glacier calving?**

**Sultan E**

MNHN

Since Mertz calving in February 2010, drastic change in East AA has occurred. As a result the change in the ice condition impose new routes in the vicinity of Commonwealth Bay and Dumont D'Urville for both supply or research vessel such as the Aurora Australis (2011, 2012), the Tangaroa (2013), the Akademik Chokalskiï (2014), the Astrolabe (2011, 2012, 2013, 2014).

The routes are registered in the logbook of the different vessels for recent expeditions and for the more oldest survey as the ones led by Dumont d'Urville for France and Wilkes for the US both in January 1840. It is clear that the ice condition faced by the recent expedition are totally different compare to the ones faced by the Australasian Antarctic Expedition led by Mawson between 1911 and 1914.

The aim of this study is to gain information on the ice condition change using the logbook and explorer's diary in the vicinity of the Mertz Glacier polynya and Adélie Land.

First we present the different voyage conducted in the area. We then describe the ice condition information from the logbooks, the diaries we collected so far. Those results are discussed using other data that gives evidence on the ice condition such as Mawson hut and Dumont D'Urville weather station, teledetection and breeding success.

An estimation of the evolution of the Mertz glacier tongue and thus its polynya is proposed based on this material.

## Land-based and adventure tourism: An eternal challenge for the Antarctic Treaty Consultative Meeting?

**Wainschenker P**

Secretariat of the Antarctic Treaty

Antarctic tourism has been an important matter of consideration and discussion at the Antarctic Treaty Consultative Meetings (ATCM) for many years. ATCM IV (1966) introduced the topic of tourism and non-governmental activities as a formal Agenda item of the ATCM, which it remains today.

During its early years, the ATCM agreed to various recommendations and guidelines to ensure that Parties took precautions to avoid the occurrence of impacts on scientific activities and the environment by tourist groups visiting Antarctica. However, though adventure tourism and land-based tourism were discussed at various ATCMs, these issues did not begin to be considered more formally until the Meeting of Experts on Tourism in 2004; and they continue to be drawn into question today. Within the consensus-based Antarctic Treaty system, pending issues on jurisdiction, differences in national legal systems, and a lack of definitions of “adventure tourism” and “land-based tourism” have all played a part in delaying government action.

Therefore, in its Multi-Year Strategic Work Plan adopted in 2013, the ATCM committed to review and assess the need for further actions regarding area management and permanent infrastructure related to tourism, as well as issues connected to land-based tourism and adventure tourism. Additionally, the Meeting agreed to give a particular focus at ATCM XXXVII (2014) to issues related to land-based and adventure tourism, and tasked its Secretariat with producing a digest of previous ATCM discussions, Measures and Resolutions on these matters.

Recognising land-based tourism and adventure tourism as unsolved and recurring themes, this paper reviews and summarises the proposals, discussions and decisions which have taken place on these matters from 2004 to the present. It also addresses the challenges that the Treaty Meeting may face in the short term with regard to these issues.

## **S35: ANTARCTIC EDUCATION, OUTREACH AND TRAINING**

### **The Uruguayan Scientific and Environmental Antarctic program**

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Instituto Antártico Uruguayo

The global information on national scientific programs is mainly managed by the Antarctic administrators and various international bodies, however, many times that information does not reach the researchers.

The Uruguayan Scientific and Environmental Antarctic program (PCAAU) consists of a set of research activities promoted, coordinated and supervised by the Uruguayan Antarctic Institute (IAU), following the national policies in science from the Ministry of Education and Culture.

Uruguay has an Antarctic Scientific Base (BCAA) on King George Island since 1984 and has developed scientific activities. From that date to present, Uruguayan researchers from different academic institutions and services have maintained a continuous activity, covering several areas of knowledge.

In the last years, Uruguay has reorganized the activities of Antarctic research and has qualified in Activities of Investigation, Institutional Activities of Investigation and Scientific Projects.

The IAU makes a public and open call to present research proposals. A Scientific Adviser Workgroup, evaluates the scientific and technical contents and selects the more suitable proposals. The Directing Council of the IAU approves the execution of the projects and activities selected. Currently the PCAAU is integrated by 10 institutions that include 11 projects, 5 institutional and investigation activities with the participation of 67 investigators and the attendance to the BCAA of 30 investigators. Following SCAR's guidelines, young researchers take part with works of thesis degrees. In the same way, international cooperation projects have been promoted. The areas of knowledge currently developed are: Microbiology, Ecology and Limnology, Earth Sciences and Social Sciences. The perspectives for the immediate future are to increase the number of calls for research projects funded by the National Agency for Research and Innovation and the remodeling and refurbishment of laboratories in BCAA and ECARE.

Implementing these measures the Uruguayan Scientific and Environmental Antarctic Program may improve both in terms of quality and number of participants and move towards international cooperation activities with other countries programs.

In the field of education and training of young researchers, the first introductory course in Antarctic research took place in Artigas Antarctic Scientific Base, in agreement with the Faculty of Science, where 17 students and 5 professors participated.

## **The role of Higher Education Institution (HEI) in promoting and strengthening the National Antarctic Research Programme in Malaysia**

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Sustaining Malaysia's agenda in Antarctic requires a strategic plan due to research involvement that needed enormous financial resources and a long-term political commitment. A long-term involvement, commitment and interest from various stakeholders such as higher education institutions (HEIs), industries, NGOs and local public are crucially needed to support the National Antarctic Research Programme. Since teaching, research and community engagement are the core business of HEIs, it is most appropriate for the HEIs to play a greater role in promoting awareness and research on Antarctic. Lack of interest among local public is also one of the major challenges in sustaining the national agenda on Antarctic. To date, there is no such study and assessment has been conducted on the need and capacity of stakeholder on Malaysian Antarctic Research Programme. The objectives of the study are to identify the perception on Malaysia Antarctic Research Programme among school student and HEI's student sustaining the National Antarctic Research Programme of Malaysia. This paper also will identify the gaps in delivering Antarctic's knowledge in Malaysia and getting public engagement to support and strengthen the National Antarctic agenda. A survey on Malaysia's young generation perception on Antarctica has been conducted for the mapping out of the future landscape of Malaysian involvement in Antarctica programme. This study shows that the positive and strong support from the young generation sustaining the Malaysia Antarctic Research Programme.

## Joint Antarctic School Expedition - A model in international collaborations

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In February 2014, three United States high school students, a high school science teacher, and a National Science Foundation (NSF) Einstein fellow, traveled to Chile to participate in an international collaborative program, called “Joint Antarctic School Expedition (JASE)”. This program allowed students and teachers from the United States to travel to Chile to learn about the research being conducted in Antarctica and the logistics involved in supporting the research.

In Chile, the JASE participants joined Chilean students and teachers sponsored by INACH (the Chilean Antarctic Institute). For 10 years, INACH has sponsored a program for high-school students, which is aimed at building Antarctic research capacity in Chile. In 2014, the Chileans invited US participation in this program in order to strengthen science ties for upcoming generations.

INACH brings participating teachers and students to the Chilean scientific research base on King George Island, Antarctica. On King George Island, students have hands-on experiences conducting experiments and learning about field research. While the total number of students involved is relatively small, the partnership is building critical science research capacity within Chile in a manner that helps to foster continuing access to Antarctica for the US scientific research community.

Research experiences for students, like JASE, are important as they influence new direction for students in science learning, science interest, and help increase science knowledge. In this presentation, we will share additional details about the experience as well as discuss how student research experiences help international collaborations.

United States participation was funded by the NSF Division of Polar Programs and administered by the Arctic Research Consortium of the United States (ARCUS), a non-profit organization in Fairbanks, Alaska.

## Giving a voice to Polar science - teachers as communicators

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PolarTREC—Teachers and Researchers Exploring and Collaborating, a teacher professional development program, began with the International Polar Year in 2004 and continues today in the United States. In 2007, the National Science Foundation designated PolarTREC as potentially transformative, meaning that the “research results often do not fit within established models or theories and may initially be unexpected or difficult to interpret; their transformative nature and utility might not be recognized until years later.”

PolarTREC brings United States K-12 educators and polar researchers together through an innovative teacher research experience model. Teachers spend three to six weeks in remote arctic and Antarctic field camps. Since 2007, over 100 teachers have been placed in field experiences throughout the Arctic and Antarctic and with half of them participating in field experiences in Antarctica. Experiences in Antarctica ranged from working on research vessels in the Southern Ocean to field work in remote regions of the Dry Valleys as well as along the slopes of Mt. Erebus. During their field experience, teachers become research team members filling a variety of roles from research technician, manual labourer, educator, data enterer, field researcher, observer, to instrument operator. They also fulfil a unique role of public outreach officer, conducting live “polar connect” presentations about their field site and research, keeping a web-based polar journal, answering student and others’ questions, and posting pictures of their daily experiences.

Evaluation data collected over the past eight years on program participants shows that PolarTREC has clearly achieved its goals and strongly suggests programs that link teachers and researchers can have the potential to transform the nature of science education. By giving teachers the content knowledge, pedagogical tools, confidence, understanding of science in the broader society, and experiences with scientific inquiry, participating teachers are using authentic scientific research in their classrooms. Not surprisingly this has also led to increases in student interest and knowledge about the Polar Regions.

In this presentation, we will highlight the best practices of teacher research experiences as well as discuss why it is vital to have teachers and researchers work together to communicate science to the broader public.

## Who wants to know Antarctica? APECS-Brazil will guide you through this adventure!!!

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How hard and pleasant can promoting polar science be in a tropical country? How challenging and lengthy will it be to involve educators, students, scientists and general public in a country as large as Brazil? What we are learning by challenging the knowledge of children and teenagers about regions as far as Antarctica? We did not even come close to know the answers to these questions when APECS (Association of Polar Early Career Scientists) established a national committee in Brazil in 2008. Although Brazil has performed activities in Antarctica since 1982, APECS-Brazil (Association of Polar and Marine Early Career Scientists and Educators) was the first organized group in polar and marine issues to encourage the formation of new leaders in science, education and governance through science dissemination providing Education and Outreach (E&O) activities. In 2013 our main activities were lectures, educational/entertaining activities, media releases, participation/organization of Workshops and Symposia, meetings with government officials, submission of grant projects to funding agencies in order to raise and widen our E&O activities. There are many activities all year round, but we focus the efforts on Early Career Scientists and educators on three main occasions, following in the footsteps of APECS international. In March and September of each year we celebrate the International Polar Weeks (IPWs), having APECS Portugal and APECS Spain as key partners. In December 1<sup>st</sup>, we celebrate Antarctica Day, disseminating information especially through educational institutions to publicize the importance of Antarctica and of the signature of the Antarctic Treaty. Ten IPWs have been organized and we are organizing the 11<sup>th</sup> for March 2014. Our main event so far was the formalization of APECS-Brazil in September 2013. Alongside the X SPI we organized the 1<sup>st</sup> APECS-Brazil Workshop for Career Development, bringing together researchers and educators from Brazil and abroad. The event was live streamed for the first time, with over 10,000 students from elementary to high school from all over Brazil taking part. Brazilian society knows only the top of the iceberg and our steps represent the beginning of a great journey into the unknown world of the poles. We are boarding into the unknown, pioneering new perspectives, and APECS Brazil is supporting each step of the discovery of these new horizons, providing an example to other countries interested in E&O in Antarctica.

## First Uruguayan Antarctic Research School: training the next generation of Uruguayan Antarctic researchers

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The Faculty of Sciences from Universidad de la República (UdelaR), Uruguay, organized the First Uruguayan Antarctic Research School held at Base Científica Antártica Artigas (BCAA), at King George Island, Antarctica. From a pool of 52 applicants, the student list for this course was narrowed down to 16 advanced undergraduate university students of Biology, Biochemistry, Human Biology, Natural Resources and Geology programs. The main aim of this 2-week school was to promote Uruguayan Antarctic Research among future scientists by providing a comprehensive view of ongoing multidisciplinary Antarctic research projects. The course consisted of theoretical lectures and practical sessions both field sample collection and laboratory work. The course was subdivided into 5 modules that covered a broad range of cutting-edge Antarctic topics:

1) Aquatic ecosystems, where the focus was to introduce the students on Antarctic subglacial lakes exploration, regarding the current state of knowledge and challenges. Students collected water samples from lakes near the BCAA, along horizontal and vertical transects, to investigate its physico-chemical characteristics.

2) Antarctic climate evolution, in which we reviewed the climate of Antarctica on several temporal scales, beginning from the continent's origin in Gondwana to recent environmental change. Students took sediment cores from Lake Uruguay and completed a paleolimnological study in order to illustrate the potential of such research for understanding past environmental and climate change in Antarctic ecosystem.

3) Biochemistry of microorganisms, focusing the training in: (i) the analysis of the bacterial diversity with a genomic approach, (ii) the isolation of microbes that produce cold-active enzymes with potential biotechnological applications, using worm-guts as biological material and (iii) using rapid diagnostic kits from Anigen, to study the possible presence of Newcastle Disease virus and Influenza A virus in depositions and fecal samples of penguins and skuas and Rotavirus in mammal populations.

4) Polar invertebrates, devoted to different aspects of the biodiversity applied to Antarctic lower animals. One is the concept and record of alien species in Antarctica. A subsidiary aspect of this is the novel report of a terrestrial non-indigenous species at King George Island (maritime Antarctica). A second aspect is devoted to a survey of the diversity of soil fauna associated to *Deschampsia antarctica* at Fildes Peninsula. A third topic concerns with the marine snail *Nacella concinna* which is a candidate for environmental studies as a sentinel species.

5) Human circadian rhythms challenged by the Antarctic environment, in which we followed the rhythms of activity and sleep-wake cycle of 16 students and correlated the impact of abrupt temperature and exposition to extreme photoperiod with melatonin and cortisol measurements in urine and salivary samples, respectively.

We have found this initiative suitable and successful for promoting national Antarctic research, the training of young scientists and their career development.

We acknowledge support from Instituto Antártico Uruguayo.

## Antarctica's images and sensations: researches about communication, multimedia, art and science

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This interdisciplinary study discusses Antarctica's images with different researches areas like communication, art and science. Our aim is to think about artistic and aesthetic expressions as political action and engagement in the world through opportunities for knowledge seeking approaches to sensory experience. In this way, we are studying authors and theoretical lines that consider images while blocks of sensations as suggest Deleuze and Guattari (2004). Faced with these theoretical perspectives, we seek contact with works of art, photos and videos to analyze the relationship between image, aesthetics, politics and different possibilities of knowledge. This proposal focused the studies on a multimedia art installation Terra Nova: Sinfonia Antarctica, produced by Paul Miller (DJ Spooky), which has been a wide international circulation. In this installation, Miller explores the Antarctic environment as images that transform into soundscapes, using the concept of remix, originating from electronic music, to compose a multimedia space where images and sounds created and recreated multiple compositions. The installation aims at provoking tensions and imbalances in the idea of "Antarctic Territory" fixed and pre-defined by common ideas and clichés often used by the media, and tries to compose an open to different meanings and sensations image-sound space. Terra Nova: Sinfonia Antarctica was established as a multimedia environment to be discovered by our senses and experienced by colors, shades, intensities, noise, that cut across the existing Antarctic and which may exist, releasing us to unpredictable sensory streams. In our studies, creations and artwork, we seek out different possibilities for generating knowledge from sensory experiences, contributing to the development of new betting creations and interdisciplinary research, broaden ways of scientific communication and outreach. These studies integrates the activities and research of the interdisciplinary group multiTÃO: prolifera-artes subvertendo ciências e educações (CNPq) from University of Campinas (Brazil), and the subnet "Scientific Communication and Climate Change from Brazilian Research Network on Global Climate Change (Rede CLIMA). This PhD research is support by **National** Counsel of **Technological** and **Scientific Development (CNPq)**, Brazil (nº: 140575/2013-8).

## Distance education, bringing the Antarctica to population

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Antarctica is a place without major modifications, it is the most preserved area of the planet but is also one of the most vulnerable place to global environmental change, because climate signals produced in Antarctica influence in other continents and vice versa. So it is very important to know all features related to such processes. Studies of different sciences have been conducted in the last decades, highlighting the growing interest of the scientific community and the world in general.

However, all these studies have been producing knowledge for what and for whom? It is not only important to reach beyond the scientific universe but also to the society, whether as a formal or informal information or as an opportunity for global environmental conscience, because for many people Antarctica is an isolated and inaccessible continent.

The knowledge about Antarctica is not yet part of the principal curriculum for basic education in Brazil. Thus, natural science teachers have little or no information and therefore no material to work with in the classroom, in addition to not being properly prepared and methodologically equipped to teach the issue. Hence it is very important to create a communication course for the insertion of Antarctic theme in the formation of Brazilian citizens, either through formal or informal.

This paper presents the process of developing a distance course for elementary school teachers in order to enable them to work the Antarctic themes: geography, climate, history of discovery, biology and the importance of Antarctica to the planet. The first class was developed in order to understand the process and technical requirements for its implementation. In Brazil, the Distance Education (DE) has been the primary means of initial or continuing training for thousands of teachers, each year. That's because the DE allows bringing knowledge to remote regions and offers flexibility of time and place of study.

The course will be placed in an interactive virtual learning environment, it will have 40 hours and course participants will have access to video classes, courseware and interactive materials that could be used in classrooms and methodologies that could be replicated with students, such as collaborative activities and project pedagogy.

It is an opportunity to strengthen the knowledge of the society about the importance of research on Antarctica and the relevance of this continent to the planet.

## **Fish beneath the ice - a video documentary**

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In recent years, outreach and communication of polar sciences to a wide audience have been acknowledged as priorities for the Antarctic scientific community. One of the basic need to improve the effectiveness of knowledge transfer and dissemination is the availability of educational products being at the same time engaging and scientifically rigorous.

In the frame of the educational project "Communicate the polar science. Fishes of Antarctica" (Italian National Programme for Antarctic Research, PNRA), and as core activity of the project, we realized the documentary movie "Fish beneath the ice" (Director R. Palozzi, Erebus Production, Italy, 2014, 27 min) aiming at bring cutting-edge science to large public, students, teachers and society, and to help heighten public awareness of the importance of polar ecosystems and polar research.

The plot revolves around the Antarctic fish that are subjects and players, leading the spectator to the exploration of the challenging environment that they dominate, the Antarctic marine coastal waters. In the video, marine biologists are followed in their sampling through the sea-ice cover in Terra Nova Bay and divers disclose to the viewer an extraordinary underwater scenario. Several fish species, living in coastal waters of the Ross Sea, are shown in their habitat for the first time. Particular focus is given to the Antarctic silverfish whose nursery area has been included in the recently established ASPA n° 173 (Cape Washington & Silverfish Bay).

In this documentary, some of the amazing adaptations and peculiar biological features of the Antarctic fish are expressed simply. In addition, fish are the starting point to shine light on the complex ecological interactions characterizing the Antarctic marine ecosystems, and on the potential implications of climate changes on the marine living communities.

Researchers in polar marine biology and ecology, as well as experts in science communication, brought their complementary competences into the project, that also included other dissemination products, such as books, and educational events focusing on Antarctic fish.

## Engaging youth and young adults in the Antarctic

### Hodgson-Johnston I

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Following a fascinating dialogue regarding engagement of Australian youth and the Australian Antarctic Territory, the researcher has explored ways in which Antarctic institutions can engage Generation Y and Z (those born between 1982 and 2012) in a meaningful way.

Through platforms such as social media (Facebook, Twitter, Instagram etc), other media, expeditions and practical exercises, and school engagement, institutions have more opportunities than ever before to engage with the younger generations.

What is 'engagement' and why would institutions want it? The research identifies reasons why Antarctic institutions in the twenty-first century need to be, and should be, accessible and attractive to Generation Y and Z. These reasons include issues of inheritance and legacy, activism, funding, and societal currency.

What platforms work best to engage younger generations is a subjective enquiry, however, in a survey done on 150+ Australian youth, interesting elements of what was 'desirable' engagement were revealed. This included information about what was not good engagement, including some school programs. These insights are explored and conclusions as to what is a 'good' platform are developed. This includes a mixture of up to date and regular social media interaction and regular opportunities to personally engage with those working and researching Antarctica.

Education is a major element in engagement. With much focus already on primary school children, it is proposed that greater Antarctic education should exist for older school children. Extending the outreach into universities is also an area where engagement, with updated approaches, is needed. This includes access to multi-disciplinary research via databases, exposure to new technologies and research methods, and exposure to educational units at a tertiary level.

The presentation will also cover a brief cost-benefit analysis, case studies, and the role that international institutions such as the Antarctic Treaty Secretariat and SCAR can play in the engagement of youth and young adults in the issues of Antarctica.

## **The Postgraduate Certificate in Antarctic Studies: Linking Antarctic education, research and outreach through experiential learning**

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The Postgraduate Certificate in Antarctic Studies (PCAS) is an intensive, multi-disciplinary summer programme offered by the University of Canterbury, New Zealand, and open to national and international applicants with an undergraduate degree in any discipline. It combines more traditional classroom-based learning with innovative student-led individual and team research and activities as well as experiential learning through an Antarctic field component. The latter requires the students to undertake a range of small field research projects focusing on snow morphology, volcanology, marine-mammal biology and meteorology in addition to contributing to Antarctica New Zealand's environmental monitoring programme. Many PCAS graduates have pursued further Antarctic postgraduate or postdoctoral research, commenced successful careers in Antarctic governance or environmental management, and contributed to Antarctic education and outreach. In essence, PCAS amalgamates postgraduate Antarctic capacity building and education and a deliberate effort is made to strengthen linkages between tertiary institutions and National Antarctic Programmes.

This presentation will outline the cornerstones of the PCAS programme, share lessons learned about the programme design, about the balance between classroom-based teaching and student-led learning and about the methodologies underlying the various field research and environmental monitoring projects, and will discuss the wider contributions made by PCAS to Antarctic research, communication, capacity building, education and outreach. This presentation will show that, through well-designed intensive, integrative and collaborative tertiary and professional educational programmes, significant contributions can be made to capacity building by bringing successive cohorts of students from various backgrounds into the Antarctic community.

## The International Antarctic Institute

McMinn A, Virtue P

IMAS

The International Antarctic Institute is a consortium developed by leading global Antarctic educational and research-intensive institutes. Its purpose is to facilitate cooperation and collaboration between member universities in undergraduate and postgraduate multi disciplinary education in Antarctic and Southern Ocean sciences. As has been seen over the past half-century, international cooperation is the key to the success of large-scale research programs in Antarctica and the Southern Ocean. By sharing teaching resources between international partner universities we can create educational opportunities on a scale unattainable by any one institute or through traditional bilateral alliances.

Through the International Antarctic Institute students enrol in their home institutions (an International Antarctic Institute -affiliated university) and take up to an agreed proportion of their course units at other member institutions. The units taken during this exchange are credited through their home university. Courses and degrees are 'jointly badged' by the participating institutions of the International Antarctic Institute with the first courses having started this year.

Members and associated members presently include institutes from: Australia, Brazil, Canada, Chile, China, France, Germany, Italy, Japan, Malaysia, New Zealand, Norway, Spain, United Kingdom and the United States of America. The International Antarctic Institute is open to institutes who presently or potentially have an Antarctic educational mandate.

## Armchair exploration of Antarctica with Google Street View

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Only a small percentage of the world's population visits or conducts research in Antarctica each year, but billions have access to the internet. Many of those users are familiar with Google Search, Google Maps, and, in particular, Google Street View: the seamless, 360-degree, geotagged panorama photography available for more than 3,000 cities across 55 countries, as well as parts of the Arctic and Antarctica. In an on-going campaign, the National Science Foundation-funded Polar Geospatial Center (PGC) collaborates with Google, Inc. to collect Street View imagery in Antarctica. The sites collected (over 35 unique locations, both indoor and outdoor) were pre-selected with educational, scientific, and historical significance in mind. Examples include the South Pole, McMurdo Dry Valleys, Cape Crozier Emperor Penguin colony, and Shackleton's Hut at Cape Royds.

We present online tools for fellow researchers, educators, and the interested public to become an "armchair" explorer of Antarctica using the Street View collections. The tools present Antarctic content via popular and familiar web interfaces (there are more than one billion monthly active users of Google Maps services), notably: 1) Location-based search via Google Maps and Earth; 2) Featured Antarctica gallery on Google websites, with descriptions and resources with a scientific focus; and 3) Historical anecdotes with the Google Cultural Institute initiative. The tools, selection of content, and scientific applications, driven by Google, the PGC, and the research community, allow a hands-on look at Antarctica, suitable for any audience -- geologists can classify rock outcrops or interpret geomorphology; researchers can showcase the physical setting of their field studies; or the public can gain insight into the historical and contemporary requirements for conducting research in Antarctica. This technology is not only an unprecedented way to view Antarctica, it is a valuable tool for millions to understand it -- all without leaving their desks.

<https://www.google.com/maps/views/streetview/antarctica>

## **Researcher Involvement in Teacher-Research Experiences: a case study of the PolarTREC program**

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PolarTREC —Teachers and Researchers Exploring and Collaborating is a program providing United States K-12 educators with hands-on polar field research experiences. Over the past eight years, over 100 educators have been placed with research teams throughout the Arctic and Antarctica, with nearly half participating in Antarctic research aboard ships, in remote camps, and at all three US bases. Beyond bringing diverse educational professionals into the field, this program serves to improve researchers' education and outreach efforts while exposing researchers to the methods and means by which science is shared in the classroom.

The PolarTREC program mission is to advance polar science education and understanding. Starting in 2007, evaluation data collected from Antarctica researchers that have hosted teachers, suggest that in addition to meeting the key mission of PolarTREC, the benefits to researchers extends well beyond the field experience into tangible transferable skills. While teachers bring unique skills and perspectives to the research program, researchers' significantly increase their understanding of US K-12 education system, resulting in increased effectiveness in outreach and dissemination of research. In this presentation, we will highlight the key impacts and findings of this program on researchers. Specifically, we'll share best practices of how teacher-researcher experiences can work to further benefit researchers' individual polar science programs and the broader scientific community.

## Iranian Antarctic scientific research program

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Antarctic has been the focus of attraction for the world because of its global significance for influencing global weather, its unique position at the South Pole, its potential for huge non-living and living resources and its pristine environment to be used as natural laboratory for scientific research. It is clear that Antarctic science will increasingly contribute to our understanding of mentioned issues and other global problems. It is therefore not surprising that, in accordance with the Iranian government focus on environmental issues, there is a new scientific goal on polar research.

Iranian National Institute for Oceanography and Atmospheric Science (INIOAS) as the national coordinator of marine research organizations proposed a long term plan to establish a year-round research station to research on the Antarctica and its circum ocean and to organize the relevant scientific attempts in a systematic approach in agreement with the SCAR concerns for the development of international collaboration in Antarctic science. As the first step of the long-term plan, National Centre for Antarctic Research (NCAR) has been established within INIOAS to coordinate all Antarctic related activities. NCAR is trying to select motivated young scientists in different scientific disciplines to develop an active new generation of polar scientists, engineers and leaders and to capture the interest of the public and decision-makers. The main objectives of Iranian Antarctic program are: To undertake multidisciplinary research and survey in Antarctic region particularly in the field of oceanography and environmental research; To participate in the international scientific programs in the Antarctic region and, to provide relevant technical information to the government of I.R. of Iran on Antarctic affairs at National and International level. Iran's Antarctic scientific program could be started by organizing workshops which will gather national scientists, academics, decision-makers and students as well as invited international experts and by getting involved in international collaborations, possibly on project fellowships for young scientist participation in the international Antarctic scientific body SCAR. Therefore, SCAR associate membership will strongly benefit the national endeavors and provide the solid basis needed for I.R. of Iran to build essential links with Antarctic research.

## Scientist Engagement in Public Outreach Events: Motivations, Experience, and Evaluation

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The International Polar Year 2007 - 2008 (IPY) involved scientists from over 60 countries and an estimated 50,000 participants. Every research programme that was endorsed by IPY was required to have an Education, Outreach, and Communication (EOC) strategy that connected the public with current scientific research, and researchers. Here we present a range of activities and initiatives that were catalysed by that effort, as well as more recent Antarctic outreach and communication events, with a specific focus on the motivations and expectations of the scientists involved, and evaluation of these activities. Examples will include an Antarctic festival with public lectures and science cafes, outreach associated with an Antarctic expedition, the global launch of a climate change documentary that had a significant focus on Antarctica, and a series of "Polar Weeks" led by an international community of scientists and educators.

While there is an excellent culture of accountability in both formal and informal science communication sectors, the same rigour is not applied to the majority of outreach activities that are initiated by the science research community. Many of these activities are undertaken based on 'what feels right' and opportunism, and are proclaimed to be a success based on little or no formal evaluation. As a result, much of this work goes undocumented, is not evaluated from the perspective of the science community, and is rarely subject to peer-review and its associated benefits, including professional rewards. Using four polar outreach case studies, we will discuss the scientists' motivations, expectations, and institutional incentives (and dis-incentives) to engage in public science, and argue that improved training, evaluation, and academic value needs to be associated with scientist-led communication efforts.

## IceCube outreach synergies: A full-dome planetarium show with the Milwaukee Public Museum and Teachers to the South Pole with PolarTREC

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University of Wisconsin-River Falls

The IceCube Neutrino Observatory was constructed in the ice sheet at the South Pole over seven seasons, with the last instruments deployed in December of 2010. Over 5000 light sensors were frozen in 86 holes that extended 2450 meters below the surface. Each hole holds 60 light detectors known as digital optical modules placed every 17 meters starting at 1450 meters. The holes are in a hexagonal grid in an area of one square kilometer, making IceCube the largest single detector ever built with a volume of one cubic kilometer. The surface IceTop array that detects cosmic ray showers consists of pairs of tanks above 81 of the holes. IceCube will continue to collect data with an anticipated lifetime of two decades. In 2013, the IceCube Collaboration published results on the highest energy neutrinos ever recorded, and this achievement was named the Breakthrough of the Year by Physics World, and one of the top ten science stories by Scientific American.

Two examples of how the IceCube Collaboration has partnered to leverage resources to enhance education and outreach efforts will be presented. A preview of a thirty minute full-dome video produced jointly by the Wisconsin IceCube particle Astrophysics Center, and the Milwaukee Public Museum will be shown.

### *Chasing the Ghost Particle: From the South Pole to the Edge of the Universe*

Deep in the ice at the heart of Antarctica, IceCube, the biggest and strangest detector in the world waits for mysterious messengers from the cosmos. Scientists are using tiny and elusive particles called neutrinos to explore the most extreme places in the universe. These ghostly neutrinos give us an exclusive way to study powerful cosmic engines like exploding stars and black holes. Information about how to get copies of the show formatted for either a flat screen or a digital dome will be provided.

The IceCube collaboration has also worked with the NSF supported PolarTREC program to provide three week deployments working at the South Pole for three teachers with a fourth scheduled for the 2014-15 season. An overview of the rewards and challenges of working with partners and tips on how to maximize the results for all involved parties will be discussed.

**Portugal education and outreach: our new educational polar projects "Profession: Polar Scientist" and "Education PROPOLAR" bringing polar science to wider audiences**

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**Portugal education and outreach: our new educational polar projects "Profession: Polar Scientist" and "Education PROPOLAR" bringing polar science to wider audiences**

One of the main reasons why Portugal was highlighted as a successful example of a recent emergent polar nation during the International Polar Year 2007-2008, was through its science, education and outreach outputs, in collaborations with numerous countries, such as Brazil, Spain and UK. Bringing the research carried out by Portuguese Polar scientists to schools, engaging teachers/educators and scientists together (with colleagues around the world), has provided an excellent route to engage the younger generations to science (and science related disciplines). After our educational program, LATITUDE60!, education and outreach was mostly carried out by individual institutions. We introduce the new educational projects "Profession: Polar Scientist" and "Education PROPOLAR", supported by Ciência Viva, and endorsed by the Portuguese Polar Program PROPOLAR, Association of Polar Early Career Scientists (APECS Portugal and APECS international) and by Polar Educators International (PEI). The first project aims to reinforce the links between polar scientists with schools, under POLAR WEEKS organized by APECS and PEI, whereas the second project aims to provide tools and materials to schools on polar science. These may include an educational pamphlet, novel educational films, educational materials, a workshop for teachers/educators and an exhibition (in cooperation with the Instituto de Educação e Cidadania). These projects started officially in 2013 and the first results will be presented while providing guidance and an example of how other countries can engage in Antarctic education and outreach initiatives at an international level.

## Antarctic education and outreach: Developing top-down and bottom-up initiatives

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The Polar Regions play an important role in the global processes of our planet. In addition, their scientific importance, extraordinary beauty and adventurous history provide the perfect ingredients for both education and public outreach. Polar examples can be an excellent way to transmit basic concepts about a wide range of Science, Technology, Engineering and Mathematics (STEM) disciplines. Since the establishment during the International Polar Year, the Association of Polar Early Career Scientists (APECS) has been promoting as one of its central goals education and outreach as an integral component of polar research and to stimulate future generations of polar researchers. Key resources initiated by APECS include the Polar Resource Book “Polar Science and Global Climate: An International Resource for Education and Outreach” as well as FrostBytes© - “Soundbytes of Cool Research”. APECS also had a central role – in cooperation with SCAR and IASC - in the ICSU-funded IPY Education and Outreach Assessment and Polar Outreach Catalogue. Both locally and internationally, APECS members continue to organize a multitude of events in schools and communities, especially during the bi-annual Polar Weeks and Antarctica Day. The formation of the Polar Educators International (PEI) provides a new forum for encouraging the exchange of ideas between educators and researchers, the development of co-operative projects and tools, the enhancement of the profile of polar education on the international scene, and shares the relevance of the Polar Regions with the global community. Within the Scientific Committee on Antarctic Research (SCAR), the Capacity Building, Education and Training advisory group, along with their science research programs (e.g.: SCAR EBA, SCAR AnT-ERA, SCAR AntECO) have been active, particularly in supporting workshops and educational initiatives, along with scholarships for early career scientists. From an Antarctic Treaty perspective, Parties have recognized that education and outreach can link the value and importance of Antarctic science to the international governance model. Treaty Parties have organised numerous public outreach activities, often as part of hosting a Treaty Meeting. With interest in education and public outreach increasing at Antarctic Treaty level, this presentation aims to review both the bottom-up and top-bottom processes, evaluating what is working well, what can be improved and emphasizing cases of success at different scales.

## S36: INNOVATIONS IN COMMUNICATING ANTARCTIC SCIENCE

### Science and photography: the photographic image as a tool to think sub-Antarctic and Antarctic conservation

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Aside from all caricatures drawn between the sciences and the arts, there are common aspects inherently shared by both of these disciplines, such as observation, reflection, experimentation, exploration and communication. Considering the notions of “*face to face*” encounters by scientist and environmentalist Aldo Leopold and of “*thoughtful photography*” by the French philosopher and semiotician Roland Barthes, we combine common and complimentary elements between scientific research and photography to promote and contribute to the intrinsic valorization of nature. Our objective is to open community based spaces of active reflection by linking the results of our scientific research in sub-Antarctic and Antarctic freshwater ecosystems with photography, as a language to promote conservation and valuing of these habitats and its inhabitants. Our team, composed of researchers and one photographer associated to the Sub-Antarctic Biocultural Conservation Program and the Omora Ethnobotanical Park, Chile (55°S) work together in the field and in the laboratory, conducting workshops and outreach materials that link environmental sciences, photography and environmental ethics through a new activity that we have called *Underwater with a Hand Lens*, which aims to contribute to valuing of freshwater invertebrates by promoting face to face encounters. In parallel to the scientific research, the photographic work covers all the scientific processes from a perspective that transcends the descriptive registry and provides a broader, critical and thoughtful look, which based on aesthetic and conceptual criteria, calls for a deeper reflection about the scientific research related to freshwater invertebrates and its relationship with their valuing and conservation. Today, we actively develop research projects in which the main subjects of study are freshwater invertebrates in sub-Antarctic Navarino Island (Chile) and the Antarctic South Shetland Islands. We conduct workshops with tourism operators and the general public in the Magallanes region (Chile), and at the same time, we publish scientific articles and are currently developing field guides and photography books, along with permanent regional media coverage.

## Communicating science - the “Thin Ice” experience

**Barrett P**<sup>1</sup>, Lamb S<sup>1</sup>, Sington D<sup>2</sup>, England, P<sup>3</sup>, Fairhead D<sup>4</sup>, Sheppard P<sup>5</sup>, Fitzgerald C<sup>6</sup>, Franklin J<sup>7</sup>, Roop H<sup>1</sup>, Keith S<sup>1</sup>, and Harle S<sup>8</sup>.

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*Thin Ice – the inside story of climate science* is a 73 minute feature documentary released in 2013. The aim was to make a film in which climate scientists told their story directly to the public. In 2007, when filming began, there was growing international acceptance that climate change was a serious issue that should be addressed, but little was being done about it. We thought that if climate scientists could tell their own story directly to the public, their credibility would be obvious and action would surely follow. At first the team comprised just Simon Lamb, an Oxford geologist with film-making experience, his friend David Sington, a London-based science documentary film producer, and Peter Barrett, a Victoria University academic with an interest in the history of the Antarctic ice sheet and some apprehension for its future. Peter took on the role of organizing support for Simon, in collaboration with Philip England at Oxford, and facilitating access to climate scientists and Antarctica.

By the end of 2009 Simon had over 100 hours of interviews, including footage from Antarctica, the Southern Ocean, New Zealand, England and Germany, along with interviews with some key US scientists. He had spent a month in the UK with David Sington and David Fairhead editing the film, and we thought it was good enough for a special Wellington screening in March 2010. Audience reaction was positive but not hugely so. We agreed it required more money and a different approach. This crucially depended on David Sington’s film-making skills, as he turned the film from “scientists talking to the public” to “Simon’s journey of discovery” driven by the ridicule being heaped by climate skeptics on his climate science colleagues.

A re-edit of the film in 2011 to include Simon as narrator showed promise, but it was not until late 2012 that the final cut was completed. Now with music from Philip Sheppard the December 12 screening confirmed we had a film that really worked. We found generous local support for organizing a global launch for the film on Earth Day, April 22, 2013, and also worked with translators to provide subtitles in 5 languages. It screened at 200 sites around the world, and the responses made it plain we had struck a chord. Phrases like “it shows the human face of climate science” and “it’s like having a chat with a knowledgeable mate down at the pub” show the film has public appeal. The comment that “Thin Ice has the most accurate description of the greenhouse effect in any documentary ever” (from a JPL engineer) showed the film also had scientific integrity.

One of the challenges in making *Thin Ice*, especially after “Climategate” in late 2009, was to produce a film that established the credibility of climate scientists. Another was not to shrink from the scientific conclusion that our societal goal should be zero carbon emissions, and at the same time convey a message of hope. It seems we succeeded. Since the film’s release it has been screened by invitation at over a dozen film festivals and won two awards. In addition director/producer/photographer Simon Lamb has been awarded the 2104 Athelstan Spilhaus Award for Science Communication from the American Geophysical Union.

We are now working to raise the film’s profile through a not-for-profit California-based distributor Green Planet Films, which is marketing it to educational institutions world-wide. We are also, with their help, working toward a 56 minute version for US public broadcasting for screening in 2015. We especially like Dave Harwood’s closing message “But for you kids, take it seriously. Don’t be alarmed or afraid, but join in this effort. Become the best scientists or engineers you can, and let’s solve this problem”. Of course, it’s not just a message for kids.

For more on the film and project see [www.thiniceclimate.org](http://www.thiniceclimate.org).

**Using audiovisual technology to show the research characteristics, the logistical difficulty and institutional collaboration necessary for the research development on the issue of global warming in the northern Antarctic Peninsula**

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These abstract shows how you can make use of audiovisual technology to show the research characteristics conducting in Antarctica condition, logistical difficulties, and the necessary institutional collaboration for the development of research activities in such complex subject like global warming.

This research of international partners joined two different research projects and involving 4 academic institutions from Chile and Germany, to make an interdisciplinary work in the northern Antarctic Peninsula surrounding the O'Higgins Station directly on the coast (BO, 63°19'15"S, 57°53'55"W), belongs to Chilean Army. The scientific objectives are summarized in: Glaciochemistry, to obtain snow and ice core that may explain the recent climatic evolution of this area, through isotopic studies; Geophysics, to study the physical characteristics of the ice (depth and thick structures and deformation), by using different radars techniques and Atmospheric Chemistry, measure chemical fingerprint to check the circulation of various types of natural and anthropogenic aerosols to the continent, and how this aerosols emitted into the atmosphere can be removed by wet and/or dried deposition phenomena. Deposition leads to the introduction of particles and/or gas in the snow, increasing its melting, accelerating the retreat of glaciers and changing the albedo, which finally impact on climate. A special role in this impact has the measure of in situ Black Carbon (BC), given its high potential as a climate forcing agent.

This abstract showed how the collaboration of the Chilean Antarctic Institute (INACH), National Commission for Scientific and Technological Research (CONICYT), Army, Air Force and Navy together with the scientists allowed for this unprecedented campaign for the first time make a camp in Laclaver Plateau and install in the Infantry Plateau on La Paloma Mountain (LPM, 63°21'20"S, 57°48'21"W, 409 m.a.s.l.), 10 km far from the BO Station a hybrid power system of wind and photovoltaic energy was installed to generate the energy for the instrument included 3 Polar Wind Turbine and a 6 m tower with 3 solar panel for the installation a complete meteorological station including a sonic snow level and albedometer sensors. The meteorological instrument has an automatic transmission system data using a YAGI Antenna with the GOES-EAST satellite. One of the purposes of this infrastructure is to transform this monitoring station at a future GAW station to participate in the international network of stations that measure radiation, gases and aerosols. This station will be generating an important data base that would be used to validate different satellite data, the chemical transport models that predict the trajectories and evolution of aerosols and gases from sources of anthropogenic or natural emissions in the Antarctic.

## The SOKI wiki: A new tool for enhanced engagement and collaboration in Southern Ocean ecosystem research

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Wikis are emerging as important tools for knowledge sharing, engagement and collaboration. They provide a dynamic environment for the development of ideas and projects, and can be used to capture evolving and cumulative bodies of knowledge on particular topics. The Southern Ocean Ecosystem Change group at the Australian Antarctic Division has developed a wiki – the Southern Ocean Knowledge and Information (SOKI) wiki – as a tool for capturing and sharing knowledge on Southern Ocean ecosystems and for facilitating collaboration between researchers. While we are now seeing a broad array of data portals and other tools for accessing and sharing data, our wiki is novel as it emphasises sharing new ideas, providing syntheses on topics of interest and facilitating access to cumulative knowledge. Through the establishment of an editorial board we are also developing a process where pages can be peer reviewed, published (with a DOI) and cited.

In this presentation we demonstrate the potential of SOKI by focusing on a simple, yet important question: with the recent release of the IPCC Workgroup Group 2 report on impacts, adaptation and vulnerability, what can we now say about the future of Happy Feet and his emperor penguin kin? We answer this question by highlighting the inherent problems with searching for relevant, current research and show how SOKI can be used to synthesise up-to-date information. Through audience participation we will write a collaborative paper in real time using available resources and the power of new technologies such as wikis and shared online spaces. SOKI can be found at: [www.soki.aq](http://www.soki.aq).

## From Bellingshausen to Rwanda: storytelling as the meaning-maker, mapmaker and reservoir of climate science. Revisiting history, foretelling a (healthy) future

Devine C<sup>1</sup>, Orbinski J<sup>2</sup>

<sup>1</sup> The Antarctic Book of Cooking and Cleaning, APECS, <sup>2</sup> Balsillie School of International Affairs, Waterloo Canada, UNEP Steering Committee on Climate Change & Disaster Preparedness and Early Warning in Africa

**“Stories, we all have stories. Nature does not tell stories, we do. We find ourselves in them...if we are the stories we tell ourselves, we had better choose them well.”**

James Orbinski, *An Imperfect Offering: Humanitarian Action in the 21<sup>st</sup> Century* 2009

*“I was there as a glaciologist but a glaciologist needs a map to plot his observations and there was no map, so we were making maps at the same time.”* Charles Swithinbank, Norwegian-British-Swedish Antarctic expedition 1949-52

Swithinbank’s scientific map-making of a newly explored continent contributed to a deeper social embedding of Antarctica as part of how humans story the earth. Sciences such as oceanography and epidemiology tell us our planet is unhealthy. For example, the Western Antarctic Peninsula is warming and malaria in East Africa is increasing –manifestations of the anthropogenic greenhouse effect. Yet measures, models and processes for investigating climate change science are new in human terms, as is our understanding of Antarctica; both are a century old. Science is a perpetually improving but always incomplete and imperfect method of understanding our world. Science is outside of subjectivity. While we gain insight from its content, the process and content are silent on human meaning.

International Climate and Antarctic policy bodies urge improved communication among actors to build consensus, manage the environment and develop humanity’s future (UNEP, SCAR). Science is central to communication. But just as the “letter is not the word”, “science is not the story.” Storytelling is essential to interpreting and sharing climate reality past, present and future. As such we build a cross-disciplinary collective story to respond to this crisis facing human survival.

Orbinski is a medical doctor, academic, global health researcher and storyteller. As a humanitarian and leader, he worked over a decade with MSF amidst war, famine, epidemic disease and genocide. Orbinski co-created the Drugs for Neglected Diseases Initiative engaging pharmacists, scientists and public and private partners. He advocates with scientists, writers and musicians. Devine also worked with MSF and co-authored *The Antarctic Book of Cooking and Cleaning* with artist Wendy Trusler: the story of a civilian cleanup at Bellingshausen station, weaving historic and contemporary images, recipes, journals and science facts. The project embodied Antarctic Treaty principles of a global commons. The book excavates details of life and exposes humanity (Marsching and Polli 2012).

From Rwanda to Antarctica, Orbinski and Devine used storytelling and experienced the potential of story-based advocacy. Storytelling is transformative, builds resilience and promotes effective agency. They explore storytelling as a meaning maker, mapmaker and reservoir for climate science to catalyze responses to climate change, and to (hopefully) foretell a healthy future.

## Connecting Antarctic by web conferencing in real time: an option for popularization of Antarctic science

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The popularization of Antarctic Science has played an increasingly important role not only in the international scientific community, but also in environmental organizations and even in the strategic decisions of the countries involved in Antarctica researches. The public opinion is an essential factor for that results of the research conducted there can generate actions in defense of the environment, in education, in new research etc. However, the fact that Antarctica is an isolated continent, distant, inaccessible, and therefore with little media exposure (compared to other research subjects), makes it much harder to win public engagement.

Some authors have suggested ways of publicizing the Antarctic Science, such as videos, exhibitions, books and blogs (Davis, 2008). In this paper, we present the use of a multimodal and multimedia web conferencing system for live broadcasting of research directly from Antarctic vessels and bases.

The multimodal and multimedia conferencing allows real-time communication by voice, text and video, sharing files (audios, videos, images), applications, desktop etc. The systems allow recording the web conferences, providing the material available for download. In previous studies (eg Dotta, 2013; Tori, 2010; Harasim, 1990), we identified that the multimodal communication, multimedia features and synchronicity among participants (presenter and audience) of a web conferencing have proved to be an important tool for attraction and retention of the public, in the sense that the virtual presence fosters a sense of belonging, and leads to engagement (Barkley, 2005). Thus, these systems become interesting alternatives for the popularization of Antarctic Science.

We present the results of the first experiments for live broadcasting of Science communication programs by web conferencing on Antarctic research conducted in a Brazilian expedition. The experiment identified the requirements for personnel (staff) and technical (hardware, software and network speed) for performing multimodal and multimedia conferencing from the Brazilian base and ship in Antarctica. Patterns of image, audio and video to be captured for the live broadcast or published the information about the research were identified. Finally, the indicators for screenplay, production and transmission of daily and live programs for communicating Antarctic Science to be produced in future expeditions were established.

## Ex+Sistencia: art & science project

### Jeffer A

INAE Ecuadorian Antarctic Institute

Contemporary Art proposals often require great investigation. If we take a look back through history, art was used to illustrate science. Artists participated alongside scientists to document and convey to the non-scientific community. Methodology in the arts (intuition) integrated with the predictive power of science (prediction), contribute to a new culture where there is equilibrium between creativity and rationality.

The generation of art-science projects develop intimacy with the non-scientific citizen, who does not have access to scientific publications, nor does he/she understand them. This path shakes their imagination and consciousness regarding the efforts of science in pro of the planet.

Science and art collaborate to produce our interdisciplinary programs on the Antarctic continent in order to understand a truly sustainable model of development. We have implemented 2 concrete projects envisioned to mobilize collective human consciousness creating visibility for the investigators, scientists and artists.

ARTEA, Antarctic Art and Science Residencies, artists are conditioned to stay at the Antarctic base for 21 days or more with a set project previously assigned with the scientist. After completion the project is presented via national media. Art becomes a massive medium for the non-scientific population to become scientifically knowledgeable and aware.

The Antarctic is not only a space for the artists' inspiration or conventional creation, but where there should be investigation and feedback with the scientific community. It is an opportunity to develop new applicable techniques and artistic proposals that can wake up the interest of the community and the importance of the Antarctic for the planet.

APOPTOSIS, is the name given to this second project due to its meaning. It is an ongoing art/biotechnology project that works with microorganisms that inhabit people, places and historical moments.

Microorganisms and scientific methodology are used to produce "living art" generating a major impact on the artists' conventional techniques and thus the interest and its communicational influence on the public. It becomes a type of art/science memoir.

Due to the outcome of these projects of research and creation, for the first time in Ecuador the Ministries of Defense and Culture have signed a five-year agreement of collaboration in the Antarctic. Organizations from Chile and Ecuador are beginning to cooperate to support and maintain the nature of these programs and their results in both countries.

ARTEA and APOPTOSIS are initiatives inspired by a visual artist by generating a network of art/science residencies and collaborations between nations that carry out scientific investigation in the Antarctic. The art/science proposals continue to yield incredible experiences and feedback with the Antarctic laboratories and non-scientific community.

## Do you see what I see? Using visual framing to support the protection and preservation of Antarctica and the Southern Ocean

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Research on the meta-communication concept of 'framing' has demonstrated that people can respond very differently to ideas, policies or even identical data when it is framed in different ways. To date most research on framing has focused on language. Retrospective analyses have suggested that visual frames can also be influential.

The primary objectives of this research were to explore whether visual imagery presented in combination with written stimulus had any impact on: a) the degree to which people believed Antarctica and the Southern Ocean were regions that should be preserved and protected from irreversible damage (salience), and b) their propensity to financially support well-known, not-for-profit (NFP) organisations that aim to protect and preserve Antarctica and the Southern Ocean. Secondary objectives included whether visual framing influenced perceptions of: 1) specific threats to these regions, 2) mitigation priorities, and 3) the effectiveness of taking various actions to protect and preserve Antarctica and the Southern Ocean.

We constructed five versions of a self-complete, on-line survey. Each survey was identical except for the digital manipulation of a base visual at the beginning and heading of each page, using the following combinations of elements: coastal scene, coastal scene with penguins, coastal scene with oil rig and land pollution, coastal scene with oil rig, land pollution and penguins, and no image. Randomly assigned versions of the survey were emailed to 15,929 currently inactive World Wide Fund for Nature (Australia) financial supporters. Approximately 2% (n=307) were completed and returned. Of those, 64% had a university or higher education level.

Results from this study showed no statistically significant differences on the primary measures. This result was in part driven by a lack of variation across the sample, with 95% of respondents providing an importance rating of 9 or 10 out of 10 at the beginning of the survey. This made it difficult to discern differences between questionnaire versions and so the outcomes were inconclusive.

Additionally, no differences were seen for the propensity to financially support NFP's to protect and preserve these regions, nor for perceptions of listed specific threats, mitigation priorities or mitigation effectiveness.

Previous research on language-based frames has suggested that for more informed or 'biased' individuals, the impact of framing is minimal. Whether that is the case here, or whether the sample size was too small to detect small variations in a framing effect, whether bias or moderating factors were at play, or whether the visual frames devised for this research were not potent enough, is unclear. Further research using different visual frames, or the same visual frames to a broader, potentially less biased segment of the community is recommended.

## Time lapse imaging in Antarctica: Speeding up the slowest landscapes on Earth

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The ice-free surfaces of the McMurdo Dry Valleys (MDV) of Southern Victoria Land are some of the slowest-changing landscapes on Earth. Cold and dry conditions produce minimal chemical weathering and an environment in which physical erosion and sediment deposition by fluvial, glacial, and aeolian processes occur sporadically, slowly, and heterogeneously across the landscape. Harsh climate conditions mean human researchers can only operate in the MDV ~4 months of the year, and busy research schedules keep teams moving between field sites. These factors often combine so that the physical processes that shape the MDV occur unseen and can only be inferred based on meteorological sensor data and periodic observations of landforms made during site visits.

Time lapse imaging has been used elsewhere to monitor the cryosphere in rapidly changing regions (chiefly to observe outlet glacier behavior). Here, we show novel ways to collect, processes, analyze, and share time lapse image data that reveal new insights into the physical processes that shape the McMurdo Dry Valleys. We highlight 1) time lapse observations made of near-surface hydrology in the Don Juan Pond watershed that provide new insights into water sources for Earth's most saline lake, and 2) observations of thermokarst formation in Garwood Valley, which suggest that Arctic-like retrogressive thaw slumps may become a significant geomorphic feature in the MDV as abundant Antarctic ground ice thaws. We also feature time lapse sequences that illustrate 1) the extreme rate of aeolian deflation possible on unconsolidated sediments, 2) snow/groundwater interactions, and 3) flow and flooding behavior in MDV streams and rivers.

In addition, we will show how custom time lapse processing software permits image datasets to be combined with distributed sensor networks into order to tie landscape response to meteorological forcing. This combination of image data with distributed measurements that track the distribution and routing of water, heat, and radiation in the Antarctic environment provides new ways of exploring landscape response to changing climate conditions. The challenges and potential for new time lapse techniques including infrared time lapse imaging and stereoscopic time lapse imaging are also explored.

Finally, session participants will be encouraged to download high-resolution time lapse sequences and image/sensor data products to their laptop and tablet computers to follow along during the presentation so that they can explore the rich datasets at full spatial and temporal resolution.

**Using an innovative, personal flipped approach to science communication. Feed the world, protect the future, live well- knowledge is power**

**Metcalf V**

Lincoln University

I've been striving to find more creative methodologies that enhance knowledge transfer and understanding through higher levels of outreach audience interaction by getting away from a standard Powerpoint enhanced talk. Last year I trialled a novel approach at a Global Awareness Day at Rangitapu High School, Christchurch, New Zealand. I ran three 1 hour sessions with 45 students aged 10-15 in each session. The Day aim was to: inspire, challenge and empower students to develop an understanding of what it is to be a New Zealander and of current global issues.

My pre-session brief to the students included:

"It's time to put you in charge! You're going to be re-enacting recent negotiations around Marine Protected Areas proposals in Antarctica to see if you reach the same decision. Under the Antarctic Treaty, Antarctica is a continent devoted to peace and science. This Treaty recognises the uniqueness, remoteness and fragility of the Antarctic region and the potential of this region for important scientific study. The waters around Antarctica are not perhaps as well protected and have been subject to varying levels of exploitation. Most recently, exploitation has centred on the Antarctic toothfish. CCAMLR manages the marine resources in the waters surrounding the frozen continent and in recent meetings its members have been debating proposals over two major MPAs. So far there has failed to be an agreement, leaving Antarctic marine organisms unprotected and vulnerable to the combined threats of climate change and fisheries. What would your decision be? Protect some areas or not? You're going to be assigned a role, a country and have a chance to quickly practice negotiations that will then lead to hopefully plenty of discussion post session."

Students were seated at tables of 5, each representing a country and randomly allocated a role with tailored guidance notes: government, diplomat representative (secretary), fishing industry representative, Antarctic scientist, or NGO. Following a brief introduction to Antarctica and the issues around MPA's, participants had 20 min to read their notes and debate (playing their role) over what their country's decision re the MPA should be. Each diplomat was asked to give an impassioned 30 second rationale for their country's viewpoint before voting.

At the end of the session we evaluated: whether the outcome mirror that of the actual CCAMLR meeting, how well it sat with their own values, and if not the beginnings of discussions they could have over what they wanted to do, if anything to affect change. The feedback from the students, teachers and assistants was so overwhelmingly positive there is interest in using this format more widely for outreach within my institution.

In this presentation I will demonstrate how this human-centred and flipped approach worked through a practical interactive demonstration- be prepared to be involved.

## The Cryosphere Writ in Light, Sound, the Written Word - and Lacquered Blue Paper

O'Connor G<sup>1</sup>, Stevens C<sup>2</sup>, Allard K<sup>3</sup>

<sup>1</sup> gabbyoconnor.wordpress.com, <sup>2</sup> NIWA, <sup>3</sup> private

Imagine a herd of six year old children who understand that polar ice, ocean and atmosphere are connected; that the frozen skin of a continent shifts and changes; that climate isn't a stasis. Imagine the art gallery-going public debating the structure of ice-crystals and how they interact with incoming and outgoing energy fluxes. Imagine driving through a raining city-scape after dark and the most prominent thing you see is a pop-up gallery lit with a blue paper ice shelf breaching into the pedestrian world.

Gabby O'Connor has built a phase of her career around constructing cryosculptures from paper. This has been contextualised by her immersion in the readings of the Heroic Era of polar exploration. The works have evolved from perspectives on the human condition and shelter provided by snow caves through to the transients of ice bergs, and then on to the climate-moderated impermanence of ice shelves.

These manifestations of the cryosphere have been mediated through collaboration with field-going physical scientists. This has proven a powerful way to engage with early school-age students. These young minds, the first generation to live their lives knowing that their climate was in part a conscious choice made by earlier generations, readily grasp the concepts around how the physical environment is constructed from entwined processes and that science has ways of representing such worlds through approximation and understanding.

While clearly centred on the installations of O'Connor as mediated by Stevens' field science experience looking at how ice is affected by the polar oceans, the team has branched out into the written word as well as sound interpretations of both the art and science of the polar cryosphere. In this talk we will involve the audience in some real-time cryo-construction sustained with surround-sound immersion in the liquid-ice interface.

## Researcher-Educator Collaborations Inspiring Global Engagement in Polar Science Through the Polar Educators International Master Class Program

Roop H<sup>1,2</sup>, Bartholow S<sup>1,3</sup>, Huffman L<sup>1</sup>, Herrmann N<sup>1,4</sup>, Wilkening B<sup>1,5</sup>, Wesche G<sup>1,6</sup>

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Polar Educators International (PEI) is a vibrant international network of educators and researchers aiming to provide a deeper understanding of current polar science. PEI represents trusted leaders working to inspire appreciation and knowledge of the polar regions, their connectedness to all Earth's systems, and importance to all humans across latitudes and cultures.

The PEI Master Class program, which launched in May 2014, aims to improve the ways in which polar scientists and educators develop robust collaborations, exchange scientifically accurate information, and inspire a future generation of scientists and effective science communicators. The Master Class program model intends to move beyond the static exchange of classroom activities or presentation tips to an open networking platform that supports virtual collaboration. This program partners polar scientists with master educators with similar experiences or interests and supports these teams in the development and sharing of age and audience appropriate polar science resources. The Master Classes utilize best practices of the Mass Online Open Courses (MOOC) interactive model of knowledge sharing and dialogue, which includes access to science and educational content, webinars and live events hosted by the researcher-educator teams, and interactive forums. Each Master Class is free and open to the public, and is contained within the network-based infrastructure of the Polar Educators International website ([polareducator.org](http://polareducator.org)).

This presentation will focus on the outcomes of the first Master Classes, which included participation by climate scientist Richard Alley and master Antarctic educator Nell Herrmann. This presentation intends to share the successes of this program, important areas of growth, tools for evaluation, and how this model generates transferable skills and knowledge for all participants. Further, we will highlight the potential for the Master Class program to serve as an innovative tool to be used to share Antarctic research and ways in which we can use this program to build on the current partnership between PEI and SCAR.

## Finding Antarctica in New Zealand

Neufeld E<sup>1</sup>, Steel G<sup>2</sup>

<sup>1</sup> Gateway Antarctica, <sup>2</sup> Lincoln University

The polar landscapes have, for a long time, held the imaginations of people around the world. These extreme and remote environments have shaped the hearts and minds not only of people who have lived there, but also those who have only heard stories and seen pictures of these far off lands of ice and sky and snow. This paper discusses how individuals can communicate their ideas and findings to others in meaningful and believable ways. Based on the findings of my dissertation, the paper examines how sense of place is developed by a variety of New Zealanders towards Antarctica, and how we can use this to influence and shape further understanding of the continent. After examining 30 questionnaires and 54 interviews, the data indicate that there is no one New Zealand sense of Antarctica, rather they are as manifold and complex as the individuals consulted. Regardless of the many differences across the various groups, a common thread was found of Antarctica as a place of hope. A hope based on scientific discovery and collaboration, on resource potential and conserving wild spaces. Findings also helped to develop a theoretical model, which builds on the existing works of Tuan (1977), Sack (1997), and Gustafson (2001). Three important theoretical aspects were identified through the analysis, including the ideas of personal connection, narrative emplacement, and one's sense of identity. The theory contributes to the ongoing discussion of how people encounter and make sense of extreme and remote environments. Both the findings themselves and the theory behind them suggest that policy makers, communicators, and tourism operators be aware of their target audience, their cultural values and changing symbolism, in order to better communicate their intended message.

# **COMNAP Symposium**

## **Success Through International Co-operation**

### **ABSTRACTS**

**A history of recent logistics sharing in support of international science projects, a perspective from British Antarctic Survey**

Mike Dinn [medi@bas.ac.uk](mailto:medi@bas.ac.uk)

British Antarctic Survey

British Antarctic Survey (BAS) has a long standing history of international co-operation within Antarctic research. This has proven fruitful in terms of its own scientific outputs, and has provided a fertile ground for both logistics and science c-operation. The last seven or eight years has seen BAS collaborating or supporting large projects through the use of its own infrastructure as well as science capabilities and also seen other programs science endeavours supported as logistics exchange tasks.

This poster cites many recent examples of large research projects where the BAS and other national programs have cooperated in the discharge of these science targets.

## Sharing Logistics to support an evolving scientific program on the Ronne Filchner Ice shelf

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British Antarctic Survey

British Antarctic Survey (BAS) have just recommenced tractor traverse in support of science projects after not having done much of this sort of activity for over 40 years. This poster discusses a collaboration with the Alfred Wegner Institute (AWI) in support of a joint science project that commenced out of discussions by BAS to seek logistics support from AWI.

BAS are undertaking a number of large science projects in the area of the Ronne Filchner ice shelf over the next three or four years. Out of recent experience using tractor traverse it has been realized that there are considerable logistics benefits to using this method in support of bigger logistics tasks. BAS was also looking to expand upon the current commitments with another large project undergoing grant review.

Out of this building challenge and without having the capitol to invest in new traverse vehicles, BAS requested from AWI that they provide two traverse vehicles to meet this logistics challenge. Discussions between BAS and AWI generated the scope to science co-operation with the planned traverse to support both AWI and BAS needs. Both BAS and AWI are committing ship time to support the logistics inputs to this remote deployment site in different seasons and a shared traverse infrastructure working across time to support the joint science activities.

The net result is a considerably lighter logistics burden on both organizations and a pronouncedly expanded joint science program being developed between the two organizations. The author sees this as an indicator of how large field campaigns can be more cheaply facilitated in the future both in terms of methods and co-operation. It is noted that a similar example of co-operation with traverse between the Australian Antarctic Division (AAD) and Institut Polaire Français Paul Emile Victor (IPEV) has coincidentally been undertaken in the last year in East Antarctica, which tends to support this proposition.

## An Operations GIS for Antarctica

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The British Antarctic Survey (BAS)

The British Antarctic Survey is developing a Geographical Information System (GIS) to support its operations and logistics activities. The aim is to provide an online unified system for managing and displaying operations data to support decision-making and situational awareness.

The system is based around an easy-to-use web-mapping portal, which requires no specialist GIS knowledge and is built on open source, non-proprietary software and data standards. This approach allows for interoperability with other systems and potential for transfer to other organisations without incurring significant software costs.

The interface will allow queries about BAS operational data such as depot locations and content, personnel and asset activities, displaying up-to-date information about the locations of field parties, ships, aircraft, and location and information about fixed assets such as Global Positioning Systems (GPS) and Automated Weather Stations (AWS). Other real-time supporting information such as weather forecasts and Polar View sea ice information will also be integrated. Underlying map data from the Antarctic Digital Database (ADD) imagery from sources such as LIMA (Landsat Image Mosaic of Antarctica) and COMNAP compliant infrastructure information for international stations will also be included. In addition a number of tools have been built into the system, (including distance/area measurement, flight time and fuel burn calculator), which allow users to derive important information from the available information.

This system is currently in development for use within the British Antarctic Survey, but it clearly has potential application to the activities of all national programmes and COMNAP. It will allow greater sharing of information, supporting safer and more efficient operations. This presentation will demonstrate the key features of the pilot Operations GIS and highlight the potential for widening its current scope to support international cooperation.

## A new phase for the Antarctic sea ice information

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The Polar View programme (<http://www.polarview.aq>) helps enhance the safety and efficiency of vessels operating in the Antarctic by providing up-to-date sea ice information. This operational service has been providing timely information since 2005. Polar View users in the Antarctic include national programme scientists, tourist vessels, fisheries vessels and private expeditions.

Polar View has also provided direct support to a number of search and rescue activities in recent years. These operations have benefitted from easier access to sea ice information required by the rescue coordinators. Most recently Polar View provided imagery to a number of vessels involved in the rescue of the MV *Akademik Shokalskiy*.

A variety of satellite images and derived information products are created and delivered by a team of international collaborators. The next European radar satellite, called Sentinel-1 and launched successfully on 3rd April 2014, will provide a significant improvement in access to satellite radar imagery that is routinely used for sea ice navigation in the polar regions.

In recent years, the International Ice Charting Working Group (IICWG, <https://nsidc.org/noaa/iicwg/>), who coordinate the world's ice centres on all matters concerning sea ice and icebergs, has increased attention on Southern Ocean requirements for sea ice information. This includes efforts to improve coordination and co-operation between the national ice services that currently produce Antarctic ice charts (USA, Russia and Norway). The next IICWG meeting, which will focus on Southern Ocean ice charting, will be held from October 20th to 25th in Punta Arenas, Chile.

This communication will highlight the existing and growing international co-operation that delivers the Antarctic Polar View and sea ice-charting services. This is an important opportunity to communicate directly with the National Antarctic Programs in order to inform them of new developments, demonstrate improvements resulting from the new European Polar Ice project, and receive feedback on requirements.

## A new series of Air Operations Planning Maps for Antarctica

Adrian Fox

British Antarctic Survey

Good maps are essential for planning safe and efficient air operations in Antarctica. Existing Air Navigation charts are out of date, predate high-quality continent-wide topographic datasets such as the SCAR Antarctic Digital Database (ADD) and Landsat Image Mosaic of Antarctica (LIMA) and are only available at small scales. They are designed for high-altitude, over-flight aviation, not the science and operations support role of aircraft in Antarctica, and they lack detail and up-to-date COMNAP compliant information about Antarctic infrastructure.

In response, several national operators have produced Air Operations maps at 1: 1M scale to support their own airborne activities, but these have been produced independently and have a variety of styles, content, sheet boundary systems, projections and units and only cover about a third of the continent. Feedback from map users is that the existing bespoke maps are very useful, but would have even greater utility as a consistent, continent-wide series.

In response, the British Antarctic Survey, Belgian Institut Geographique National, Norwegian Polar Institute and US Polar Geospatial Centre are collaborating to produce a new series of Air Operations Planning Maps at 1:1M scale. The maps will have a consistent scale, projection, content and style to provide coherent, standardized coverage of the Antarctic continent. The maps are focused on planning for science and operations support by twin-otter type aircraft, and are not Air Navigation charts.

The initial objective is to provide coverage of priority areas for Antarctic summer season of 2014-15. The maps will be freely available for download from the SCAR Map Catalogue, either for printing or for further overlay of users' specific operational information.

This collaborative project shows how international co-operation can produce key operational resources for the Antarctic community that would be beyond the scope of each individual organization and much less useful if produced independently without international coordination for consistency and standardization.

## **Aurora Basin ice core drilling through international co-operation**

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Over five weeks, between December 2013 and January 2014, some 24 scientists, in two field teams, drilled a 300 metre long ice core and two approximately 100 metre long ice cores at the remote Aurora Basin North site, which is some 550 km inland from Australia's Casey Station. The long ice core will fill a major gap in an array of 2000 year ice core climate records distributed across Antarctica, and the two shorter cores and associated activities detailed records of changes in atmospheric composition and circulation over recent centuries.

The project was highly successful and was a result of outstanding international co-operation in both logistics and science. On the logistics front, France and Australia worked together to deliver the camp and build a skiway at the remote site. This used French shipping along with French/Italian traverse equipment and expertise. The traverse being a capability Australia does not have. Australian aviation resources then completed the input and finally undertook the extraction of the Australian run camp at the end of the expedition. On the science side the project involved fourteen partner organisations contributing from six nations: Australia, China, Denmark, France, Germany and the USA. The camp hosted up to 18 science and support personnel working on the three cores and associated activities, including detailed snow-pit studies, shallow cores and snow radar. The borehole of one core was utilised to pump large volumes of trapped air from porous subsurface layers for analysis of trace composition changes in recent decades. The traverse provided a platform for science activities, including extraction of several shallow cores (up to 20 m) and radar profiles of sub-surface layering across a large transect of previously unexplored terrain. The radar also assisted ice core interpretation by characterising layering along the flow-line upstream of the borehole. The fantastic success of the project was only made possible through international co-operation on both the operational and science fronts.

## Dronning Maud Land Air Network

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The Dronning Maud Land Air Network (DROMLAN) constitutes a substantial international collaboration on air operations in the Dronning Maud Land (DML) region, Antarctica. In 1999 the European Polar Board initiated a working group to search for solutions allowing easier access to the Polar Regions. Norway took the initiative to organize a test flight into DML in January 2001 and invited adjunct national programs to join in. This was followed up with a meeting with the partners from the test flight and other relevant national programs, in conjunction with the COMNAP meeting in Shanghai in 2002. The meeting resulted in an agreement between the national programs in DML, which later formed the foundation for DROMLAN.

The initial period of five years began with the signing of DROMLAN Terms Of Reference in July 2003 by eleven national COMNAP members operating in the DML region. As the partnership has proved to be beneficial for all members, a second Terms Of Reference signed in 2009 ensures continued cooperation of the members without stipulating a definite time period. Over the first years joint investments in combination with additional national investments were made to establish new or to upgrade existing infrastructure related to the activity. Likewise, the operational management of intercontinental and Antarctic flights as well as the mobilization and charter of appropriate aircraft were developed. In parallel a meteorological forecasting service was established to assist all DROMLAN air operations. Other structures have been jointly developed such as coordinated Search and Rescue and medical evacuation. As an offspring, some of the DROMLAN members are sharing vessel and costs related to maritime transport to their stations. To keep the DROMLAN running every season the national programs organise fuel provision, runways and/or prepared ski-ways, weather information and accommodation beyond their national needs. Since the season 2003/04, DROMLAN have regularly allowed easier and more frequent access into DML and the sharing of running costs has enabled more affordable transportation of personnel and equipment for scientific activities.

To date, a cargo aircraft IL-76TD has performed the vast majority of DROMLAN intercontinental flights, i.e. 108 round trip flights between Cape Town and the both runways at Novo (Russia) and Troll (Norway) were accomplished from the 2003/04 season until 2013/14. The majority of inland Antarctic flights were performed with two BT-67 aircraft to the various destinations. Highlights of national activities, supported by DROMLAN, have been the construction of new research stations between 2006 and 2010, the performance of the European Project of Ice Coring in Antarctica (EPICA) at Kohnen Station from 2004 to 2006, deployment of various field parties in DML during the International Polar Year 2007/09 and the regular operational support of aircraft deployed for scientific flight missions. Also inspection teams under the Antarctic Treaty have been using the airlink access from Cape Town to visit stations within DML such as the inspection by Norway in 2008/09, the inspection by Japan in 2009/10 and the international inspection teams Russia–US and Germany–South Africa during summer season 2012/13.

The organisational structure of DROMLAN consists of a Steering Committee, Executive Directorate, and an Operational Working Group. Decisions are reached through consensus. The DROMLAN Executive Directorate, currently consisting of two co-chairs, acts on behalf and within the framework agreed by the DROMLAN Steering Committee.

DROMLAN is still developing and will probably develop in the future. The consortium has proved to be beneficial for all involved nations. The flexibility, potentiality and saved cost are factors that have led to success, as for now and should do so for the future.

## Two methods for prediction of snow drifts around buildings in the Antarctic

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Japanese Antarctic Research Expedition

The Japanese Syowa Station has suffered from heavy snowdrifts around the buildings in the center area since some buildings were constructed adjacently. Snow accumulation is a serious burden on stress to buildings, snow removal and passage. It is obviously important to plan an appropriate design and layout of the buildings in order to minimize the snow drifts. Therefore, the Japanese Antarctic Research Expedition has developed two methods to predict snowdrifts around buildings.

One is wind tunnel experiments using scaled terrain and building models with artificial snowflakes. Recently, a wind tunnel test was implemented for a new big building (24m length and 12m width), the results of the test provided guidance on the best shape for the new building. Subsequently, a two-story building was constructed in the central region of the station. As a result, the snow drifts around the building are decreasing in size. The wind tunnel experiment is useful but needs time and adds costs associated with preparing the fabrication and performance. Another prediction method is a three-dimensional numerical simulation over complex terrain and buildings. We completed a simulation using the RIAM-COMPACT which was developed by T. Uchida, an associated professor of the Research Institute for Applied Mechanics (RIAM), Kyushu University. The method can predict unsteady three-dimensional airflow around buildings. The numerical result demonstrated a good agreement with actual snowdrifts. We intend to apply the same simulation to other areas and buildings, and to make heavy use of the method for building planning in Antarctic stations in the future.

## **A decade of art in Antarctica: 2004 –2014**

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The Cultural Project Department of Dirección Nacional del Antártico (DNA), enhances and promotes the exploration of aesthetic proposals for developing artistic projects focalised in the Antarctic.

The Art in Residency Program and International Co-operation Program are included in the Antarctic summer campaign, which takes place between November and March of each year. Art works are then shown in national and international, temporary and itinerant exhibitions entitled “Polar South, Art in Antarctica”, as well as in other venues including seminars, lectures, printed material and exchanges.

Some goals of the project are to enhance links between arts and sciences by promoting the interaction of the different disciplines, to improve links with institutions, associations, and universities to build international co-operation, and to generate an international Antarctic artists link.

The Art and Culture Project was outlined in May 2004 by the DNA. The project was initiated with Argentinean artists and was included in the International Co-operation Program in 2006 with artists from Spain and Canada, by finding out aesthetic possibilities of contemporary art associated with current matters concerning environment and by diffusing works at national and international levels.

The Art Program in Antarctica received other artists who worked with the aesthetic research on different disciplines, by combining art and science to produce a reflexive conscience for spreading works related to Antarctica. Artists from Chile, Brazil, Uruguay, Ecuador, Mexico, USA, Canada, Spain, France, Italy, UK, Bulgaria, Germany, Austria, India, Australia, New Zealand and Russia have participated in our program. The program is open to all disciplines such as: painting, sculpture, printing, drawing, music, performance, video, photography, and literature among others.

## **International co-operation at the J.G. Mendel Czech Antarctic station**

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Czech Republic National Antarctic Program

The presented poster describes the current achievements gained from the international scientific, as well as logistic co-operation, at the J.G. Mendel Czech Antarctic station, James Ross Island, Antarctic Peninsula Region, as one of many examples for the COMNAP symposium's main topic of international co-operation.

Above all, the main purpose is to declare the intention of the Czech Republic's Antarctic research programme, the youngest member of the COMNAP, to open access to its facility to be shared according to Antarctic community's ideals and to provide the background facilities to the research in the best manner of international co-operation.

## **Field, laboratory and numerical studies of snowdrift around the German Antarctic station, Neumayer III**

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To date, our ability to predict snowdrift around buildings have been limited in Antarctica, because of lack of field data and understanding of the snowdrift development processes. To provide design tools for Antarctic buildings which can be used in practice to minimize the snowdrift problems, an international joint project was conducted between the Polar Engineering Group of National Institute of Polar Research (NIPR) and the Department of Operations and Research Platforms of Alfred Wegener Institute (AWI).

We carried out a series of laboratory experiments using the low temperature wind tunnel at Shinjo Cryospheric Environmental Laboratory, Japan, which could reproduce natural blowing snow using artificial snowflakes. Numerical simulation was also performed with the use of “Airflow Analyst” integrating Computation Fluid Dynamics (CFD) simulation with ArcGIS software. Furthermore, V & V (verification and validation) were conducted using the field snowdrift accumulation data provided from AWI.

## Medevac in Antarctica during deep winter – an outstanding example of international collaboration

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During the Antarctic winter season of 2013, the vessel RV Polarstern of the Alfred Wegener Institute (AWI) stayed for several scientific cruises in the southern hemisphere crossing the Weddell Sea which was covered by pack ice. In the middle of July, a medical emergency call from onboard reached the institute. A young American scientist developed a Guillain Barré Syndrome accompanied by symptoms of paralysis, especially the threatening complication of the paralysis of breathing.

The next possible location for a medevac by aircraft during winter was King George Island and RV Polarstern set course towards Eduardo Frei base. Immediately AWI got in contact with the Chilean Antarctic Program (INACH) requesting for possible air lift via Eduardo Frei.

Further other national Antarctic programs operating on the Peninsula (Argentina and the UK) were contacted in case we had to look for an alternate. Likewise the US Antarctic Program (NSF) was involved and informed about the operations. NSF was tasked to take care of the patient's transport for further medical treatment.

At the same time, the German Foreign Office and the Chilean Air Force worked on schedules for sending in an aircraft corresponding to the progress of the vessel approaching King George Island.

The Argentine Antarctic Program (DNA) was on standby in case RV Polarstern should not be able to reach Eduardo Frei base due to ice and weather conditions and had to deviate to Ushuaia, Argentina.

Nearly one week after receiving the emergency call, a Hercules C-130 aircraft of the Chilean Air Force landed at Eduardo Frei and took the patient to a hospital in Punta Arenas, Chile from where the patient went back to the USA. Thanks to the outstanding international collaboration the medevac operation was carried out successfully.

## Antarctic Peninsula interactive station information map: a tool to promote international collaboration and co-operation

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Many successful collaborations and co-operative agreements begin with sharing information and increasing awareness of opportunities and common interests. In order to share information about opportunities, there must be opportunities to share information. International scientific collaborations often spring from scientists discovering common interests while presenting at conferences or identifying shared pursuits through publications in journals. Collaborations could benefit from earlier realization of such commonalities and awareness of opportunities and facilities through which to pursue them. To that end, we are developing an interactive, informational map of the stations in Antarctic Peninsula. We have chosen to focus on the Peninsula region given the relative density and proximity of stations. We are creating this map with these aims in mind: ease-of-use, informative visuals, comprehensiveness, and accessibility. In order to promote collaboration and co-operation through awareness, the information about the stations that we intend to incorporate into the map includes: statistics, descriptions and pictures of the station; information and pictures of scientific facilities; details about ongoing onsite and local environmental monitoring and data collection; and the areas of research focus. We believe that this informative, centralized, user-friendly tool will serve both the Antarctic scientific and program management communities. In the interest of promoting future collaborations, co-operation from national programs will be required in order to build this comprehensive interactive map and to maintain up-to-date information over time.

## COMNAP's role in fostering international co-operation

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Co-operation as mandated by the Antarctic Treaty is a principle objective of the Parties, of their national Antarctic programs and of the Council of Managers of National Antarctic Programs (COMNAP). There is a wide range of ways in which such co-operation can take place. As an organisation, COMNAP works to foster international co-operation in the support of science by serving as a forum for the 29-member national Antarctic programs to develop practices that improve effectiveness of activities in an environmentally responsible manner, by facilitating and promoting international partnerships, and by providing opportunities and systems for information exchange.

International co-operation is often evidenced by the number of jointly operated Antarctic stations. While this is indeed the ultimate demonstration of international co-operation in Antarctica in support of science, there exists a range of other ways national Antarctic programs co-operate. A recent survey of national Antarctic programs revealed that to one extent or another every COMNAP member national Antarctic program participates in or provides support for international scientific co-operation in Antarctica and in their home institutions.

There are always opportunities to improve efficiency in Antarctic operations, including increasing international co-operative efforts. Such is not without its challenges which will be presented along with some suggestions for improving our efforts in the future.

## **Eight years activities of workshop on Antarctic medical research and medicine promoting Asian co-operation**

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The Japanese Workshop on Antarctic Medical Research and Medicine has been held every year since 2004 to organize medical research and operational medicine in Japanese Antarctic activities and to discuss medical research of next expedition team. Participants from other Asian nations have been invited to attend since 2006. This is ideal because Antarctic medical research group of individual nations is small, therefore we must join with others in an action internationally. In total, the number of participants is beyond 400, including Asian members of about thirty from Korea, China and India. This network also provides a place for the exchange of information about practical operational medicine such as construction of new station and inner high land operation and so on.

This workshop begins to perform the function of an Asian local network on Antarctic medical research. It is expected that the workshop would stimulate research of each nation and encourage international Antarctic medical research.

## Spanish 2013-14 Antarctic campaign as an example of international co-operation

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Since 1988, Spain has successfully operated two Antarctic stations. They are "Juan Carlos I" in Livingston Island, and "Gabriel de Castilla" in Deception Island. During these 25 years, co-operation with the neighboring countries of the Antarctic Peninsula has been an important topic, including scientific exchanges, logistics and operational issues.

Regularly the Spanish Antarctic Program through these 25 years has used its polar vessels, the BIO Hespérides and BIO Las Palmas, to conduct marine research and logistical support at both stations. Noteworthy is that during the 2013-14 season, for various reasons, none of these vessels were available for research and/or logistical support to our stations. Based on a continuous and long-standing relationship with the Antarctic Programs of Brazil, Chile and Argentina and through excellent sustained international co-operation, we were able to complete most of the organisational requirements in relation to the Spanish Antarctic stations. This grateful and successful co-operation involved many major infrastructures such as ships and aircraft from the three mentioned countries, which were used to transport scientists and technical staff, as well as all the scientific equipment needed to properly run the two stations. A total of five ships-Ary Rongel (BRA), Achilles and Oscar Viel (CHL) and Castle and notice Beagle (ARG) and FAB, FACH and DAP planes were used.

Undoubtedly, the implementation of the Spanish campaign could not have been possible without the excellent relationship with these three Antarctic Programs, through the co-operation and assistance over the years, which is promoted and maintained within the COMNAP community.

This is a good example of how, through international co-operation, among national Antarctic program, many obstacles can be resolved through tough times. In the specific case of Spain, this was very useful to carry out a full Antarctic campaign, with all the complex implications in terms of resources, manpower and infrastructure.

## **The Argentinean, Brazilian, Bulgarian, Chilean, Portuguese and Spanish Antarctic Programs: an example of excellent co-operation in science**

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The Chilean Antarctic Institute (INACH) project Geochemical signatures of tephras from Quaternary Antarctic Peninsula volcanoes was realized with the logistic support by the Chilean Navy and the Brazilian, Bulgarian and Spanish Antarctic programs. The Antarctic stations of Bulgaria, Chile and Spain helped with facilities for laboratory and field work. The project contributed substantially to a better understanding and interpretation of individual climatic events as well as tendencies in the climatic evolution of the northern Antarctic Peninsula. The project Permafrost and Climate Change in the Maritime Antarctic (PERMANTAR) is an excellent example of international collaboration which contributes to the global scientific effort to bridge the gap in the knowledge of Antarctic permafrost characteristics, sensitivity and implications for climate change. PERMANTAR involves researchers from Portugal, Spain, Bulgaria, the USA and Argentina and there is multifunctional collaboration between all of research centres in all scientific tasks. The logistics are provided by the Spanish Antarctic Program (UTM), Bulgarian Antarctic Institute and an experienced Swiss company is responsible in permafrost drilling. Argentinean and Bulgarian scientific co-operation has a long standing history. Twenty years ago in 1994 Bulgarian geologists worked in the Argentinean field camp in Bayers Peninsula, Livingston Island. The data obtained have produced a series of paleogeographic maps, with the relative positions of the Antarctic Peninsula and Patagonia, from Late Jurassic to the present, which provide new insights. Last austral season two Bulgarian biologists took part in the project Algae from terrestrial and temporary aquatic habitats on the South Shetland Islands: species diversity, ecology and biogeography realized in the vicinity of the Argentinean base in Deception Island. During the survey several unknown diatom species were found. Four diatom species were described as new to science.

## Implementation of a Facility Management System(FMS) using a Building Information Model (BIM) and 3D GIS for the King Sejong, Korea Antarctic Station

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Gaia3D Inc, Korea Institute of Construction Technology (KICT) and the Korean Polar Research Institute (KOPRI)

The Korea Polar Research Institute (KOPRI) will launch a new 3D Facility Management System (FMS) for King Sejong Station this summer. This system adopts cutting-edge technology – Building Information Model (BIM) on GIS interoperability technology – and is the first time in the world to help people manage facilities and buildings efficiently and effectively. The system basically displays all BIM data in the station on 3D GIS, providing 3D experience to all users of the system. The system shows terrain, buildings and facilities in 3D and provides functions to roam around facilities. Users of the system can search objects or even parts of the facilities with criteria and can identify the properties of facilities in the station.

The system aims at providing two web services – public web for general users and private web for internal users of KOPRI. Public web allows users can virtually travel the station without physically getting to the station and experience the whole station in 3D. Private web helps professionals in KOPRI manage the facility and train people who plan to go to the station for research, facility management and so on. It is expected that this system provides a virtual experience which is an interesting introduction to the station for general users and improves the performance of the efficiency of facilities management.

To build BIM data of the station, converting of original 2D layout to 3D BIM and field survey was conducted. Core software technologies of this system are from a joint research project of Korea Institute of Construction Technology (KICT) and Gaia3D that are aiming at developing the BIM-on-GIS Interoperability Open Platform.

## Chilean strategies to increase international collaborations

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The Chilean Government took the decision to move the Chilean Antarctic Institute (INACH) headquarters down south from Santiago to Punta Arenas, at the end of the year 2003.

Being that Punta Arenas one of the major world gateways for National Antarctic Programs to Antarctica, the new location presented many opportunities to increase the international collaborations INACH had at the time.

However, at the same time, several members of staff left the Institute and therefore expertise and personal contacts were lost. Also, INACH changed the way scientific projects were selected, the number of Chilean Universities involved in Antarctic research increased and new projects and Principal Investigators arrived at the National Antarctic Program.

Therefore, INACH soon realized that new strategies, “bottom-up” and “top-down”, were needed to cope with this new scenario not to affect international co-operation.

This paper describes the implementation of different strategies and the results obtained so far. Several examples of sharing facilities and logistics are presented together with education and other initiatives.

## **XXXII Antarctic operation “OPERANTAR XXXII” and international co-operation**

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The representatives of the Secretariat of the Inter-ministerial Commission for the Resources of the Sea (SECIRM), members of the delegation of Brazilian Antarctic Program, intend to present a summary of the XXXII Antarctic Operation, which was recently completed, emphasizing the co-operation with the Antarctic Programs of Chile, Bulgaria, Portugal, Germany, Republic of Korea, Ecuador, Peru, Poland and Spain regarding the logistical aspects of the operation. Especially in regards to the transport of personnel and cargo using logistical flights, which were carried out by the Brazilian Air Force and the ships of the Brazilian Navy. The support given, in some cases, was essential to initiate the activities of Antarctic stations. It was remarkable also the use of the facilities of the Argentinian Base Teniente Câmara, for research purposes during the summer. The relevance of the subject lies in sharing this experience with others, as well as the satisfaction of having contributed to the achievements of other countries in Antarctica. The Brazilian Antarctic Program, especially the Brazilian Navy, will be available in case there is any need of support in the future.

## Dirck Gerritsz laboratory at Rothera research station: a successful UK–NL collaboration

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International collaboration is the only way for the Netherlands Polar Program (NPP) to carry out polar research.

Dutch Governmental policy is to minimize environmental impact in Antarctica. For this to succeed, it does not want to flag its commitment to Antarctica under the Antarctic Treaty by adding its own national station. The Antarctic part of the NPP is funded under the condition that access to Antarctica for NL scientists is realized through international collaboration. This policy stimulates the NPP to make use of and/or add to existing infrastructure and logistics. It creates opportunities to contribute and add strength to existing science programs and facilities.

In the Antarctic summer season 2012/13, the Dutch Dirck Gerritsz laboratory became operational at the British Rothera Research Station. The laboratory consists of a general purpose docking station that is built by BAS. Four containerized mobile laboratories, to be inserted in this station, are designed and constructed in the Netherlands. On integration of both components a flexible mobile lab facility is realized. A successful result of close cooperation between the NPP and the British Antarctic Survey (BAS).

The UK–NL collaboration is formalized in a Memorandum of Understanding. It realizes bilateral collaboration in three ways: (1) In logistics, (2) In infrastructure and (3) In science. Periodic calls for proposals, dedicated for using the lab facilities, are announced under the NPP for Dutch polar scientist. Collaboration between Dutch and UK scientists in each proposal is mandatory. BAS scientists are involved in the peer review process and its managers in the pre-assessment of the logistic feasibility of project applications. Each year pre- and post-season science and logistic meetings are organized for planning and to monitor progress. Appropriate polar training through BAS is part of the collaboration. This integrated collaborative approach has been positively evaluated in the NL polar sciences community and acts as an instrument in our national polar science policy to create focus and mass.

## **An opportunity for new collaboration in East Antarctica aviation operation for logistics and science: The new Chinese fixed-wing aircraft project**

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Aircraft have been playing a vital role, not only in supporting scientists to do their research as a logistic mean, but also in acting as a unique scientific platform itself. However, due to the limited availability of ground facilities in Antarctica and the complexities of operating fixed-wing aircraft in the harsh environment, Antarctica aviation has been a privilege only for some countries and a symbol of an advanced level of logistic technology.

It has been 30 years since the first CHINARE departed from Shanghai, China. Until today, there is no fixed-wing aircraft operation, which has limited Chinese activities in Antarctica, especially taking the function of emergency response by the fixed-wing aircraft into consideration.

Since 2011, China has been seeking to procure one medium-size, fixed-wing aircraft. Several models have been examined based on their merits according to the needs of logistics and science. Finally, the Antarctic veteran aircraft, Basler BT-67 modified from a DC-3, has been chosen. Basler BT-67 has been widely used in Antarctica for decades, and it proved that this kind of BT-67 has many advantages over other models.

The CHINARE BT-67 will be expected to operate in East Antarctica in the season of 2015/2016, using the Chinese Zhongshan Station as its logistic base. Aviation support to Dome Argus and other fields adjacent to the route from Zhongshan to Dome Argus will be priority for the CHINARE BT-67.

Regarding the airborne science, the aircraft will be installed with ice penetrating radar, gravity and magnetic devices enabling the aircraft to be an airborne survey platform. The initial airborne survey area will mostly focus on the Princess Elizabeth Land.

To make the good use of CHINARE BT-67 and to benefit the scientific community, China is open to other parties and looking for forward collaboration. Currently, China has been discussing with DROMLAN, Australia, UK, Russia, US and other interested parties for any kind of collaborations under the COMNAP umbrella.

The identified collaboration areas would include but not limited on: Operation and safety; Joined scientific projects; Ground support and facilities sharing; SAR and other Emergency response; Training and personnel exchange; and Long-term facility development strategy.

## International exchanges and co-operation in the new Chinese polar research vessel program

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CHINARE

“Globally joint design and made in China” has been upheld as the fundamental principle since the very beginning of the new Chinese polar research vessel program. The thought could be spotted in each phase of the program, spanning from the preliminary research to inviting two classification societies to check the drawings, from the international bidding to the basic design, all of which promised the smooth operation and the future success.

### A. Extensive International Research

Through exchanging ideas with European and Korea Polar Research Institute (KOPRI) counterparts and attending related seminars as part of COMNAP, we have learnt from our colleagues the effective and practical ways of organization according to the advantages of different enterprises. This has allowed us to meet the demands as well as their important experience based on the use of major facilities on board and derived from the design and construction of the vessels. All of these inspired us to integrate domestic and overseas design and research workforce to manufacture a world class icebreaker.

### B. Co-operation of Two Classification Societies

The “joint design” means far more than the cooperative drawings of the basic design in a narrow sense; it includes the idea of collaborations in all perspectives. The introduction of prestigious foreign classification societies is a typical example. It not only bridged the gap in classification of icebreakers, but also simplified participation in drawing check, supervision, survey and classification which ensured that the newly-built ship would live up to our expectations to the largest extent. Furthermore, the involvement of international classification societies helped create explicit classing standards and facilitates the design. In addition, the dual classing systems enabled two classification societies to bring features into play and avoid shortcomings which made the process feasible and efficient.

### C. International Bidding for Basic Design

As the most critical stage of the program, the basic design demonstrated the principle of “globally joint design” required by the State Council of China. International bidding made it possible for us to reach the qualified and world-renowned design companies with rich experience and good performances in manufacturing of polar research vessels, who can offer reasonable, reliable and cutting-edge solutions.

We invited China Classification Society (CCS) and Lloyd’s Register of Shipping to review the technical and business contents in the bid invitation documents of the basic design. We also included Korean and Canadian experts in the evaluation panels. All the bidding companies took pride in their experience of manufacturing world leading icebreakers. Finally, after four rounds of negotiations that lasted for four months, an agreement on design was signed with Aker Arctic Technology Inc (AARC), a Finnish company.

It is the perseverance in international co-operation that turns our hope for a world-class icebreaker into a reality and helps meet our expectations for the new vessel.