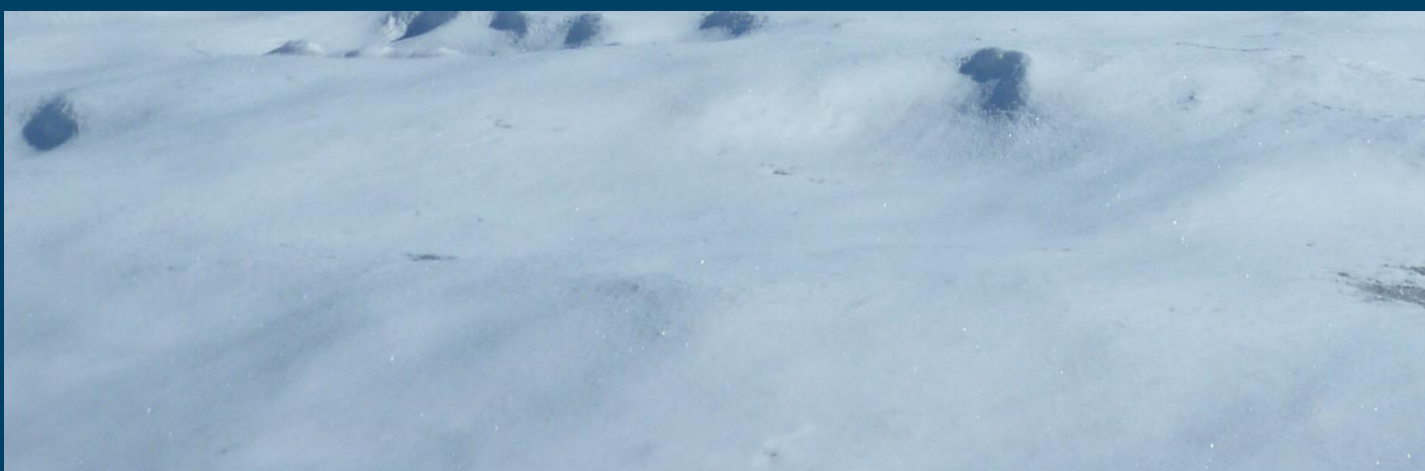
IASC Arctic Science Summit Week 2021
19-26 March | Online, Portugal

ASSW2021 Science Conference Book of Abstracts

19-26 March 2021



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www.assw2021.pt

The Arctic: Regional Changes, Global Impacts
http://www.assw2021.pt

Invitation to Lisbon for the ASSW2021

On behalf of the Portuguese Minister of Science, Technology and Higher Education, the Portuguese Foundation for Science and Technology (FCT) and the Local Organizing Committee we are pleased to invite you to take part in the Arctic Science Summit Week 2021, which will take place in Lisbon from 20 to 26 March 2021. The Conference is organized by FCT, Ciência Viva, AIR Center, the Portuguese Arctic Community and by IASC and partners.

Framed by the overarching theme for the Science Conference "The Arctic: Regional Changes, Global Impacts", Lisbon invites International experts on the Arctic and Indigenous Peoples to discuss the "New Arctic" and also its impacts and interactions to and with the lower latitudes.

It will be a pleasure to warmly receive you all in Lisbon for the ASSW2021.

Looking forward to seeing you all Lisbon next year.

Helena Pereira

Helena Pereira
President of the Board of Directors of the Portuguese Foundation of Science and Technology

João Canário
Chair of the ASSW2021

Gonçalo Vieira
Chair of the ASSW2021 International Scientific Committee

Arctic Science Summit Week 2021

19-26 March 2021
Lisbon, Portugal

INTERNATIONAL ARCTIC SCIENCE COMMITTEE

EDITORS

Canário, J.
Vieira, G.
Pina, P.
Baptista, J.
Folhas, D.
Freitas, P.
Miranda, V.
David, A.

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IASC Medal Lectures

Sue Moore - 2020 IASC Medalist

University of Washington Seattle, USA

Arctic marine ecosystems have undergone a profound transformation in recent decades, with decreases in sea ice extent and volume and increases in fresh water and ocean heat paramount among the myriad of physical changes. Except for measures provided by satellites, biological responses to these physical changes are often difficult to elucidate at regional and local scales. As upper trophic level predators, marine fishes, birds and mammals can act as sentinels of ecosystem variability and transformation. This presentation focuses on marine mammal responses to ecosystem variability in the Pacific Arctic region over the past four decades. Topics emphasized include their ecological relationships to sea ice, benthic productivity and aspects of advection and wind-forced upwelling that can lead to aggregations of pelagic prey. The conceptual Arctic Marine Pulses model is used to frame the interconnectedness of various biophysical components of the Pacific Arctic region. Marine mammals are essential to many Arctic Indigenous communities for sustenance and cultural identity, and serve as ‘charismatic megafauna’ for people living outside the Arctic. In Alaska, partnerships between researchers and Indigenous community members have provided a foundation for interpreting marine mammal body condition and health responses to ecological shifts. Fostering further development of Conventional Science-Indigenous Knowledge partnerships can strengthen our shared understanding of Arctic marine ecosystems, contribute to international efforts to promote improved stewardship of these places and respect the cultures that depend on their living resources.

Atsumu Ohmura - 2021 IASC Medalist

Swiss Federal Institute of Technology - Zurich, Switzerland

The surface of the Arctic has a relatively simple physiography of which 75% is the sea, leaving 17% to the tundra and 8% to glaciers, respectably. This condition offers an unmatched opportunity to develop and test natural laws. An example is the energy balance of the Arctic surfaces. The energy balance determines the regional climates, unique to Arctic seas, the tundra surfaces and the glaciers. Further, the energy balance distinguishes the Arctic from the lower latitudes. The investigation of the energy balance in the Arctic began in the 1960s at a modest level. For example, the classic work on the world energy balance by Michael Budyko avoided the region north of 70°N. Later works by a younger generation presented contradictory signs of the annual net radiation for the Central Arctic Ocean. This area has developed at present into a fully-fledged science, that can be used for climate prediction. For example, we presently have firm information on the distribution of radiation and its components. The series of the North Pole drifting stations made a decisive contribution. It has also become possible to detect the direction and magnitude of the current changes, so that the quality of climate predictions to the end of this century can be tested. The WCRP's (World Climate Research Programme) long-term projects, such as the GEBA (Global Energy Balance Archive) and BSRN (Baseline Surface Radiation Network) are making unique contributions. Several short-term case studies on this subject also made important contributions. They will be presented, from the field experiments carried out on the sea, tundra and glaciers. We are presently approaching a high level of understanding the future changes of the cryosphere in the Arctic.

Despite all these progresses, the knowledge of the icebergs in the Arctic Ocean remained unexplored. As the use of the marginal Arctic seas is accelerating every year, the eyes of the scientists are fixed only on the sea ice. There is no internationally coordinated information on the iceberg situations necessary for safe navigation. Modelling of the glacier curving stops at the moment of the curving from the ice front and does not develop to the stage of the iceberg movement and distribution. The use of the RADAR with a frequency for the iceberg detection is hampered for defense reasons. This situation poses a serious risk for the Arctic navigation for the present and near future. Further, a possible direction for the future development of Arctic science will be discussed.

Key Note Lectures

Sheila Watt-Cloutier

Canada

The Arctic as your North Star: Re-Imagining a Way Forward by Humanizing Climate Change

When we speak of the future of the Arctic, we are speaking of the future of the world. Everything is inter-related and connected. We must now speak leadership, environment, economy, foreign policy, health and human rights in the same breath," says Sheila Watt-Cloutier. In this truly globe-spanning talk, Watt-Cloutier provides a clear, meaningful, and comprehensive understanding of why we must shift our thinking from a solely scientific view to one of the human dimensions. More so now, in light of the pandemic, we must move away from how the many issues are often portrayed as a battle between competing interests. On that note Watt-Cloutier makes the connection between the pandemic and climate change and offers a shift in re-imagining a way forward with re-aligning Indigenous values and principles to our economic values.

Zita Martins

Instituto Superior Técnico, University of Lisbon, Portugal

The Arctic as a Planetary Analogue for the Detection of Signatures of Life on Icy Moons of our Solar System

The possibility of extra-terrestrial life existing somewhere in the solar system is a subject that captivates humanity and remains an unanswered scientific topic. Some of the moons of Jupiter and Saturn (e.g. Europa, Ganymede, and Enceladus) have an icy surface with a subsurface ocean. These are habitable environments that may host life, which may be indirectly detected by the presence of biosignatures in the surface of the icy moons. Future space missions, such as NASA's Europa Clipper and ESA's JUICE have the goal to determine whether life exists in icy moons. To prepare for these space missions, scientists use the Arctic as a planetary analogue, i.e. terrestrial samples from a field site that mimic the icy moons of Jupiter and Saturn in terms of extreme conditions (e.g., cold temperatures, salinity, pH, and water availability). In particular, the Artic is used to (i) perform in-situ measurements to test protocols and equipment, and (ii) collect samples for state-of-the-art analyses in the laboratory to detect biosignatures, investigate the interactions between biosignatures/rock/water (liquid and ice), and to identify microorganisms from extreme environments. Therefore, the Artic is a crucial player in space science and astrobiology, especially on the validation of the methods of detection of potential extra-terrestrial biosignatures, and of the instrumentation and payload of future space mission.

Letizia Tedesco

Finnish Environment Institute Helsinki, Finland

Emerging Ecological Consequences of Arctic Sea-Ice Decline

The Arctic sea-ice decline is among the most emblematic manifestations of climate change and is occurring before we can understand its ecological consequences. Arctic food webs are short and relatively species poor, rendering them vulnerable to changes or perturbations at any individual trophic level. High-latitude warming represents one major source of potential perturbation to Arctic marine and terrestrial food webs, which may experience cascading effects derived from changes in primary production through so-called “bottom-up” effects. In this talk Iwill review current knowledge and deliver a set of predictions for key biogeochemical and ecological indicators representative of the ice-covered Arctic Ocean. In particular, I will give an overview of the changing Arctic icescape, the drivers of biological changes for Arctic marine algae, the different pulses of Arctic marine primary production,some patterns of trophic and phenological changes, and some mechanisms through which sea-ice dynamics ostensibly influence terrestrial primary productivity. I will close my talk with an overview of the challenges ahead for reaching a holistic and comprehensive understanding of the ecosystem dynamical consequences and associated impacts on human life of warming-related sea-ice decline.

Vyacheslav Shadrin

Chair of Council of Yukaghir Elders, Russian Federation

Traditional Knowledge and Climate Change: Challenges and Opportunities

Climate Change Challenges for Traditional Knowledge

- traditional ways of predicting the weather are changing
- the local landscape is changing
- the traditional time of hunting, fishing, wandering is shifting
- loss of terms related to cold, snow, ice, etc
- the scope of the language is decreasing with the reduction of traditional industries

Old Science Approaches to Traditional Knowledge:

- colonial / unequal approach to traditional knowledge;
- paternalistic attitude - to change: nothing for us without us
- TK keepers - only informants, i.e. object of research, must be coauthors, subject of research
- inequality in opportunities (grants, salary, publications, claims in scientific journals and publishing houses, ...)
- inequality in functioning - the basis of functioning, state support, financing, ...

Opportunities

Similarities

- complexity, accumulation of experience / knowledge, description

Differences

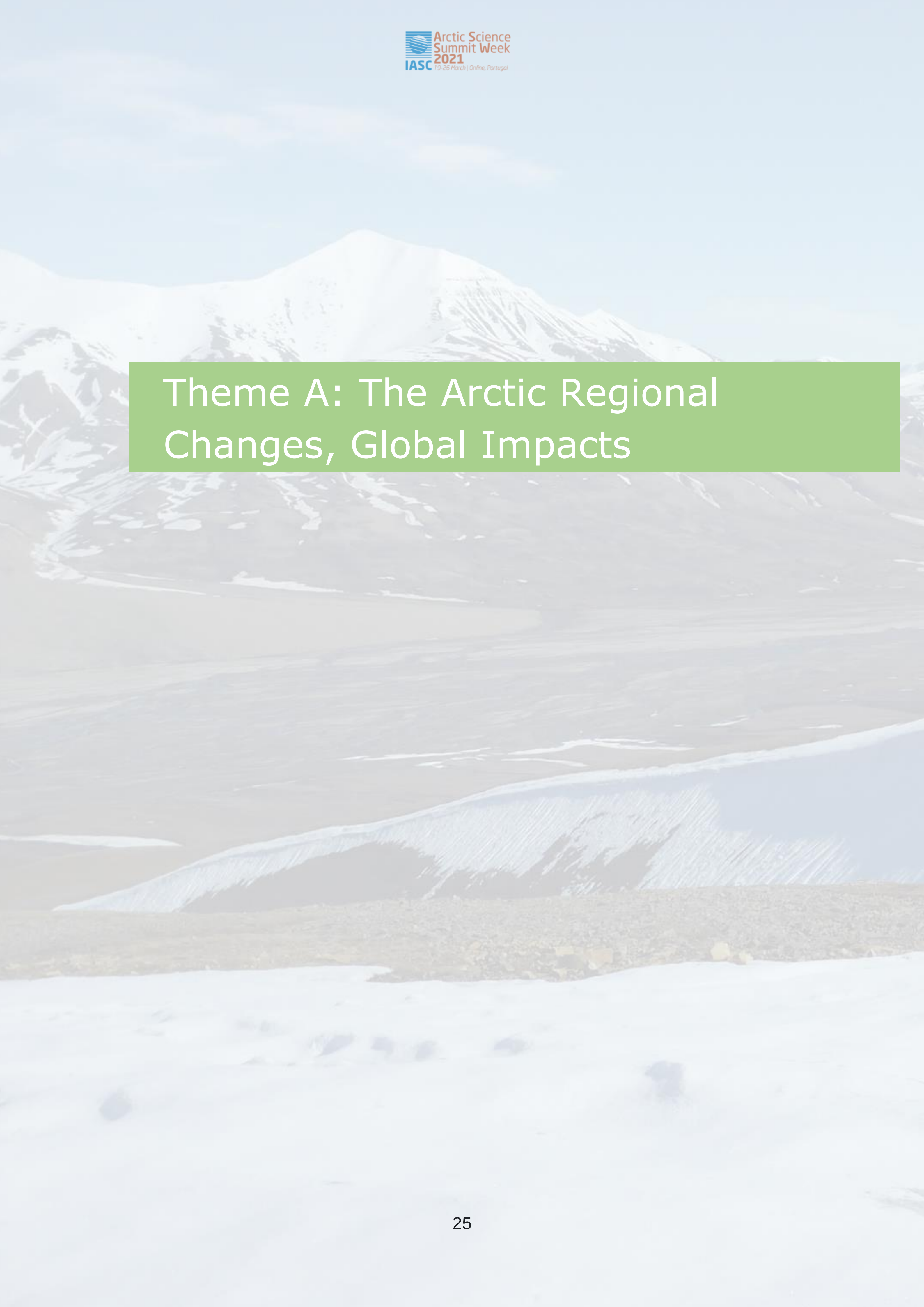
- Different worldview approach, vision of details;
- A more practice-oriented vision - the results are important, not the process itself;
- Experience / memory of previous generations, opportunities and practices of adaptation;

Collaboration between traditional knowledge holders and leading scientific researchers can lead to the joint production of new knowledge that will lead to effective responses to climate change.

Warwick F. Vincent
Laval University, Quebec City, Canada

Arctic Connections: Lands, Seas, Culture and Last Ice

The oldest, thickest sea ice in the Arctic Ocean occurs along the northern edge of Greenland and the Canadian Arctic Archipelago. Ocean currents transport sea ice into this coastal zone from as far away as the Laptev Sea, and summer ice is projected to persist longer in this area than elsewhere in the Arctic Ocean. This ‘Last Ice Area’ is thereby considered the ultimate refuge for ice-dependent species in the rapidly warming North, including the newly protected area Tuvaijuittuq, meaning ‘lasting ice’ in Inuktitut. There is a strong reciprocal coupling between the land and ocean in this region: the land barrier allows the accumulation of sea ice, while the local ice-dependent climate is critical to maintaining many of the land-associated features, including glaciers, ice shelves, ice-capped lakes and perennial snowbanks that feed water tracks across the polar desert landscape. The coastal zone passes across Canada’s northernmost land conservation region, Quttinirpaaq National Park, where a strategic plan in development pays special attention to Inuit cultural values, and where a new project on ‘Last Ice Microbiomes’ connects the lands, ice and seas, and also links the IASC projects T-MOSAiC and MOSAiC. This area contains a remarkable diversity of ecosystems, but these habitats are changing rapidly in response climate warming, underscoring the need for urgent climate action at global scale combined with a holistic Indigenous approach to assure their regional conservation.



Theme A: The Arctic Regional Changes, Global Impacts

ID:62 - Arctic climate change and its impacts on weather and climate in the midlatitudes

Conveners

Thomas Jung | Alfred Wegener Institute

Yongqi Gao | Nansen Environmental and Remote Sensing Center

Guokun Lyu | University of Hamburg

A clear role of Arctic sea ice loss for the winter Warm Arctic Cold Eurasia trend

Rohit Ghosh, University of Reading, Reading, United Kingdom
Elisa Manzini, Max Planck Institute for Meteorology, Hamburg, Germany
Yongqi Gao, Nansen Environmental and Remote Sensing Center and Bjerknes Center for Climate Research, Bergen, Norway
Guillaume Gastineau, Sorbonne Université, CNRS/IRD/MNHN, UMR LOCEAN, Paris, France
Annalisa Cherchi, Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici, Bologna, Italy
Claude Frankignoul, Sorbonne Université, CNRS/IRD/MNHN, UMR LOCEAN, Paris, France
Yu-Chiao Liang, Woods Hole Oceanographic Institution, Massachusetts, U.S.A
Young-Oh Kwon, Woods Hole Oceanographic Institution, Massachusetts, U.S.A
Lingling Suo, Nansen Environmental and Remote Sensing Center and Bjerknes Center for Climate Research, Bergen, Norway
Jennifer V. Mecking, Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton, Southampton, UK
Tian Tian, Danish Meteorological Institute, Copenhagen, Denmark
Ying Zhang, Nansen-Zhu International Research Center, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, People’s Republic of China

Keywords: Warm Arctic-Cold Eurasia, Ural blocking, Arctic Oscillation, midlatitude response to Arctic sea ice loss

The role of Arctic sea ice (SIC) loss in the recent Eurasian winter cooling remains debated due to contradictory results from observations and models. Here, a large multi-atmospheric-model ensemble experiments, with and without observed Arctic SIC forcing, confirms that during 1979 to 2014 the Barents SIC loss forces Eurasian cooling by inducing a strengthening trend in the Ural blocking related second mode of Eurasian surface air temperature (SAT) variability, the Warm Arctic-Cold Eurasia (WACE) pattern. However, this Eurasian cooling is overshadowed in the models by the significant yet unrealistic warming associated with the positive trend in the Arctic Oscillation related leading mode of Eurasian SAT variability. Further observations until 2019 shows that the Eurasian cooling trend from the WACE pattern has increased in the recent years, though the effect of the cooling is dampened by warming from the recent shift to a positive phase of the Arctic Oscillation.

Arctic sea-ice loss intensifies the aerosol transport to the Tibetan Plateau

Fei Li, Geophysical Institute, University of Bergen and Bjerknes Centre for Climate Research, Bergen, Norway
Xin Wan, Key Laboratory of Tibetan Environment Changes and Land Surface Processes, Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing, China
Huijun Wang, Collaborative Innovation Center on Forecast and Evaluation of Meteorological Disasters/Key Laboratory of Meteorological Disaster, Ministry of Education, Nanjing University of Information Science & Technology, Nanjing, China ,4,5,
Yvan Joseph Orsolini, NILU−Norwegian Institute for Air Research, Kjeller 2007, Norway
Zhiyuan Cong, Key Laboratory of Tibetan Environment Changes and Land Surface Processes, Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing, China
Yongqi Gao, Nansen Environmental and Remote Sensing Center and Bjerknes Centre for Climate Research, Bergen, Norway
Shichang Kang, Key Laboratory of Cryospheric Sciences, Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences, Lanzhou, China

Keywords: The Arctic sea ice, the Tibetan Plateau pollution, the Northern Hemisphere teleconnection

The Tibetan Plateau (TP) has recently been polluted by strong anthropogenic emissions from South Asia. However, the mechanisms controlling the atmospheric circulations conducive to the aerosol transport to the TP are poorly understood. Here we show that winter loss of Arctic sea-ice over the sub-polar North Atlantic boosts the aerosol delivery toward the TP in April, when the aerosol loading is at its climatological maximum, preceding the Indian summer monsoon onset. Low sea-ice in February weakens the polar jet, which leads to the decreased Ural snowpack through a lessened transport of oceanic air. The decreased snowpack persisting to April reinforces the Ural pressure ridge and the East Asian trough, parts of a quasi-stationary Rossby wavetrain extending across Eurasia. These conditions facilitate the enhanced subtropical westerly jet at the southern edge of the TP, invigorating upslope wind combined with mesoscale updrafts wafting upstream emissions over the Himalayas onto the TP.

Arctic-midlatitude linkages: role of sea ice loss versus full Arctic Amplification

Yannick Peings, Department of Earth System Science, University of California Irvine, Irvine, CA, USA
Zack Labe, Department of Earth System Science, University of California Irvine, Irvine, CA, USA
Gudrun Magnusdottir, Department of Earth System Science, University of California Irvine, Irvine, CA, USA

Keywords: Arctic mid-latitude linkages, Climate modelling, sea ice loss, Arctic Amplification, Warm Arctic Cold Siberia

The impact of Arctic sea ice loss on the mid-latitude climate can be isolated by prescribing sea ice anomalies in climate models. We present results from large ensemble of simulations that explore the impact of Arctic sea ice loss at global warming levels of +2°C. In winter, the model simulates a weakening of the westerlies on the poleward flank of the mid-latitude jets. However, when the simulations are extended the response is no longer consistent, highlighting the low signal to noise ratio and influence of internal variability. With an interactive ocean, the spread in the response is even greater due to additional internal variability from ocean dynamics. Since sea-ice decline is only one contributing factor to Arctic amplification (AA), sea ice loss experiment do not capture the total warming of the atmosphere due to Arctic climate change. In a second set of experiments, we impose AA warming as found in the CESM-Large Ensemble (RCP8.5) near years around 2030, 2060, and 2090. The 2060 and 2090 AA warming experiments reveal a stronger and more consistent wintertime atmospheric response in mid-latitudes. In particular, the elusive Warm Arctic Cold Siberia pattern emerges, with a strengthening of the Siberian High that induces a cooling over eastern Asia. We find that the amplitude of this signal depends on the vertical extent of Arctic warming, highlighting that sea-ice loss simulations may not observe the complete role of Arctic-mid-latitude climate teleconnections

Direct Observations of Arctic-Midlatitude Connections

James Overland, NOAA/Pacific Marine Environmental Laboratory, Seattle WA, USA
Baek-Min Kim, Pukyong National University, Busan, Republic of Korea
Yoshihiro Tachibana, Faculty of Bioresources, Mie University, Tsu, Japan.

Keywords: arctic-midlatitude connections, jet stream, sea-ice loss, arctic atmospheric dynamics

There is considerable controversy over the extent that Arctic change can influence midlatitude extreme weather. Three potential interactive physical processes are involved in amplifying Arctic-midlatitude connections through atmospheric long-wave dynamics: 1) local thermodynamic surface forcing, often associated with loss of sea ice; 2) warm and humid air advection into an existing longwave ridge; and 3) internal atmospheric blocking processes that add to the persistence of a wavy jet stream pattern. All three processes were active in two recent observational studies: winter 2015-16 in the Barents Sea and early winter 2017 in the Bering/Chukchi Sea. The Barents event was initiated by low potential vorticity (less than 5 PVU on the 330 K isentropic surface, approximately 300 hPa) that intruded into the Arctic with an associated northward warm air flow that initiated an atmospheric blocking regime. Daily surface air temperatures, sea ice, and area-averaged turbulent heat fluxes indicated an overall multi-week average upward surface flux, punctuated by episodic horizontal warm air advection. The Chukchi event was similar; there was a northern excursion of the jet stream with warm air advection, and multi-week average upward surface heat flux. Both events resulted in increased local atmospheric geopotential thickness and downstream cold air advection into midlatitudes.

Making advanced Arctic predictions a reality: the APPLICATE project

Thomas Jung, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany

Keywords: Arctic climate change, Arctic Mid-latitude linkages, APPLICATE project, predictive capacity, sea ice predictions

The Arctic region is undergoing dramatic changes in its environment and climate, and these changes have the potential to influence and transform the weather and climate in lower latitudes. A European consortium of scientists has undertaken the mission to find out the breadth of these transformations in the EU-funded H2020 project APPLICATE. The project started in 2016 with the objective of improving the representation of key processes in coupled atmosphere-sea ice-ocean models, delivering enhanced numerical weather forecasts, seasonal to interannual climate predictions and centennial climate projections. The project's focus also concerns the linkages between the Arctic and mid-latitudes, which are explored through a coordinated multi-model approach using coupled atmosphere-ocean models (i.e., the Polar Amplification Model Intercomparison Project). APPLICATE is contributing to the design of the future Arctic observing system to improve the capacity to reanalyse the climate system and enhance predictive capacity, establishing collaborations with other programs (e.g., with projects within the EU-funded Polar Cluster). Moreover, the user engagement team works to disseminate scientific results to the community of stakeholders and seeks to provide policy-makers and other users with the necessary knowledge to make decisions regarding weather and climate strategies. APPLICATE is also invested in training and education endeavours that aim to widen and strengthen the community working on weather and climate research in the polar regions. With the project closing in April 2021, this presentation will give an overview of APPLICATE outcomes as part of our effort to understand changes in the Arctic and their far-reaching impacts for both environment and communities. It will be the occasion to look back at the past four years of work and research and summarize the achievements, success stories and impact the project, as well as the community behind it, accomplished.

Increasing occurrence of heat waves in the terrestrial Arctic and middle latitudes

Luca Pozzoli, European Commission - Joint Research Centre, Ispra, Italy
Srdan Dobricic, European Commission - Joint Research Centre, Ispra, Italy
Simone Russo, European Commission - Joint Research Centre, Ispra, Italy
Julian Wilson, European Commission - Joint Research Centre, Ispra, Italy
Elisabetta Vignati, European Commission - Joint Research Centre, Ispra, Italy

Keywords: Heat Waves, Cmip Scenarios

Heat waves in the Arctic may strongly impact environment and local communities. Recently several indices have been proposed for monitoring environmental changes in the Arctic, but heat waves have not been addressed. By applying a structured approach for evaluating occurrences of periods with exceptionally high temperatures, this study demonstrates that in the last decades there was an increase of heat wave occurrences over the terrestrial Arctic. The increase is mainly over the Canadian Arctic Archipelago and Greenland that are surrounded by ocean undergoing a sea-ice melting trend, while the Eurasian Arctic, that may experience a stronger impact from the weather in the mid latitudes, shows no significant change in heat wave occurrence. Since 2002 the probability of experiencing heat waves in the Arctic has been similar or even higher than in the middle and low latitudes and heat waves have already started to increasingly threaten local vegetation, ecology, human health and economy. The CMIP5 and CMIP6 ensemble simulations show a faster increase of heatwave occurrence in the Arctic compared to the middle latitudes in 2050.

Re-emergence of SST anomalies as an important source of predictability of wintertime sea ice cover in the Barents Sea

Pawel Schlichtholz, Institute of Oceanology of the Polish Academy of Sciences, Sopot, Poland

Keywords: Barents Sea, Sea-Ice, Predictability, SST Re-Emergence

Changes in Barents Sea ice cover affect the Arctic climate system and possibly weather and climate variability at lower latitudes. Using observations and reanalysis data, we investigate statistical linkages between winter sea ice cover in the Barents Sea region to ocean temperature anomalies during the era of satellite observations (1981-2018) and its two subperiods, an EARLY epoch with insignificant sea ice loss in the region and a LATE epoch with rapid sea ice decline. We show that the ocean temperature anomalies generated by local air-sea interactions at the end of winter constitute a significant source of predictability for sea ice area (SIA) in the Barents Sea the following winter. First, relations of summer and autumn Atlantic water temperature in the region to the sea surface temperature (SST) and atmospheric conditions during the previous winter-to-spring season and to the sea ice cover the following winter are analyzed. Then, the structure of time-lagged cross-correlations between seasonal mean Barents Sea SIA and area-averaged SSTs in the southern Barents Sea is explored. Finally, the leading mode of spring-to-the-next-winter coupling between ocean temperatures is extracted from the cross-covariance matrix of SST anomalies in the Barents Sea region, and the associated sea ice and atmospheric variability is examined. Differences in this variability between the EARLY and LATE epochs are emphasized.

Wind conditions in the summer seasons in the Arctic region of Oscar Land II (NW Spitsbergen) in the period 1975-1989

Rodrigo Rudge Ramos Ribeiro, São Paulo, Brazil
Getulio Vargas Foundation, São Paulo, Brazil

Keywords: Extreme Weather, Wind, Svalbard

This study examines the average wind speed changes in Arctic region of northwest Spitsbergen, Svalbard. The Polar Regions are integral components of the Earth system. As the beat sinks of the climate system they both respond to and drive changes elsewhere on the planet. The methodology was done by analysis of meteorological observation data from the Oscar Land (Spitsbergen) during the summer seasons during 1975, 1977, 1978, 1979, 1980, 1982, 1985 and 1989. The data is from the Polish station of Nicolaus Copernicus University Polar Station in Kaffiøyra. The results indicated and average wind speed for the all years of 4.65 m/s and the year of 1979 with the biggest variance value of 8.03. The analysis of the maximum wind speed indicates the year of 1985 with 13.2 m/s. As conclusion, it is observed a tendency of increase the wind speed during the period analysed.

ID:65 - Mid- and low-latitude impacts on the Arctic and Antarctic

Conveners

Timo Vihma | Finnish Meteorological Institute, Helsinki, Finland

Genrikh Alekseev | Arctic and Antarctic Research Institute, St. Petersburg, Russia

Natalia Gnatiuk Nansen | International Environmental and Remote Sensing Centre, St. Petersburg, Russia

Interaction between Atlantic cyclones and Eurasian atmospheric blocking drives warm extremes in the high Arctic

Sonja Murto, Department of Meteorology (MISU), Stockholm University, Sweden
Rodrigo Caballero, Department of Meteorology (MISU), Stockholm University, Sweden
Gunilla Svensson, Department of Meteorology (MISU), Stockholm University, Sweden

Keywords: High-latitude blocking, Arctic warming, diabatic heating, midlatitude cyclones

Atmospheric blocking can influence Arctic weather by diverting the mean westerly flow polewards, bringing warm, moist air to high latitudes. Recent studies have shown that diabatic heating processes in the ascending warm conveyor belt branch of mid-latitude cyclones are relevant to blocking dynamics. This leads to the question of the extent to which diabatic heating associated with midlatitude cyclones may influence high-latitude blocks and drive Arctic warm events. In this study we investigate the dynamics behind 50 extreme warm events of wintertime high Arctic surface temperature anomalies. We find that 30 of these events are associated with “Ural” blocking, featuring negative upper-level PV anomalies north of the Ural Mountains. Lagrangian back-trajectory calculations show that almost 70% of the air parcels making up these negative PV anomalies experience lifting and diabatic heating (average 14,7K) in the 9-days prior to blocking. Further, 43,4% of the heated trajectories undergo maximum heating and lifting in a compact region of the midlatitude North Atlantic, temporally taking place between 6 and 2,5 days before arriving in the blocking region. We also find anomalously high cyclonic activity (on average 5,43 cyclones within a 3,5-day window around the time of maximum lifting) within a sector northwest of the main lifting domain. This study highlights the importance of the interaction between mid-latitude cyclones and Eurasian blocking as driver for Arctic warm extremes.

Multi-decadal tropical-Arctic atmospheric teleconnections and their influences on summer Greenland Ice Sheet melt

Dániel Topál, Institute for Geological and Geochemical Research, Research Center for Astronomy and Earth Sciences, MTA-Center for Excellence, Budapest, Hungary & Department of Geography and Earth Research Institute, University of California-Santa Barbara, Santa Barbara, CA, USA
Qinghua Ding, Department of Geography and Earth Research Institute, University of California-Santa Barbara, Santa Barbara, CA, USA
Thomas J Ballinger, International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, AK, USA

Keywords: Greenland, Arctic, Teleconnections, Paleoclimate

Despite the contribution of the Greenland Ice Sheet (GrIS) to global sea level rise, the lack of a complete understanding of its driving mechanisms largely constrains future model projections. Brief observational records limit model development efforts, however, the assimilation of paleoclimatic proxy data in climate models provides new opportunities to place recent climate changes in and around the Arctic in the context of long-term high-latitude variability. Building off of previous work, we investigate the relative role of internal atmospheric variability in modulating GrIS surface mass balance (SMB) using the newly available Ensemble Kalman Fitting Paleo-Reanalysis (EKF400) version 2, with monthly resolution for the period 1602-2003 AD, and the Last Millennium Reanalysis (LMR) version 2, which has an annual resolution from 0-2000 AD. We apply maximum covariance and empirical orthogonal function analyses on these two datasets to reveal co-varying patterns of Arctic upper-tropospheric changes and the GrIS SMB over centennial and millennial timescales with a special focus on remote tropical drivers of this local coupling. In light of these tropical-Arctic linkages in shaping GrIS conditions over the past two millennia, the application of proxy-assimilated model experiments provides deeper insights into the formation of such atmospheric dynamical connections that may impact GrIS SMB in the future.

Non-stationary relation between El Nino-Southern Oscillation and sea surface temperature in the Barents Sea

Sourav Chatterjee, National Centre for Polar and Ocean Research, Ministry of Earth Sciences, Goa, India
Urmila P, Cochin University of Science and Technology, Kochi, India

Keywords: ENSO, Barents Sea, Sea Surface Temperature, Teleconnection

Tropical climate variabilities at different time scales ranging from intraseasonal to decadal are known to influence the Arctic climate. Here, in this study, we investigate the role of a major tropical climate mode, El Nino-Southern Oscillation (ENSO) on sea surface temperature (SST) in the Arctic Ocean (AO), more particularly in the Barents Sea. The shallow depth, lateral advection of warm Atlantic water, and seasonal sea ice cover changes make this particular area of the AO a ‘hot-spot’ for Arctic amplification. While numerous studies have been conducted to understand the driving mechanisms for the observed changes in the Barents Sea, one of the aspects which are still understudied is the role of tropical climate variability. A few studies do suggest a possible link between ENSO and Barents Sea SST based on a limited number of observations but the robustness of the dynamical linkage requires further attention. This is more important given the recent changes in ENSO characteristics itself and also its interactions with other climate modes. Here we reassess the ENSO-Barents Sea relation during the last few decades and suggest that the ENSO influence in the BS is not stationary and modulated by the mid-latitude climate variability. The finding of the study indicates that tropical influence on Arctic climate may be significantly determined by the interactions between tropical and extratropical climate variability.

Stratospheric modulation of marine cold air outbreaks in the Arctic

Hilla Afargan-Gerstman, ETH Zurich, Switzerland

Keywords: Cold Air Outbreaks, Stratosphere, Large Scale Circulation, Predictability, Barents Sea

Marine cold air outbreaks (MCAOs) in the Arctic are associated with a range of hazardous conditions, posing risks for marine vessels and offshore infrastructure. MCAOs can cause multiple correlated hazards, including cold temperature extremes, strong surface winds, and the occurrence of extreme cyclones known as polar lows. MCAO frequency has been linked to the strength of the stratospheric polar vortex. However, the remote influence of the stratosphere on MCAOs has remained unresolved. In this study, we examine how extreme stratospheric events, known as sudden stratospheric warmings (SSWs), affect the variability, frequency, and magnitude of MCAOs in the Arctic using reanalysis data. We show that changes in the large-scale tropospheric circulation in the North Atlantic after SSW events lead to more frequent MCAOs in the Barents Sea and the Norwegian Sea, and less frequent MCAOs in the Labrador Sea, compared to climatology. An anomalous dipole pattern of 500-hPa geopotential height, which consists of a ridge anomaly over Greenland and a trough anomaly over Scandinavia, is found to be a key element for increasing the likelihood of MCAOs in the Barents Sea and the Norwegian Sea. As SSW events tend to have a long-term influence on surface weather, these results could help improve the predictability of marine cold air outbreaks in the Nordic Seas for winters with SSW events.

The vertical structure of life in the oceans tracks temperature toward the poles

Julek Chawarski, Centre for Fisheries Ecosystem Research, Memorial University of Newfoundland, St. John's, NL Canada
Thor Klevjer, Institute of Marine Research, Bergen, Norway
Maxime Geoffroy, Centre for Fisheries Ecosystem Research, Memorial University of Newfoundland, St. John's, NL Canada

Keywords: Deep-Scattering Layer, Mesopelagic, Fish, Zooplankton, Polar

The oceans sequester 22.6% of atmospheric carbon annually, but the magnitude of biologically enhanced sequestration is not evenly distributed across the globe. Measuring surface primary productivity offers a reasonable proxy for estimating carbon flux in the ocean6, but entirely misses the processes that affect the downward flux in the water-column. A high proportion of the downward flux is broken up or respired by organisms at mesopelagic depths (200-1000 m). At low and mid-latitudes, daytime biomass peaks are clearly present at mesopelagic depths, detectable as sound-scattering layers, and studies suggest that a high fraction of sequestered carbon passes through these components. Here we show that backscatter from midwater fish in open ocean ecosystems sharply decreases toward the poles, and that this decrease is accompanied by a drastic drop in backscatter from both zooplankton and fish in the deep mesopelagic, showing that the vertical structure in high latitude ecosystems is different. This drastic reduction in mesopelagic backscatter is observed both in the Arctic and Antarctic and coincides with polar fronts. The latitudinal transformation in vertical structure, through reduced biomass and/or community diversity, suggests that carbon flux attenuation is structured differently in ocean twilight zones of polar ecosystems. As species expand pole-wards with climate warming, this gradient in backscatter may shift, altering biogeochemical cycles at high latitudes.

Using reconstructed Irminger Water changes within the past three decades to connect the West Greenland shelf to the production of Labrador Sea Water

Kevin N. Wiegand, University of Bremen / MARUM, Bremen, Germany
Dagmar Kieke, University of Bremen, Bremen, Germany
Paul G. Myers, University of Alberta, Edmonton, Canada

Keywords: West Greenland Shelf, West Greenland Current, Irminger Water, Time Series Reconstruction, Water Mass Variability

In this study we analyze the exchange processes between the West Greenland shelf and the Labrador Sea. This region is affected by warm and saline waters from the North Atlantic, as well as cold and fresh waters from the Arctic and the Greenland Ice Sheet. Heat and freshwater both impact the local formation of Labrador Sea Water (LSW) that itself is a major contributor to the Atlantic Meridional Overturning Circulation and therefore also to the amount of heat transported into the Arctic at longer timescale. We use the ARMOR3D large-scale hydrographic data set from the Copernicus Marine Environmental Monitoring Service (CMEMS) and validate it with ship-based measurements in the period between 1993 to 2018. By extracting cross-shelf sections from ARMOR3D for various locations around Greenland, we reconstruct time series of local water masses like the Irminger Water (IW) for the past three decades. Previous studies from the West Greenland shelf have shown that IW properties are locally anti-correlated to changes in LSW. We analyze the interannual and decadal variability of these IW time series and compare them towards hydrographic changes observed in the interior Labrador Sea. Since ARMOR3D allows us to investigate interannual and decadal changes along cross-shelf sections, the goal of this study is to unravel the complex connection between changes in the shelf regions around Greenland and the interior Labrador Sea, especially the local water mass production.

AMOC Evolution at 47°N in the last decades in a High-Resolution Ocean Model and Observations

Simon Wett, Institute of Environmental Physics, Center for Marine Environmental Sciences MARUM, University of Bremen, Bremen, Germany
Monika Rhein, Institute of Environmental Physics, Center for Marine Environmental Sciences MARUM, University of Bremen, Bremen, Germany
Arne Biastoch, GEOMAR Helmholtz Centre for Ocean Research Kiel, Christian-Albrechts Universität zu Kiel, Kiel, Germany
Claus Böning, GEOMAR Helmholtz Centre for Ocean Research Kiel, Christian-Albrechts Universität zu Kiel, Kiel, Germany
Klaus Getzlaff, GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany I am sorry for the inconvenience

Keywords: AMOC, Observations, Ocean Model, Comparison, North Atlantic

The Atlantic Meridional Overturning Circulation (AMOC) is an important player for the climate in Europe and the Arctic. It transports warm and saline subtropical water northward in the upper layers and returns cold and fresh water, formed in polar and subpolar regions, in the deep. Since the early 2000s, observations from ship-based measurements and moorings are available which allow estimates of the individual components of the AMOC. However, the spatial resolution of mooring measurements is coarse and ship-based surveys are mostly done only once a year, adding to the uncertainty of these measurements. Though, in the subpolar North Atlantic, individual AMOC components show decadal trends, it is unclear from observations whether the whole AMOC exhibits a trend, too. Thus, knowledge about the development of the AMOC in the last decades is mainly based on model simulations. Comparing these model simulations with observations remains an important task to understand the changes in the AMOC strength in the last decades and improve model representations of the AMOC. Here, we analyze a realization of the high-resolution VIKING20X ocean model from 1980 to 2018 featuring a large overlap with observations. The goal is to merge observations and model simulation to better estimate recent AMOC changes and increase our understanding of the underlying processes. Ultimately, this should lead to a more realistic representation of the AMOC in climate models.

Influence of sea surface temperature in the tropics on the Antarctic sea ice during global warming

Anastasia Vyazilova, Arctic and Antarctic Research Institute, St. Petersburg, Russia
Genrikh Alekseev, Arctic and Antarctic Research Institute, St. Petersburg, Russia
Natalia Kharlanenkova, Arctic and Antarctic Research Institute, St. Petersburg, Russia
Natalia Glok, Arctic and Antarctic Research Institute, St. Petersburg, Russia
Alexander Smirnov, Arctic and Antarctic Research Institute, St. Petersburg, Russia

Keywords: Low Latitudes, Atmospheric Circulation, Sea Ice, Antarcic

Sea ice cover in the Antarctic, in contrast to the Arctic, doesn’t show a reduction under the conditions of observed global warming, while global climate models show a decrease. The aim of the study is to explain this climatic phenomenon on base of the idea of joint dynamics of ocean structures in the Southern Ocean – the Antarctic polar front (APF) and the edge of the maximal extent of sea ice. We used ERA5, HadISST data and sea ice data base for 1979–2019. It is found that locations of these structures are changed under the influence of SST anomalies in low latitudes. The dependence between SST anomalies in the low latitudes of the Northern Hemisphere and the position of the Antarctic polar front, maximum sea ice extent is estimated. The results confirm the opposite trends in the change of sea ice extent in the Arctic and in the Antarctic under the influence of SST anomalies in the tropical Atlantic. This influence is spread by means of the atmospheric circulation modes shift (intertropical convection zone (ITCZ), the Hadley circulation) to the north under positive SST anomaly and vice versa for negative anomaly with the corresponding shift of zonal ocean modes of the Southern Ocean, followed by the boundary of sea ice extent. Study supported by RFBR projects 18-05-60107, 18-05-00324.

Influence of springtime Okhotsk high on rapid discharge increase accompanied by river ice melt in eastern Siberia

Kazuhiro Oshima, Aomori University, Aomori, Japan
Hotaek Park, Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan
Masatake E. Hori, The Tokyo University, Kashiwa, Japan
Yasuhiro Yoshikawa, Kitami Institute of Technology, Kitami, Japan

Keywords: River Discharge, River Ice, Ice Jam, Siberia, Okhotsk

Siberian rivers freeze during winter, and the river ice melts and breaks in the spring. Accompanied by the ice melt, the river discharge rapidly increases. The broken ice sheets occasionally accumulate in a river channel and induce a sudden rise of water level, which is called ice jam. The ice jam sometimes incurs a flood. Therefore, the river ice condition and changes in river discharge are important information for local residents. While the previous studies have examined the inter-annual variations and long-term trends of precipitation, river discharge, river water temperature and river ice in Siberia, year-to-year variations in the timing of rapid discharge increase and associated atmospheric circulation are still unclear.

We examined the timing of rapid discharge increase at Tabaga, eastern Siberia. As expected, the timings were negatively correlated with air temperature in May when the temperature changes from negative to positive. We revealed that an atmospheric circulation associated with the rapid discharge increase shows positive pressure anomalies over the Sea of Okhotsk, i.e., Okhotsk high. In conclusion, when the Okhotsk high enhances in May, it induces warming over eastern Siberia, resulting in early river ice melt and early rapid increase in discharge in this region.

The role of low latitudes in the Arctic warming

Genrikh Alekseev, Arctic and Antarctic Research Institute, St.-Petersburg, Russia
Anastasia Vyazilova, Arctic and Antarctic Research Institute, St.-Petersburg, Russia
Natalia Glok, Arctic and Antarctic Research Institute, St.-Petersburg, Russia
Veronica Govorkova, Voeikov Main Geophysical Observatory, St.-Petersburg, Russia
Natalia Kharlanenkova, Arctic and Antarctic Research Institute, St.-Petersburg, Russia

Keywords: Arctic Warming, Heat And Moisture Transport, Low Latitudes, SST, Insolation

The main contribution to the warming of the Arctic in winter come with the atmospheric and oceanic inflows of heat and moisture from the Atlantic, and their sources are located in low latitudes], where the heat of solar radiation is accumulated. Here, with the participation of interannual changes in insolation, positive trends in ocean surface temperature, air temperature, and water vapor content are formed, which ultimately affect warming in the Arctic. Estimates of the impact of low latitudes on climate and sea ice changes in the Arctic over the past 40 years are given. Comparisons with the results of models from CMIP5 are fulfilled.

Study supported by RFBR project 18-05-00334.

ID:41 - An ambivalence/paradox of Arctic development: the environment vis-à-vis economy

Conveners

Mário Pontes | UArctuic Thematic Network on Geopolitics and Security

Francisco Cuogo | University of Minho

Heather Exner-Pirot | Arctic Yearbook

Geo-economics, Arctic, and Circular Economy

Mário Pontes, APCIE, Lisbon, Portugal

Keywords: Geo-economy, Circular Economy, Sustainable Development

The Sustainable Development Goals (SDGs) are a collection of 17 global goals set by the United Nations General Assembly in 2015. Circular Economy in opposition to the concept of Linear Economy, use keywords as long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, recycling, and upcycling to define a regenerative system in which resource input and waste, emission and energy leakage are minimized, and recognizes the importance of the economy working effectively at all scales – for large and small businesses, for organizations and individuals, globally and locally. Business increase in the Arctic is a reality today. No longer 'IF' but 'How'. The Arctic connects about 90% of world economy and the major challenges, like building infrastructures, pollution, trade wars or protective measures would hit undiversified economies hard, more in the Arctic than elsewhere because of weak value chains. Most of Arctic Stakeholders agree that business development in the Arctic must be rooted by innovative measures, and this article want to highlight that Circular Economy could be the support for sustainable development. Moreover, the framework of implementation and burden-sharing of the necessary investment will be crucial considering the number and diversity of interests related to the process.

How can transnational cooperation among subnational actors help to overcome the paradox of Arctic development?

Michał Łuszczuk, Institute of Socio-Economic Geography and Spatial Management, Maria Curie-Skłodowska University in Lublin, Poland
Jacqueline Goetze, Deutsches Institut für Entwicklungspolitik, Germany
Katarzyna Radzik-Maruszak, Institute of Political Science and Administration, Maria Curie-Skłodowska University in Lublin, Poland
Arne Riedel, Ecologic Institute, Germany
Dorothea Wehrmann, Deutsches Institut für Entwicklungspolitik, Germany

Keywords: Transnational Cooperation, Non-State Actors, Regional And Local Governance, Participatory Approaches

International cooperation has already been and will continue to be essential for the Arctic as the future of the region is predominantly shaped by the bordering "Arctic states". As a consequence, most research has focused on political platforms for interstates cooperation, such as the Arctic Council. In the proposed paper – being the preliminary result of studies conducted in the Sustainable Urban Development in the European Arctic (SUDEA) Project – we argue that it is important to closely investigate also transnational forms of cooperation in the Arctic, as economic development and environmental protection (the paradox of Arctic development) are not shaped by states alone but also by a variety of influential non-state actors. While international cooperation matters greatly for encouraging and regulating economic growth to avoid environmental harm, transnational cooperation that considers also non-state actors, regional and local authorities is essential for the implementation and application of such measures. We particularly strive to deepen the existing knowledge about transnational cooperation in the European Arctic by considering also the subnational levels and their participatory approaches. We will identify limits of such cooperation as well as incentives and barriers for transnational collaboration. Moreover, we will compare to what degree such cooperation is driven by environmental or economic aims. In our conclusion, we are thus able to clarify the relevance ascribed to the paradox of environmental vs. economic development by non-state actors. The research is based on the secondary data and literature analysis.

Scenarios for sustainable socio-economic development in the Arctic till 2050

Alexey Kalinin, SKOLKOVO Institute for Emerging Market Studies, Moscow, Russia
Anastasia Lazariva, SKOLKOVO Institute for Emerging Market Studies, Moscow, Russia
Alexandra Middleton, Oulu Business School, University of Oulu, Oulu, Finland
Frode Nilssen, Nord University Business School, Nord University, Bodø, Norway

Keywords: Arctic, Scenarios, Arctic Economy, Regional And Global Interests

The Arctic region has increasingly come in a difficult position because of the global transformations facing the disruptive challenges of climate change and shifting global political, social and economic patterns. On the one side, the Arctic represents an increasingly important global source of mineral and bio-resources. The area does also represent a geopolitical area of tension. On the other side, the Arctic represents a "temperature gauge" on distant pollution and waste in the sea. Close to none of the total pollution level in the Arctic stem from the Arctic economic activity. At the same time, powerful voices from supranational institutions, organizations and non-governmental organization (NGO) put rising pressure on preserving the Arctic as a kind of "nature protected area" with strong restrictions on economic activity and human impact on nature. The paper draws attention to this tension between regional interest to maintain and develop a social, economic and biological sustainable and modern residence and the more detached global movements to preserve the Arctic as a nature reserve. The research builds on scenario methodology and qualitative expert interviews combined with comprehensive literature studies.

Sustainable Development in Yakutia: Economic, Environmental and Innovative Aspects

Anisiia Lazareva, North-Eastern Federal University, Yakutsk, Russia

Keywords: Regional Development, Sustainability, Creative Economy, Digital Economy

Sources of regional development are becoming critical in Yakutia, the biggest Russian region with enormous amounts of natural resources. After the 1990s, Yakutia focused mainly on extraction and export of oil and gas. However, this resource-dependent development is no longer sustainable due to changes in federal tax law regulations (2013) and the environmental situation. Currently, there are no sources for sustainable development of Yakutia, and the federal funding is inadequate to support the regional infrastructure development. This decline affects every aspect of living in Yakutia. It is therefore time to focus on new development advantages and possibilities in the region.

The “Arctic Paradox” and development of Russian extractive projects in the Arctic

T. Burmenko, Siberian Federal University, Krasnoyarsk, Russia

Keywords: Arctic Paradox, LNG, Russian Arctic

Viewed strictly from a business point of view, global warming and the rapid reduction of Arctic sea ice are advantages for development of extractive indutries (Yamal LNG, Rosneft). The hotter the Arctic gets, the better business will be – at least for a little while. From an environmental point of view, natural gas has certain advantages over other fossil fuels, since when it is burned, much less CO2, SOx, NOx are released into the atmosphere (IGUb, 2015, Vard, 2015). At the same time, as in any other production, every element in the LNG life cycle – including the construction of industrial facilities, preparation and liquefaction of gas, storage, transportation and regasification – has an environmental impact. Gas liquefaction plants and regasification terminals, as well as LNG transportation, damage the air, soil, water bodies, flora, and fauna. Speaking about the development of natural resources extraction in the Arctic and climate change, we should not forget to consider the so-called “Arctic Paradox”. Some of the researches believe that the ice-melting process in the Arctic is so rapid because of the burning of fossil fuels, some of which are extracted in the Arctic. This fact in its turn attracts mining companies to the Arctic, thereby increasing the volume of mining. As a result, we have a vicious circle between increased mining and climate change in the Arctic. This situation can lead to biological, environmental, socio-economical etc. disasters.

The Regulation of Heavy Fuel Oil in Arctic Shipping:Interests, Measures and Impacts

Jiayu Bai, Ocean University of China, Qingdao,P.R.China

Keywords: HFO Regulation; Regulatory Strategy; Stakeholders' Interests; Regulation Implementation

Since the International Maritime Organization (IMO)'s ban on the use and carriage for use of heavy fuel oil (HFO) for ships operating in Antarctic waters came into effect in 2011, the international community has been engaged in a discourse on whether to adopt a similar standard for ships operating in Arctic waters. The issues are complex as in addition to reducing the environmental risks posed by HFOs, there are economic and social consequences, including dependence on such fuels by indigenous peoples. The discourse has involved the IMO, Arctic Council, industry associations, environmental NGOs, and indigenous people. The issue was first raised during the development of the Polar Code and is considered unfinished business of the code. This chapter discusses the nature of the problem and the challenges to explore a possible regulatory strategy. The chapter will contextualize the discussion in the larger context of the public and private maritime law conventions to consider how an HFO regulatory strategy complements and remains consistent with other elements of maritime regulation.

Observing the arctic from canada`s “north”

Valter Claudio. University of Lisbon

Keywords: Arctic, Challenges, History, Myths, Geopolitics, Policies, Strategies.

Climate change leading to bigger accessibility to maritime routes and natural resources, investments in the reinforcement of military capabilities and operations to defend sovereignty, native peoples, all of these aspects must be taken into account when we speak about the arctic and the arctic states. In a region of the globe that has been a region of appraisal between superpowers and nowadays is subject not only to the attention of the arctic states but also from non-arctic states and at the same time has become a region of various disputes given the value it can add through resource extraction with impacts on regional economies and local populations. Canada is one of the arctic states, one that has adapted and evolved in the face of various challenges throughout history, a look over canadian myths, geopolitics and the evolution of its policies and strategies, and how some indigenous populations are adapting to climate change and how this affects canada´s behaviour towards these arctic issues.

ID:05 - The Object: Regional Messenger, Global Message

Conveners

Frigga Kruse | Kiel University

Franziska Paul | Kiel University

A 19th Century Inuvialuit House: Messenger of Profound Cultural and Climatic Change

Max Friesen, University of Toronto, Canada

Keywords: Archaeology, Inuvialuit, Architecture, Interaction, Mackenzie Delta

Indigenous Arctic societies have dynamic histories, reflecting the impacts of multiple factors including those that are internal (e.g., politics, social organization, world view) and external (e.g., environmental change, contacts with “others”). In this paper, I will discuss a single house built by the Inuvialuit of the Mackenzie Delta region in Inuit Nunangat (Arctic Canada), and last occupied in the mid-19th century. This large and complex structure tells the story of a society successfully dealing with several external factors, including increasingly frequent contacts with Europeans, and some of the coldest years of the Little Ice Age. However, it also reflects directly on one of the central issues facing the contemporary world: the impact of modern climate change on global society. The house discussed here is subject to the catastrophic erosion currently being experienced in the Mackenzie Delta region due to permafrost thaw, rising sea levels, and longer open water periods. When excavation began, one margin of the house had already been lost to erosion, and it is unlikely that the remainder will last another decade. Irreplaceable heritage sites are being lost at ever-increasing rates around the world, but nowhere as rapidly as in the Arctic.

Carving an Ipiutak identity. A 1. Millenia AD burial site at Point Hope in Alaska

Claire Houmard, PhD, Post doc / France
Ulla Odgaard, PhD, Senior Researcher / Denmark

Keywords: Carvings, Technology, Metal, Ivory

At Point Hope in Alaska a large site from the Ipiutak culture was excavated in the 1940ties. The Ipiutak is known from only a few sites. Because of its uniqueness, especially in its carvings, and its relatively short time of existence from around AD 200 – 900 with an intensive blossoming before its disappearance, it has been characterized as "mysterious". At the same time in other parts of the world, far away from the Arctic hunting societies, the Iron age technology, ecology, and ideology was prevailing. In Alaska, however, only a few small pieces of metal have been found, although small in size and numbers, indicating some kind of contact. Although smelting metallurgy never came to the Arctic regions, the artwork carvings of the Ipiutak reflect knowledge of both early metallurgy and shamanistic ideas connected to it. Contemporary scholars' fascination for the Ipiutak culture and its fantastic openwork ivory carvings probably mirrors the Ipiutak fascination for metal. The numerous carvings reflect how this culture, although being restricted in their choices of materials, was mentally connected to the wider world and took part in ideas on a macro-regional level.

Impacted Archaeology and Communities in a changing environment: a view from SW Alaska

Edouard Masson-MacLean, University of Aberdeen, Scotland
Rick Knecht, University of Aberdeen, Scotland
Charlotta Hillerdal, University of Aberdeen, Scotland
Alice Watterson, University of Dundee, Scotland
Anna Mossolova, Tallinn University, Estonia
Claire Houmard, Université de Franche-Comté, France
Kate Britton, University of Aberdeen, Scotland

Keywords: Yup'ik, Precontact, Archaeology, Arctic Heritage

Archaeological sites in the Arctic benefit from some of the best preservation conditions encountered around the world as a result of frozen or waterlogged contexts providing us with a unique archive to document past societies. However, this archaeological record is under threat primarily due to coastal erosion and melting permafrost as a result of current climatic conditions. The Thule-era site of Nunalleq, located on the shores of the Bering Sea in SW Alaska, represents one such site. Excavated because of its imminent destruction by coastal erosion, the site has produced one of the largest assemblages of material culture in the Arctic and represented a unique opportunity to explore precontact Yup'ik lifeways and culture in SW Alaska, a region where archaeological research has been limited. This collaborative project between researchers and Yup'ik partners in Quinhagak has been community-driven and went far beyond filling a gap in the archaeological record. It revealed the Yup'ik archaeological heritage and its artefacts in particular to be a dynamic vector of cultural transmission and exchange between generations and people that may not have taken place otherwise and, as seen elsewhere in Alaska, has proved to be a powerful medium for cultural revitalization. This paper will present some of the major findings from the excavations at the site, Yup'ik perspectives on the project and a discussion on moving forward beyond Nunalleq.

Seeking the Origin of Bear Ceremony

Hirofumi Kato, Centre for Ainu and Indigenous Studies, Hokkaido University, Sapporo, Japan

Keywords: Indigenous Peoples, Archaeological Heritage, Indigenous Participation, Research Ethics

The cultural heritage is a tangible heritage, and also visible historical memories for indigenous communities. It has a function as a place where community members can confirm their identities, and identities are reproduced through it. The values of cultural heritage are constantly changing. There is no guarantee that the current value and future value will be similar. From a long-term perspective, its value will have the potential to change significantly. Cultural heritage and archaeological sites have a function as a time capsule that inherits value and memories from generation to generation. Indigenous communities have not always had opportunities to participate in assessments for archaeological heritage and conservation plans. From the viewpoint of research ethics, the independent participation of community members is required. In this report, I would like to discuss the possibility of community-based cultural heritage conservation efforts based on the regional case of the Pacific Northwest.

Sharing the Game. Archaeological evidence of hunting ethics and strategies – past and present

Ulla Odgaard, PhD, Senior researcher / Independent

Keywords: Hunting, Ethics, Waste

Based on studies in a landscape in Western Greenland, where people have hunted caribou through millennia, this paper will discuss different concepts of hunting rights and ethics, and how they relate to the concept of “sustainability”. In 2013 a team of 252 researchers published a report “Arctic Biodiversity Assessment”, pointing out that Greenland is a severe case of overharvesting of game animals, and the hunters were accused of wasting the meat. We, however, got a different experience in a camp of modern caribou hunters, where the ideal of “nothing is wasted” is cherished. A similar contradiction seemed to be found in the archaeological material. At many ancient camps we were able to discover bone patterns reflecting the ideal of “nothing is wasted”, at other sites however, the bone pattern showed that a lot of meat had been wasted. Did they have differing hunting ethics in the past, and is there a link from the past to the dilemmas of today?

The Central North Atlantic Marine Historical Ecology Project

George Hambrecht, University of Maryland
Nicole Misarti, University of Alaska Fairbanks

Keywords: Zooarchaeology, MHE, Iceland, Cod, SI

This paper will present a new NSF funded project, the Central North Atlantic Marine Historical Ecology Project (CAMHEP) as well as provide an overview of the of marine fish zooarchaeological data from Iceland. CAMHEP will utilize marine zooarchaeological data from Icelandic archaeological sites dating from the first settlement of Iceland in the second half of the 9th century CE through the 19th century. It will create a record of the complex relationships between changing marine and climate conditions, human fishing, and cod populations over the last millennium. CAMHEP will combine archaeological, historical, and biochemical analytical methods to build a deeper record of the relationship between cod and humans in Iceland that will serve as an important tool in managing this relationship in the present and future. This presentation is a product of the North Atlantic Biocultural Organization (NABO) and it is part of an ongoing collaboration with the Paleoecology of Subarctic Seas (PESAS) research group.

Polar CHESS, Cultural Heritage and Environmental Scientific Studies

Bryan Lintott , Scott Polar Research Institute, University of Cambridge . ICOMOS International Polar Heritage Committee

Keywords: Cultural, Heritage, Environmental, Science

Cultural heritage in the polar regions is a potential source of information and insights for a range of environmental science. In turn, this engagement with environmental science may enhance historical knowledge about polar cultural heritage. Already, there have been successful examples of material culture providing information, e.g. environmental pollution from hydrocarbons and pesticides. This presentation will provide examples of related research, from the Arctic and Antarctica. and consider the potential for future joint research.

The Actualisation of Past Architecture in Arctic's Future Urban Landscape

Asta Mønsted, SAXO Institute, University of Copenhagen, Denmark

Keywords: Archaeology, Oral Tradition, Orientation, Human's Role, Kalaallit

The landscape of Greenland bears archaeological remains of several cultural groups, who settled down in the country for longer and shorter periods before they vanished. However, the people of the Thule culture stayed, and today they are the predecessors of modern Greenlanders. What did these people, the Kalaallit, have that separated them from the prior cultural groups and allowed them to survive, and thrive, when living in the Arctic? The Inuulluni-project aims to combine oral tradition with the archaeological record in order to uncover the concepts and ideas behind the architectural design that are characteristical to the traditional winter houses before the Danish colonisation made an impact on the building designs of the country. The project goes to show how the human survival strategy and adaptation to the unfriendly living conditions can be witnessed in the architectural output of the winter house. The form and orientation of the Kalaallit winter house document how these people saw their own role in this world. Nowadays, the houses built in Greenland are inspired by Western ideology and ideas of building designs. Perhaps, it is time not only for building environmentally sustainable houses in Greenland, but also culturally sustainable houses inspired by the ancestors of the Kalaallit themselves.

ID:43 - Arctic Security: from the geostrategic ‘game’ of superpowers to global resource competition or societal security?

Conveners

Sandra Balão | University of Lisbon

Ecaterina Crihan / Sara Coutinho | University of Lisbon

Lassi Heininen | University of Helsinki

From Peary to Pompeo: the history of United States' (de)securitizations of Greenland

Marc Jacobsen, Scott Polar Research Institute, University of Cambridge, Cambridge, England.
Sara Olsvig, University of Greenland, Nuuk, Greenland.

Keywords: Greenland, Securitization, United States, History, Security

This presentation scrutinizes how Greenland appears in United States' narratives of (de)securitization since the idea of purchasing the island was first articulated in 1832. With this point of departure, the analysis will move forward asking how (de)securitizations have been made in specific periods, what they were guided by, and how the developments within the Danish Realm have influenced the US' approach to Greenland. As the analysis will show, Greenland has often been described as a geostrategically important piece in the defense of US national security throughout history where the 1941 agreement was decisive for establishing Greenland as part of the US security sphere as it explicitly extended the Monroe Doctrine to Greenland. Since then, the US has been permanently present in Greenland and related activities have had – and continue to have – cascading effects beyond their original purposes as extraordinary measures have been effectuated by others to meet the needs of the US. In step with Greenland's gradually enhanced autonomy, new security aspects have been articulated while altering the sovereignty configurations of the trilateral relations between Denmark, Greenland and the US. By analyzing the communication in official documents and minutes from central governmental meetings as well as speeches and media statements, this presentation will elucidate how (de)securitizations have been legitimized and with what consequences for the US and beyond.

Evolution of changes in the Arctic from the perspective of the Regional Security Complex

Leszek Krzysztof Sadurski, Maria Curie-Sklodowska University, Lublin, Poland

Keywords: Arctic, security, Regional Security Complex

Climate change in the Arctic over the last few years has led to a revision of the perception of the Arctic by the states of the region. This has led to a greater focus on the polar region. The impact of climate change has led to the appearance of new challenges, opportunities and threats. As a result, the Arctic states are creating and updating their strategies and taking action to strengthen their position in the area and ensure their security. As part of their common existence in the Arctic, the activities of some regional actors meet with the reaction of others. In this respect, they are creating a system of regional links which influence the creation and transformation of the security environment in the Arctic. An example of such interdependence is the Regional Security Complex, which provides an analytical framework for examining the security activities of the Arctic states in the region and indicating the direction of change in which they are evolving, transforming the security environment of the Arctic. The aim of the speech will be to present the changes that have taken place in the area of security in the Arctic over the last few years and to indicate the direction of their further evolution. This will be done by using the theory of the Regional Security Complex as a research framework to describe the region.

The new geopolitical competition on the very top of the globe

Ecaterina Crihan, University of Lisbon, Lisbon, Portugal

Keywords: Arctic, Geopolitics, Cold War, Russia, NATO

Until yesterday, the Arctic has remained out of play but today everything changed. The Arctic of the past is already gone. Climate change is one of the biggest challenges of our time, that includes not only the negative aspects but also - the new opportunities. The Arctic "is routinely described as an emerging frontier, and many polar nations, along with a few that have no Arctic borders, are angling for access to the region's rich stores of fish, gas, oil, and other mineral resources" (Shea, 2019), and the new shipping routes. As economic interests in the north have grown, so have military patrols to defend territorial boundaries. The geostrategic competition is heating up as the ice melts, the Arctic is the new geopolitical arena where the old "new" players just started to run, and some nations already have a solid base. One hundred years ago the Arctic region was severely struck by the Spanish Flu when the region experienced some of the most severe consequences of the epidemic (UArctic, 2020). The Covid-19 also threatens the region, the consequences of the pandemic may be detrimental due to lack of local infrastructure, long distances and in many places, marginal economic capacity (Ivushkina and Nedyuk, 2020). Only together, the parties interested in the security and development of the Arctic can change the way of things. Arctic security depends on the main players of this geopolitical game, who should keep in mind they are responsible not only for the indigenous people of the region but also of the security of our Planet.

Thinking about human security in the Russian Arctic

Alexander Sergunin, St. Petersburg State University, St. Petersburg, Russia

Keywords: Russia, Arctic, Human Security, Sustainable Development

This paper aims:

• To examine whether the human security concept is applicable to the Arctic Zone of the Russian Federation (AZRF) or not?

• To analyse an emerging Russian discourse on human security and its relationships with other security-related concepts – national security, soft security, societal security, personal security, sustainable development, etc. Major Russian social science paradigms' interpretations of the human security concept will be analysed.

• To examine whether the human security concept is embedded in the AZRF federal, regional and municipal documents, such as strategies, programs and plans of socioeconomic and environmental development or not? The recent strategic documents, including the Strategy on the AZRF Development and Ensuring National Security up to 2035, as well as the new generation of regional and city development plans, will be discussed.

Methodologically, this study is based on the UNDP 1994 Human Development Report's definition of human security which includes seven components: economic security, food security, health security, environmental security, personal security, community security, and political security.

Keeping the Peace in the Arctic: Strategic Choices & Perceived Risks Among Stakeholders

John De Rosa, Carter School for Peace and Conflict Resolution, George Mason University, Arlington, USA
Christine Rosenfeld, Geography and Geoinformation Science, George Mason University, Fairfax, USA
Violeta Ferati, Institute of Political Science, Eberhard Karls University of Tübingen, Tübingen, Germany (presenter)
Sara Cobb, Carter School for Peace and Conflict Resolution, George Mason University, Arlington, USA

Keywords: Arctic Council; Arctic; Strategy; Policy; Risk; Security

The pathways to peace and cooperation in the changing Arctic among regional and global stakeholders have not yet been fully paved. Long-term peace depends on the integration and recognition of the varying understandings of what “security” means and how it would materialize in collective decision-making processes.Given the rapid changes, understanding interpretative frameworks of key stakeholders will play a central, if not conditioning role, in their actions. The way parties construct their preferences has import for how they are making sense of situations and gauging their own participation in relation to others.Achieving stability within a geographically unstable Arctic is thus anchored in the analysis of party preferences - their statements and positions, and not through interference. We ask: what are the strategic choices of Arctic actors, including state members, Indigenous permanent participants, and non-Arctic state observers of the AC? How do they frame and position themselves as being entitled to make strategic choices within and about the Arctic realm?What are their perceived risks and how do they compare to the perceived risks of other actors?To answer this, we examine the policy and strategy declarations of the AC actors by relying on narrativized strategic choice theory, coding 3500 excerpts across 34 documents. Results indicate varying understandings of security and categories and levels of risk, revealing avenues that could lead both towards conflict and peace.

Arctic security: main risks and challenges

Onur Limon, Turkish Armed Forces General Staff, Ankara, Turkey

Keywords: Arctic, Arctic Security, Security, Securitization, The Cophenhagen School

Geographically, the Arctic is the area north of the Arctic Circle (66° 34'N) encompassing Russia, Canada, the United States of America (USA), and five Nordic states, all of which possess Arctic territories. The Arctic is the "last frontier" and it does not have a real political presence. During the Cold War, the Arctic was one of the most militarized regions in the world by the major nuclear powers, the United States and the Soviet Union. The end of the Cold War alleviated but did not eliminate traditional security problems in the Arctic region. This means that security can now be viewed in the context of alternative security approaches that go beyond traditional approaches based primarily on military security. Today, the Arctic is one of the regions most rapidly affected by global climate change. Perception of the accessible Arctic tightly links the region to the global geopolitical agenda. Military, economic, political, societal, and environmental risks and challenges associated with Arctic security are gaining more importance, and the geostrategic importance of the Arctic in world politics and the globalizing world economy is increasing. Discourses on issues such as resource competition, cooperation, and conflict are increasing. While Russia stands out as a unique Arctic State in military, economic, and political terms, rising China is already challenging the global hegemony of the USA. The aim of this study is to analyze Arctic security risks and challenges using the Copenhagen School of Security Studies as a theoretical framework. The hypothesis of the study is that the impacts of global climate change, the current and potential value of new energy basins, and the availability of the Arctic Ocean sea passages can create military, political, economic, societal, and environmental competition in the Arctic. However, the probability of international conflict in the region is low. Because the Arctic countries adhere to a rules-based approach to security.

Necropolitics and Arctic security: identifying key contested concepts in the energy sector

Ángel Eduardo Rivera, Autonomous National University of Mexico, Mexico city.

Keywords: Energy, Necropolitics, Security, Development

Now introduced as one of the world's last energy frontiers, Arctic oil, gas and metallic minerals have captured the attention of regional countries, energy companies and outsiders to develop extractivist projects. However, we also have witnessed resistance and denial for new projects due to, among other things, lack of technology for crisis response, high prices of offshore activities, denial of social licenses to operate and local resistance movements; challenging what in the past used to be an unlimited and unrestricted economic growth. Under this scenario, this work introduces a radical analytical framework to understand these contemporary dynamics in the energy sector. On the one hand, we use the concept of necropolitics (Mbembe 2003) to illustrate how governmental practices have exposed Arctic inhabitants to physical, social or political death in the name of national security, energy security or economic security (for example, dispossession by uranium mining, natural gas and tar sands megaprojects). On the other, we used the resistance movements of indigenous people and environmental nongovernmental organizations to explain how concepts such as environmental security, societal security and human security have been winning spaces in local and regional political debates. The main question to be answered is: how does traditional security concepts based on necropolitics are being contested by new ones based on human rights, environmental concerns and sustainable development?

The Arctic Region: a matter of societal security or securitization diplomacy?

Sandra Balão, Universidade de Lisboa - ISCSP, Lisboa, Portugal

Keywords: Arctic, (Geo)Politics & Strategy, Great Power Politics, Security Diplomacy, Societal Security.

As the ice melts new reserves of rich and rare resources become known and easy to explore. If the second part of the previous sentence can be (and still is) discussed, the growing use of 'new' sea lines of communication in the region (as is the case of the northern sea route) is easily demonstrated and sustained. Furthermore, it can be argued that it was due to these facts that the region achieved the (geo)political and correspondent (geo)strategic interest of the so-called international 'community' towards it, that is to say: that the Arctic Region managed to call enough attention as to deserve a spot in the global agenda-setting. Therefore, the main objective of this paper is to discuss if the Arctic Region agenda and actors show enough evidence that can sustain the perspective according to which it is moving, evolving, towards a 'societal security' arrangement that will allow the exchange of hard security, (geo)politics and (geo)strategy structures, concern and framework of analysis and decision-taking by 'soft substitutes'. Our argument is that the so-called and claimed desirable 'societal security' statu quo seems to be, in fact (at least for now), 'securitization diplomacy'. This will be an exploratory research. The method will be qualitative, document based, Interpretative and comparative.

ID:66 - Arctic Science Diplomacy in the Rapidly Changing World: Global Trends and Regional Impacts

Conveners

Yulia Zaika | International Arctic Science Committee (IASC), Kola Research Centre of the Russian Academy of Sciences

Yekaterina Kontar | National Science Foundation, Office of Polar Programs, Arctic Sciences Section

Tatiana Iakovleva | UK Science and Innovation Network in Russia (SIN Russia)

Growing stronger Arctic science networks through diplomacy: the role of the UK Science and Innovation Network

Tatiana Iakovleva, UK Science and Innovation Network in Russia, British Embassy Moscow, Moscow, Russia
Rosa Degerman, UK Science and Innovation Network in Finland, British Embassy Helsinki, Helsinki, Finland

Keywords: Arctic, Science Diplomacy, Cooperation, Knowledge exchange

Science Diplomacy lies at the heart of the UK Science and Innovation Network's activities. For well over a decade SIN has been a notable player in the field, delivering science diplomacy across a range of thematic and geographical contexts, building bilateral and multilateral scientific links, facilitating dialogues and fostering new collaborative partnerships on issues of global importance. SIN's Arctic work has been commended as an excellent example of Arctic science diplomacy in action. A hotspot of global warming, the Arctic is increasingly becoming a region of profound scientific significance. The urgent need to better understand the complex Arctic system and the way it is responding to change calls for closer international research cooperation and knowledge exchange. In our joint presentation, we would like to cover the role of SIN in building bridges between the UK and international Arctic science communities. We will seek to showcase some recent examples of our work in this space delivered in collaboration with partners from across the UK, in the Arctic States and international fora and institutional players: from Arctic Bursaries to dynamic science workshops and interactive webinars. We would like to demonstrate the tangible outcomes of these activities aimed at creating solid platforms for expert dialogue and opening up new exciting opportunities for fruitful exchanges and practical collaborations across all strands of Arctic research.

Arctic nature protection as a base of scientific diplomacy development: case study of Institute of Northern Industrial Ecology Problems' international co-operation

Elena Klyuchnikova, Institute of Northern Industrial Ecology Problems, Kola Science Centre of the Russian Academy of Sciences, Apatity, Russia
Vladimir Masloboev, Institute of Northern Industrial Ecology Problems, Kola Science Centre of the Russian Academy of Sciences, Apatity, Russia
Dmitry Makarov, Institute of Northern Industrial Ecology Problems, Kola Science Centre of the Russian Academy of Sciences, Apatity, Russia
Eugene Borovichev, Institute of Northern Industrial Ecology Problems, Kola Science Centre of the Russian Academy of Sciences, Apatity, Russia

Keywords: Arctic, Nature Protection, Sustainable Development, International Co-Operation, Kola Science Centre RAS

Analyzing the international co-operation of Institute of Northern Industrial Ecology Problems of Kola science Centre of RAS (INEP) since establishing the Institute till present, the report advocates the nature protection issue as a natural base of science diplomacy development in the Arctic. Drawing on case study methodology, the report demonstrates how the "diplomacy for science" in beginning of perestroika serves as a stimulus for "science in diplomacy" and "science for diplomacy" practices development. INEP scientific research contributes Arctic sustainable development and is of interest in many Arctic countries. INEP's research directions are: Arctic biodiversity changing, methods for the damaged terrestrial ecosystems restoration and bioremediation of industrial dumps, creation of biotechnologies for the extraction of metals from poor ores and waste of enrichment and purification of environments from pollutants, interaction of society and nature. The aforementioned areas of research often serve as the basis of international projects. Having started its international cooperation with projects on environmental monitoring, INEP has risen to projects for regional and global decision-makers scientific advice development.International co-operation and creation of international scientific alliances contributes to improving the quality of environmental research as well as to improving relations between countries.

Mapping venues for science diplomacy in the multidimensional network of Arctic international relations

Nicolas Rüffin, WZB Berlin Social Science Center, Berlin, Germany

Keywords: Arctic Strategy, Collaboration, Competition, Science Diplomacy, Semantics

In the last years, Science diplomacy (SD) has been advertised as an instrument of managing relations in the Arctic. Scientific collaboration and science-informed political agreements have been proposed to avoid or mitigate conflicts among stakeholders in the region. Yet underlying some of these sometimes quite successful initiatives is a one-sided understanding of SD. The most recent literature takes a more differentiated approach towards the means and ends of SD. It points out that international scientific interaction can be shaped by the twofold logic of competition and collaboration. Similarly, instruments of SD can be meant to serve genuinely national interests or collective regional/global agendas. Even more, science-based interactions in the North are placed in the context of economic and security-related interests that are shaped by similar rivaling logics. The proposed paper disentangles these confounding discourses of collaboration and competition in Arctic SD. It analyzes the mutual observations of national governments interested in the region. Based on national arctic strategies and similar publications, the article examines the semantics of collaboration and competition in the spheres of international science, security and economy. The paper thus contributes to the visualization and understanding of the complex network of relations among Arctic stakeholders. Finally, it aims to identify venues as well as roadblocks for future applications of Arctic SD.

Science diplomacy and preparing a next generation of Arctic STEM professionals

Lauren Culler, Institute of Arctic Studies & Environmental Studies Program, Dartmouth College, Hanover, NH USA
Ross Virginia, Institute of Arctic Studies & Environmental Studies Program, Dartmouth College, Hanover, NH USA
Kasper Busk, Government of Greenland, Ministry of Education, Culture & Church, Nuuk, Greenland
Lars Demant-Poort, Institute of Learning, University of Greenland, Nuuk, Greenland
Rikke Jørgensen, Government of Greenland, Ministry of Education, Culture and Church, Greenland & Vestegnen HF og VUC, Denmark
Mitdlarak Lennert, Department of Social Science, University of Greenland, Nuuk, Greenland
Erica Wallstrom, Institute of Arctic Studies, Dartmouth College & Rutland City Public Schools, Rutland, VT USA
Mary Albert, Thayer School of Engineering, Dartmouth College, Hanover, NH USA
Matthew Ayres, Institute of Arctic Studies & Biology Department, Dartmouth College, Hanover, NH USA

Keywords: Education, Interdisciplinary, Students, Science Diplomacy, Greenland

The Joint Science Education Project (JSEP) is a collaboration between Greenland, the United States, and Denmark to educate and train the next generation of polar and STEM professionals. Since its initiation during the International Polar Year in 2007, students, teachers, and scientists from each country have worked together in Greenland to study Arctic environments and human dimensions of rapid change. JSEP is built around the concept of science diplomacy. It enables each country to provide interdisciplinary scientific training to students while fostering long-lasting, international, and intergenerational relationships. Participants leave as enlightened scientists and advocates for the future of Arctic landscapes in their own communities. This is accomplished through student-driven research and an emphasis on effective communication and sharing research with broad audiences. The continuity of the program and commitments of educators and institutions have created significant trust among the leaders. This allows continuous innovation focused on best science and educational practices and an ability to navigate seemingly insurmountable challenges, such as running an Arctic field program during a global pandemic. JSEP is always evolving and improving based on the feedback of all participants. The creative and deliberate design centered around science diplomacy prepares participating students, educators, and scientists to shape and improve future Arctic research and policy.

Scientific cooperation catalyses ecological insight in a changing Arctic: a review and perspectives from a bilateral UK-Russia marine science collaboration

Martin Solan, University of Southampton
Tom Williams, University of Southampton
Clement Garcia, Cefas, Lowestoft
Jasmin. A. Godbold, University of Southampton
Natalia Shunatova, Saint-Petersburg State University
Andrew Naumov, Zoological Institute of Russian Academy of Sciences
Dmitry Aristov, Zoological Institute of Russian Academy of Sciences
Rhiannon Jones, University of Southampton
Wassim Dbouk, University of Southampton
Gareth Giles, University of Southampton
Alexy Sukhotin / Zoological Institute of Russian Academy of Sciences

Keywords: Scientific Diplomacy, Scientific Co-operation, Arctic Policy, Arctic Strategy, Multilateral Co-Operation

The pace and scale of climate change demands both international and regional co-operation to provide the necessary scientific evidence to inform local and global response strategies and engender better societal decisions on mitigation and adaptation. Insights forged through scientific interaction are abundant, but the challenges of merging different perspectives can hinder long term interaction and are seldom explored. Here, we provide an overview of the ecological consequences of climate change in marine Arctic ecosystems based on scientific literature from Russia, the UK and bilateral/multilateral collaboration. We highlight similarities and differences in the construction and framing of environment change narratives and the extent to which the merger of contrasting or complementary perspectives have facilitated new understanding. Drawing on experience of a collaborative UK-Russian knowledge sharing network, we conclude by discussing how open exchange of opinion can facilitate the development of a solution-based narrative to support decision and policy making strategies that tackle the consequences of climate change in the Arctic.

Scientists using Twitter in Arctic Science Diplomacy

Alexandra Middleton, Oulu Business School, Oulu, Finland

Keywords: Arctic, Science Diplomacy, Social Media, Scientists

The cancellation of in-person scientific conferences during the times of COVID-19 accelerated scientists' usage of social media platforms for communicating their research and engagement in science diplomacy to share their research findings with a broad range of stakeholders. In this article, I focus on the usage of Twitter as a tool for science communication and science diplomacy. Twitter is selected because of its ability to promote scholarly discussion, disseminate research rapidly, and extend and diversify the scope of audiences reached (Bombaci et al. 2016). The potentially broad Twitter audience is especially important for the Arctic research that has global implications in spheres of, e.g. climate change and societal adaptations. I use an open-ended questionnaire in which I ask Arctic researchers to indicate their motivation to use Twitter, potential advantages and disadvantages of this social media platform. Additionally, I ask researchers to contemplate on the role of communicating their research and engagement in science diplomacy via Twitter, especially during COVID-19 times. The findings contribute to the discussion of the increasing significance of scientists as science diplomacy actors (Moomaw 2018) and provide some practical insights into the usage of Twitter as a tool for practising science diplomacy for Arctic researchers.

The Flawed Logics of Arctic Geopolitics at the Nexus of Arctic Science Diplomacy

Corine Wood-Donnelly, Nord Universitet, Bodø, Norway
Marianne Pascale Bartels, University of St Andrews, St Andrews, Scotland

Keywords: Science Diplomacy, Arctic, Geopolitics, Oil And Gas, Climate Governance

The discourse of the Arctic region stands out as the poster child for consideration of the contradictory logics underpinning decision-making in international affairs. As the weather kitchen of the world, it serves as the barometer for global warming and climate change with the world watching in real time as the ice melts. On its other side, it demonstrates the role that national interests, and specifically, energy security, play in strategic gameplaying in international relations. At the nexus of these positions is the role of science diplomacy, which ironically, serves both dimensions. While science diplomacy has been instrumental in facilitating the continuation of peace in the region, science has also served to undermine radical progress in Arctic decision-making toward the goals of climate governance through the projection of vast energy potential in the region. This article surveys marriage of science and policy through the impact of USGS reports of Arctic oil and gas, its transformation to common knowledge in Arctic discourse and adoption into Arctic policy. It argues that critically evaluating the role of scientific knowledge in policymaking creates the opportunity for a reevaluation of the role of science diplomacy in the Arctic. Finally, it suggests that removing oil and gas from the logics underpinning geopolitical decision-making is necessary to remove existing obstacles to climate governance.

The Role of Science Diplomacy in China-Nordic Arctic Relations

Egill Thor Nielsson, Senior Advisor, The Icelandic Centre for Research - Rannis, Reykjavik, Iceland

Keywords: Arctic relations, Science Diplomacy, China, Nordic Countries, Regional Studies

The aim of the article is to analyse the different uses of science diplomacy in China-Nordic Arctic relations. A key focus will be on the “triple-helix” between science, industry, and governance in the context of China’s Arctic strategy, which is geared toward developing both bilateral relationships with individual Nordic countries as well as regional cooperation mechanisms. Developments, such as increased impact of climate change, more engagement from Asian countries in Arctic affairs and escalating geopolitical tension have already affected the Arctic region. In the article, the three policy strands of science diplomacy introduced by the Royal Society´s report on “New Frontiers in Science Diplomacy” (2010) will be explored as a way of improving interstate relations and governance in the Arctic.

1) To show how scientific advice can inform and affect foreign policies of states
2) To explore how diplomacy can facilitate international science cooperation
3) To identify instances of science cooperation, which can serve the purpose of improving interstate relations

All three modes of science diplomacy are evident in Arctic cooperation and they take various forms in bilateral, plurilateral, regional and multilateral relations. The article will analyse the nature and scope of science diplomacy in Arctic cooperation, focusing on the role of science diplomacy in China-Nordic Arctic relations and how it fits within the framework of the three policy strands of science diplomacy.

The Diplomacy of Arctic Operational Research

Douglas Causey, Harvard Kennedy School Belfer Center, Cambridge, MA USA
Randy Kee, U Alaska Arctic Domain Awareness Center, Anchorage, AK USA
Jason Roe, U Alaska Arctic Domain Awareness Center, Anchorage, AK USA
Jeffrey Welker, Ecology Research Unit, U Oulu, Finland

Keywords: Operational Research, Search and Rescue, Science Diplomacy

Scientific research is most commonly considered as consisting of two types—basic and applied—but there are far more nuanced approaches which share similarities but differ significantly. We here discuss a particular type of research based on the needs of critical Arctic operations, assets, and infrastructure, such as air and marine transport, communication, and engineering. The Arctic environment is shared by many nations, peoples, and organizations, and consequently there is a long history of international collaboration of sharing work and results. We give examples of where international collaboration directed at increasing efficiency and safety of Operators transcended normal diplomatic approaches to finding solutions to complex issues in the Arctic region (e.g. associated with the 2011 agreement on Search and Rescue in the Arctic, Polar Code certification). We view Operational Research Diplomacy as being closely allied with the concept of Disaster Diplomacy, and together they form a strong working model of alternative diplomatic approaches to negotiating life in the Arctic. The most successful Arctic Operational Research addresses immediate and practical needs, and partners industry, agencies, universities and other research centers, indigenous peoples, and local communities.

A Global-optimization Approach to Predicting Changes in Arctic Cargo Vessel Traffic

Wenjie Li, George Mason University, Fairfax, Virginia, USA
Elise Miller-Hooks, George Mason University, Fairfax, Virginia, USA
Ralph Pundt, Maine Maritime Academia, Maine, USA

Keywords: Global, Shipping, Maritime, Traffic, Vessels

This presentation discusses a developed strategic cargo routing model that is based on concepts of mathematical programming and discrete choice. The model considers both liner and bulk shipping markets and aims to estimate real-world traffic flows for the study of maritime traffic patterns at a global scale. To calibrate this strategic cargo routing model with its behavioral assumptions to observed data, a heuristic gradient descent method is employed. In support of this global analysis, a second key contribution is required. Thus, this presentation also discusses the representation of the global cargo maritime network that uses updatable data, including identification of key ports, shipping routes, vessel classes and number of transits, bulk and container origin-destination demand, and other needed parameters to support this analysis of international seaborne trade. Using the developed maritime network and mathematical models, real-world maritime traffic flow patterns are estimated and studied. The use of this set of tools for predicting vessel traffic along Arctic passageways and other shifts in global maritime trade flows with increasing thawing of ice within the Arctic passageways into the future is discussed.

Arctic Science Diplomacy from the Cold War via Circumpolar Cooperation to Sino-American bipolar Competition and Russian Resurgence

Rasmus Gjedssø Bertelsen, UiT The Arctic University of Norway, Tromsø, Norway

Keywords: Cold War, Post-Cold War, Sino-American Bipolarity, Science Diplomacy

This paper will discuss Arctic science diplomacy under differing international systemic conditions from the Cold War via Post-Cold War Circumpolar cooperation to the emerging loose Sino-American bipolar competition and the resurgence of Russia. During the Cold War, Circumpolar Arctic science diplomacy was extremely limited. The Post-Cold War period of Circumpolar Arctic has been a golden age for Arctic cooperation and peoples. Science diplomacy has thrived under these conditions with much science IN diplomacy, diplomacy FOR science, and science FOR diplomacy. The Post-Cold War era in the Arctic and globally was not a natural state or the End of History. The world continues to change and so does the Arctic. The international system is now marked by emerging loose Sino-American bipolarity because the US and China are the world's two by far largest national economies. Russia has resurfaced as a more normal great power from the depths of post-Soviet socioeconomic crisis. These processes reshape the Arctic with American determination to exclude rising China from the Arctic. The Ukraine crisis is separating Russia and the West also in the Arctic and pushing Russia in the direction of Chinese partnership. What will Arctic science diplomacy look like under loose Sino-American bipolarity and resurgent Russian great power? Arctic science diplomacy will both be more difficult and more important.

Kola Science Centre of the Russian Academy of Sciences: Building the Science for and in Diplomacy for 90 years

Yulia Zaika, Federal Research Centre "Kola Science Centre of the Russian Academy of Scienes", Apatity, Murmansk region, Russia
Alexey Karpov, Yulia Zaika, Federal Research Centre "Kola Science Centre of the Russian Academy of Scienes", Apatity, Murmansk region, Russia
Eugene Borovichev, Yulia Zaika, Federal Research Centre "Kola Science Centre of the Russian Academy of Scienes", Apatity, Murmansk region, Russia

Keywords: Arctic, Science Diplomacy, Interdisciplinarity, International Cooperation, Science Infrastructure

The Kola Science Centre of the Russian Academy of Sciences celebrated its 90th Anniversary in 2020. It is the only research institution of RAS which is entirely located in the Arctic, and the largest one beyond the Arctic Circle. The geographical location provides a huge advantage in studying the features of the high latitude region and the wide range of cross-border cooperation possibilities within the transborder area “Murmansk region-Finland-Norway”. Since December 2017, the Kola Science Centre (KSC) of the Russian Academy of Sciences has the status of the Federal Research Centre (FRC). At present it includes 10 institutes and research centres, 3 youth laboratories, own social and other infrastructural facilities, and involves every-day work of more than 1200 researchers and employees. The Centre provides theoretical, fundamental, and practical outlook within the inter- and transdisciplinary dimension at regional and national levels by building the strong “society-science-governance” connection through times and generations. With this presentation we aim at showcasing the efforts undertaken by researchers of KSC RAS in building the successful international cooperation and science diplomacy practices in the region and beyond.

Remote sensing of the impact of climate change on northern Russian forests

Gareth Rees, Scott Polar Research Institute, University of Cambridge, UK
Olga Tutubalina, Moscow State University, Russian Federation
Sergey Bartalev, Institute for Space Research, Russian Academy of Sciences, Moscow, Russian Federation
Andrey Medvedev, Institute of Geography, Moscow, Russian Academy of Sciences, Moscow, Russian Federation
Gareth Marshall, British Antarctic Survey, Cambridge, UK
Elena Golubeva, Moscow State University, Russian Federation
Nikolay Shabanov, Institute for Space Research, Russian Academy of Sciences, Moscow, Russian Federation
Vasily Zharko, Institute for Space Research, Russian Academy of Sciences, Moscow, Russian Federation
Natalia Telnova, Institute of Geography, Moscow, Russian Academy of Sciences, Moscow, Russian Federation
Mikhail Zimin, Moscow State University, Russian Federation
Polina Mikhaylykova, Moscow State University, Russian Federation
Anna Terskaia, Moscow State University, Russian Federation
Ekaterina Sklyar, Scott Polar Research Institute, University of Cambridge, UK
Jack Tomaney, Scott Polar Research Institute, University of Cambridge, UK

Keywords: Remote Sensing, Russia, Forest, Climate Change

The world's boreal forest plays an important though imperfectly understood role in the climate system. The status of the carbon budget worldwide is unclear. This is particularly true of the large Russian component of the boreal forest, where only a small proportion has been inventoried and little is known about its recent evolution over time. We describe an ongoing project which aims to develop and apply new technologies for studying the dynamics of the Russian boreal forest during the 21st century over a wide range of spatial scales, and to understand it in the context of climate change. The project is a collaboration between two institutions in the UK and three in Russia, and builds on institutional links that have been developed over nearly 30 years. We present some early results from the project, discuss the support framework within which it has been developed, and outline a strategy for its enlargement in the future to include other forms of disturbance to the boreal forest.

Russia's Arctic science diplomacy: challenges and opportunities

Alexander Sergunin, St. Petersburg State University, St. Petersburg, Russia
Maxim Gutenev, South Ural University, Chelyabinsk, Russia

Keywords: Russia, Arctic, Science Diplomacy, Cooperation

The paper aims to:

- Find out what the strategic motivations behind Russia's Arctic science diplomacy are? What is the driving force in this case: purely scientific interests driven by the desire to understand what is happening in this rapidly changing region impacted by the global dynamics, or is Russian scientific diplomacy part of a soft power strategy in the Far North? Or maybe Moscow's motivation is determined by a combination of several different factors?
- Examine how the 2017 Agreement on Enhancing International Arctic Scientific Cooperation is being implemented by Russia and what should be done to improve the implementation process?
- To identify priority areas for Russia's Arctic studies which could include global climate change, ice dynamics, permafrost, continental shelf, mineral and bio-resources, flora and fauna, socioeconomic implications of climate change, and indigenous peoples.
- To explore major venues for Russia's scientific cooperation with international partners: (1) the Arctic Council's working and expert groups; (2) international non-governmental scientific organisations; (3) the Russian Academy of Sciences' cooperative programs with similar foreign bodies, and (4) bilateral projects between Russian and foreign scientific and educational institutions.

Science Diplomacy and the Future of Arctic Governance

Ebru Caymaz, Canakkale Onsekiz Mart University, Canakkale, Turkey
Y. Barbaros Buyuksagnak, Piri Reis University, Istanbul, Turkey
Burcu Ozsoy, Tubitak Mam Polar Research Institute; Istanbul Technical University, Istanbul, Turkey

Keywords: Arctic Governance, COVID-19, Governance, Science Diplomacy.

Global challenges such as human induced climate change, food security, poverty and recently the COVID-19 pandemic have highlighted the significance of international scientific cooperation and collaboration. Scientific activities, which have recently become an important component of foreign policy, are gradually gaining priority. This process has also renewed the interest in science diplomacy to address pervasive challenges affecting the world. On the other hand, as unique zones of peace and collaboration, polar regions have been undergoing substantial transformation due to human induced climate change. Since the Arctic region has been warming more than twice fast compared to the rest of the world, there is a rising international interest based upon the motivation of conducting scientific researches as well as utilizing economic opportunities. Therefore, the Arctic Council has been evolved into a more comprehensive high-level forum in which non-Arctic states are also accepted as observers. Consequently, a new and many-sided diplomatic system has emerged consisting of scientific institutions, network of regulators, media and non-governmental organizations alongside with governments. The aim of this paper is to examine the future of Arctic governance from science diplomacy perspective.

The Political Geographies of Science Diplomacy: A Case Study of the Politicization of Chinese Arctic Research

Trym Eiterjord, Max Planck Institute for the History of Science, Berlin, Germany

Keywords: China, Science Diplomacy, Securitization

Science diplomacy has become crucial to addressing the consequences of Arctic warming, manage regional resources, and to allowing the international scientific community to take advantage of the unique scientific opportunities that the polar north provides. This article examines how the return to more contentious global politics might create obstacles for efficient science diplomacy. China's Arctic research program is used as a case study to explore how politics might impede efforts to conduct science diplomacy on issues of both scientific and national security relevance in the Arctic. By analyzing circumpolar journalistic and government representations of Chinese Arctic research, and by eliciting experiences from Chinese polar researchers and their circumpolar peers, this article asks whether China's Arctic research program is subject to forms of politicization and securitization that might reduce the Chinese science community's ability to fully engage in science diplomacy in the Arctic. It also asks how science diplomacy as a policy might contribute to the politicization of international collaboration. In this sense, the article takes a critical look at various ?assumptions about science diplomacy found within the existing literature and looks for ways to improve the concept of science diplomacy.

The Track Least Taken: Arctic International Science Collaborations…A New Direction in Diplomacy

Douglas Causey, Harvard Kennedy School Belfer Center, Cambridge, MA USA
Randy Kee, U Alaska Arctic Domain Awareness Center, Anchorage, AK USA
Brenda Dunkle, U Alaska Arctic Domain Awareness Center, Anchorage, AK USA
Jeffrey Welker, Ecology Research Unit, U Oulu, Finland

Keywords: Science Diplomacy, Research Collaborations, Negotiation Tracks

We describe how formal international collaborations among Arctic scientific researchers constitute a critical and effective diplomatic venue by which multinational issues of the North can be addressed with data, knowledge and wisdom. Ongoing changes across the Arctic, including sea ice loss, are resulting in a suite of Pan Arctic ecological and economic consequences and are amplifying sovereignty considerations, land claims, rights of free passage, territorial disputes, and resource claims. We describe a "hybrid diplomacy" approach that blends features of formal diplomatic tracks of negotiation (eg., Track 1 and Track 2) addressing the agreed purposes of research investigation, informal tracks engaging local non-profit organizations (eg. Track 1.5), and consensus on shared research goals and funding. We discuss selected case studies involving research collaboration networks that successfully achieve international comity in environmental security [(e.g., International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT), International Polar Year (IPY)), Multi-disciplinary Observatory to Study Arctic Climate (MOSAiC). Key components of diplomatic effectiveness and success in these collaborations include multinational consensus on research goals, shared pool-funding (eg., Belmont Forum), and conjoined efforts to support logistics and access, data sharing, and open publication.

UKPN and APECS Russia ECRs collaboration: Short-term and long-term partnerships for capacity building in the Arctic

Saule Akhmetkaliyeva, UK Polar Network, Manchester Metropolitan University, Manchester, UK
Chelsey Baker, UK Polar Network, National Oceanography Centre, Southampton, UK
Benjamin Boyes, UK Polar Network, University of Brighton, Brighton, UK
Maria Gunko, APECS Russia, Institute of geography Russian Academy of Sciences, Russia, National Research University Higher School of Economics, Russia
Vicky Fowler, UK Polar Network, British Antarctic Survey, Cambridge, UK
Archana Dayal, UK Polar Network, University of Sheffield, Sheffield, UK, University Centre in Svalbard Longyearbyen, Norway
Yulia Zaika, APECS Russia, Federal Research Centre "Kola Science Centre of the Russian Academy of Sciences", Russia
Uliana Yakusheva, APECS Russia, Northern Arctic Federal University, Russia
Kyle Mayers, UK Polar Network, NORCE Norwegian Research Centre, Bergen, Norway

Keywords: Early Career Researchers, Scientific Cooperation

The Association of Polar Early Career Scientists (APECS) is a global organisation of early career researchers (ECRs) interested in the cryosphere. Recently, two national branches of APECS, APECS Russia and the UK Polar Network (UKPN) collaborated extensively to run a series of events for ECRs in both countries. These national committees (NCs) jointly organized workshops in Moscow and Cambridge (2018) and two Arctic Interdisciplinary Studies field courses (ARCTIS, 2019 and 2020) in the Russian North. These events upheld the values of the International Polar Year (IPY) and the Arctic Council's Agreement by enhancing international Arctic scientific cooperation. In this study, we aim to evaluate and present how the facilitation of short-term capacity building and bilateral activities at a regional level, among two NCs, help to build long-term and enduring internationally recognized partnerships. This will be achieved via research drawing on data obtained from participants of the previous bilateral events. Providing these collaborations as successful examples of science diplomacy in action, contributes to propelling and stimulating the initiation of similar capacity-building partnerships, and consequently the training of the next generation of polar scientists.

ID: 94 - Addressing Arctic Change – from Knowledge to Action

Conveners

Volker Rachold | German Arctic Office, Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research

Tahseen Jafry | Centre for Climate Justice, Glasgow Caledonian University

Anna Gebruk | School of GeoSciences, University of Edinburgh

Thorsteinn Gunnarsson | Icelandic Centre for Research (RANNIS)

Framing Co-Productive Conservation for Partnership with Arctic Indigenous Peoples

Victoria Qutuuq Buschman, University of Washington/Greenland Institute of Natural Resources, Nuuk, Greenland

Keywords: Indigenous-led Conservation, Indigenous Knowledge, Co-production of Knowledge

Indigenous communities at the front lines of climate change and biodiversity loss are increasingly shaping the conservation of lands, waters, and species. As the Arctic becomes a hotbed for emerging local, national, and international conservation efforts, researchers, managers, and communities alike will benefit from a framework that improves approaches to Indigenous partnerships. Co-productive conservation is a framework that encompasses both a co-production of knowledge and a co-production of public services to pursue ethically-conscious, culturally-relevant, and fully knowledge-based approaches to biodiversity concerns. Co-productive conservation recognizes that conservation can be practiced in a way that embodies Indigenous perspectives, knowledge, rights, priorities, and livelihoods. While conservation efforts typically focus on research and the co-management of species and natural spaces, limited effort is spent on the human dimensions and social processes necessary for conservation to affect change. Co-productive conservation encompasses six co-production processes, including co-planning, co-prioritizing, co-learning, co-managing, co-delivering, and co-assessing. By opening discussions on how to structure conservation efforts in partnership with Indigenous communities, we can move away from narratives that perceive Indigenous participation as an obligation or part of an ethical narrative, and instead embrace a process that broadens the evidence base and situates conservation efforts within Indigenous contexts.

Feedbacks from a warmer Arctic: implications for international climate goals

Rachael Treharne, Woodwell Climate Research Center, Falmouth, USA
Brendan Rogers, Woodwell Climate Research Center, Falmouth, USA
Thomas Gasser, IIASA, Laxenburg, Austria
Merritt R. Turetsky, University of Colorado at Boulder, Institute of Arctic and Alpine Research, Boulder, USA
Erin MacDonald, Woodwell Climate Research Center, Falmouth, USA
Carly Phillips, Union of Concerned Scientists Cambridge, Cambridge, MA, USA
Sue Natali, Woodwell Climate Research Center, Falmouth, USA

Keywords: Carbon Budgets, Feedbacks, Fire, Thaw, Paris Agreement

Arctic warming is expected to drive net loss of carbon from permafrost soils to the atmosphere. However, these emissions are not accounted for by the majority of Earth System Models (ESMs). Furthermore, where models do incorporate permafrost, thawing is typically simulated as a gradual top-down process. This ignores critical, non-linear processes such as abrupt thaw, wildfire, and fire-induced thaw. As a result, despite broad recognition in the scientific community, the potential for a strong positive feedback to future climate change from permafrost regions is not well understood among policy makers. There is therefore an urgent need for a comprehensive, policy-relevant assessment of permafrost carbon feedbacks and their implications for the temperature goals of the Paris Climate Agreement. To address this, we developed a simple but robust modelling framework that links global climate change scenarios to emissions from permafrost carbon feedbacks. This framework builds upon a reduced complexity ESM and gradual permafrost thaw emulator (Gasser et. al., 2018) by incorporating abrupt thaw, wildfire, and fire-induced thaw. We assessed the implications of these feedbacks for carbon budgets constraining warming to 1.5°C and 2°C. We found that the impact of non-linear processes on carbon budgets is similar to or greater than gradual thaw, and that combined feedbacks - gradual thaw, abrupt thaw, and fire - substantially reduced carbon budgets to remain below 1.5°C and 2°C.

Knowledge Mobilization and Exchange Portal in Support of Sustainable Development of the Arctic (IRIS Portal)

Pascale Ropars, ArcticNet, Université Laval, Quebec city, Canada

Keywords: Adaptation, Integration of Knowledge, Knowledge Mobilization, Web Portal

Over the last decades, impact studies and knowledge synthesis have multiplied in order to increase the social impact and concrete use of the knowledge produced by the various scientific programs. From its inception, ArcticNet has shown proof of innovation by developing Integrated Regional Impact Studies (IRIS), an approach based on the integration of knowledge from various research sectors, decision makers and indigenous knowledge that yield better understanding of priority issues for adaptation to global change and modernization in the North. To enhance the scope of these studies, ArcticNet is working on the IRIS Portal, a dynamic and editable portal that allows decision makers to rely on a wide range of regularly updated regional, national and circumpolar information to ensure sustainable development in the North. The portal is composed of three main modules: the editable module will speed up the scientific editing process, notably by adopting independent publication of chapters of the same report; the visualization module will allow users to easily navigate through the reports and related documentation; the search module on a website accessible to all will allow end users to search through a myriad of publications for information relevant to them. We would like to obtain your comments and suggestions to make this tool as useful and relevant as possible.

Arctic Expressed in Contemporary Art - How to Create Emotions to Understand Knowledge

Hyunjung Park, Hokkaido University, Sapporo, Japan

Keywords: Contemporary Art, Science Communication, Artist And Scientist, Collabolation

Contemporary art has questioned traditional art expressions based on the question of what art is. The answers to these questions are the use of a variety of media, the diversity of the subject matter of the work, and the frequent fusion with other fields. This study explores the current situation and future possibilities of creating contemporary art in the Arctic. The purpose of this research is to explore the conditions, influences and significance of art production in the Arctic. Through these activities, we will make clear the possibility of creating art by connecting more people to learn about the Arctic region. At the same time, the necessity of interdisciplinary fusion and the conditions for it are described. Science communication is expanding from a one-sided approach that explains difficult science in an easy-to-understand manner to two-way communication that creates a place for people to think about science in society, specially in Japan. Science communication through art does not use art as a means of transmitting science, but aims to be effective as both art and science communication by looking at the overlaps between art and science and promoting them while respecting different viewpoints. In addition to translating the results of scientists' research, new discoveries can be made from the viewpoints unique to each field by presenting the viewpoints unique to artists and interacting with scientists. In this research, science communication through art will be conducted in the Arctic to provide opportunities to accurately examine common points and differences among fields, and to present diverse perspectives and deepen understanding of the Arctic. I'm an artist specializing in media art, and also working as a researcher conduct practical research on science communication. This time, I will take as an example the exhibition held at the Hokkaido University Museum from December to January 2020. The project aims to clarify the limits and possibilities of how scientists and artists have changed their understanding of and perspectives on the environment, including the Arctic, by sharing their research and work on the environment.

A New Knowledge Gathering Process to Inform Pro-active Co-management of Climate Adaptation: A Case Study in the Western Canadian Arctic

Donald McLennan, Polar Knowledge Canada, Cambridge Bay NU Canada
Eddy Carmack, Emeritus DFO, Saanich BC Canada
Milla Rautio, University de Quebec a Chicoutimi, Chicoutimi QC Canada
Johann Wagner, Polar Knowledge Canada, Cambridge Bay NU Canada
Lynda Orman, Polar Knowledge Canada, Cambridge Bay NU Canada
Ann Balasubramaniam, Polar Knowledge Canada, Cambridge Bay NU Canada

Keywords: Climate Change, Arctic, Knowledge Co-Development, Systems Approach

Developing effective climate change policy to support proactive co-management requires the development and communication of timely and useful knowledge to inform decision-making. Unfortunately, Arctic ecosystems are changing in complex ways that interact to create uncertainty about how, and how rapidly, these changes are occurring, and what these changes mean for traditional and modern northern livelihoods, food security systems, regional and national priorities, and the global climate system. We propose here that the existing knowledge system we use to develop this information cannot meet these challenges for a number of largely systemic reasons that restrict our ability to look, in a coordinated way, across geographic scales, and across institutions, agencies and jurisdictions. Here we use the CHARS ERA as a case study area to: 1) review climate change drivers, effects and scenarios; and 2) propose a new knowledge gathering and sharing process aimed at understanding and communicating these changes. The process we are proposing combines co-generation of Indigenous knowledge with emerging integrative science approaches, directed by a consortium of invested regional actors. To demonstrate the knowledge gathering component of the overall adaptation process, we use two issues identified by communities as critically important to community food security – the long term fate of Arctic char populations, and the recent steep decline of the Dolphin and Union Caribou Herd.

Clientelism in the Rural North?: A Grounded Framework for Understanding Pressures for Oil Extraction in the Northwest Territories and Alaska

Kelsey Schober, University of Alberta, Alberta, Canada (from/living in Alaska, USA)

Keywords: Oil And Gas, Climate Change, Alaska, Northwest Territories

Oil has driven migration, community growth, and governance of the last century in the North. Today, as Arctic global warming surpasses 1°C with "profound consequences" (IPCC, 2019) for the North, the relationship between oil and climate change cannot be ignored. In light of this tension, my research asks: how is oil development structurally and politically incentivized, even as the North faces disproportionate impacts of climate change that directly threaten the culture, infrastructure, and economy of communities? What pressures exist for communities to approve oil drilling projects? Ultimately, this work examines oil and gas extraction in the Northwest Territories and Alaska from a Northern perspective, animated by frameworks of settler colonialism, clientelism, and rural theory. It demonstrates the inaccuracies of the dichotomous environment vs. development narrative, analyzing instead the ways in which the ongoing assertion of rights and sovereignty have built political power in the North. Within this context, this research takes a comparative stance, articulating the ways in which the North shares a political chronology – as well as what can be learned from how these trajectories have diverged. The results have implications for understanding how climate change and oil development can be reconciled in regions that are ground zero for both, as well as understanding broader systems of political power in the North.

Connecting policy, law and science for better decision-making for the Arctic: Arctic Council, IPCC, Arctic Science Agreement, and ASM-3

Kie Abe, Kobe University Polar Cooperation Research Centre, Kobe, Japan
Akiho Shibata, Kobe University Polar Cooperation Research Centre, Kobe, Japan
Hiroyuki Enomoto, National Institute of Polar Research, Tachikawa, Japan

Keywords: Arctic, Policy-Law-Science Nexus, Institutional Design, Scientific Cooperation

The important role science plays in law and policy has rapidly increased. This is particularly so in the Artic law and policy making, as, on one hand, the scientific research in and on the Arctic is crucial in understanding and responding to the global environmental challenges including climate change and, on the other, gaps in scientific knowledge are still prevalent in the Arctic. This fact urgently requires us, first, to examine how to better connect science with Arctic law and policy making, by better designing relevant international institutions where such connection would occur. Second, we need to examine how the relevant law and policy can further promote Arctic science to gain crucial scientific knowledge necessary for better decision-making for the Arctic. Against this backdrop, the overall objective of this research is to analyze the policy-law-science nexus within several international institutions addressing emerging critical issues in the Arctic. The targeted institutions of our analysis will be the Arctic Council and its Working Groups, the Intergovernmental Panel on Climate Change (IPCC), and the Meeting of the Parties (MoP) established under the Arctic Science Cooperation Agreement. We will also examine the 3rd Arctic Science Ministerial, although the meeting will not have been convened yet by the time this presentation is made at ASSW in March 2021. We will investigate the lessons learned from and the challenges faced in those international forums and mechanisms that try to connect legal and policy needs with Arctic sciences or vice versa. In turn, the institutions established to tackle the Arctic issues may provide significant lessons and clues to understand how an effective science-based decision-making can be realized more generally and for other regions.

Need for Inclusion of Mainland communities in Arctic Research- It's a matter beyond Poles

Vinod Kumar Nathan, SASTRA Deemed to be University, India

Keywords: Arctic, Climate Change, Indigenous, Mainland, Polar Science

When we address the issues of Arctic regions especially in view of climate change, we actually neglect the contributions of mainland population. Arctic indigenous communities alone cannot conserve and restore the polar regions and combat the climate change related issues. The mainland population are the major contributors of greenhouse gases and are melting the Arctic. Moreover, the impact of marine pollution had reached till the Arctic. It is essential that the mainland population is more aware of the polar science and to further know the consequence of their activities beyond their geographical boundaries. Hence, I advocate the need of more outreach activities on polar science, in the mainland. The indigenous community awareness is a must, but scientific community should share the real picture beyond these communities to the global citizens. This will enable the other scientific community also to join hands to protect and restore the Arctic. Not only oceanic countries alone should understand about Arctic and polar sciences, the equatorial or mainland countries and its stakeholders also should be involved in Arctic research and its restoration. Combating climate change must be a collective effort of global citizens and we need to focus more on the root cause for the climate change rather on the end point victims of climate change.

ID: 10 - Governance in the Central Arctic Ocean: from local to global

Conveners

Austin Ahmasuk | Kawerak, Inc., Alaska, USA

Liling Xu | Dept. of Geography, Royal Holloway, University of London, UK

Henry Huntington | Ocean Conservancy, Eagle River, Alaska, USA

Locating China’s Arctic engagement in China’s strategic transformation to the sea and ocean

Liling Xu, Royal Holloway University of London

Keywords: China, Arctic governance, “Strong Maritime Country”,

China’s active engagement in the Arctic has drawn increasing international attention since it was granted an observer status in the Arctic Council in 2013. This presentation locates China’s involvement in the Arctic within its strategic transformation towards the sea and ocean. In 2012, China incorporated the “Strong Maritime Country”(“Haiyng Qiangguo????”) as its national strategy. Many studies and comments link China’s involvement in Arctic waters with the “Strong Maritime Country” strategy from the perspective of power projection or navy strategy. However, this presentation argues that the scope of “Strong Maritime Country” is far beyond the military capability and power competition, and embraces the maritime economy, maritime science and technology, maritime ecological protection, and maritime managements, which directly impacts China's participation in Arctic waters. The presentation explores the following questions: (1) How has China’s “nearness” with the Arctic region been built through China’s dynamic associations with the rapidly changing Arctic waters through scientific research, resource utilisation, shipping routes, and CAO governance, etc.? (2) How does the strategic target of “Strong Maritime Country” shed light on China’s interests and perspectives about the Arctic? (3) how could China contribute to environmental protection, sustainable development, and governance in the Arctic by building itself into a “Strong Maritime Country”?

Safeguarding Local Communities in the Bering Strait with Indigenous Knowledge Inclusion and Frontline Efforts

Austin Ahmasuk, Marine Advocate, Kawerak, Inc., Alaska, USA

Keywords: Shipping, Heavy Fuel Oil, Marine Debris

As the Arctic thaws increased shipping threatens the indigenous way of life in the Bering Strait region. Indigenous perspectives are essential for the future of the people whom live and work in the northern Bering Sea. Alaska Natives own 85% of the coastline of the Bering Strait region as well as Little Diomede Island, situated at the confluence of national and international dialogue. As the Arctic becomes more globalized local perspectives have not been adequately heard to form Arctic policy. Indigenous advocates struggle to engage locally, nationally, and internationally while urban thinktanks and policy decisions are made without local perspectives. Local people in the Bering Strait region have taken it upon themselves to protect their way of life from the impacts of foreign shipping related pollution because there is no response capability other than their own. Heavy Fuel Oil (HFO) used as a source of energy for shipping contributes to pollution and poses threats to Arctic Communities. Indigenous perspectives have contributed international efforts to mitigate the threat of HFO use and carriage. Despite good faith and grassroots efforts indigenous perspectives struggle to inform policy.

The BBNJ Agreement and the Implementation of Ecosystem-Based Management in the Central Arctic Ocean

Kentaro Nishimoto, National Institute of Polar Research, Tokyo, Japan

Keywords: BBNJ Agreement, Marine Biological Diversity, Ecosystem-Based Management, Ecosystem Approach

The currently negotiated agreement on marine biological diversity in areas beyond national jurisdiction (BBNJ) will create another layer of governance for the Central Arctic Ocean (CAO). The agreement will likely facilitate the implementation of the ecosystem approach in the high seas portion of the CAO by establishing a mechanism for the coordination of regulatory regimes in designating area-based management tools (ABMTs) and by providing guidance on conducting environmental impact assessments. What is yet unclear is how the BBNJ agreement will interact with the various strands of Arctic ocean governance and the measures adopted by Arctic coastal States. While this depends on the design of the agreement to be negotiated and whether all coastal States will participate in the agreement, some critical issues can be identified. First, the extent to which the BBNJ agreement adopts a regional or global approach will determine the forum in which the main efforts towards ecosystem-based management of the CAO will take place. Second, whether further regional efforts towards a mechanism for the exercise of management functions will be pursed in response to the new agreement will significantly affect governance of the CAO. Third, the provisions of the BBNJ agreement concerning the relationship between ABMTs within and beyond areas of national jurisdiction will affect whether ecosystem-based management can be ensured across the artificial jurisdictional boundary.

ID: 47 - Regional Changes, Global Impacts in Arctic Fisheries

Conveners

Brooks Kaiser | University of Southern Denmark

Linda Fernandez | Virginia Commonwealth University

Melina Kourantidou | Woods Hole Oceanographic Institution

Bioeconomic analysis accounting for environmental effects in data-poor fisheries: The Northern Labrador Arctic Charr

Melina Kourantidou, Woods Hole Oceanographic Institution, Marine Policy Center, Woods Hole, MA, U.S. & University of Southern Denmark, Department of Sociology, Environmental and Business Economics, Esbjerg, Denmark
Di Jin, Woods Hole Oceanographic Institution, Marine Policy Center, U.S.
Andrew Solow, Woods Hole Oceanographic Institution, Marine Policy Center, U.S.

Keywords: Nunatsiavut, Data-Poor Fisheries, Arctic Charr, Environmental Variability, Bioeconomic Model

Fisheries managers are calling for more nuanced understandings of the complex interactions between exploitation and environmental variability. In data poor settings, this need is even larger. We develop a bioeconomic model for the Northern Labrador Arctic Charr out of Nain bay, a data-deficient fishery, where only catch and effort data are available. We expand the standard bioeconomic model to incorporate climate variability into growth, using the Newfoundland and Labrador composite climate index anomaly. Through an optimization procedure we derive parameters necessary for the bioeconomic analysis and identify the optimal equilibrium conditions for the model with and without climate variability. Accounting for climate variability results in a slightly higher optimal harvest, effort and stock level. The most recently available index anomaly for 2014, yields a socially optimal effort level of 591 fishing weeks, corresponding to a harvest of 156,920 kg, suggesting that the stock was largely underharvested in that year and that fishing effort was way below optimal. We also find that a temperature increase leads to a higher optimal effort level and higher net benefits at steady state. This is the first effort identifying the equilibrium harvesting conditions for this, currently non-profitable, fishery that has a large social, cultural and potential economic value for the region.

Russian King Crab Sourcing in the United States and Traceability Pilot

John Simeone, Simeone Consulting, LLC, Hill, New Hampshire, USA
Neil Aeschliman, World Wildlife Fund (WWF), Washington, DC, USA
John Steinmetz, Orca Bay Foods, LLC, Seattle, WA, USA

Keywords: King Crab, Global Supply Chains, Seafood Trade, Traceability, IUU

Ending illegal, unreported, and unregulated (IUU) fishing remains one of the most urgent priorities for achieving healthy ocean ecosystems and protecting the welfare of people around the world who depend on fishing for their livelihoods and food security. Governments, businesses, and civil society stakeholders have increasingly focused on a combination of fisheries monitoring, product traceability, and regulatory trade controls to ensure that all seafood reaching consumers comes from legal and responsible sources. This research, brought forward through collaboration between three World Wildlife Fund offices (WWF -Russia, South Korea, United States), Orca Bay Foods, LLC, and Simeone Consulting, LLC, demonstrates that the application of some basic tools can substantially reduce the risk of “IUU infection” even in the relatively complex and multinational supply chains of king crab. While the aims of this research project were specific to US sourcing of Russian-origin king crab, much of the information, and verification mechanisms related to Russian total allowable catch, quotas, and fisheries harvest permitting apply to other Russian fish and seafood species. All project partners hope that this project serves as just an initial template for similar practices and initiatives globally when sourcing other Russian-origin seafood.

Walking a Tight Line: Management of a New Arctic Fishery With Spatially Differentiated Ecological-Economic Externalities

Linda Fernandez,Virginia Commonwealth University,Richmond,USA,
Brooks Kaiser, University of Southern Denmark, Esbjerg,Denmark,
Melina Kourantidou, Woods Hole Oceanographic Institution, Marine Policy Center, Woods Hole, MA, US.

Keywords: Barents Sea Red King Crab, Invasive Species with Market Value and Ecological Impacts

We study management decisions taken jointly and independently by Russia, who purposefully introduced the Red King Crab (Paralithodes camtschaticus, RKC) in the 1960s, and Norway, into whose waters RKC has spread in the Barents Sea. The invasion has impacted unique benthic species. Management of the RKC by Russia and Norway reflects differing output market choices and perception of damages. We compare historical management to the optimal management taking into account spatial connectivity and incentives in a spatial dynamic model. The RKC presents particularly interesting challenges due to its dual nature as an invasive species and a market commodity. Part of the management of the RKC spread has focused on spatial containment, where the containment procedure depends on economic incentives of open access fisheries. This research sheds light on the economic and ecological tradeoffs faced in rapidly changing Arctic waters and the challenges presented by transboundary resources with differing net benefits.

Dense mesopelagic sound scattering layer and vertical segregation of pelagic organisms recorded at the Atlantic gateway to the Arctic Ocean during the midnight sun

Pierre Priou, Fisheries and Marine Institute of Memorial University of Newfoundland, St John's, NL, Canada
Anna Nikolopoulos, Institute of Marine Research, Bergen, Norway
Hauke Flores, Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany
Rolf Gradinger, The Arctic University of Norway, Tromsø, Norway
Erin Kunisch, The Arctic University of Norway, Tromsø, Norway
Christian Katlein, Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany
Giulia Castellani, Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany
Torsten Linders, University of Gothenburg, Göteborg, Sweden
Jørgen Berge, The Arctic University of Norway, Tromsø, Norway
Jonathan Fisher, Fisheries and Marine Institute of Memorial University of Newfoundland, St John's, NL, Canada
Maxime Geoffroy, Fisheries and Marine Institute of Memorial University of Newfoundland, St John's, NL, Canada

Keywords: Mesopelagic, Svalbard, Deep Scattering Layer, Hydroacoustics, Drifting Observatories

Changes in vertical and spatial distributions of zooplankton and small pelagic fish impact the biological carbon pump and the distribution of larger piscivorous fish and marine mammal species. However, their distribution and abundance remain poorly documented in the Arctic Ocean. Ice-tethered and ship-based echosounders operated over the Yermak Plateau in the high European Arctic in June 2017 provided under-ice vertical distribution and acoustic backscatter of zooplankton and fish during the midnight sun. A surface scattering layer composed of copepods consistently occupied the top 70 m and was associated with cold polar surface water. A deep scattering layer (DSL) persisted between 280 m and 600 m and was associated with modified Atlantic water. Target strength analyses suggest that gas-bearing organisms (e.g., swimbladdered fish, siphonophores) constituted the DSL. The DSL backscatter strength increased over the deep continental slope where the Atlantic water circulation was intensified. The consistent segregation between copepods at the surface and their predators at mesopelagic depths suggests limited predator-prey interactions during pre-bloom conditions. Predation on copepods by mesopelagic fish could thus be limited to very pulsed events during the seasonal vertical migration of copepods to and from overwintering depths. This suggests that the Arctic mesopelagic food web may be decoupled from secondary production in the epipelagic layer throughout most of the year.

Russian IUU Regulation and Snow Crab Fisheries in the Northwestern Pacifica: Impacts on Japanese Markets

Kanae Tokunaga, Gulf of Maine Research Institute, Maine, USA
Brooks Kaiser, University of Southern Denmark, Denmark
Masashi Yamamoto, University of Toyama, Japan

Keywords: Snow Crab, IUU Fishing, Russia, Japan, Fisheries Trade

Snow crab (Chionoecetes opilio) is one of the commercially most important crab species in Japan, and its fishing activities take place in the 36°N - 45°N latitude range. There are four stocks within Japanese exclusive economic zones, of which the two largest stocks are shared with Russia and South Korea. Japan also serves as an important market for snow crab and imports from both of these countries. In particular, Japan imports a large amount from Russia, with 5-year average annual imports of snow crab amounting to 16,617 metric ton. This study investigates the linkages between foreign fisheries management and domestic fishing activities when both the stock and market are shared. In particular, we examine the impacts of Russian IUU fisheries regulation on Japanese snow crab fishing activities by using Japanese trade statistics and landing statistics from major domestic ports. There are two possible outcomes. First, Russian crabs being substitutes to domestically caught crabs, more stringent IUU regulation in Russia increases the ex-vessel prices at Japanese domestic ports. Second, more stringent IUU regulation increases the cost of production for Russian fleets, which creates a favorable condition, and thus, higher catch for Japanese fleets that share the stock with Russia. Therefore, the real resource conservation effect of the Russian IUU regulation may be smaller than it appears in the trade statistics.

Theme B: The Changing Arctic Ocean Dynamics and Impacts

ID:93 - Climate change and the Arctic Ocean

Conveners

Annica Ekman | Stockholm University

Marius Årthun | University of Bergen

William Perrie | Bedford Institute of Oceanography, Canada

Nordic Seas Heat Loss, Atlantic Inflow, and Arctic Sea Ice cover over the last century

Lars H. Smedsrud, Geophysical Institute, University of Bergen, Norway
Ailin Brakstad, Geophysical Institute, University of Bergen, Norway
Erica Madonna, Geophysical Institute, University of Bergen, Norway
Morven Muilwijk, Geophysical Institute, University of Bergen, Norway
Clemens Spensberger, Geophysical Institute, University of Bergen, Norway

Keywords: Atlantic Inflow, Arctic Sea ice, Nordic cooling

Poleward ocean heat transport is a key process in the earth system. Here we detail the changing Atlantic Water (AW) inflow to the Nordic Seas and the associated heat transport and heat loss to the atmosphere since 1900, in relation to the sea ice cover. Our synthesis is largely based on a sea ice-ocean model forced by a reanalysis atmosphere (1900-2018) corroborated by a comprehensive hydrographic database (1950-), measurements of AW inflow (1996-), and other key long-term regional time series. Since the 1970s, ocean temperatures have increased in the Nordic, Barents and Polar Seas, in particular on the shelves. The AW loses heat to the atmosphere as it travels poleward, mostly in the Nordic Seas, where ~60% of the Arctic Ocean total heat loss resides. Nordic Seas heat loss variability is large, but the long-term positive trend is small. The Barents Sea heat loss is ~30% of the total, but has larger consistently positive trends, related to AW heat transport and sea ice loss. The Arctic seas farther north see only ~10% of the total heat loss, but show a consistently large increase in heat loss as well as decrease in sea ice since 1900. The oceanic warming is congruent with increased ocean heat transport and a loss of sea ice, and has contributed to the retreat of marine terminating glaciers on Greenland. After 2000, the warming has accelerated, creating a “new normal” that appears to also affect deep water volumes and temperature.

Arctic ocean and sea ice seen from CMIP6 models

Muyin Wang, University of Washington, Seattle, WA US,
James E. Overland, NOAA/PMEL, Seattle, WA, USA
Qi Shu, First Institute of Oceanography, Ministry of Natural Resources, China
Shizhu Wang, First Institute of Oceanography, Ministry of Natural Resources, China

Keywords: CMIP6, Sea-Ice Extent, Salinity, Fresh-Water Content

The Arctic is one of the regions where the strongest climate change signals are observed on our planet. Projections of future atmosphere, ocean, and ice conditions in Arctic are important not only for the climate change studies, but also for stake holders and decision makers. In this paper we investigate how the most up-to-date climate models (CMIP6) simulate the present-day Arctic climate and what are their future projections under different emission scenarios. Overall speaking the CMIP6-era models show considerable improvement from ith its precursors, CMIP3 and CMIP5. Compared with the observational records, the CMIP6 multi-model mean (MMM) overestimated the March and September sea-ice extent, and under estimated the trend of September sea-ice cover in the last 20 years. For ocean surface salinity and freshwater content in the upper 250m, the MMM reproduce a reasonable agreement with observed pattern. Late-summer (September) sea ice stabilizes at more than half its present value under SSP1-2.6, while the Arctic Ocean's sea-ice extent falls below the “ice-free” threshold of 1 million square kilometers by 2100 under the other scenarios. A dipole change pattern of the salinity and fresh water content is projected by the MMM: saltier in Eurasian Basin, and fresher in the Amerasian Basin . The warming in the Arctic will continue to be amplified under all scenarios, with the largest warming projected to happen in winter.

Present and future drivers of regional Arctic winter sea-ice variability

Jakob Dörr, Geophysical Institute, University of Bergen, Bergen, Norway
Marius Årthun, Geophysical Institute, University of Bergen, Bergen, Norway
Tor Eldevik, Geophysical Institute, University of Bergen, Bergen, Norway
Erica Madonna, Geophysical Institute, University of Bergen, Bergen, Norway

Keywords: Sea Ice, Internal Variability, Climate, Atmosphere, Ocean

Recent Arctic sea ice loss is overlaid by strong internal variability. In winter, sea ice retreat and variability are currently dominated by the Barents Sea, primarily driven by variable ocean heat transport. In the future, as winter Arctic sea ice loss spreads to other regions of the Arctic, it is unclear how the influence of ocean heat transport will change and to what extent and in which regions other drivers, such as atmospheric circulation or river runoff, will gain importance. Using a combination of observations and output from the Community Earth System Model Large Ensemble we analyze and contrast present and future drivers of regional winter sea ice variability. We find that for the recent past, sea ice variability in the Atlantic and Pacific sector of the Arctic Ocean is influenced by ocean heat transport through the Barents Sea and Bering Strait, respectively. While the dominant modes of atmospheric circulation only weakly influence the sea ice, atmospheric circulation anomalies associated with regional sea-ice variability show distinct patterns for the Atlantic and Pacific sectors consistent with heat and humidity transport from lower latitudes. Future simulations show a gradually expanding footprint of Pacific and Atlantic inflows, covering the whole Arctic by 2050-2079, highlighting the importance of future Atlantification and Pacification of the Arctic Ocean.

Mechanisms of Arctic amplification triggered by the sea ice loss

Vladimir Ivanov, Lomonosov Moscow State university, Moscow, Russia

Keywords: Arctic Amplification, Sea Ice, Feedback Loops, Ocean-Air Interaction

It is generally acknowledged that the phenomenon of the so-called Arctic amplification is behind about 2.5 larger increase of the surface air temperature in the Arctic than in the lower latitudes. Rapid decrease of the Arctic sea ice in the recent two decades acted as a “trigger” that provided an intensification of positive feedbacks, which were either not manifested earlier, or were ineffective under the conditions of the dominance of thick consolidated ice. In addition to the well-known and described in the literature feedbacks that are acting in high latitudes, two new mechanisms are introduced: "seasonal memory" in the ice cover properties and "atlantification". It has been shown that these mechanisms contribute to the further reduction of the Arctic sea ice. In the East-Atlantic sector of the Arctic Ocean both mechanisms operate in concert, enhancing the end result. According to climate scenarios, Arctic warming is projected to intensify in the coming decades, causing changes in various environments. It can be expected that an important role in this will be played by positive feedbacks that provide Arctic amplification in modern conditions, when the Arctic climate system is in an unstable transitional state.

Verification of regional climate model simulations over Arctic sea ice in late winter using in-situ and remote sensing data

Günther Heinemann, University of Trier, Trier, Germany
Sascha Willmes, University of Trier, Trier, Germany
Lukas Schefczyk, University of Trier, Trier, Germany
Alexander Makshtas, Arctic and Antarctic Research Institute, St. Petersburg, Russia
Vasilii Kustov, Arctic and Antarctic Research Institute, St. Petersburg, Russia
Irina Makhotina, Arctic and Antarctic Research Institute, St. Petersburg, Russia

Keywords: Regional Climate Model, Sea Ice, Verification, Arctic, MODIS Ice Surface Temperatures

The parameterization of ocean/sea-ice/atmosphere interaction processes is a challenge for regional climate models (RCMs) of the Arctic, particularly for wintertime conditions, when small fractions of thin ice or open water cause strong modifications of the boundary layer. Thus, the treatment of sea ice and sub-grid flux parameterizations in RCMs is of crucial importance. However, verification data sets over sea ice for wintertime conditions are rare. In the present paper, data of two ship-based experiments during the end of the Arctic winter for thin ice conditions (IRO-2, March 2014) and thick ice conditions (Transarktika, April 2019) are used for the verification of the regional climate model CCLM. In addition, Moderate Resolution Imaging Spectroradiometer (MODIS) data are used for the comparison of ice surface temperature (IST) simulations of the CCLM sea ice model. CCLM is used in a forecast mode (nested in ERA5) for the Norwegian and Barents Seas with 5km resolution and is run with different configurations of the sea ice model and sub-grid flux parameterizations. The use of a new set of parameterizations yields improved results for the in-situ comparisons. Particularly the parameterization of the sea ice thickness for thin-ice regions (grid-scale and sub-grid scale) is of large importance for low temperatures, but is usually not considered in most RCMs. Comparisons with MODIS IST allow for a verification for large areas and show also the good performance of CCLM. The comparison with twice-daily radiosonde ascents during Transarktika shows a very good representation of the temperature, humidity and wind structure of the whole troposphere for CCLM.

Heat uptake of the Arctic climate system and of the MOSAiC area

Leopold Haimberger, Department of Meteorology and Geophysics, University of Vienna, Vienna, Austria
Johannes Mayer, Department of Meteorology and Geophysics, University of Vienna, Vienna, Austria
Michael Mayer, Department of Meteorology and Geophysics, University of Vienna, Vienna, Austria and European Centre for Medium-Range Weather Forecasting, Reading, UK

Keywords: Heat Budget, Energy Storage, MOSAiC, Ocean State

Recent assessment of the coupled atmosphere-ocean-sea-ice energy budget of the Arctic using largely independent observational data sources demonstrated a high level of consistency of yearly means and annual cycles of lateral and vertical energy fluxes and storage terms. The annual mean heat uptake averaged over the Arctic, is not stronger than the global mean heat uptake, despite the strong warming. However the Arctic mean consists of ice-free regions where there is very high heat uptake and ice covered regions with below average heat uptake (see upcoming OSR5, https://marine.copernicus.eu/science-learning/ocean-state-report/). It has also been found that the annual cycle of the observed Arctic energy budget has amplified over the past two decades, with marked changes in seasonal patterns of energy fluxes and storage. The budget method used to estimate the net surface flux is tried also on a more local scale over the MOSAiC area, using monthly means. Preliminary results are shown, to be compared with flux estimates from the expedition as soon as they become available.

Structure of the freshened surface layer in the Eastern Arctic during ice-free periods

Alexander Osadchiev, Shirshov Institute of Oceanology, Moscow, Russia

Keywords: Freshened Surface Layer, River Plume, Freshwater Transport, River Discharge, Eastern Arctic

This work is focused on the structure and inter-annual variability of the freshened surface layer (FSL) in the Eastern Arctic, i.e., in the Kara, Laptev and East-Siberian seas, formed by discharge from the large Siberian rivers. FSL in the Earstern Arctic covers wide area (up to 800 000 km2) and consists of two separate areas: the first is formed in the Kara Sea, the second is formed in the Laptev and East-Siberian seas. Kara FSL is formed mainly by two large estuarine rivers (Ob and Yenisei), while Laptev/East-Siberian FSL is formed mainly by deltaic rivers (Lena, Kolyma and smaller rivers). Shallow and narrow channels of the Lena Delta are limitedly affected by sea water. As a result, undiluted Lena discharge inflows to sea from multiple channels and forms relatively shallow Lena plume, as compared to the deep Ob-Yenisei plume which mix with subjacent saline sea water in deep and wide estuaries. As a result, Kara FSL and Laptev/East-Siberian FSL are very different. First, the area of Laptev/East-Siberian FSL is almost twice greater than the area of Kara FSL, while the total annual freshwater discharge to the Laptev and East-Siberian seas is 1.5 times less than to the Kara Sea. Second, the area and position of Laptev/East-Siberian FSL have large inter-annual variability governed by local wind forcing conditions, while Kara FSL has almost the same area and position at different years.

New properties of the Eurasian Arctic ocean surface layer from in situ and satellite data

Anastasiia Tarasenko, Arctic and Antarctic Research Institute, St.Petersbourg, Russia/Centre National de la Recherche Météorologique (CNRM), Université de Toulouse, Météo-France, CNRS, Lannion, France
Alexandre Supply, Sorbonne Université, CNRS, IRD, MNHN, Laboratoire d'Océanographie et du Climat, Expérimentations et Approches Numériques (LOCEAN), Paris, France
Nikita Kusse-Tiuz, Arctic and Antarctic Research Institute, St.Petersbourg, Russia
Vladimir Ivanov, Arctic and Antarctic Research Institute, St.Petersbourg, Russia/ Moscow State University, Moscow, Russia
Stanislav Malinovskiy, Arctic and Antarctic Research Institute, St.Petersbourg, Russia
Jacqueline Boutin, Sorbonne Université, CNRS, IRD, MNHN, Laboratoire d'Océanographie et du Climat, Expérimentations et Approches Numériques (LOCEAN), Paris, France
Gilles Reverdin, Sorbonne Université, CNRS, IRD, MNHN, Laboratoire d'Océanographie et du Climat, Expérimentations et Approches Numériques (LOCEAN), Paris, France

Keywords: Surface Layer, Satellite Data, In Situ Data, Transarktika-2019, Arktika-2018

The new state of the surface layer in the Eurasian seas of the Arctic Ocean is discussed using observations from the Arktika-2018 and Transarktika-2019 expeditions and satellite retrievals. While the Arctic ocean stays ice-free longer, the use of satellite estimates can enrich existing in situ measurements. The validity of some recent satellite data (especially, the sea surface salinity) was demonstrated in (Supply et al., RSE 2020, Tarasenko et al., OS 2020 in press). High resolution in situ measurements in summer 2018-2019 allowed to follow changing properties of the ocean surface layer on meso- and submesoscale (from daily to weekly) and document the rapid transformation of summer-autumn water masses in the Kara, Laptev, and the East-Siberian seas. Combined with novel sea surface temperature, salinity and other satellite datasets over last 10 years, we could reconstruct the new climate means of the Arctic temperature and salinity and the effects of their variability on the environment: the pathways of the fresh riverine waters entering into the Eastern and the Central Arctic, the redistribution of the heat content and the role of these properties for the sea ice formation and melt.

Modelling phytoplankton dynamics in the Arctic's marginal ice zone

Fabian Große, Department of Mathematics and Statistics, University of Strathclyde, Glasgow, UK
Neil Banas, Department of Mathematics and Statistics, University of Strathclyde, Glasgow, UK
Marie Porter, Scottish Marine Institute, Scottish Association for Maine Science, Oban, UK
Sian Henley, School of Geosciences, University of Edinburgh, Edinburgh, UK
Jinlun Zhang, Polar Science Center, Applied Physics Laboratory, University of Washington, Seattle, WA, USA
Ingrid Ellingsen, Environment and New Resources, SINTEF Ocean AS, Trondheim, Norway

Keywords: Phytoplankton, Spring Bloom, Numerical Modelling, Sea Ice

High-latitude marine food webs are fundamentally shaped by magnitude, timing, and composition of phytoplankton blooms. In the Arctic marginal ice zone, the growth environment for phytoplankton is rapidly changing due to the loss of seasonal sea ice. Physical-biological models are widely used to study ecosystem response to (changes in) environmental conditions, yet often with specific regional focus not necessarily accounting for differences in ecosystem dynamics across the Arctic. Here, we present a new 'sandbox' framework for modelling phytoplankton dynamics and model comparisons using a case study for the Barents Sea. Our sandbox consists of a flow-following water column model forced by physical fields from the three-dimensional model SINMOD. The water column model represents two different biological models originally developed for the Bering Sea: the Biology-Ice-Ocean Modeling and Assimilation System (BIOMAS) and CLADACH (a new NPZD-type model). We present an analysis of the spring bloom dynamics in the Barents Sea in 2017 and 2018, two contrasting years with respect to sea ice conditions, as simulated by BIOMAS and CLADACH and as observed during the Arctic PRIZE project. We specifically focus on the suitability of the two 'Bering Sea' models for representing year-to-year differences in phytoplankton in the Barents Sea, and discuss the causes and implications of spring bloom dynamics in response to the changes in sea ice.

Shifting food sources change Arctic benthic faunal behaviour and ecosystem functioning

Adam Reed , University of Southampton
Izzy Cooper , University of Southampton
Jasmin Godbold , University of Southampton
Martin Solan , University of Southampton
Laura Grange , Bangor University

Keywords: Benthic-Pelagic Coupling, Carbon Budget, Bioturbation, Food Supply, Species-Environment Interactions

Extensive reductions in sea ice extent and thickness are leading to alterations in the quantity, quality and timing of primary productivity, with reductions in polyunsaturated fatty acid (PUFA) rich sea ice algae and a shift towards later pelagic algal blooms changing pelagic-benthic coupling. Despite these dramatic changes, the behavioural and physiological consequences for benthic invertebrate communities is poorly understood. Here, we examine the effect of food quality on the behaviour and associated sediment nutrient release of the infaunal bivalves Bathyarca glacialis and Astarte crenata, and seastar Ctenodiscus crispatus from the Barents Sea. When fed on a sinking PUFA enriched food source, all species demonstrate increased levels of bioturbation when compared to those fed on pelagic phytoplankton. Feeding on higher quality food also resulted in reduced sediment nutrient release, which can be attributed to greater faunal assimilation efficiency, and increased energy storage and gonad proliferation. Although demonstrating plasticity in feeding, we show that benthic activity is strongly associated with the timings and quality of primary production. Our observations strongly suggest that as climate forcing continues to have a transformative effect on the nature of pelagic primary productivity, rapid changes to regional ecosystem functioning will occur and are likely to have ramifications for species physiology and persistence.

Methane surges in Arctic coastal seas: risks to humanity and ecosystems, and methods of mitigation

Peter Wadhams, Dept. of Applied Maths and Theoretical Physics, Cambridge University UK
Peter Fiekowsky, Global Methane Removal Program, Los Altos, Ca., USA
Susan Lee, Global Methane Removal Program, Los Altos, C. USA
Chris Hope, Clare Hall, Cambridge University UK

Keywords: Methane, Outbreaks, Seabed, Removal, Zeolites

Ships have detected increasing quantities of methane emerging from seabed permafrost on the East Siberian Arctic Shelf (ESAS). A serious outbreak looks increasingly likely as warming accelerates. Though shorter-lived in the atmosphere than CO2, methane is 100 times as potent a greenhouse gas on first release. A large, sudden release could destabilize climate and create a global emergency. Methane reduction is not as well studied as CO2 reduction even though methane Is increasing faster than CO2. We examine risks of methane outbreaks through maps of recent emissions; analysis of ESAS data; computer modelling; and hothouse precedents in geological history. We then compare efficacy and cost-effectiveness of three pathways to restore and maintain safe methane levels: aerosol-based methane removal, solid-based removal, and reduction of methane emissions. Finally, we consider the funding and implementation of a program to reduce methane levels. We find that atmospheric removal—using aerosols that catalyse oxidation of methane into CO2 and water—has the best chance of keeping levels in a safe range. It also costs least. Solid-based methods, requiring airflow past solid materials such as zeolites, would cost 1,000 times more. To control methane emissions at their source by protecting the seabed could cost a million times more. Control of global methane is urgent. We are launching a new, non-profit Global Methane Removal Program to handle research and implementation.

Atmosphere momentum ‘window’ for Beaufort Gyre variability during the Arctic rapid changes

Shuhao Tao, Ocean University of China, Qingdao, China
Ling Du, Ocean University of China, Qingdao, China

Keywords: Beaufort Gyre, Master Circulation Mode, Key ‘Window’,Atmospheric Momentum Input,Long-Term Change

In this paper, the influence of atmospheric momentum input on the long-term changes of Beaufort Gyre are discussed by investigating the observed CTD and mooring data with the reanalysis datasets. The typical changes of Beaufort Gyre from 1980 to 2018 can be divided into three stable stages. Compared to the first stage (1980-1995), Beaufort Gyre expanded and moved northwestward, which the gyre evolves to dominate the upper circulation of the Chukchi Platform during the third stage (2008-2018). And the gyre strength has increased nearly twice, and reached to a new stable state during the third stage. Meanwhile, the first leading mode of upper ocean circulation had shifted significantly. In first stage, the leading Canadian basin mode is illustrated as the reduced circulation, located to the east of 160°W. While during the third stage, the leading circulation mode exhibits as a uniform mode in the Pacific Arctic sector. Atmospheric momentum input (AMI) has increased notably, especially for August-October. Increased AMI plays an increasingly important role in recent years and accounts for the equivalent portion compare to the sea ice momentum input. The increased AMI induces the mean kinetic energy rising, Ekman pumping mounting, the lower halocline deepening. Thus, an AMI "window" occurs in the southwestern slope of Canada basin, which the gyre is prone to energetic. Under the perspectives of Arctic rapid change, the AMI window responds to atmosphere wind anomalies.

Influence of SST in the tropical Atlantic on the inflow of Atlantic water and freshwater balance in the Arctic Ocean

Genrikh Alekseev, Arctic and Antarctic Research Institute, St.-Petersburg, Russia
Alexander Smirnov, Arctic and Antarctic Research Institute, St.-Petersburg, Russia
Andrey Pnyushkov, Arctic and Antarctic Research Institute, St.-Petersburg, Russia
& International Arctic Research Center, University of Alaska, Fairbanks, USA

Keywords: Arctic Ocean, Atlantic Water, Fresh Water, Tropical Atlantic, SST

An increase of the inflow and temperature of incoming Atlantic water (AW) affects the structure of water masses in the central Arctic Ocean and the influx of heat to the overlying layer and the lower surface of the sea ice above the main stream AW. Our research has pointed to a link between changes in the tropical North Atlantic and the Arctic Basin. In the early 1990s, a shift towards warming took place in the Arctic climate system, which was accompanied by changes in temperature and salinity of the water masses of the Arctic basin under the influence of increased inflow of Atlantic water, influx from river runoff, precipitation and ice melting. We show that the rise in sea surface temperatures in the tropical North Atlantic influenced these changes. Study supported by RFBR project 18-05-60107

Interannual variability of temperature in an Arctic fjord, Kongsfjorden and its possible connection with large scale atmospheric circulation

Subeesh M. P, National Centre for Polar and Ocean Research, Ministry of Earth sciences, Vasco Da Gama, Goa
Anju V. S, Cochin University of Science and Technology, Cochin, Kerala
Sourav Chatterjee, National Centre for Polar and Ocean Research, Ministry of Earth sciences, Vasco Da Gama, Goa
Divya David T, National Centre for Polar and Ocean Research, Ministry of Earth sciences, Vasco Da Gama, Goa
Finlo Cottier, Dunstaffnage Marine Laboratory, Scottish Association for Marine Science, Oban, UK
Nuncio M, National Centre for Polar and Ocean Research, Ministry of Earth sciences, Vasco Da Gama, Goa
Ravichandran M, National Centre for Polar and Ocean Research, Ministry of Earth sciences, Vasco Da Gama, Goa With regards Subeesh M P NCPOR

Keywords: Arctic fjords, Kongsfjorden, ROMS

Over the past decades, the Arctic Ocean is undergoing enormous warming due to increased heat transport from lower latitudes, reduced sea ice, and more complex air-sea-ice exchanges. Arctic fjords respond to these changes which resulted in increased glacial melt, water mass modification, variation in primary productivity etc. In this study, a long-term mooring observation (2002-2019) of temperature from an Arctic fjord Kongsfjorden is utilized to understand the variation of temperature in the fjord during the last two decades. An increasing trend in the temperature and heat content is noticed during the period with seasonal preference in the winter. Time series showed large inter-annual variations, indicating the influence of large scale variability in the ocean and atmosphere. We further utilized reanalysis data and inter-annual simulations from the high-resolution fjord model, Regional Ocean Modelling System (ROMS), to explore the possible mechanisms of the observed variability. The contribution of heat advection from the open ocean and air-sea exchanges to the fjord temperature is estimated from the model simulation. Our study points out the importance of large-scale atmospheric circulation in the fjord temperature variability in an inter-annual time scale.

The Arctic Subpolar gyre sTate Estimate (ASTE): a data-constrained, dynamically consistent ocean-sea ice estimate for 2002–2017

An T. Nguyen, University of Texas at Austin, Austin, TX, USA

Keywords: Ocean-Sea Ice Reanalysis, Model-Data Synthesis, Arctic Mediterranean, Freshwater Budget, Heat Budget

An assessment of the first release of the Arctic Subpolar gyre sTate Estimate (ASTE_R1), a medium-resolution data-constrained ocean-sea ice model-data synthesis spanning the period 2002–2017 is presented. The fit of the model to ~1 billion satellite and in situ observations was achieved through adjoint-based non-linear least-squares optimization. The improvement of the solution compared to an unconstrained simulation is reflected in misfit reductions of 77% for Argo, 50% for satellite sea surface height, 58% for the Fram Strait mooring, 65% for Ice Tethered Profilers, and 83% for sea ice extent. Exact dynamical and kinematic consistency is a key advantage of ASTE_R1, distinguishing the state estimate from existing ocean-sea ice reanalyses. Through strict adherence to conservation laws, all sources and sinks within ASTE_R1 can be accounted for, permitting meaningful analysis at decal timescale of closed budgets, such as contributions of horizontal and vertical convergence to the tendencies of heat and salt. ASTE_R1 thus serves as the biggest effort undertaken to date of producing a specialized Arctic ocean-ice estimate over the 21st century. Transports of volume, heat, and freshwater are consistent with published observation-based estimates across important Arctic Mediterranean gateways. Interannual variability and low frequency trends of freshwater and heat content are well represented in the Barents Sea, western Arctic halocline, and east subpolar North Atlantic.

Variability of Underwater Sound in the East Siberian Sea during 2017-2018

Dong-Gyun Han, Korea Polar Research Institution, Incheon, Republic of Korea
Jongmin Joo, National Air Emission Inventory and Research Center, Cheongju, Republic of Korea
Wuju Son, (Korea Polar Research Institution, Incheon / University of Science and Technology, Daejeon), Republic of Korea
Kyoung Ho Cho, Korea Polar Research Institution, Incheon, Republic of Korea
Jee Woong Choi, Hanyang University ERICA, Ansan, Republic of Korea
Eun Jin Yang, Korea Polar Research Institution, Incheon, Republic of Korea
Jeong-Hoon Kim, Korea Polar Research Institution, Incheon, Republic of Korea
Sung-Ho Kang, Korea Polar Research Institution, Incheon, Republic of Korea
Hyoung Sul La, Korea Polar Research Institution, Incheon, Republic of Korea

Keywords: Arctic Ocean, East Siberian Sea, Underwater sound, Airgun sound, Sea ice

This study describes the variability of underwater sound pressure levels in the marginal ice zone of the East Siberian Sea. Underwater sounds were measured using an autonomous passive acoustic recorder from August 2017 to August 2018 and the sound pressure levels of the acoustic data were compared to sea ice concentration, wind speed and ocean current. Our results reveal that the East Siberian Sea is quieter than other regions in the Arctic Ocean and the spectrum levels are strongly negative correlated with sea ice concentration. The sea-ice concentration at the mooring site was greatly varied during September and the spectrum levels were relatively high during the days when sea ice concentrations were low. The sound pressure level of September was 15 dB higher than that of the annual average as the seismic airgun sounds were also intensively measured in September. Different types of biological sounds were measured such as the vocalizations from walrus, bearded seal (Erignathus barbatus), beluga and similar sound like bowhead whales. In particular, the bearded seal vocalizations were recorded from March to July and their spectra were most prominent in May. The results imply that the underwater sound levels of the East Siberian Sea could increase with the accelerated sea-ice melting in the future and the increased ambient noise levels from the sound from anthropogenic noise could cause the negative effects on the Arctic marine ecosystem.

ID: 14 - Linkages and impacts of sea ice conditions and changes in the central Arctic

Conveners

Marcel Nicolaus | Alfred-Wegener-Insititut Helmholtz-Zentrum

Jessie Creamean | Colorado State University

Melinda Webster | University of Alaska Fairbanks, Geophysical Institute

Atmospheric processes in the Central Arctic during MOSAiC

Matthew Shupe, University of Colorado/NOAA, Boulder, CO, USA
Markus Rex, Alfred Wegener Institute, Potsdam, Germany
and the MOSAiC Atmosphere team

Keywords: Atmosphere, Observations, Modeling, MOSAiC

The atmosphere plays a central role in the Arctic climate system and its recent changes. Enhanced Arctic atmospheric warming over the past decades is linked with many key processes, including variability in large-scale circulation patterns, changes in fluxes of heat, sea-ice decline, impacts on the ecosystem, and many more. It is this collection of interdependent processes, and their recent changes, that has motivated the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC, 2019-2020) expedition. Based on the Polarstern icebreaker, an international and interdisciplinary team of scientists conducted an intensive, year-long scientific exploration of the Central Arctic climate system while drifting with the sea ice. This presentation highlights the atmospheric components of this scientific expedition. These include the most comprehensive set of field observations to ever be made of the Central Arctic atmosphere, spanning from the stratosphere to the surface. Specific research activities examine atmospheric structure, winds, clouds, precipitation, aerosols, and surface fluxes of heat, momentum, gases, and moisture. Complementing these observational aspects are numerous modeling activities, including observation-based model assessment, model development, and regional process studies, among others. Finally, key links between the atmosphere and the sea ice, snow, and ocean through a variety of physical, chemical, and biological processes are discussed.

Overview of the MOSAiC expedition – Snow and Sea Ice

Marcel Nicolaus, Alfred-Wegener-Institut, Bremerhaven, Germany
Donald K. Perovich, Dartmouth Collage, Hanover, USA
MOSAiC ICE Team

Keywords: Arctic, Climate System, Seasonality, Observations

Year-round observations of the properties and processes that govern the ice pack and its interaction with the atmosphere and the ocean were the key element of the MOSAiC field experiment. The aim was to completely characterize the properties of the snow and ice cover across different spatial scales over an entire annual cycle. This was done by monitoring snow and ice mass balance, observing the evolving partitioning of solar energy, studying dynamical features, and by documenting snow and ice dynamics over nested spatial scales. We conducted in-situ observations at multiple scales, which will be integrated in numerical models and remote sensing methods. Overall, we performed the most comprehensive snow and sea ice program to date. Here, we summarize the observational snow and sea ice program during the drift from October 2019 to September 2020. We will present improved concepts and diagnostics of the field program and demonstrate connections to satellite retrievals and numerical models. We will highlight individual events and characteristics of the snow and ice pack during the different seasons. The presentation will be based on time-series that were obtained from numerous sea-ice programs of the MOSAiC ICE team. We will discuss the various activities with respect to discuss the coupled system and the life cycle of sea ice along the transpolar drift.

A full year of extreme sea-ice and atmosphere conditions in the Eurasian Arctic: the OCEAN environment during MOSAiC

Benjamin Rabe, Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany
Céline Heuzé, University of Gothenburg, Sweden
Team MOSAiC OCEAN

Keywords: Arctic Ocean; Atmosphere-Ice-Ocean Feedback; Seasonal Cycle; Water Mass; MOSAiC

The Arctic ocean is an environment remote to most of us, yet linked to lower latitudes. Strongly coupled to the rapidly changing Arctic atmosphere and sea-ice, the ocean is subject to amplification and change amid global trends in climate. The relatively fresh and cold upper mixed-layer in the Arctic basin exhibits a strong seasonal cycle, yet the deeper warm water of Atlantic origin largely stays isolated from the ice. Further, changes in heat, salt and momentum due to exchange with ice and atmosphere cannot penetrate very deep due to a strong halocline. Nevertheless, we observed signals due to storms and brine release during freezing in the upper water column during the year-long MOSAiC experiment. This was further expressed by significant variability on the (sub)mesoscale, including eddies and frontal adjustment. We will present results from ocean observations during the MOSAiC drift using a variety of manually operated devices and autonomous platforms within several 10s of kilometres from the drifting icebreaker Polarstern. Preliminary analyses of our data show that there was a pronounced seasonal cycle in mixed-layer depth and upper ocean stratification connected to brine release, turbulent events triggered by storms and geographic background variability. We will further detail the observed full-depth water mass distribution and attempt to untangle temporal and spatial variability. Finally, we will give an overview of OCEAN analyses and interdisciplinary projects.

MOSAiC Ecosystem research – implementation and first field observations from the year-long ice drift in the Central Arctic

Allison A. Fong, Alfred-Wegener-Institut Helmholtz-Zentrum für Polar-und Meeresforschung, Bremerhaven, Germany
Rolf R. Gradinger, UiT Norges Arktiske Universitet, Tromsø, Norway
MOSAiC Ecosystem Team Consortium

Keywords: MOSAiC, Ecosystem, Sea Ice, Time-Series, Biogeochemistry

The MOSAiC project provided an unparalleled opportunity to observe and measure the temporal evolution of a suite of co-varying Arctic climate system variables from the Central Arctic atmosphere, ice, and ocean as well as explore currently unknown connections within the Arctic system. The MOSAiC Ecosystem team aimed to assess annual changes in the biodiversity estimates, elemental and faunistic standing stocks, and nutrient and carbon fluxes, complemented by process studies and high frequency measurements during intensive observation periods. In total the program sampled a diverse set of ~ 65 ecological and biological properties from snow, sea ice, and seawater, culminating in > 30,000 samples comprising year-long time-series data sets. The ecological program followed 1) the development of consolidated first year ice, 2) cycling of nutrients and organic matter in different ice regimes and in the upper ocean, 3) changes in the distributions and activities of microbes to macrofauna, and 4) explored the impact of short-term changes of environmental conditions on ecological process rates. In addition to the time series, dedicated experimental and field components targeted specific habitats or food web components. This presentation highlights the design and implementation of the MOSAiC Ecosystem work program, the motivations driving enhanced cross-cutting actions in the field, and unique observations over the year-long drift.

Biogeochemistry in the MOSAiC Coupled-System Drifting Observatory

Brice Loose, URI Graduate School of Oceanography, Narragansett, RI USA
Ellen Damm, Alfred Wegener Institut, Bremerhaven, Germany

Keywords: Biogeochemistry, Carbon Cycle, Ice-Water Exchange, MOSAiC

Sea ice is an integrating element in the Arctic Ocean System – its formation and destruction at the air-sea interface tends to capture important seasonal, geographic, and biological influences on the biogeochemical cycles of the Arctic. The 13-month drifting MOSAiC Observatory was a singularly unique opportunity to observe Arctic biogeochemistry from the reference point a drifting ice floe and measure the changes and exchanges as they took place. What emerges is a picture of critical biogeochemical variability, depending on where the ice was formed and important regime changes throughout the year as boundary layer dynamics and chemo-dynamics in the ocean and atmosphere exert their influence on the ice interface. We observe important cycles of greenhouse gases, including methane, nitrous oxide, and dimethyl sulfide, in addition to the halocarbon compounds each respond in their own way to these influences. We traced the aerosol, volatile and dissolved compound fluxes at the air-water and ice-water boundaries and these have revealed new insights into the scales and processes that merge to create the biogeochemical reservoir that we is found within the ice.

Annual Snow Cycle on Arctic Sea Ice

Amy Macfarlane, WSL Institute for Snow and Avalanche Research SLF, Switzerland, D-USYS, ETH Zürich, Switzerland
Stefan Hämmerle, Scanco Medical AG, Switzerland
Ruzica Dadic, Antarctic Research Center, Victoria University of Wellington, New Zealand & WSL Institute for Snow and Avalanche Research SLF, Switzerland
Stefanie Arndt, Alfred-Wegener-Institut, Helmholtz Center, Germany
David Wagner, WSL Institute for Snow and Avalanche Research SLF, Switzerland, Cryos, EPFL, Switzerland
Martin Schneebeli, WSL Institute for Snow and Avalanche Research SLF, Switzerland

Keywords: Snow, Sea Ice, Surface Scattering Layer, Micro-Computed Tomograph, MOSAiC

Snow on Arctic sea ice is a crucial component in the formation and decay of sea ice, and directly affects heat and momentum fluxes between the atmosphere and the ocean. We had the unique opportunity to measure the annual formation and decay of the snowpack during MOSAiC. Thanks to the drifting icebreaker R/V Polarstern, we could install a micro-computed tomograph (microCT) on board and measure the snow microstructure of samples that were transported in an undisturbed state from the snowpits. First measurements show variations in the stratigraphy of snow on first-year sea ice compared to snow on second-year sea ice. Strong winds and rapid air temperature changes, together with high temperature-gradients, were the critical factors influencing the winter snow cover formation and internal snow properties. During summer, we measured the transformation of the sea ice surface into a “snow-like'' porous ice, called “surface scattering layer” (SSL). This layer becomes an integral part of the snowpack formation starting in autumn. We hypothesize that a hard depth hoar layer found between the sea ice and the seasonal snow during winter, is the remnant SSL from the previous summer. We are currently testing our hypothesis using micro-computed tomography data and stable water isotope analysis from numerous snow samples. This example illustrates the challenges in identifying and understanding the processes that are driving the formation and metamorphism of the snowpack on Arctic sea ice.

Enhanced Late-season Arctic Sea-ice Growth Following Early-season Atmospheric Warming: A Key Role for Snow

Arash Bigdeli, University of Texas at Austin, Austin, US
An Nguyen, University of Texas at Austin, Austin, US
Helen Pillar,University of Texas at Austin, Austin, US
Patrick Heimbach,University of Texas at Austin, Austin, US

Keywords: Arctic Sea-Ice Sensitivity To Atmospheric Warming, Snow Melt As Preconditioner To Ocean Conductive Heat Loss Supporting Lagged Sea Ice Growth

We explore the relationship between Arctic sea ice growth and near surface air temperature in a modeling framework. By mapping the time and space evolving sensitivity of the Arctic ice volume to changes in air temperature, we show that warming at the end of the melting season can lead to thicker ice at the end of the following winter. Warmer air temperatures can melt snow and remove the insulation it provides, exposing the ice surface to subfreezing air temperatures. We show that removal of this insulating snow layer is essential for enhancing sea ice growth later on, by allowing more heat to be conducted up and out of the underlying ocean, supporting seawater freezing. Our results highlight the importance of measuring snow thickness for accurately fore-casting Arctic sea ice.

Thermal sea ice classification during the MOSAiC expedition

Linda Thielke, University of Bremen, Bremen, Germany
Marcus Huntemann, University of Bremen, Bremen, Germany
Gunnar Spreen, University of Bremen, Bremen, Germany
Stefan Hendricks, Alfred Wegener Institute Helmholtz-Center for Polar and Marine Research Bremerhaven, Bremerhaven, Germany
Arttu Jutila, Alfred Wegener Institute Helmholtz-Center for Polar and Marine Research Bremerhaven, Bremerhaven, Germany
Robert Ricker, Alfred Wegener Institute Helmholtz-Center for Polar and Marine Research Bremerhaven, Bremerhaven, Germany

Keywords: Sea Ice, Airborne, Surface Temperature, Ice type, Thermodynamic

Thermal infrared imaging was applied during 41 helicopter survey flights during the MOSAiC drift expedition from September 2019 to October 2020. We analyze the infrared brightness temperature of snow, sea ice, and ocean water surfaces in winter from airborne measurements. While the snow covered sea ice appears very cold, thin ice and open water are significantly warmer and dominate the heat exchange between the ocean, ice, and atmosphere. This becomes even more important in the currently changing Arctic, where the sea ice gets thinner, moves faster, and breaks up easier. After georeferencing and merging the recorded images to a mosaic, we can provide maps of infrared brightness temperatures in a high spatial resolution of 1 m. The spatial range varies from local (5 km) to regional (30 km). From this, we study the spatial and temporal variability of sea ice characteristics. We derive the physical surface temperature from the brightness temperature, surface emissivity, and downwelling radiation from sky or clouds. Using the surface temperature, we calculate the heat flux based on thermodynamic assumptions and atmospheric measurements on the MOSAiC ice floe. By comparing the same temperature to the surface temperature from a more complex thermodynamic model. The model calculates for the surface temperatures a specific ice thickness and heat flux based on the knowledge about the surface's thermodynamic history. The known ice thickness allows a sea ice classification.

Wind amplifies the polar sea ice retreat

Ramdane Alkama, European Commission - Joint Research Centre, Ispra, Italy
Ernest N Koffi, European Commission - Joint Research Centre, Ispra, Italy
Stephen J Vavrus, University Wisconsin-Madison, Madison, WI, USA
Thomas Diehl, European Commission - Joint Research Centre, Ispra, Italy
Jennifer Ann Francis, Woods Hole Research Center, Falmouth, MA, USA
Julienne Stroeve, University College London, London, United Kingdom
Giovanni Forzieri, European Commission - Joint Research Centre, Ispra, Italy
Timo Vihma, Finnish Meteorological Institute, Helsinki, Finland
Alessandro Cescatti, European Commission - Joint Research Centre, Ispra, Italy

Keywords: Polar Sea Ice, Wind Speed, Poleward Transfer Of Heat And Moisture

The rapid polar sea ice retreat and its drivers are challenging issues in climate change research. In particular, the relationship between near-surface wind speed and sea ice extent remains unclear for two main reasons: (1) observed wind speeds over Polar Regions are very sparse, and (2) simulated winds by climate models are associated with large uncertainties. Here, we use observation-based data (passive microwave sea ice concentration and six reanalysis datasets) together with output from 26 climate models to quantify the relationships between near-surface wind speed and sea ice concentration over the past 40 years. We find strong inverse relationships between near-surface wind speed and sea ice concentration that are consistent among the six reanalysis datasets. The poleward wind component is particularly increasing in years of reduced sea ice concentration, which contributes to the enhancement of the atmospheric and surface oceanic poleward heat fluxes, therefore boosting the impact of polar sea ice loss and contributing to polar amplification of climate warming. In addition, our results show a marginal contribution of the dynamical effects of wind on sea ice compared to the thermodynamic effects. Climate models generally produce similar results but with lower magnitude. Ultimately, our findings may lead to an improved model representation of the wind-sea ice feedback, affecting the speed of the polar sea ice retreat and the global climate system.

Tracking ice nucleating particles in the central Arctic during the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) experiment

Kevin R. Barry, Colorado State University, Fort Collins, Colorado, USA
Thomas C.J. Hill, Colorado State University, Fort Collins, Colorado, USA
Sonia M. Kreidenweis, Colorado State University, Fort Collins, Colorado, USA
Paul J. DeMott, Colorado State University, Fort Collins, Colorado, USA
Jessie M. Creamean, Colorado State University, Fort Collins, Colorado, USA

Keywords: Ice Nucleating Particles, Aerosol Cloud Interactions

The Arctic is of the utmost importance for studying due to release of greenhouse gases from thawing permafrost, melting glaciers contributing to sea level rise, and a darker overall surface (from melting snow and ice) contributing to a positive ice-albedo feedback. One avenue that may affect the magnitude of surface warming feedbacks in the Arctic comes from the prevalence of clouds. Cloud formation is inherently dependent on aerosols, however, observations of aerosols and specifically ice nucleating particles (INPs) are limited in this region. Their number exerts a large influence on cloud lifetime through production of ice, as well as modifying the level of supercooling that can persist in clouds and altering their fundamental radiative properties. The Multidisciplinary drifting Observatory for Study of Arctic Climate (MOSAiC) provided the first full year of INP measurements conducted in the central Arctic, as well as the first data in this region during the winter and spring. Here, we present preliminary INP results from total and size-resolved aerosol, seawater, sea ice core, and snow samples for the duration of the campaign. The goal of this work is to characterize INPs, both in their abundance and type, to see how they affect the Arctic during a complete annual cycle and thereby inform future modeling efforts.

The Arctic, Russia and Freedom of Navigation: the importance of the Law as a means of moral coercion

Viktoriya Nikitina, Instituto das Ciências Sociais e Políticas, Lisboa, Portugal

Keywords: Law of the Sea, Russia, Freedom of Navigation, Arctic, Militarization.

As we all know, global warming is a serious concern and it affects directly the Arctic due to ice melting, which in consequence, enables new opportunities never heard before, such as the exploitation of natural resources and the gradual opening of maritime routes. Therefore, as new opportunities emerge, the stage for potential tensions and conflicts between the Arctic States starts to appear. As the largest territory in the Arctic region, with its resources to explore and with its sea route, the Northern Sea Route (NSR), Russia is the Arctic State that most invests in its development. Through the lens of classical geopolitical approach, as ice melting keeps evolving, the more international traffic goes through NSR, and the stronger the argument for control. In this context, the Ministry of Transport of the Russian Federation (henceforth MTRF) has legislated towards the NSR “The Rules of Navigation in the water area of the Northern Sea Route”, imposing strict navigational rules directed to foreign vessels, and consequently, restricting freedom of navigation by default. This investigation will assume the geographic and geopolitical changes mentioned above, analyzing freedom of navigation in the NSR considering the United Nations Convention on the Law of the Sea (UNCLOS) and the Polar Code. Therefore, we will discuss certain gaps of the International Law of the Sea to be used by the MTRF to impose restrictions to freedom of navigation in the NSR, in order to protect its waters. Accordingly, we intend to equate International Law of the Sea as a means of moral coercion to understand how it is arranged and employed by the MTRF, taking into account the Russian militarization of the Arctic, establishing a relation between freedom of navigation and militarization, through inductive reasoning. Thus, our hypotheses are that gaps in the International Law of the Sea allow Russia to consider it as a means of moral coercion, and in turn, apply it to strategic efforts; freedom of navigation restrictions are aimed at ensuring maritime sovereignty and national security; and, Russian militarization, based on Sea Denial and Sea Control, enables the Law of the Sea as a means of moral coercion.

Improving bio-physical characterization of Arctic sea ice habitats using an Underwater Hyperspectral Imager

Benjamin A. Lange, Norwegian Polar Institute, Tromsø, Norway
Ilkka Matero, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
Evgenii Salganik, Norwegian University of Science and Technology, Trondheim, Norway
Karley Campbell, UiT The Arctic University of Norway, Tromsø, Norway
Janina Osanen, UiT The Arctic University of Norway, Tromsø, Norway
Christian Katlein, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
Felix Linhardt, Kiel University, Kiel, Germany
Philipp Assmy, Norwegian Polar Institute, Tromsø, Norway
Dmitry V. Divine, Norwegian Polar Institute, Tromsø, Norway
Jessie Gardner, UiT The Arctic University of Norway, Tromsø, Norway
Sebastian Gerland, Norwegian Polar Institute, Tromsø, Norway
Rolf Gradinger, UiT The Arctic University of Norway, Tromsø, Norway
Eva Leu, Akvaplan-niva AS, Tromsø, Norway
Oliver Müller, University of Bergen, Bergen, Norway
Marcel Nicolaus, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
Tristan Petit, Norwegian Polar Institute, Tromsø, Norway
Julia Regnery, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
Lasse M. Olsen, University of Bergen, Bergen, Norway
Mats Granskog, Norwegian Polar Institute, Tromsø, Norway

Keywords: Sea Ice Algae, First-Year Sea Ice, Sea Ice Ridges, Sea Ice Habitats, Innovative Technology

Thinning Arctic sea ice and the replacement of older multi-year ice by first-year ice has contributed to a more dynamic ice cover with a higher probability of forming sea ice ridges, which have been identified as potential ice-algal hotspots. Assessing spatio-temporal dynamics of bio-physical sea ice habitat properties remains challenging due to logistical difficulties of sampling the under-ice habitat. Improved technologies can overcome limitations intrinsic to existing sea ice sampling techniques and fill some of the spatio-temporal gaps in our understanding of sea ice processes. During leg 4 (June-Aug) of the year-long drift study MOSAiC, Arctic Ocean, we deployed an underwater hyperspectral imager (UHI) mounted on a remotely operated vehicle to characterize the biophysical properties of different under-ice habitats. During July, we conducted five gridded UHI surveys of the sea ice bottom covering both level first-year ice and an adjacent ridge. These field observations were complemented by laboratory experiments where microcosms containing different algal cultures were imaged with the UHI system at different time intervals for calibration/validation of algorithms to characterize bio-physical sea ice properties. We present these different algorithms applied to both field- and laboratory-based UHI surveys, and compare the level- and ridged-ice bio-physical sea ice habitat properties, with a focus on spatio-temporal distribution of ice algae.

Record low Russian Arctic seas ice extent in 2020

Denis Frolov, Geographical faculty of Lomonosov Moscow State University, Moscow, Russia

Keywords: Sea Ice Extent, Russian Arctic, Climate Warming, Record Low 2020

There goes climate warming on the Earth. It has become more than one degree warmer in the whole world and more than two degrees warmer in Arctic in recent decades. The year 2020 is considered as almost the warmest. As a reason of anomalous warm winter 2019/2020 in Russia is considered non-typical situation in Arctic, where the extremely stable area of low pressure in the vicinity of North Pole was present and which does not let the cold air masses to move away from its borders. Such situations lead to the consequences that on the most of the territory of Russia the temperature of winter months and as well as of the other months of the year were on few degrees more than usual. This lead to the fact that sea ice area in the Laptev Sea was also at an all-observation-time low for the end of June 2020, as it was in the entire Arctic sector of Russia. The area of sea ice extent in the Arctic Ocean for the end of June 2020 was 260,000 km2 less than in the 2010s, 930,000 km2 less than in the 2000s, 1,540,000 km2 less than in the 1990s, and 2,150,000 km2 less than in the 1980s. The situation developed further and in September 2020 there was Arctic sea ice minimum just as low as second after record low of 2012. Due to extremely warm September, October and November in North Siberia there was almost not sea ice in Russian Arctic seas (Kara, Laptev and East Siberian seas) in October and November 2020 and so far as well, which is remarkable.

Seasonal variation in organic matter sources related to Arctic sea ice extent

Jong-Ku Gal, Korea Polar Research Institute, Incheon, Korea
Dongseon Kim, Korea Institute of Ocean Science & Technology, Busan, Korea
Sun-Yong Ha, Korea Polar Research Institute, Incheon, Korea
So-Young Kim, Korea Polar Research Institute, Incheon, Korea
Boyeon Lee, Korea Polar Research Institute, Incheon, Korea
Kyung-Hoon Shin, Hanyang University, Ansan, Korea
Sung-Ho Kang, Korea Polar Research Institute, Incheon, Korea
Eun Jin Yang, Korea Polar Research Institute, Incheon, Korea

Keywords: Planktonic Biomarkers, Sinking Particle, Highly Branched Isoprenoids, IP25, Brassicasterol, Dinosterol

Sea ice conditions play an important role in controlling ocean circulation and distribution patterns of organic matter in the Arctic Ocean. Therefore, studies of the distribution and origin of organic matter in the Arctic Ocean can improve our insight on the impact of sea ice changes on the marine environment. Lipid biomarkers are a useful tool for identifying the origin of organic matter in the marine environment. Recently, IP25, a C25 highly branched isoprenoid (HBI) monoene, has been proposed as an indicator of sea ice diatoms in the Arctic. In particular, sea-ice related HBIs and pelagic phytoplankton-derived lipid biomarkers, such as trienes, brassicasterol, and dinosterol, have been successfully used to identify the origin of organic matters in the Arctic environments. In this study, we investigated lipid biomarkers using a one-year recoreds of sinking particles from August in 2017 to August in 2018 at the East Siberian Sea (KAMS1-17) and the Chukchi Sea (KAMS2-17). HBIs (IP25, dienes, and trienes), and sterols (cholesterol, brassicasterol, campesterol, coprostanol, stigmasterol, ß-sitosterol, and dinosterol) were analyzed using gas chromatography-mass spectrometry. Similar patterns of total mass flux (TMF) were observed in the Chukchi Sea in thesummer of both 2017 and 2018. Seasonal variations in the HBIs also tended to follow this pattern. However, phytoplankton derived-sterol and terrestrial sterols showed remarkably high fluxes in 2017. On the other hand, TMF of sinking particles in the East Siberian Sea showed a clear trend of increasing in summer 2018 compared with 2017. Moreover, the fluxes of HBIs and pelagic plankton-derived sterols in 2018 were higher than in 2017. Seasonal variation in the origin of organic matter in the Arctic Ocean maybe related to changing sea ice extent. We expect to provide evidence for this relationship by identifying the biological source of organic matter and their connection to seasonal biomarker changes.

ID: 09 - Ocean Biogeochemistry in the Rapidly Changing Arctic: Research and Impacts

Conveners

Darren Pilcher | University of Washington, Joint Institute for the Study of Atmosphere and Ocean

Agneta Fransson | Norwegian Polar Institute, Fram Centre

Takuhei Shiozaki | Atmosphere and Ocean Research Institute, The University of Tokyo

The next decade of Ocean Acidification Research in the Bering Sea: What we learned, where 2020 fits, and what's coming next

Jessica N. Cross, NOAA Pacific Marine Environmental Laboratory, Seattle, WA USA
Darren Pilcher, University of Washington Cooperative Institute for Climate, Oceans, and Ecosystem Studies, Seattle, WA USA
Natalie Monacci, University of Alaska, Fairbanks Ocean Acidification Research Center, Fairbanks, AK, USA
Elizabeth Siddon, National Marine Fisheries Service, Alaska Fisheries Science Center, Juneau, AK, USA
W. Christopher Long, National Marine Fisheries Service, Alaska Fisheries Science Center Kodiak Laboratory, Kodiak, AK, USA
Thomas Hurst, National Marine Fisheries Service, Alaska Fisheries Science Center, Newport, OR, USA

Keywords: Ocean Acidification, Carbonate, Climate, Fisheries

Over the last decade, ocean acidification (OA) has emerged as one of the most prominent issues in Arctic marine research, and a possible threat to culturally and commercially important marine resources in the region. Given the pace of the observed changes due to OA, the Arctic is commonly referred to as a bellwether and the proverbial "canary in the coal mine" for the rest of the global ocean. Here, we will take a look back at the last ten years of OA research in the Bering Sea, and highlight new, cutting-edge biogeochemical modeling, forecasting, and projection efforts that have dramatically increased our capacity to understand Arctic OA from a large-scale perspective just in the past year. For example, we have scaled point observations to the entire Bering Sea shelf to show that corrosive conditions have covered almost 60% of critical habitat areas in the last ten years, and forecasts indicate that 2020 was even more strongly corrosive compared to the 2003-2019 average. These new insights have been quickly picked up by our colleagues engaged in ongoing laboratory studies of species-specific OA vulnerability and larger-scale ecosystem and bioeconomic analyses of OA impact. Our goal is to continue refining our capacity to identify new risks and emerging resilience of Alaskan ecosystems, and guide sound, evidence-based decisions that support sustainable marine resources in the future.

Seasonal responses of arctic marine organisms to ocean acidification

Allison Bailey, Norwegian Polar Institute, Tromsø, Troms, Norway
Ane Cecilie Kvernvik, Norwegian Polar Institute, Tromsø, Troms, Norway
Philipp Assmy, Norwegian Polar Institute, Tromsø, Troms, Norway
Anette Wold, Norwegian Polar Institute, Tromsø, Troms, Norway
Amalia Keck Al-Habahbeh, Norwegian Polar Institute, Tromsø, Troms, Norway
Haakon Hop, Norwegian Polar Institute, Tromsø, Troms, Norway
Clara J. M. Hoppe, Alfred Wegener Institute, Bremerhaven, Bremen, Germany

Keywords: Ocean Acidification, Seasonality, Phytoplankton, Copepods

The Arctic and its ecosystems are currently experiencing some of the strongest effects of climate change and ocean acidification, and it is of crucial importance to predict how Arctic organisms will respond to these changes. While logistical challenges in the high North often restrict studies to a single point in time, there are strong seasonal cycles in biotic and abiotic variables that have been shown to affect the sensitivity of organisms to climatic drivers. To determine how seasonal changes influence the effects of ocean acidification on energy transfer at the base of the marine food web, we conducted a series of nine ocean acidification experiments in Ny-Ålesund, Svalbard, covering the entire growing season from late April to early September 2019. In each experiment, the natural assemblage of phytoplankton and Calanus copepods were collected from Kongsfjorden and exposed in combination to elevated carbon dioxide partial pressure (pCO2), simulating ocean acidification, in the lab for four days. The response of phytoplankton growth rates and copepod grazing rates to simulated ocean acidification varied throughout the study period. During pre- and post-bloom periods, simulated ocean acidification did not affect copepod grazing. However, during the pelagic spring bloom, copepods increased their grazing in response to elevated pCO2 due to a positive effect of elevated pCO2 on Phaeocystis pouchetii growth rates. When other phytoplankton species dominated the assemblage, elevated pCO2 elicited no or minor growth responses in the phytoplankton and no effect on copepod grazing was observed. These data highlight the need for seasonal studies on the effects of climatic drivers in the Arctic: there is a potential to make erroneous conclusions about the effect of a driver if only one time point is studied. By examining the concurrently collected biological and chemical data from the fjord, we will be able to learn about what drivers make the marine ecosystem in Kongsfjorden more, or less, sensitive to ocean acidification throughout the seasons.

Modern estimation of the carbon dioxide flux in the Kara Sea

Alexander Polukhin, Shirshov Institute of Oceanology RAS, Moscow, Russia
Georgy Gusak, St Petersburg University, St Petersburg, Russia
Julia Pronina, Shirshov Institute of Oceanology RAS, Moscow, Russia
Anna Chultsova, Shirshov Institute of Oceanology RAS, Moscow, Russia
Valeria Muravya, Shirshov Institute of Oceanology RAS, Moscow, Russia
Andrey Skorokhod, Obukhov Institute of Atmospheric Physics RAS, Moscow, Russia
Igor Belikov, Obukhov Institute of Atmospheric Physics RAS, Moscow, Russia

Keywords: Kara Sea, Carbon Dioxide, Flow Rates, Biogeochemistry

Determining fluxes of gases between the ocean and atmosphere is critical for biogeochemical cycles, most notably the carbon cycle. Especially the knowledge of the CO2 fluxes rate is crucial in the Arctic region, difficult to access and notably prone to climate change. The approach used to determine regional fluxes of CO2 is perfectly described by Rik Wanninkhof. We used pCO2 values in the surface layer of the Kara Sea and near-water layer of the atmosphere to calculate CO2 flux rate and direction. The data was obtained during 81 cruise of Russian RV “Akademik Mstislav Keldysh” in September 2020. The study area was located near the Novaya Zemlya and the southern part of the central trough of St. Anna Trough. Here we have found transformed riverine water with the salinity value 24.65 psu. Moreover, above the slope of the trough, a frontal zone is localized, which is formed as a result of the along slope current and is characterized by a decrease in isolines of the content of hydrochemical parameters, including pCO2. The rate of CO2 flux is estimated from +0.34 mmol/m2*day in the freshened surface layer to -22.04 mmol/m2*day in the ambient water of the Kara Sea.
The work supported by the State agreement of Shirshov Institute of Oceanology RAS (theme 0149-2019-0008) and the grant of President MK 860.2020.5.

Nutrients in the European Arctic: trends and limits to primary production

Pedro Duarte, Norwegian Polar Institute

Keywords: Nutrients, Atlantic Water, Polar Surface Water, Primary Production

There is strong evidence about an increase in primary production (PP) in the Arctic Ocean (AO) over the last decades. By how much PP will further increase is still an open question. Answering this question requires an in-depth understanding of the interplays between the release of phytoplankton and ice algae from light limitation, as sea ice extent and thickness decreases, and the availability of nutrients, which is controlled by (but not limited to), nutrient inputs from the Atlantic and the Pacific Oceans. While these inputs are the major nutrient sources to the AO, vertical mixing or isopycnic lifting is required to bring the nutrients to the photic zone. We analyze data collected in the Western Eurasian Basin – an area under the direct influence of the Atlantic Water (AW) - between 1980 and 2016. We conclude that there were no significant changes in the AW masses regarding the concentrations of the main limiting nutrients for the spring-summer bloom. AW is the main nutrient source to the Polar Surface Water (PSW) where most of PP takes place. We observed some decreasing nutrient trends in PSW that are consistent with the reported increase in PP. We show that nutrient replenishment of PSW from AW is not complete in winter, with a nitracline persisting frequently, and that this may be a limiting process for the subsequent bloom. Predicting how this replenishment will evolve in a more ice free and stormy AO is crucial to address PP changes in the future Arctic.

Sources and sinks of methylmercury in the water column of the East Siberian Sea

Seunghee Han, Gwangju Institute of Science and Technology, Gwangju, Korea
Jihee Kim, Gwangju Institute of Science and Technology, Gwangju, Korea
Tae Siek Rhee, Korea Polar Research Institute, Incheon, Korea
Young Keun Jin, Korea Polar Research Institute, Incheon, Korea

Keywords: Methylmercury, East Siberian Sea, Shelf, Sediment, Mass Budget

Biological concentrations of methylmercury(MeHg) are elevated throughout the Arctic Ocean. However, to date, the major sources and sinks, and the spatial variability of MeHg are not well quantified. In this study, we measured MeHg concentrations in the seawater and sediment of the East Siberian Sea obtained onboard R/V Araon from August to September in 2018. We found that the MeHg concentrations in seawater (0.070 ± 0.032 pM, 0-60 m) and pore water (6.1±3.0 pM, 0-2 cm) were higher on the slope than the shelf, while those in sediment (0.012-0.45 pmol g-1) were higher on the shelf than the slope. To identify the major inputs and outputs of MeHg to the East Siberian Sea water column, a mass budget for MeHg were examined using the survey data. It was found that the benthic diffusion and resuspension largely exceeded other sources, such as atmospheric deposition and river water input, which explains why spatial trends of MeHg concentrations were similar between seawater and pore water. The major sinks of MeHg in the water column were dark demethylation and evasion. When we extrapolated our findings on benthic diffusion to the entire Arctic shelf system, the annual MeHg diffusion from the shelf sediments was estimated to be 23,070 ± 940 mol yr–1, appoximately twice higher than previously proposed river discharge, suggesting that MeHg input from shelf sediments in the Arctic Ocean is significant, and has been previously underestimated.

Temporal variability of heavy metal concentrations in sediments of two Arctic fjords

Paulina Rudnicka, Institute of Oceanology of Polish Academy od Science, Sopot, Poland
Agata Zaborska, Institute of Oceanology of Polish Academy od Science, Sopot, Poland

Keywords: Environmental Pollution, Marine Sediments, Arctic, Heavy Metals, Climate Change

The global-warming related melting of the Arctic glaciers can increase the supply of pollutants accumulated on their surfaces for last decades. The increase in pollutant loads eg. heavy metals, can have a negative effect on ecosystem (bioaccumulation). Sediment cores were collected from Hornsund and Kongsfjorden fjords (Svalbard) to retrieve the history of marine sediments pollution by heavy metals. The sampling stations were located close to the glacier fronts and in the central part of the fjords. The sediment layers were dated using the 210Pb method. Heavy metal concentrations and 206Pb/207Pb ratios were by ICP-MS and AAS. The concentrations of individual heavy metals were of: Pb 6.8-30.4 mgkg-1, Cd 0.14-0.53 mgkg-1, Zn 53.8-94.9 mgkg-1 and Cu 16.1-67.4 mgkg-1. Fjord sediments were slightly enriched in heavy metals. The enrichment factors (after normalization to Fe/Al concentration) ranged from 0.8 to 2.4 for Pb, from 0.9 to 4.7 for Cd, from 0.8 to 1.4 for Zn and from 0.7 to 2.4 for Cu. The 206Pb/207Pb isotopic ratios ranged from 1.16 to 1.21 (natural regional 206Pb/207Pb > 1.22), suggesting diverse but significant input of anthropogenic origin Pb. Although anthropogenic share of metal concentrations measured at the glacier fronts were not particularly elevated, heavy metal loads delivered from the glaciers were significant due to very high sediment accumulation rates. This can suggest that glaciers can be important secondary sources of pollutants to the Arctic fjords. The research was financed by the National Science Center grant 2015/17/B/ST10/03390. We thank Jolanta Walkusz-Miotk, M.Sc. for heavy metal concentration measurements.

Dissolved organic matter seasonality across the land-sea transition zone in the Mackenzie River - Beaufort Sea region

Bennet Juhls, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Atsushi Matsuoka, Takuvik Joint International Laboratory, Université Laval (QC, Canada) and CNRS (France)
Martine Lizotte, Takuvik Joint International Laboratory, Université Laval (QC, Canada) and CNRS (France)
Guislain Bécu, Takuvik Joint International Laboratory, Université Laval (QC, Canada) and CNRS (France)
Pier Paul Overduin, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Jan El Kassar, Department of Earth Sciences, Institute for Space Sciences, Freie Universität Berlin, Berlin, Germany
Marcel Babin, Takuvik Joint International Laboratory, Université Laval (QC, Canada) and CNRS (France)

Keywords: Dissolved Organic Matter, Ocean Colour Remote Sensing, Fluvial-Marine Transition Zone

The fluvial-marine transition zone across the Mackenzie River and the Beaufort Sea is strongly affected by high concentrations of dissolved and suspended matter exported from land. Rapid changes in the Arctic, such as increasing air temperatures and associated permafrost thaw in Arctic river catchments, are expected to change the quantity and quality of terrestrial dissolved organic carbon (DOC) fluxes as well as impact the global carbon cycle. Currently, the seasonal variability of DOC export and its distribution and fate in Arctic shelf waters is poorly understood. With improved performance, Ocean Colour Remote Sensing (OCRS) may be used to measure the distribution and transport pathways of DOC in surface waters at synoptic scales. In order to better understand the seasonal variability of the Mackenzie River plume and the distribution of DOC on the Beaufort Sea Shelf, and in order to refine remote sensing DOC algorithms, extensive in situ sampling was carried out in the fluvial-marine transition zone during four expeditions in 2019. Existing OCRS atmospheric corrections (AC) and coloured dissolved organic matter (CDOM) retrieval algorithms were evaluated for the Ocean and Land Colour Instrument (OLCI). The best performing OCRS algorithms were used to calculate DOC concentrations from satellite data by applying a new merged relationship between CDOM and DOC. The results illustrate strong variability in the extent of the river plume and its DOC concentrations throughout the open water season. Satellite-derived maps of DOC concentration placed the in situ observations into a larger context and revealed distribution, transport pathways, and additional sources of DOC in the Mackenzie-Beaufort Sea region.

Studying changing carbonate chemistry in the Arctic Ocean using satellite Earth observation

Hannah Green, University of Exeter Penryn, Cornwall, United Kingdom and Plymouth Marine Laboratory Plymouth, Devon, United Kingdom
Helen Findlay, Plymouth Marine Laboratory Plymouth, Devon, United Kingdom
Jamie Shutler, University of Exeter Penryn, Cornwall, United Kingdom
Peter Land, Plymouth Marine Laboratory Plymouth, Devon, United Kingdom
Richard Bellerby, Norwegian Institute of Water Research, Bergen, Norway and East China Normal University, Shanghai, China

Keywords: Ocean Acidification, Satellite Earth Observation

Recognised as being at the forefront of global change, the Arctic Ocean is the first place to have severe acidification that might impact ecosystems. Understanding this impact will allow us to help mitigate and adapt Arctic marine management, but also provide us with information to apply to other locations that will face similar problems in the future. The nature of the Arctic Ocean means collecting in situ data at high-resolution spatial and temporal scales is impractical. Here we discuss a novel method of synoptic scale monitoring of ocean acidification in the Arctic Ocean using satellite Earth observation and the potential applications of the data provided by this method. Ocean acidification can be monitored by measuring the carbonate chemistry parameters, total alkalinity (TA), dissolved inorganic carbon (DIC), pH and pCO2. TA and DIC can be calculated using empirical relationships with measurable oceanographic variables for example salinity and temperature. Satellite Earth observation now routinely monitor these variables, so empirical algorithms for carbonate chemistry parameters can now be applied to the satellite data. Here we have first evaluated published relationships for their use with satellite data in the Arctic Ocean, with future work improving these relationships for TA and DIC. We can then calculate the full carbonate system to characterise contemporary variability of aragonite saturation state and pH. Finally, we will then use the TA and DIC products to calculate the full carbonate system to characterise contemporary variability of aragonite saturation state and pH. The data provided from this method will enable us to identify vulnerable regions that are experiencing greatest rates of change in carbonate chemistry, as well as inform experimental studies, modelling and marine management strategies.

Variability and drivers of pelagic carbonate fluxes in the Arctic Ocean: the contribution of planktonic foraminifera

Franziska Tell, MARUM – Center for Marine Environmental Sciences, University of Bremen, Bremen, Germany
Michal Kucera, MARUM – Center for Marine Environmental Sciences, University of Bremen, Bremen, Germany
Lukas Jonkers, MARUM – Center for Marine Environmental Sciences, University of Bremen, Bremen, Germany
Julie Meilland, MARUM – Center for Marine Environmental Sciences, University of Bremen, Bremen, Germany

Keywords: Carbon Cycle, Calcite, Biomineralisation, Plankton, Foraminifera

A significant component of the marine carbon cycle is the flux of planktonic foraminifera shells to the seafloor. To predict how this calcite flux in the Arctic Ocean will behave in response to global change, we need to better constrain the calcification depth and the environmental parameters affecting the flux. Using plankton net vertical profiles of abundances of living and dead specimens, as well as shell sizes, weights and measurements of stable isotopes, we show that calcification is occurring across the entire range of the species habitat (upper 200 m). We then use this observation to convert concentrations of shells in the water column below the productive zone to flux, obtaining an estimate of spatial variability and species composition in the fluxes during summer. In the western Fram Strait, the dominant species N. pachyderma contributes to 66% and another 17% are made up by T. quinqueloba. First estimates from samples from the eastern Fram Strait indicate average fluxes of about 2.8 mg m-2 d-1, representing about 15% of total CaCO3 fluxes measured in that area (Bauerfeind et al., 2015). Last, to characterize the seasonal pattern of flux, abundance data from existing sediment trap time-series are combined with new flux measurements, collectively providing constraints on spatial and temporal variability of planktonic foraminifera calcite flux in the region in a way that would allow prediction of the impacts of future warming on this element of the Arctic carbon cycle.

Glacial meltwater and carbonate minerals impact the sea-ice and seawater carbonate chemistry, CO2 fluxes, ocean acidification and drivers in Svalbard fjords

Agneta Fransson, Norwegian Polar Institute, Fram Centre, Tromsø, Norway & University Centre in Svalbard (UNIS), Longyearbyen, Norway
Melissa Chierici, Institute of Marine Research, Fram Centre, Tromsø, Norway & University Centre in Svalbard (UNIS), Longyearbyen, Norway
Daiki Nomura, Faculty of Fisheries Sciences, Hokkaido University, Hakodate, Japan
Mats A. Granskog, Norwegian Polar Institute, Fram Centre, Tromsø, Norway
Svein Kristiansen, Department of Arctic and Marine Biology, UiT The Arctic University of Norway, Tromsø, Norway
Tõnu Martma, Institute of Geology, Tallinn University of Technology, Estonia
Gernot Nehrke, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany

Keywords: Glacial Water, Ocean Acidification, Ocean CO2 Sink, Biogeochemical Processes, Carbonate Minerals

Svalbard fjords with tidewater glaciers are affected by glacial meltwater and on-going glacier retreat. Due to climate change and warming, these tidewater glaciers are expected to further retreat and contribute to increased meltwater and may also change to land-terminating glaciers. These changes will impact the sea ice and seawater carbonate chemistry and biogeochemical processes in the fjords. In this study, we investigate the effect of different freshwater sources on wintertime sea-ice and seawater carbonate ions, CO2 fluxes, ocean acidification and drivers in the Svalbard fjord, Tempelfjorden, from the glacier front to the outer fjord. We focus on two contrasting years, warm and cold years, where March/April in 2012 was mild, and the fjord was mainly covered with drift ice, in contrast to the observed thicker fast ice in the colder April 2013. This resulted in different physical and chemical properties of the sea ice and under-ice water. We also compare and discuss these results to other Svalbard fjords with tidewater glaciers such as Kongsfjorden. Results showed that the sea ice at the glacier front in 2012 contained on average 54% of frozen-in glacial meltwater, which was five times higher than in 2013. In 2012, the largest excess of sea-ice total alkalinity, carbonate concentrations relative to salinity was mainly related to dissolved dolomite and calcite from bedrock while in 2013, the excess was mainly due to ikaite dissolution from sea-ice processes.

Changes in CO_2 sink of the western Arctic Ocean over 1994 to 2019

Zhangxian Ouyang, University of Delaware, Newark, DE, USA
Wenli Zhong, Ocean University of China, Qingdao, China
Di Qi,Third Institute of Oceanography, Xiamen, China
Wei-Jun Cai, University of Delaware, Newark, DE, USA

Keywords: CO2 Flux, Carbon Sink, Arctic Ocean, Sea Ice

In the past a few decades, rapid sea ice loss has turned the Arctic Ocean from perennial ice-covered ocean to a seasonal opened ocean. Such a status shift in air-ice-sea interface has resulted in substantial changes in Arctic carbon cycle and related biogeochemical processes. Our recent study of long-term pCO2 trends in the western Arctic Ocean have suggested that summer carbon flux dynamics greatly differ regionally – the inflow Chukchi Sea continues to absorb CO2 in pace with atmospheric CO2 increase, whereas the oligotrophic Canada Basin become a weakened or diminishing carbon sink. To confirm our proposed implications and better evaluate how the ocean carbon sink responds to rapid sea ice changes, we examined the changes in CO2 flux and carbon sink in the western Arctic Ocean over 1994 to 2019 by two approaches: (1) observation-based estimation and (2) box model-based evaluation. Our results showed that carbon sink in the Chukchi Sea significantly increased at a rate of 1.6 Tg C decade-1, which was likely due to an increase of primary production on the shelf. However, there was no significant change in carbon sink of the Canada Basin and Beaufort Sea although sea ice extent has significantly decreased in those areas. We attribute this unchanged carbon sink in the central Arctic Ocean to a rapid decreased sea-air pCO2 gradient.

Budgeting air-sea CO2 fluxes during the ice melt season in an Inland Arctic Shelf Sea

Mohamed Ahmed, University of Calgary, Calgary, Canada
Brent Else, University of Calgary, Calgary, Canada
Brian Butterworth, University of Wisconsin-Madison, Madison, USA
David Capelle, University of Manitoba, Winnipeg, Canada
Céline Guéguen, Université de Sherbrooke, Sherbrooke, Canada
Lisa Miller, , Fisheries and Oceans Canada, Sidney, Canada
Tim Papakyriakou, University of Manitoba, Winnipeg, Canada

Keywords: Air-Sea CO2 Flux, Hudson Bay, Underway pCO2, Sea-Ice Melt, Arctic Shelf Sea

Hudson Bay is a large shallow inland sea located in central Canada and receives nearly one-third of Canada's river discharge and transitions from complete ice cover in winter to open water in summer. However, Hudson Bay has not been included in many global and Arctic-specific carbon budgets, which is a significant gap considering that the total area of this region (including Hudson strait) is about 16% of the total Arctic shelf area. Here, we present the first spring and early-summer underway measurements of pCO2 and estimates of air-sea CO2 fluxes in Hudson Bay and Hudson Strait. We calculated an average net CO2 flux of about -5 mmol CO2 m?² day?¹ during the spring and early summer seasons and about -7.2 Tg C during the open water season. This result indicating that the bay on average is a weaker CO2 sink than most other Arctic seas. Currently, we are using a combination of remote sensing and neural network algorithms to extrapolate the ship observation and generate a comprehensive estimate of air-sea CO2 fluxes for this important shelf sea.

Distribution of hydrocarbons in the Barents Sea a

Ekaterina Koltovskaya, P.P. Shirshov Institute of Oceanology Russian Academy of Science, Moscow, Russian Federation

Inna Nemirovskaya, P.P. Shirshov Institute of Oceanology Russian Academy of Science, Moscow, Russian Federation
Anastasia Khramtsova, P.P. Shirshov Institute of Oceanology Russian Academy of Science, Moscow, Russian Federation

Keywords: Barents Sea, Hydrocarbons, Suspended Matter, Oil Potentional Of Arctic Sea

The study of hydrocarbons (HC) in the composition of organic matter and its components: suspended organic carbon and lipids, is due to the high oil and gas potential of the Arctic shelf and, in particular, the Barents Sea. The data obtained during the 75th voyage of the RV "Akademik Mstislav Keldysh" are presented. In 2019, higher HC concentrations (6–62 µg / l) were found in the suspension of surface waters of the Barents Sea, compared to studies carried out earlier. However, as before, the increased HC concentrations gravitated towards the southern part of the Barents Sea, which may be due to the supply of oil HCs in the navigable regions. At present, in the open areas of the Barents Sea, the content and composition of hydrocarbons form natural processes. In the bottom horizon, the HC content at almost all stations was lower than at the surface. The composition of HCs in suspended matter is determined not only by their natural input in autochthonous processes (formation as a result of phytoplankton activity and ice melting), but also by oil pollution in navigable areas. In the surface layer of bottom sediments, the average HC concentrations increased in the sequence (µg / g): Norwegian Sea (19) <South of the Barents Sea <(23) <Spitsbergen (26). The composition of hydrocarbons in bottom sediments was investigated. Their composition changed depending on facies conditions and transformations to which they undergo in the sediment layer.

Hydrological and hydrochemical structure in the St. Anna Trough (Kara Sea)

Anna Kostyleva, Shirshov Institute of Oceanology RAS, Moscow, Russia
Aleksandr Shchuka, Shirshov Institute of Oceanology RAS, Moscow, Russia
Alexander Polukhin, Shirshov Institute of Oceanology RAS, Moscow, Russia
Ivan Zamiatin, Shirshov Institute of Oceanology RAS, Moscow, Russia
Anna Chultsova, Shirshov Institute of Oceanology RAS, Arkhangelsk, Russia
Anna Seliverstova, Shirshov Institute of Oceanology RAS, Moscow, Russia
Georgii Gusak, St.Petersburg State University Institute of Earth Sciences, St.Petersburg, Russia
Uliana Kazakova, Lomonosov Moscow State University, Moscow, Russia

Keywords: Kara Sea, Frontal Zone, Dissolved Oxygen, Fluorescence Of Chlorophyll-a

The work was based on the data obtained in September 2020 during the 81st cruise of the R/V Akademik Mstislav Keldysh. The purpose of this work is to consider the features of the hydrological and hydrochemical structure in the St. Anna Trough. The studies were carried out in the northeastern Kara Sea on a section with a length of 156.6 km. The distribution of temperature, salinity, dissolved oxygen, pH, alkalinity, main nutrients and fluorescence of chlorophyll-a was analyzed. It was shown that in the slope of the section there is a high-gradient frontal zone about 7.6 km long.The southern part of the frontal zone is constrained by an almost vertical wall of colder waters (up to 3.05 °C at a depth of 17 m), which are of Kara Sea origin. This part of the frontal zone is characterized by a subsurface oxygen maximum and a subsurface maximum of chlorophyll-a fluorescence (1.6 mg/m3 at a depth of 3.8 m). The northern part of the frontal zone is distinguished by a higher and evenly distributed temperature (from 5.95 °C at the surface to 2 °C at a depth of 60 m), a relatively homogeneous content of oxygen and mineral phosphorus, a lower depth of nitrate nitrogen onset, as well as the highest content of ammonium nitrogen and nitrite in the water column. This work was supported by the State Agreement of The Ministry of Science and Education of the Russian Federation (theme ?0128-2019-0008) and the RFBR (project ? 18-05-60302).

Ocean carbon exchange and drivers from winter to summer in the Atlantic water inflow to the Arctic Ocean

Melissa Chierici, Institute of Marine Research, Tromsø, Norway
Maria Vernet, SIO, La Jolla, USA
Agneta Fransson, Norwegian Polar Institute, Tromsø, Norway
Knut Yngve Børsheim, Institute of Marine Research, Bergen, Norway

Keywords: Ocean CO2 Sink, Biological CO2 Consumption, Calcium Carbonate, N*

The eastern Fram Strait and area north of Svalbard, are influenced by the inflow of warm Atlantic water, which is high in nutrients and CO2. Data on carbonate chemistry and nutrients from three cruises in 2014 in the CarbonBridge project (January, May, and August) and one in Fram Strait (August), which describe the seasonal variability and the major drivers explaining the inorganic carbon change (CDIC) in the upper 50 m, such as photosynthesis (CBIO), and air-sea CO2 exchange (CEXCH). The focus area encompasses the meltwater-influenced domain (MWD), the Atlantic water inflow (AWD) and the West Spitsbergen shelf (SD). The largest CBIO was 2.2 mol C m-2 in the MWD derived from the nitrate consumption between January and May. The ocean in our study area mainly acted as a CO2 sink throughout the period of between 0.1 and 2.1 mol C m-2 in the AWD in August. By the end of August, the AWD acted as a CO2 source of 0.7 mol C m-2, attributed to vertical mixing of CO2- rich waters and contribution from respiratory CO2 as net community production declined. The calcium carbonate (CCALC) dissolution of 6% to 18% was attributed to a combination of the dissolution of sea-ice ikaite and advected CaCO3 shells from the south. Indications of denitrification were observed, associated with sea-ice meltwater and bottom shelf processes. CBIO played a major role (48 to 89%) for the impact on CDIC.

Summer pCO2 dynamics in eastern Bering Sea and Chukchi Sea based on autonomous surface vehicles and underway measurements from 2017 to 2019

Hongjie Wang, University of Washington Cooperative Institute for Climate, Ocean, and Ecosystem Science, 7600 Sand Point Way NE, Seattle, WA 98115
Hongjie Wang, NOAA Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115
Jessica N. Cross, NOAA Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115
Natalie Monacci, University of Alaska, Fairbanks, College of Fisheries and Ocean Sciences, Ocean Acidification Research Center, 2150 Koyukuk Drive, 245 O'Neill Building, PO Box 757220, Fairbanks, Alaska 99775-7220
Adrienne Sutton, NOAA Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115
Stacey Maenner, NOAA Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115
Calvin Mordy, NOAA Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115
Christian Meinig, NOAA Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115

Keywords: Ocean Acidification, Bering And Chukchi Sea, Air Sea CO2 Flux, Saildrone Unmanned Surface Vehicle

Annually, the Arctic Ocean absorbs up to 14% of total human-produced carbon dioxide (CO2). The continuous uptake of CO2 by seawater causes a cascade of chemical reactions that allow acid to build up, a process collectively known as ocean acidification (OA). One of the most concerning impacts of OA relates to marine seafood: OA can have direct and indirect impacts on fisheries resources. In the Bering and Chukchi seas, previous laboratory research has shown that some culturally and commercially important fishery species may be vulnerable to OA conditions in the Bering and Chukchi Seas. Accordingly, better knowledge of the regional CO2 uptake patterns and OA rates is urgently needed in this at-risk area. However, data collection in the Pacific Arctic Region (PAR) is especially difficult, given high logistic and economic costs of conducting research in this harsh, remote environment. The novel Autonomous Surface Vehicle CO2 (ASVCO2) system deployed on mobile autonomous platforms has lowered the data acquisition cost by orders of magnitude compared to traditional approaches. In this study, we will report the first set of ASVCO2 partial pressure of carbon dioxide (pCO2) measurements in the Bering and Chukchi Seas. By combining the ASVCO2 and traditional underway pCO2 measurements in summer of 2017, 2018 and 2019, we will provide an up-to-date understanding of OA conditions in the PAR, which is crucial to support the management and sustainability of local marine resources.

ID: 02 - Changing Arctic Coasts

Conveners

Hugues Lantuit | Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research

Leneisja Jungsberg | Nordregio

Benjamin Jones | University of Alaska Fairbanks

Abiotic environment characterization and influencing factors of microphytobenthic community abundance

Claude-Eric Souquieres
Jana Kvíderová
Josef Elstera

Keywords: Arctic Coastal Ecology, Microphytobenthos, Environmental Gradients, Biogeochemistry

Estuarine abiotic parameters depend upon complex and interdependent processes including geological, hydrodynamic, geochemical, and biological processes. Together these processes achieve a specific habitat where unique algal communities thrive. General information about abiotic features provide key insights on the local ecosystem functioning as well as a foundation for further applications including ecosystem management, monitoring and ecological modelling. This study aims to characterize the local abiotic complexity of Adventfjorden tidal flat and to understand its relative function on the distribution and structure of the local benthic microflora. Here, we carried out a short-term survey during August 2017. A set of chemical and physical parameters were investigated respectively from the water column and the sediment seafloor at distinct sites along the estuary, including: salinity, temperature, pH, sediment moisture, granulometry, organic carbon content as well as concentrations of major cations, anions, nitrogen-based compounds, silica and phosphorus-based compounds. Furthermore, the estuary was surveyed by means of drone to map Vaucheria sp. spatial distribution and to estimate its abundance at the respective sampling sites.

Assessment of intra-seasonal permafrost bluff dynamics in the Beaufort Sea Coast using TerraSAR-X imagery

Gonçalo Vieira, Centre of Geographical Studies, IGOT, University of Lisbon, Lisbon, Portugal
Carla Mora, Centre of Geographical Studies, IGOT, University of Lisbon, Lisbon, Portugal
Pedro Pina, CERENA, IST, University of Lisbon, Lisbon, Portugal
Dustin Whalen, NRCAN, Dartmouth, Canada
Anna Irrgang, Alfred Wegener Institute, Potsdam, Germany
Annett Bartsch, bGeos, Korneuburg, Austria
Hugues Lantuit, Alfred Wegener Institute, Potsdam, Germany

Keywords: Coastal Erosion, Permafrost, Bluff, Intraseasonal, Microwave

Arctic permafrost coasts represent about 34% of the Earth's coastline, with long sections affected by high erosion rates, increasingly threatening coastal communities. Year-round reduction in Arctic sea ice is forecasted and by the end of the 21st century, models indicate a decrease in sea ice area from 43 to 94% in September and from 8 to 34% in February (IPCC, 2014). An increase of the ice-free season leads to a longer exposure to wave action. Monitoring the Arctic coasts is limited by remoteness, climate harshness and difficulty of access for direct surveying, but also, when using satellite remote sensing, by frequent high cloudiness conditions and by illumination. In order to overcome these limitations, three sites at the Beaufort Sea Coast (Komakuk, Stokes Point and Kay Point) have been selected for monitoring using very high-resolution staring-spotlight TerraSAR-X (TSX) microwave imagery. The sites have been surveyed using RTK unmanned aerial vehicle (UAV) in July 2018 and very high resolution CNES Pleiades multispectral imagery has been acquired to extend the analysis beyond the UAV-surveyed sectors. Bluff top and water lines were extracted from TSX imagery acquired at monthly or smaller time-steps (June-October 2019) and changes in the coast were analysed. The results show that TSX imagery allows quantifying coastal changes and identifying the evolution of erosion processes, such as bluff toppling failures or retrogressive thaw slumps.

Beaufort Sea Coastal Dynamics - complex issues, complex impacts and solutions

Dustin Whalen, Natural Resources Canada, Geological Survey of Canada, Dartmouth, Canada
Paul Fraser, Natural Resources Canada, Geological Survey of Canada, Dartmouth, Canada
Michael Lim, Northumbria University, Newcastle upon Tyne, UK.
Goncalo Vieira, Centre of Geographical Studies, IGOT, University of Lisbon, Portugal
Pedro Pina, Centre of Natural Resources and Environment, IST, University of Lisbon, Portugal
Tianna Ruben-Gordon, TCCRP, Tuktoyaktuk Community Corporation, Tuktoyaktuk, Canada
Kendyce Cockney, Tuktoyaktuk Community Corporation, Tuktoyaktuk, Canada
Shawn Stuckey, Hamlet of Tuktoyaktuk, Tuktoyaktuk, Canada

Keywords: Erosion, Mapping, Community, Inuvialuit, TK

The Canadian Arctic coastline contained within the Inuvialuit Settlement Region is one of the most vulnerable to climate change. The rate of coastal change in some parts of the Beaufort Region has accelerated due to declining sea ice, and stronger climate forcing (increased air temperature and storminess). Natural Resources Canada and its partners have been conducting ‘on the ground’ and ‘aerial’ observations in the region for close to 50 years. Much of the coastline is eroding at long term rates of 1-2 m/yr but can be in excess of 47 m/yr. The complex issue of how frozen coasts react to the ocean is not so clear-cut therefore for a deeper understanding of the landscape is necessary. Linkages between scientific research, mapping innovation and traditional knowledge (TK) is required. The co production of knowledge with the Inuvialuit People is important to improve our understanding of these complex coastal change processes, their impacts, and their implication on Northern people, communities, infrastructure, critical ecosystems. A prominent community located in the region is the Hamlet of Tuktoyaktuk. This community is facing severe threat from the ocean and thawing of permafrost. Recently accelerated climate driven changes have exacerbated the problem such that current shore protection measures are not working and the shoreline continues to disappear. For this reason, continued research, mapping and TK is critical to better understand this rapidly changing environment.

Coastal communities' adapting to permafrost thaw in Northwest Greenland

Leneisja Jungsberg, Ph.D. student Copenhagen University & Research Fellow Nordregio
Justine Ramage, Research Fellow, Nordregio
Shinan Wang, GIS analysist & cartographer, Nordregio
Axelle Gaffet, Littoral Environnement et Sociétés, La Rochelle Université, La Rochelle, France

Keywords: Adaptation, Coastal Communities, Permafrost, Northwest Greenland

Arctic regions are impacted by increased permafrost temperature, a reduced permafrost extent and a deepened active layer. Degrading permafrost destabilize essential infrastructure and changes the landscape that local people use for subsistence and leisure activities. In this study, we examine current impacts from permafrost thaw and how these are perceived locally for the coastal communities in Northwest Greenland. First, we will consider the current permafrost extent and examine local observations on changes in the frozen ground. Second, we will study the local perceptions on social impact from these changes, and thirdly, we will study the range of adaptive responses to permafrost thaw in North West Greenland. The research objective is to assess the regional resilience for permafrost thaw in Northwest Greenland. The results illustrate how inhabitants and institutions respond to permafrost thaw. While many inhabitants experience cracking walls and doors that will not close only few homeowners experience bigger structural problems. The government institutions are responsible for all public infrastructure. Some temporary solutions occur, i.e. adding new asphalt on roads that are sinking due to a downward movement of the ground due to higher ground temperatures. Projections for 2050 illustrate further reductions in the permafrost extent which will require adaptation planning for settlements at risk in Northwest Greenland.

Impact of River Forcing on Simulated Ocean-Sea Ice Coupling in the Arctic Mackenzie Shelf (South-Eastern Beaufort Sea)

Clément Bertin, LIttoral ENvironnement et Sociétés (UMR 7266), La Rochelle Université, La Rochelle, France
Dimitris Menemenlis, NASA Jet Propulsion Laboratory-California Insitute of Technology, Pasadena, USA
Dustin Carroll, Moss Landing Marine Laboratories, San José State University, Moss Landing, USA
Hong Zhang, NASA Jet Propulsion Laboratory-California Insitute of Technology, Pasadena, USA
Bertrand Decharme, CNRM, Université de Toulouse, Météo-France, CNRS, Toulouse, France
Vincent Le Fouest, LIttoral ENvironnement et Sociétés (UMR 7266), La Rochelle Université, La Rochelle, France

Keywords: Numerical Modelling, River Discharge, Sea-Ice Phenology

From its terrestrial watersheds to interior ocean, the Arctic is undergoing rapid and unprecedented change due to climate warming. These changes have led to greater export of riverine freshwater, reduced sea-ice extend and thickness, and have impacted marine ecosystems and primary production. The increasing river runoff signal is modulated by complex coastal dynamics, where interactions between river plumes, sea-ice, coastal currents, and bathymetric steering constrain the Arctic ocean-ice-biological response. To better understand the impact of increased river runoff on coastal Arctic systems, we use a regional numerical ocean model (MITgcm) forced by boundary and initial conditions from the Estimating the Circulation and Climate of the Ocean (ECCO) Consortium. We test the sensitivity of sea-ice phenology and open-water conditions to five datasets of Mackenzie River discharge, including river temperature. Our results suggest that weaker riverine freshwater export results in lower sea-ice extent with earlier melting and an increased period of open water. Coupling river temperature forcing with discharge tends to amplify this signal. The location of point-source runoff forcing on the Mackenzie Delta also has a significant impact on coastal sea-ice phenology. Our numerical study is particularly relevant and timely as sea-ice phenology strongly impacts the biogeochemical response and carbon cycle on Arctic shelves.

Multi-disciplinary Site Investigations for improved infrastructure design North Greenland

Thomas Ingeman-Nielsen, Technical University of Denmark, Kgs. Lyngby, Denmark
Rafael Caduff, GAMMA Remote Sensing, Gümligen, Schweiz
Niels Foged, Technical University of Denmark, Kgs. Lyngby, Denmark
Kåre Hendriksen, Technical University of Denmark, Kgs. Lyngby, Denmark
Eva Mätzler, Asiaq Greenland Survey, Nuuk, Greenland
Thomas G. Petersen, Technical University of Denmark, Kgs. Lyngby, Denmark
Johanna Scheer, Technical University of Denmark, Kgs. Lyngby, Denmark
Soňa Tomaškovičová, Technical University of Denmark, Kgs. Lyngby, Denmark

Keywords: Permafrost, Geotechnics, Construction Practices, Infrastructure

Many small Arctic communities experience infrastructure deterioration that is often attributed to climate change and related permafrost thaw. Here we present a case study of multi-disciplinary site investigations of permafrost geotechnical conditions in Qaanaaq in Greenland, one of the northern-most communities in the world (77°28'N). Severe problems with differential settlements of building foundations are observed, and cause damages to the building envelopes. The study was initiated due to a pressing need for infrastructure expansion, both in terms of housing, water supply and transportation infrastructure (e.g. harbour facilities). We combined geotechnical drilling and ground temperature monitoring, ERT measurements, and InSAR derived surface deformation mapping, with lab experiments and a thorough mapping of housing conditions and a review of the local construction history. We conclude that for this particular community, major challenges are related to the construction history and construction (mal-) practices in the 1980'ies during rapid community expansion, and consider climate warming and permafrost degradation an amplifying factor. The remoteness and related logistical challenges play a significant role in understanding the historical practices, while recent projects have been implemented with appropriate adaptation measures by a local entrepreneur. Our findings have contributed to the planning of the much needed infrastructure expansion which is now on-going.

Protection of Arctic coastlines by nearshore and shorefast ice

Lucia Hosekova, Applied Physics Laboratory, Seattle, USA
Jim Thomson, Applied Physics Laboratory, Seattle, USA
Erick Rogers, US Naval Research Laboratory, Stennis Space Center, USA
Emily Eidam, University of North Carolina, Chapel Hill, USA

Keywords: Arctic, Erosion, Waves, Shorefast Ice

Erosion rates along Arctic coasts are increasing, leaving human communities and ecosystems at greater risk of flooding by storm surges. While the shoreline types and coastal erosion patterns are highly variable, key drivers behind these trends are increasing air and water temperatures, and increasing wave energy associated with sea ice retreat. The project “Coastal Ocean Dynamics in the Arctic” (CODA) aims to quantify the role of coastal sea ice in controlling these drivers. We utilize field measurements collected in the Alaskan Arctic in 2019-2020, in combination with publicly available models and satellite products. Drifting buoy observations of waves propagating through coastal pancake ice were collected during a November storm event in the Chukchi Sea, and are used to determine attenuation coefficients in coastal conditions near the ice edge, which constrain parametrizations of wave-ice interactions in wave models. Mooring observations of inshore and offshore wave and temperature conditions in the Beaufort and Chukchi sea provide a year-long view into the role of shorefast ice in controlling coastal erosion drivers. A significant delay in the onset of waves and increased temperature is observed in spring at locations with persistent shorefast ice. We compare these measurements to public datasets and estimate trends in shorefast ice as a protector of Arctic coasts. Supported by the National Science Foundation and the Office of Naval Research.

Record high Pacific Arctic seawater temperatures and delayed sea ice advance in response to episodic atmospheric blocking

Tsubasa Kodaira, Graduate School of Frontier Sciences, The University of Tokyo, Kashiwa, Japan
Takuji Waseda, Graduate School of Frontier Sciences, The University of Tokyo, Kashiwa, Japan
Takehiko Nose, Graduate School of Frontier Sciences, The University of Tokyo, Kashiwa, Japan
Jun Inoue, Arctic Environment Research Center, National Institute of Polar Research, Tachikawa, Japan

Keywords: Chukchi Sea, PDO, Atmospheric Blocking, R/V Mirai

Arctic sea ice is rapidly decreasing during the recent period of global warming. One of the significant factors of the Arctic sea ice loss is oceanic heat transport from lower latitudes. For months of sea ice formation, the variations in the sea surface temperature over the Pacific Arctic region were highly correlated with the Pacific Decadal Oscillation (PDO). However, the seasonal sea surface temperatures recorded their highest values in autumn 2018 when the PDO index was neutral. It is shown that the anomalous warm seawater was a rapid ocean response to the southerly winds associated with episodic atmospheric blocking over the Bering Sea in September 2018. This warm seawater was directly observed by the R/V Mirai Arctic Expedition in November 2018 to significantly delay the southward sea ice advance. If the atmospheric blocking forms during the PDO positive phase in the future, the annual maximum Arctic sea ice extent could be dramatically reduced.

Release of Bioavailable Dissolved Organic Matter into the Arctic Coastal Zone: Simulating Coastal Permafrost Soil Erosion

Anders Dalhoff Bruhn Jensen, National Institute of Aquatic Resources, Technical University of Denmark, Kgs. Lyngby, Denmark
Colin A. Stedmon, National Institute of Aquatic Resources, Technical University of Denmark, Kgs. Lyngby, Denmark
Johanna Sjöstedt, Aquatic Ecology, Lund University, Lund, Sweden
Atsushi Matsuoka, Institute for Earth, Oceans, and Space, University of New Hampshire, Durham, NH, USA
Jérôme Comte, Eau Terre Environnement Research Centre, Quebec, Canada
George Tanski, Vrije Universiteit, Amsterdam, Netherlands
Niek Speetjens, Vrije Universiteit, Amsterdam, Netherlands

Keywords: Global Warming, Permafrost Soil, Terrestrial Dissolved Organic Matter, Marine Microbial Community, Chemostat Setup

As a consequence of global warming, large areas of permafrost soil along the Arctic coast are threaten by erosion at accelerating speed. To study the impact on marine microbial communities in the Arctic coastal zone (ACZ), extracted dissolved organic matter (DOM) from three different permafrost soil types (fluvial, lacustrine and moraine) was provided as substrate to marine bacteria using a chemostat setup. The results revealed that the composition (SUVA, SR and fluorescence intensities) and biodegradability of DOM differed among the three permafrost soil types. DOM extracted from fluvial and moraine soil types showed terrestrial characteristics having weak aromaticity, while lacustrine showed to contain most aromatic compounds. The difference in composition of extracted DOM led to three different microbial communities, with a dominance of Alphaproteobacteria for fluvial and lacustrine soil types (respectively 67% and 87%) and a dominance of Gammaproteobacteria for moraine soil type (respectively 88%). Bacterial growth efficiency (BGE) was 66% in moraine, while BGE in fluvial and lacustrine soil types was 13% and 28% respectively. These results suggest that marine microbial communities and activities are significantly influenced by the quality of substrate including different DOM compositions likely resulting from glacial processes. Our results further indicate that increasing coastal erosion of permafrost soil in the Arctic might affect marine microbial communities in the ACZ and that differences can even be observed between specific soil types. The effect on marine microbial communities will potentially further impact the ecosystem and higher trophic levels and ultimately the overall cycling of carbon in the ACZ.

Sea spray deposition in Svalbard snow – depending dependence on topography? Lessons learned from two projects in the Hornsund area

Krystyna Kozioł, Gdansk University of Technology, Gdansk, Poland
Adam Nawrot, Institute of Geophysics, Polish Academy of Sciences, Warsaw, Poland
F. Pawlak, Gdansk University of Technology, Gdansk, Poland
Ł. Stachnik, University of Wroclaw, Wroclaw, Poland
A. Uszczyk, University of Silesia, Sosnowiec, Poland
M. Frankowski, Adam Mickiewicz University, Poznan, Poland
Ż. Polkowska, Gdansk University of Technology, Gdansk, Poland

Keywords: Aerosol, Marine Salt, Sodium, Atmospheric Deposition

Sea spray is an abundant source of multiple ions and metals in the Svalbard snow cover, and a predominant component of inorganic species composition at many sites (Hodgkins and Tranter, 1998; Matoba et al., 2002; Nawrot et al., 2016). At a trajectory towards a sea-ice-free Arctic, this component in precipitation may become even more important. Na+ and Cl-, as well as elemental Na concentrations, serve as indicators of sea spray abundance in snow and allow to calculate the sea spray fraction in the other inorganic species concentrations. Here, we compare the sea spray deposition in snow at two different topographic forms in high Arctic (Hornsund area, Svalbard): a mountain slope (inorganic ions concentrations, 9 transect points) and a valley (tidewater) glacier, where elemental concentrations have been determined in seasonal snow cover at 18 points. Together, the locations represent elevations between 0 to 569 m asl and distance from the sea of 0-9 km. Differing analytical methods for both sites limit the comparison to elements of similar concentration in ionic and elemental form (Na, Ca, Mg). The sea spray ion/element composition has been explored for spatial distribution patterns, with respect to the predominant easterly wind and the seeder-feeder effect (Nawrot et al., 2016). As a result, we gain a better understanding of topographic exposure to sea spray deposition, which may be used for modeling of other sea spray components, including pollutants transported in this mode.

Sea-level rise floodmapping using hydrodynamic and bathtub water-level models over UAV and LiDAR DSMs in Tuktoyaktuk, Northwest Territories, Canada

Daniel Pinheiro, Centre of Geographical Studies, IGOT, University of Lisbon, Portugal
Gonçalo Vieira, Centre of Geographical Studies, IGOT, University of Lisbon, Portugal
Dustin Whalen, Natural Resources Canada, Dartmouth, Nova Scotia, Canada
Pedro Pina, Centre of Natural Resources and Environment, IST, University of Lisbon, Portugal
João Canário, Centre of Structural Chemistry, IST, University of Lisbon, Portugal
Pedro Freitas, Centre of Geographical Studies, IGOT, University of Lisbon, Portugal
Shawn Stuckey, Hamlet of Tuktoyaktuk, Tuktoyaktuk, Canada

Keywords: Global Warming, Sea Level Rise, Coastal Erosion, Hydrodynamic, Remote Sensing

Arctic warming is leading to an increased reduction in sea ice, with models for 2100 indicating a reduction in the Arctic sea ice area from 43 to 94% in September and from 8 to 34% in February (IPCC, 2014). The increase of the sea-ice free season duration will result in more exposure of the coasts to wave action, with changing climate also modifying the contribution of terrestrial erosion processes. Coastal erosion can also be increased by warmer seawaters and sea-level rise, with more frequent storms and associated surge events leading to the increase in flooding.(Fritz et al., 2015, Ramage et al 2018, Irrgang et al 2018). This work focusses on the Hamlet of Tuktoyaktuk (Northwest Territories, Canada), where extensive ultra-high-resolution surveys with unmanned aerial vehicles (UAVs) have been conducted, allowing to generate orthophoto mosaics, digital surface models (DSM), derived land use, geomorphological and socio-economic activity maps. DSMs, bathymetry and meteorological data are used as inputs for flood modelling in MOHID Water software. Validation is conducted using tide gauge and DGPS data from 2019, with the boundary conditions obtained by FES2014 tide model (Finite Element Solution). Both approaches run on LiDAR data from 2004 and the UAV DSMs for direct comparison. This research is funded by the European Commission H2020 project NUNATARYUK and by the Climate Change Preparedness in the North Program (CCPN).

Projections of Arctic coastal erosion and consequent carbon fluxes

David Marcolino Nielsen, Center for Earth System Research and Sustainability, University of Hamburg, and International Max Planck Research School on Earth System Modelling, Hamburg, Germany
Patrick Pieper, Center for Earth System Research and Sustainability, University of Hamburg Hamburg, Germany
Victor Brovkin, Center for Earth System Research and Sustainability, University of Hamburg, and Max Planck Institute for Meteorology, Hamburg, Germany
Paul Overduin, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Johanna Baehr, Center for Earth System Research and Sustainability, University of Hamburg, Hamburg, Germany
Mikhail Dobrynin, Center for Earth System Research and Sustainability, University of Hamburg, and Deutscher Wetterdienst, Hamburg, Germany

Keywords: Arctic Coastal Erosion, Permafrost, Climate Change, CMIP6 Scenarios, Climate Proojections

Climate change increases the vulnerability of Arctic coasts to erosion. On one hand, surface warming causes permafrost thaw and erosion by thermal denudation. On the other hand, sea-ice cover loss increases the duration of the open-water period and the fetch for waves, increasing erosion by mechanical abrasion. During the present climate, the estimated organic carbon mobilized by Arctic coastal erosion is comparable with the total amount released by the Arctic rivers. However, with climate change, that amount is expected to increase to an uncertain extent. In this study, we provide projections of Arctic coastal erosion rates and their associated carbon fluxes, based on an intermediate and a high-emission scenario from a 10-member ensemble of simulations of the Max Planck Institute Earth System Model (MPI-ESM) performed for the Coupled Model Intercomparison Project Phase 6 (CMIP6). We incorporate the MPI-ESM simulations into a semi-empirical Arctic coastal erosion model, which reproduces well the mean and the spatial distribution of observed erosion rates. In our erosion model, temporal changes are driven by Arctic-mean thermal and mechanical forcings, represented by yearly accumulated wave heights and positive temperatures, which are combined with local ground-ice content estimates to also explain the spatial variability of coastal erosion rates. The Arctic mean erosion is projected to increase between 2- and 3-fold, depending on the emission scenario, and to likely exceed the historical range of variability by 2100. The organic carbon fluxes due to coastal erosion are projected to increase from 7.4±3.1 Tg/year during the historical period to between 11.7±3.5 Tg/year and 14.3±4.1 Tg/year by 2100 for intermediate and high-end scenarios, respectively. Our results provide the first estimates of the future-climate evolution of Arctic coastal erosion and consequent carbon fluxes at a pan-Artic scale, compatible with the resolution and mechanisms represented in Earth system models.

A shelf in disequilibrium: how Arctic continental shelves may respond to climate-driven changes in sea states

John Malito, University of North Carolina, Chapel Hill, USA
Emily Eidam, University of North Carolina, Chapel Hill, USA
Jaap Nienhuis, Utrecht University, Utrecht, Netherlands

Keywords: Arctic Shelves, Hydrodynamics, Morphodynamic Modelling, Coastal Change

Polar coastal environments, including the Alaskan Beaufort Shelf (ABS), are experiencing rapid declines in sea ice coverage and duration, increasingly energetic sea states, and rapid coastal retreat. This study will evaluate the evolution of the ABS given expected increases in wave energy related to declining sea ice coverage and an increase in duration of exposure to open water. A stable 2D cross-shelf model has been developed in Delft3D using Beaufort shelf bathymetry and wave records scaled to represent morphodynamically significant waves. To compare morphological responses to a changing wave climate, 1000-year simulations were conducted with a historical scaled wave climate and a projected wave climate for the years 2081-2100 following RCP8.5. We find that a uniformly sandy shelf is resistant to changes in wave conditions. When exposed to projected waves, slopes on the middle and outer shelf steepen by less than 1% of their initial value over 1000 years. Projected waves propagate more effectively across the shelf, with a wave energy increase of 23% from the initial value over 1000 years at 5 m water depth, compared to a 12% increase for historical waves. This suggests a feedback in which waves grow over time due to both climate-driven changes and morphologic adjustment, leading to more wave energy at the coast. Feedbacks between shelf adjustment and nearshore wave action have the potential to accelerate coastal change. This can disrupt coastal communities and ecosystems.

Fluxes investigation of organic matter in the delta of the Mackenzie River with satellite imagery.

Philippe Bryère, ARGANS-FRANCE, Brest, France
David Doxaran, Laboratoire d'Océanographie de Villefranche, Villefrance-sur-mer, France
Juliette Maury, Laboratoire d'Océanographie de Villefranche, Villefrance-sur-mer, France
Sonia Amaaouch, ARGANS-FRANCE, Brest, France
Antoine Mangin, ARGANS-FRANCE, Sophia-antipolis, France
Bennet Juhls, Alfred Wegener Institute, Potsdam, Germany
Matsuoka Atsushi, Takuvik University of Laval, Canada.
Marcel Babin, Takuvik University of Laval, Canada.

Keywords: Organic Matter Fluxes, Macenzie River, Remote Sensing, Suspended Matters

Due to the acceleration of the permafrost thaw, the amount of organic matter released in the Arctic Ocean is continuously increasing. In the frame of the EU-H2020 Nunataryuk project several teams are investigating, with satellite imagery, the fluxes of organic matter (OM) in the delta of the Mackenzie River, in particular, surface concentrations of terrestrial dissolved organic carbon (DOCt), of suspended matter (SPM) and of coloured dissolved organic matter (CDOM). Based on numerous match-ups with field measurements carried from June to September 2019, we develop regional calibrations and intercomparison between algorithms for the Sentinel-2&3, MODIS and VIIRS satellite data right at the mouth of the Mackenzie River. For SPM, the consistency between different sensor satellite products has been carefully checked; matchups are satisfactory for all sensors when comparing satellite-derived to field-measured SPM concentrations. Fluxes of SPM discharged by the river into the Arctic Ocean over a whole summer period have then been estimated. For OLCI and MSI, results were compared to those obtained with published remote sensing algorithms. For CDOM different retrieval algorithms were tested. The results were used to calculate DOC using an empirical DOC-CDOM relationship and to map the DOC concentration over the entire open water season to illustrate the seasonal variability of DOC and the Mackenzie River plume. Results of algorithms inter-comparison and OM fluxes are presented.

Morphodynamics and sedimentary processess in arctic transitional environments: Dicksonfjorden, Svalbard

Dohyeong Kim, Seoul National University, Seoul, Republic of Korea
Joohe Jo, Seoul National University, Seoul, Republic of Korea
Seung-il Nam, Korea Polar Research Institute, Incheon, Republic of Korea
Kyungsik Choi, Seoul National University, Seoul, Republic of Korea

Keywords: Spit, Transition Zone, Fjord, Morphodynamics, Climate Change

Despite its role as an interface between terrestrial and marine systems, transition zone between marine and fluvial environments is least understood partly because of the lack of understanding about various physical processes that govern sediment flux and transport over time and space. This is particularly the case for arctic coastal areas, where thawing permafrost and sea-ice loss facilitate rapid environmental changes such as coastal erosion due to climate change. This study aims to understand processes controlling sediment distribution and morphologic changes in arctic transitional environments in Dicksonfjorden. Actively migrating braided channels are predominant in the fluvially-dominated upstream area and near the alluvial fans. The braided channels merged into meandering channels in the downstream area, where extensive tidal flats are developed. A series of spits, along the margin in the downstream area indicate longshore and landward transport of coarse sediments by storm waves during spring high tides and/or high-discharge period. DoD analysis indicate spits migrated as much as 10 m between 2016 and 2017, suggesting active coarse-grained sediment transport and coastal erosion. This reconnaissance study highlights the spatio-temporal variability and complexity of sediment transport in Dicksonfjorden, warranting further coordinated research to understand sedimentary processes in the fjord and to properly address future changes therein.

Remote sensing analysis of recent coastal change and its controlling factor in Tuktoyaktuk Peninsula (Beaufort Sea Coast, Canada)

Bernardo Costa, Instute of Geography and Spatial Planning, University of Lisbon, Lisbion, Portugal.
Gonçalo Vieira, Centre of Geographical Studies, IGOT, University of Lisbon, Lisbon, Portugal.
Dustin Whalen, NRCAN, Dartmouth, Canada.

Keywords: Coastal Erosion, Permafrost, Remote Sensing, UAV, Beaufort Sea.

The average rate of coastal erosion in the Arctic Ocean is 0.5 m year-1, despite a significant local and regional variation, with large areas well above 3 m year-1 (Lantuit et al., 2012). Recent data suggests an acceleration of coastal retreat in key areas, as a result of an increasingly shorter sea ice season, higher storminess, warmer ocean waters and to sea-level rise (O'Rourke, 2018). Moreover, climate warming is inducing the subaerial degradation of permafrost and increasing sediment transport from land to sea. This work consists on the characterization and analysis of the main controlling factors affecting recent coastline changes in Tuktoyaktuk Peninsula (Beaufort Sea, Northwest Territories, Canada). The specific objectives are: I. mapping Tuktoyaktuk Peninsula's coastline at different time-steps using remote sensing imagery, II. quantifying the recent coastal change rates, III. identifying the main controlling factors of the coastal change rates, IV. analyzing the local controlling factors for coastal change in key study areas. For this, we are using historical aerial imagery, Landsat and Sentinel-2 imagery, a very high resolution Pleiades survey from 2020, as well as surveys using unmanned aerial vehicles at detail study areas. In this e-poster, we will present the preliminary results from this research, focusing on the multitemporal analysis of coastal changes. This work is a contribution to EC H2020 NUNATARYUK.

Remote sensing analysis of recent coastal change and its controlling factors in the Darnley Bay region (Beaufort Sea Coast, Canada)

Rodrigue Tanguy, University of Algarve, Faro, Portugal
Gonçalo Vieira, Centre of Geographical Studies, IGOT, University of Lisbon, Lisbon, Portugal
Gonçalo Prates, Centre of Geographical Studies, IGOT, University of Lisbon, Lisbon, Portugal and University of Algarve, Faro, Portugal
Dustin Whalen, NRCAN, Dartmouth, Canada
Pedro Pina, CERENA, IST, University of Lisbon, Lisbon, Portugal

Keywords: Coastal Dynamics, Permafrost, MPA, Darnley Bay, Remote Sensing

Arctic permafrost coasts show high erosion rates in several regions, increasingly threatening coastal communities and also modifying sediment and nutrient budgets from land to sea. However, research has been focussing on relatively limited areas with others, more remote being still neglected. The Darnley Bay area from Cape Parry to Paulatuk is still a poorly studied coastal stretch, but it is a very significant ecological area, including the Marine Protected Area Anguniaqvia niqiqyuam, an important habitat for Arctic char, cod, beluga whales, ringed and bearded seals, polar bears and sea birds. It is also a culturally important area for the Inuvialuit, as it supports subsistence harvesting and it includes the hamlet of Paulatuk. This research aims at the detailed remote sensing characterization of the coast and its recent dynamics, by analysing the Landsat and Sentinel data series, together with a new very-high resolution survey based on CNES Pleiades imagery of August 2020. Key areas, such as Paulatuk and Argo Bay have been surveyed with unmanned aerial vehicles in 2019 and will be used as ground truthing of satellite-derived data. This work is integrated in EC H2020 Nunataryuk.

Synergistic use of remote sensing and field observations for assessing recent changes along the Canadian Beaufort coast

Gonçalo Vieira, Centre of Geographical Studies, IGOT, University of Lisbon, Lisbon, Portugal
Pedro Pina, CERENA, IST, University of Lisbon, Portugal
Dustin Whalen, NRCAN, Dartmouth, Canada
Carla Mora, Centre of Geographical Studies, IGOT, University of Lisbon, Lisbon, Portugal
João Canário, CQE, University of Lisbon, Lisbon, Portugal
Pedro Freitas, Centre of Geographical Studies, IGOT, University of Lisbon, Lisbon, Portugal
Daniel Pinheiro, IST, University of Lisbon, Lisbon, Portugal
Anna Irrgang, Alfred Wegener Institute, Potsdam, Germany
Annett Bartsch, bGeos, Korneuburg, Austria
Hugues Lantuit, Alfred Wegener Institute, Potsdam, Germany

Keywords: Coastal Erosion, Permafrost, Remote Sensing, UAV, Microwave

Arctic permafrost coasts are major carbon (Schuur et al., 2015) and mercury pools (Schuster et al., 2018). They represent about 34% of the Earth's coastline, with long sections affected by high erosion rates (Lantuit et al., 2012), increasingly threatening coastal communities. Year-round reduction in Arctic sea ice is forecasted and by the end of the 21st century, models indicate a decrease in sea ice area from 43 to 94% in September and from 8 to 34% in February (IPCC, 2014). An increase of the sea-ice free season leads to a longer exposure of coasts to wave action. Further, climate warming is also expected to modify the contribution of terrestrial erosion (Fritz et al., 2015, Ramage et al., 2018, Irrgang et al., 2018). Within the project NUNATARYUK, we are updating the mapping of the Arctic coast with the Canadian Beaufort coast as a case-study. The surveying methodology is based on the synergistic use of satellite imagery and field data, with the main approaches being the following: i. a high-resolution update of the coastline mapping and change rates using Pleiades (CNES) satellite acquisitions from 2018 and 2020, ii. surveys using RTK-UAV aerial imagery of long-term monitoring sites, iii. experimental use of TerraSAR-X staring spotlight scenes and PAZ at key sites to monitor intraseasonal dynamics of coastal changes. This research is funded by the EC H2020 Project NUNATARYUK. Support on remote sensing imagery access is provided by the WMO Polar Space Task Group.

ID: 55 - System of knowledge production for the Central Arctic Ocean: a model for the region and the globe

Conveners

Hyoung Chul Shin | Korea Polar Research Institute, Republic of Korea

Alfred Jakobsen | Oceans North Greenland, Greenland

Ingeborg Mulder | Wageningen Marine Research, Netherlands

Implications of Bering Summer Water on the zooplankton community in the Northern Chukchi Sea

Jee-Hoon Kim, Korea Polar Research Institute, Incheon, Republic of Korea
Kyung-Ho Cho, Korea Polar Research Institute, Incheon, Republic of Korea
Hyoung Sul La, Korea Polar Research Institute, Incheon, Republic of Korea
Sung-Ho Kang, Korea Polar Research Institute, Incheon, Republic of Korea
Eun Jin Yang, Korea Polar Research Institute, Incheon, Republic of Korea

Keywords: Zooplankton, Calanus glacialis, Arctic, Chukchi Sea, Bering Summer Water

The Arctic Chukchi Sea is a region where the marine ecosystem experiences dramatic changes, especially in terms of warming and sea ice cover shifting. To examine the effect of water mass and sea ice cover shifting on the zooplankton community, we conducted surveys at 17 stations in August 2016 and August 2017 in the Chukchi Sea. In August 2017, a substantial increase in the Calanus glacialis copepodite population in the zooplankton community was found under the melted sea ice. Water mass analysis revealed that the influx of Bering Summer Water (BSW) was strong at this period. The BSW entering the Chukchi Sea introduces a large amount of C. glacialis copepodites, as well as melting sea ice at warm water temperatures. This increase of the Pacific water is accompanied by phytoplankton and the eggs of zooplankton, which provide food during the critical development time for C. glacialis. In addition, the northern inflow of BSW causes the large-scale migration of C. glacialis copepodites in the C4/C5 stage in a short time, which first grow in the warmer region, and then enter the polar region. This grown C. glacialis can consume other competing zooplankton eggs and nauplii, thus may further accelerating its dominance in the Chukchi Sea.

Passive acoustic monitoring combined with local and indigenous knowledge of the Arctic coastal communities; a case of cooperation between modern science and indigenous wisdom

Dong-Gyun Han, Korea Polar Research Institute, Republic of Korea
Wuju Son, Korea Polar Research Institute, Republic of Korea
Jeong-Hoon Kim, Korea Polar Research Institute, Republic of Korea
Hyoung Chul Shin, , Korea Polar Research Institute, Republic of Korea
Hyoung Sul La, Korea Polar Research Institute, Republic of Korea

Keywords: Passive Acoustic Monitoring, Indigenous Knowledge, Arctic Ocean

Passive acoustic monitoring (PAM) may provide an eco-friendly method to observe and record the underwater environment. Passive acoustic system installed for long-term should be more useful in polar regions, where accessibility is almost always limited, when applied to observe the marine mammal, wind, rainfall, sea ice, earthquake and so on. We measured underwater sound using an autonomous passive acoustic recorder in the East Siberian Sea from August 2017 to August 2018. Bearded seal (Erignathus barbatus) vocalizations were recorded from March to July and their spectra were most prominent in May. Different types of biological sounds such as the vocalizations from walrus, beluga and similar sounds like bowhead whales and sounds from the sea ice deformation were measured. This type of monitoring can offer a great deal of potential when applied in the Arctic coastal fishing communities. Indigenous peoples in the Arctic region depend on the natural environment and their livelihoods are based on the Arctic Ocean, especially for coastal fishing communities. Their experience and wisdom gained while cooperating with nature for a long time is a valuable asset and more powerful tool when archived and jointly used with modern technology. In this presentation, a proposal to develop ways to use an autonomous passive acoustic recorder system for observation close to the Arctic communities, that can coproduce new information combined with local and indigenous knowledge, will be presented.

A Step-Wise Progression to Fisheries Ecosystem Science in the Central Arctic

Franz Mueter, University of Alaska Fairbanks, Juneau, Alaska, USA
Jacqueline M. Grebmeier, University of Maryland Center for Environmental Science, Solomons, Maryland, USA
Henry P. Huntington, Ocean Conservancy, Eagle River, Alaska, USA
Peter L. Pulsifer, University of Colorado, Boulder, Colorado, USA
Jeremy Davis, Ocean Conservancy, Bellingham, Washington, USA

Keywords: Arctic Ocean, Fisheries, Ecosystem, Oceanography, Management

The high seas area of the Central Arctic Ocean (CAO) has been ice covered until recent years where summer sea ice loss removes the physical barrier to fishing vessels. In response to concerns about potential harm to the Arctic marine ecosystem, Canada, Denmark/Greenland, the European Union, Iceland, Japan, the People's Republic of China, the Republic of Korea, Norway, the Russian Federation, and the United States of America signed the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean in October 2018. Under the agreement, once fully ratified, parties pledge not to begin commercial fishing for 16 years to conduct scientific research. A central activity is to develop scientific information, including Indigenous knowledge, about ecosystem dynamics and fish stocks in the CAO to support the agreement and to create a fisheries ecosystem management plan for commercial fisheries. Limited oceanographic research in the high Arctic makes international cooperation essential. We propose a step-wise approach where basic monitoring is undertaken to detect ecosystem component status and change compared to identified thresholds, followed by increased ecosystem research, including more intensive tracking of fish population dynamics, specific ecosystem components, and to identify ecosystem outcomes of variable fishing activities. This process provides an approach to fisheries-related research in the CAO coincident with a systems-level study of the high Arctic.

The knowledge production and sharing mechanisms for the Central Arctic Ocean management: What the different stakeholders have in common

Yunjin Kim, Korea Legislation Research Institute, Sejong, Korea
Yeona Son, Korea Legislation Research Institute, Sejong, Korea

Keywords: Central Arctic Ocean, International Law, Arctic Governance, Scientific Research, International Cooperation

The entry into force of the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean will be an important step in the the evolution of Arctic Ocean governance. The Agreement commits the Parties to fulfill responsibilities in preventing unregulated fishing activities and also to promote scientific cooperation in the CAO. There are, however, a wide range of stakeholders with different understanding of the CAO ecosystem though sometimes complementary capabilities to produce and assimilate the information and knowledge about the CAO. One of the major difficulties in pursuing scientific research and in making governance decisions is to involve the perspectives of diverse stakeholders. The participation of those stakeholders are at different levels and roles in producing and utilizing knowledge. Effective implementation of the CAO Fisheries Agreement will require the Parties to ensure that (1) stakeholders are informed about knowledge of the Central Arctic Ocean from the scientific research programs, (2) stakeholders are consulted and generate input for the research programs, (3) stakeholders are involved in related policy decision-making process that contributed to the Central Arctic Ocean governance. We aim to address the following questions: How will the current cooperation mechanisms play out among the stakeholders? How will scientific cooperation likely work in the mechanisms? What can we expect from the different levels of contribution?

Interesting Aspects of Interesting Aspects of the Central Arctic Ocean Fisheries Agreement

Peter Harrison, Oceans North, Ottawa, ON, Canada
Marc Meloche, Arctic Policy Advisor, Ottawa, ON, Canada
Henry P. Huntington, Ocean Conservancy, Eagle River, AK, USA

Keywords: Arctic, Ocean, Fisheries, Indigenous Knowledge

The "Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean" was negotiated by ten jurisdictions (Canada; China; Denmark/Greenland; Iceland; Japan; Republic of Korea; Norway; Russia; United States of America; and the European Union). It was signed in Ilulissat on October 3rd, 2018 and has been ratified/approved by all except China (whose approval, as of November 2020, is pending). Concluding such an agreement acknowledges the importance of applying the "precautionary principle" in managing marine ecosystems. Also of note - in parallel to the Signatories' official deliberations several activities were organized by non-government actors which had a positive influence on the outcome of the negotiations and the implementation of the Agreement. This presentation will outline these activities and will underline the ground-breaking inclusion of Indigenous Knowledge in the science program required by the Agreement, the taking into account of work by other relevant scientific and technical organizations, bodies and programs (i.e. coordination) as well as the requirement of the Agreement's scientific program to employ an ecosystem/holistic approach.

Inuit Knowledge, Indigenous Rights and the co-production of knowledge

John Crump on behalf of the Inuit Circumpolar Council

Keywords: Inuit, Indigenous Knowledge, Indigenous Rights, Ecosystem, Science

The Central Arctic Ocean fisheries agreement is important because it is the first international treaty to consider Indigenous Knowledge as equal to scientific knowledge. The CAO agreement is also significant because it involved Inuit during its formulation and recognizes the on-going role of Indigenous Peoples in its implementation. Inuit have important contributions to make to the health of Arctic Ocean ecosystems through knowledge and direct involvement in the development and implementation of the CAO agreement that includes long-term research, monitoring, and management. The Inuit Circumpolar Council is working with regional Inuit organizations and other partners to develop a protocol for bringing Indigenous Knowledge into the science and research programme of the CAO agreement. This presentation will focus on how the work is being carried out and offer examples of Indigenous Knowledge engagement in Inuit Nunaat, the Inuit homeland. It will provide a status report on the international process and touch on steps being taken by Inuit regions to contribute to the implementation of the treaty.

Inuvialuit Settlement Region Beluga Tagging Program: A community and co-management driven success story

Lisa Loseto, Fisheries and Oceans Canada, Winnipeg, Canada
Shannon MacPhee, Fisheries and Oceans Canada, Winnipeg, Canada
Jim Elias, Inuvialuit Game Council, Inuvik, Canada
John Noksana, Fisheries Joint Management Committee, Inuvik, Canada
Jimmy Kalinek, Inuvialuit Game Council, Inuvik, Canada
Jen Lam, Inuvik, Joint Secretariat, Inuvik Canada
Davonna Kisook, Inuvialuit Game Council, Inuvik, Canada
Kiyo Campbell, Fisheries Joint Management Committee, Inuvik, Canada

Keywords: Beluga, Knowledge Co-Production, Inuvialuit Knowledge, Telemetry, Co-Design

Telemetry is a powerful tool that provides information on movement, behavior and habitat use, generating data to support conservation. However, the invasive capture, handling, and implantation of transmitters presents risk to the animal and contravenes Inuit cultural norms to respect wildlife. As such this project took steps to respectfully include Inuvialuit Knowledge with Western Science along with equitable participation of Inuvialuit (Inuit of the western Canadian Arctic) in project design, implementation and data interpretation. Priorities and knowledge gaps pointed to the use of beluga tagging as a tool and was discussed over a two-year consultation phase prior to approval. A critical development was the creation of a governance group that included representation of Inuvialuit from regional boards, staff and scientists that together reviewed and decided on actions for all project components including the community partnered workshops to co-develop Animal Use Protocols (AUPs). In this way, the relevant boards and communities had a voice on project direction and decision-making. Communities requested less invasive approaches to tagging whales that was supported through workshops and field testing with the expertise of engineers, biologists and Inuvialuit that resulted in the first successfully remote deployed tags by Inuit hunters. This innovation was founded on equal partnerships and respect for all knowledge. Next steps are to co-interpret the results.

Inclusive Knowledge Production to Ensure Multiple Sustainable Ocean Uses with Changing Ecosystems

Candace Nachman, Senior Policy Advisor and HQ Arctic Liaison, Office of Policy, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Silver Spring, Maryland, USA
Robert Foy, Director, Alaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Juneau, Alaska, USA

Keywords: Fisheries, Central Arctic Ocean, Local and Indigenous Knowledge, Collaboration, Equity and Inclusion

The Signatories to the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean (CAO) (the Agreement) recognized the value of using both science and local and Indigenous knowledge to inform future decisions about fisheries and ecosystems in the region. Recognizing local and Indigenous knowledge is a necessary component alongside science to conserve and sustainably use living marine resources and is paramount to the success of the Agreement. To ensure decision-makers receive the most comprehensive information available, all relevant knowledge holders with local, regional, and national perspectives need to cooperate and collaborate at every stage of information gathering. Although the Agreement recognizes the need for decision makers to use diverse knowledge systems, it does not include mechanisms and processes of how that will be accomplished. To be successful, the Signatories need to grapple with issues of equity (i.e., providing equal opportunities to successfully participate) and inclusion (i.e., respecting and fully including all knowledge holders). This presentation will propose a path for inclusion and equity to ensure the intent of the Signatories to the Agreement is met. The proposed path will also include a specific focus on how the U.S. National Oceanic and Atmospheric Administration can improve communication, coordination, and collaboration with Alaskan Indigenous groups as a valuable contribution to the CAO discussions and decisions.

Towards a shared understanding and agreeable mechanism of knowledge co-production in the Central Arctic Ocean: A non-coastal Signatory perspective

Jihoon Jeong, Korea Polar Research Institute, Incheon, Korea
Hyoung Chul Shin, Korea Polar Research Institute, Incheon, Korea

Keywords: Central Arctic Ocean Fisheries Agreement, Local And Indigenous Knowledge , Knowledge Co-Production, And Joint Research And Monitoring

The Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean (CAOFA), stipulates that indigenous and local knowledge (ILK) shall be taken into account with other forms of relevant knowledge, for the Joint Program of Scientific Research and Monitoring (Article 4, Para. 4). The CAOFA also provides an avenue to involve representatives of Arctic communities in the form of committees or similar bodies (Article 5, Para. 2). As CAOFA is expected to enter into force soon, incorporating ILK assumes a higher priority. It is also critical to introduce mechanisms for ILK inclusion that are agreeable to all ten Signatories, as any decisions on questions of substance will be taken by consensus of the Parties (Article 6). This presentation summarizes relevant developments since the first Preparatory Meeting of CAOFA Signatories (Ottawa, Canada; May 2019) and will examine conditions and options for knowledge co-production. We advocate formation of a flexible, task force-type body that assembles ILK holders and modern scientists for a facilitated dialogue with a designed work plan.

What Role for the Arctic Council in Central Arctic Ocean Management?

Jeehye Kim, Korea Maritime Institute, Busan, Republic of Korea
Minsu Kim, Korea Maritime Institute, Busan, Republic of Korea

Keywords: Central Arctic Ocean, Arctic Council, Ocean Stewardship, High Seas

The Arctic Council, since its inception in 1996, has made important contributions in filling the knowledge gap about the Arctic through its working groups and subsidiary bodies. Thus this presentation will examine the role and achievements of the Arctic Council so far in terms of Arctic ocean management, as well as its limitations, and then examine what role there is for the Arctic Council when it comes to managing the Central Arctic Ocean, in light of the recently signed International Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean, and the ongoing BBNJ negotiations.

Labrador Shelf freshening linked to Beaufort Gyre freshwater release

Jiaxu Zhang, University of Washington and NOAA/Pacific Marine Environmental Laboratory, Seattle, USA
Wilbert Weijer, Los Alamos National Laboratory, Los Alamos, USA
Michael Steele, University of Washington, Seattle, USA
Wei Cheng, University of Washington and NOAA/Pacific Marine Environmental Laboratory, Seattle, USA
Tarun Verma, Los Alamos National Laboratory, Los Alamos, USA
Milena Veneziani, Los Alamos National Laboratory, Los Alamos, USA

Keywords: Beaufort Gyre, Freshwater Release, North Atlantic, Greenland Meltwater, Modeling

The Beaufort Gyre (BG), the largest Arctic Ocean freshwater reservoir, has drastically increased its liquid freshwater content by 40% in the past two decades. If released within a short period, the excess freshwater could potentially impact the large-scale ocean circulation by freshening the upper subpolar North Atlantic. Here we show that this freshwater exited the Arctic mostly through the Canadian Arctic Archipelago, rather than Fram Strait, during an historical release event. The Labrador Sea is the most affected region in the subpolar North Atlantic, with a freshening of 0.2 psu on the western shelves and 0.4 psu in the Labrador Current. These results are based on a passive tracer approach to estimate BG-sourced freshening in a global ocean sea-ice model. Given that the present BG freshwater content anomaly is twice the historical analog studied here, the impact of a future rapid release on Labrador Sea salinity could be significant, easily exceeding similar fluxes from Greenland meltwater.

ID: 74 - Plankton Microbial Communities and its Functions in a Changing Arctic

Conveners

Catarina Magalhães | CIIMAR-Interdisciplinary Centre of Marine and Environmental **Research**

Pedro Duarte | NPI – Norwegian Polar Institute

Maria Paola Tomasino | CIIMAR-Interdisciplinary Centre of Marine and Environmental Research

Impacts of glacial meltwater discharge on the spatial distribution of microprotist and mesozooplankton communities in Bowdoin Fjord, northwestern Greenland

Toya Hazumi, Faculty/Graduate School of Fisheries Science, Hokkaido University, Hokkaido, Japan
Kohei Matsuno, Faculty/Graduate School of Fisheries Science, Hokkaido University, Hokkaido, Japan, Arctic Research Center, Hokkaido University, Hokkaido, Japan
Naoya Kanna, Atmosphere and Ocean Research Institute, The University of Tokyo, Chiba, Japan
Shin Sugiyama, Arctic Research Center, Hokkaido University, Hokkaido, Japan, Institute of Low Temperature Science, Hokkaido University, Hokkaido, Japan
Atsushi Yamaguchi, Faculty/Graduate School of Fisheries Science, Hokkaido University, Hokkaido, Japan, Arctic Research Center, Hokkaido University, Hokkaido, Japan

Keywords: Microprotist, Mesozooplankton, Greenland, Glacier meltwater, Marine-terminating glacier

To understand the effect of glacial meltwater from the bottom of marine-terminating glacier on the marine ecosystem, we investigated the distribution and structure of microprotist and mesozooplankton communities in Bowdoin fjord. Field sampling was conducted on July 26, 29, 2016 at 14 stations in Bowdoin Fjord. Microprotist in surface water was collected by a bucket and mesozooplankton was collected by horizontally towing a single-NORPAC (mesh size 335 µm, diameter 45 cm) at 2-3 m below the sea surface. Seawater for nutrients measurement was also collected in plastic tubes. In Bowdoin Fjord, the discharge water from Bowdoin Glacier affected the microprotist and mesozooplankton communities. Regarding to microprotists, diatom bloom had already declined when sampling was performed probably due to low salinity, light limitation and nutrients depletion, while ciliates and heterotrophic dinoflagellates were dominant. Heterotrophic dinoflagellates were confirmed have positive correlations with nutrients and copepods by the structural equation model (SEM) analysis. This result suggested that they play an important role in connecting primary producers and higher trophic levels. In the mesozooplankton communities, barnacle larva, Calanus glacialis, and Pseudocalanus spp. were dominant. Large zooplankton such as Calanus spp. and chaetognath was abundant near the glacier, which was probably transported by deep fjord current and upwelling subglacial discharge near the glacier.

A comparative approach between metabarcoding and microscopy analysis to study the Arctic Ocean Eukaryotic Microbiome

Marta Sousa, CIIMAR – Interdisciplinary Centre of Marine and Environmental Research, University of Porto, Portugal
Maria Paola Tomasino, CIIMAR – Interdisciplinary Centre of Marine and Environmental Research, University of Porto, Portugal
Catarina Magalhães, CIIMAR – Interdisciplinary Centre of Marine and Environmental Research, University of Porto, Portugal

Keywords: Arctic Ocean, Phytoplankton, Protists, Climate Change, Morphology, 18S Metabarcoding, Diversity

Climate change is affecting the Arctic Ocean through the decrease of the sea ice extent and thickness and consequently the dynamics of phytoplankton has been changing, radically redefining the biogeography of marine Arctic ecosystem. The aim of this research was to proceed with a comprehensive comparison between the metabarcoding approach and the classic microscope cell identification to study the Arctic phytoplankton diversity and distribution along two oceanographic transects (Kongsfjorden and Rijpfjorden) in the Marginal Ice Zone (MIZ) around Svalbard. Fieldwork was performed during the Arctic monitoring campaign MOSJ (Environmental Monitoring of Svalbard and Jan Mayen) in the summer 2016. Microscope phytoplankton counts and identification were performed by NPI while metabarcoding analysis (by rRNA 18S-V4 gene marker) were carried out at CIIMAR (Porto, Portugal). The results revealed that these Arctic environments comprises a highly complex and diverse protist community structure, with strong links between protist community's distribution and environmental gradients. Methodological comparison showed significant differences on protists abundance and diversity recovery, suggesting that metabarcoding and microscopic counts are complementary tools to study the dynamics of phytoplankton.

Climate change induced shifts in polar phytoplankton nutrient content: species, community and trophic implications

Rebecca Duncan, University Technology Sydney, Australia & UNIS Svalbard, Norway
Katherina Petrou, University Technology Sydney, Australia
Janne Søreide, UNIS Svalbard, Norway
Øystein Varpe, University of Bergen, Norway

Keywords: Phytoplankton, Sea Ice, FTIR-Microspectroscopy, Ocean Acidification,

The polar regions are experiencing some of the most accelerated rates of environmental change on the planet, with ongoing warming driving a persistent trend in the reduction of Arctic sea ice extent and substantial changes to the ocean chemistry including ocean acidification (OA). Understanding the implications of these changes on Arctic and Southern Ocean phytoplankton is particularly important, as they are responsible for the majority of primary production in the polar waters. As phytoplankton are limited by a range of environmental factors including water temperature, pH and light availability, the ongoing changes will shape the phytoplankton community composition and influence the macromolecular composition of the individual species. Combined, these effects alter the nutrients supplied to higher trophic levels. Even small changes in nutrient availability at the production level can have large cascading effects on higher trophic organisms. We use FTIR-microspectroscopy to perform single-cell analyses to investigate how polar phytoplankton shift in carbon partitioning between the macromolecular storage of proteins, lipids and carbohydrates in response to ocean acidification and light availability. For instance, in response to OA, we found the community was dominated by smaller, less silicified taxa, which generally increased both lipid and protein stores, whilst the larger taxa showed a preferential energy allocation toward proteins over lipids. As the phytoplankton-zooplankton link is the key to secondary production in polar oceans, these changes to the nutritional quality and grazability of primary producers are expected to have broad, cascading effects on food web dynamics in the polar marine ecosystems.

The types of prokaryotic rarity in the Arctic Ocean

Francisco Pascoal, Centro Interdisciplinar de Investigação Marinha e Ambiental, Porto, Portugal
Rodrigo Costa, Instituto Superior Técnico, Lisboa, Portugal
Catarina Magalhães,Centro Interdisciplinar de Investigação Marinha e Ambiental, Porto, Portugal

Keywords: Rare Biosphere, Arctic Ocean, Types Of Rarity, Community Assembly

The prokaryotic rare biosphere represents the low abundance populations of prokaryotes and is important for ecosystem resistance and resilience. The few previous studies on the prokaryotic rare biosphere of the Arctic Ocean assert that water masses harbor specific microbial ecotypes and most prokaryotic taxa remain rare across biogeography and seasons. For the purpose of uncovering the different types of rare populations in the Arctic Ocean and respective dynamics during a winter to spring transition, we used seawater samples from the Norwegian Young Sea Ice Expedition (2015). Our results found that most of the rare taxa were transiently rare, meaning that they appear and disappear in different samples, probably as a result of dispersal limitation caused by the different water masses. Furthermore, we suggest that conditional rarity, which represents taxa that vary between abundant and rare across time/space, are more prevalent at epipelagic layers, where seasonal variation in light availability occurs. Rare prokaryotes tend to maintain low abundance within specific Arctic Ocean water masses, but they can become abundant or disappear across seasonal variation and different water masses. Future work should tackle how the rare biosphere responds to climate change and which are the consequences of this response for ecosystem functioning.

Effects of nitrogen availability on phytoplankton photophysiology in the Chukchi Sea in summer

Eunho Ko, University of Science and Technology, Korea Polar Research Institute, Incheon, Republic of Korea
Maxim Y. Gorbunov, Department of marine and Coastal Sciences, Rutgers University, New Jersey, USA
Jinyoung Jung, Korea Polar Research Institute, Incheon, Republic of Korea
Youngju Lee, Korea Polar Research Institute, Incheon, Republic of Korea
Eunjin Yang, Korea Polar Research Institute, Incheon, Republic of Korea
Kyung-Ho Cho, Korea Polar Research Institute, Incheon, Republic of Korea
Sung-Ho Kang, Korea Polar Research Institute, Incheon, Republic of Korea
Jisoo Park, Korea Polar Research Institute, Incheon, Republic of Korea

Keywords: Phytoplankton Physiology, Electron Transfer Rate, Nitrogen Stress, The Chukchi Sea

Phytoplankton in the Arctic Ocean are subject to nitrogen limitation in the summer, so nitrogen availability is essential to understand how it affects the growth and physiological properties and community structure of phytoplankton. However, how severely the nitrogen stress affects phytoplankton physiology remains largely unknown. The aim of this study was 1) to quantify the extent of nitrogen stress using active fluorometry, and 2) to understand the relationship between phytoplankton photophysiological characteristics and community size structure. In the summers of 2015-2018, four field campaigns were conducted across two contrasting regions in the Chukchi Sea with distinctly different levels of nitrogen availability in the upper water column. Our results indicated phytoplankton photosynthesis was severely nitrogen-stressed in the vast region of the Chukchi Sea. Thereby, the maximum quantum yield of photochemistry in photosystem II (Fv/Fm) showed only a small decrease (12 ± 9%) relative to its nutrient-replete values, while the maximum electron transfer rates (ETRmax) under saturating irradiance were impaired to a greater extent (40 ± 17%). This phytoplankton photosynthesis response is indicative of a severe nitrogen limitation, which results in dramatic reduction in growth and net primary production rates. Nutrient enrichment incubations also showed a marked increase in large-size phytoplankton growth (>10 µm) after the nitrogen stress was alleviated, suggesting that the larger cells were more susceptible to nitrogen stress. This results have important implications for understanding how climate-driven variation of nitrogen flux in the Arctic Ocean would affect phytoplankton communities and primary production.

Links between Arctic microbial taxonomy and nitrogen functional traits Across the Svalbard Shelf

Catarina Magalhães, Interdisciplinary Centre of Marine and Environmental Research, University of Porto, Matosinhos, Portugal
Miguel Semedo, , Interdisciplinary Centre of Marine and Environmental Research, University of Porto, Matosinhos, Portugal
Maria Paola Tomasino, Interdisciplinary Centre of Marine and Environmental Research, University of Porto, Matosinhos, Portugal
Mafalda Baptista, Interdisciplinary Centre of Marine and Environmental Research, University of Porto, Matosinhos, Portugal
Philipp Assmy, Norwegian Polar Institute, Tromsø, Norway
Pedro Duarte, Norwegian Polar Institute, Tromsø, Norway

Keywords: Arctic Ocean, Metabarcoding, Metagenomics, N Cycle, Nitrification

The decrease in Arctic sea ice extent and thickness has significant implications for Arctic primary productivity and biogeochemistry. Given the central role of nitrogen (N) in driving the Arctic Ocean productivity we need to improve our understanding on the role of microbial dynamics in the Arctic N cycle. By combining 16S rRNA metabarcoding with metagenomics and biogeochemical activity we investigated the links between Arctic prokaryotic communities and N functional traits in two transects along Kongsfjorden and Rijpfjorden in Svalbard coast. Results revealed a biogeographic pattern in the distribution of planktonic communities involved in N cyle, with a prevalence of Thaumarchaeota in coastal and open ocean stations with a depth differentiation. In bottom stations Thaumarchaeota co-occur with Nitrospinae (nitrite-oxidizing bacteria), suggesting a syntrophic relationship between Thaumarchaeota and Nitrospinae. Nitrate tend to accumulate in stations where these two groups co-occur and ammonia, the substrate of ammonia oxidation, reach its lower values. In addition, metagenomes showed highly proportion of sequences assigned to ammonia oxidation pathway in the samples for which high relative abundance of Thaumarchaeota was registered and where isotope measurements confirm higher ammonia oxidation activity. We believe that all these results together represented a real case of the importance of Thaumarchaeota and Nitrospinae in N mobilization in the Arctic Ocean.

Monitoring the diversity of eukaryotic phytoplankton communities in the surface waters of the Beaufort Sea

Victoria Jackson, University of Exeter, UK
Estelle Kilias, University of Exeter, UK (currently University of Oxford)
Connie Lovejoy, Université Laval, Canada
Adam Monier, University of Exeter, UK

Keywords: Phytoplankton, Marine Microbiology, Microbial Ecology, Biogeography

Ecologically important phytoplankton form the base of the Arctic Ocean food web as primary producers and contribute to biogeochemical cycling of carbon and other key elements. Previous research has shown that changing environmental conditions may lead to shifts in phytoplankton community assemblages and spatiotemporal species distributions, potentially altering ecosystem function. To investigate the variation in community composition and its drivers across the Beaufort Sea, surface water samples were collected along transects during a month-long cruise in September 2018. Oceanographic measurements, such as temperature, salinity and nutrient levels were also recorded. 18S cDNA sequences from the samples were processed using DADA2 to produce an amplicon sequence variant table. Beta-diversity analyses followed by hierarchical clustering produced four distinct sample clusters, each differing in phytoplankton community composition and diversity. These data highlight the spatial heterogeneity of microbial eukaryote communities in the polar mixed layer within one Arctic sea. Oceanographic drivers of the observed diversity patterns included sea ice concentration and nutrient levels, both of which are affected by global environmental change. These findings may help identify the phytoplankton communities most at risk from the effects of environmental change and predict what the functional implications of this might be.

Theme C: Arctic Climate Dynamics

ID: 97 - Open Session on the Arctic Atmosphere

Conveners

Daniele Bortoli | Institute of Earth Sciences, Evora University

Carlos Toledano | Universidad de Valladolid, Grupo de Óptica Atmosférica (Valladolid, Spain)

Kent Moore | University of Toronto, Canada

A new detailed long-term COSMO-CLM hindcast for Russian Arctic: first results of estimations

Vladimir Platonov, Lomonosov Moscow State University, Moscow, Russia
Mikhail Varentsov, Lomonosov Moscow State University, Moscow, Russia
Anna Shestakova, A.M. Obukhov Institute of Atmospheric Physics of Russian Academy of Sciences, Moscow, Russia

Keywords: COSMO-CLM, Regional Climate Modeling, Hindcast, Arctic Climate, COSMO

This study presents a new detailed hydrometeorological dataset for Russian Arctic region, obtained as a long-term hindcast with the nonhydrostatic atmospheric model COSMO-CLM for 1980–2016 period. The model domain included Barents, Kara, and Laptev seas with ˜12 km grid spacing. The optimal model set up was chosen based on preliminary test simulations for several summer and winter periods with varied options, and includes usage of ERA-Interim reanalysis as forcing data, new model version 5.05 with a so-called ICON-based physics and spectral nudging technique. Since the total volume of dataset is ~120 Tb, we have prepared a subset included 7 main surface variables within the entire 37-years period now and uploaded it to the free available online service (https://figshare.com/collections/Arctic_COSMO-CLM_reanalysis_all_years/5186714). Wind speed and temperature climatology in the new COSMO-CLM data set closely agrees with ERA-Interim reanalysis but has much detailed spatial patterns. The added value of COSMO-CLM data with respect to ERA-Interim is most pronounced in higher wind speeds during downslope windstorms, influence of mountain ranges on temperature patterns including surface temperature inversions. Extreme wind speeds preliminary comparison COSMO-CLM hindcast vs. ASR v.2 reanalysis has shown similar long-term statistics and regional differences in downslope windstorms intensity, over water and coastal areas. Potential applications and plans of further product development are also discussed.

Case study of a polar low simulated with the Canadian Regional Climate Model

Marta Moreno Ibáñez, University of Quebec in Montreal (UQAM), Centre ESCER (Étude et Simulation du Climat à l'Échelle Régionale), Department of Earth and Atmospheric Sciences, Montreal, Canada
René Laprise, University of Quebec in Montreal (UQAM), Centre ESCER, Department of Earth and Atmospheric Sciences, Montreal, Canada
Philippe Gachon, University of Quebec in Montreal (UQAM), Centre ESCER, Department of Geography, Montreal, Canada

Keywords: Polar Low, Maritime Cyclone, Severe Weather, High-Resolution Atmospheric Model

Polar lows (PL) are high-latitude maritime mesoscale weather systems associated with severe weather such as gale-force winds and heavy snow showers. They form over open water near the sea ice margin and near the coastlines. Therefore, they pose a threat to coastal communities, transportation and offshore drilling platforms. Since PLs are small and have a short lifetime, forecasting these systems is challenging. However, the representation of PLs in numerical models has significantly improved with the advent of high-resolution atmospheric models. We present a case study of an PL that formed in 2019. We conducted high-resolution simulations of the PL using the developmental version of the convection-permitting Canadian Regional Climate Model (CRCM6) with a horizontal grid mesh of 2.5 km and 62 levels in the vertical. The simulations were driven by ERA5 reanalysis and were initialised at different times. The best simulation of the PL development was verified against observational data with the aim of assessing the skill of the CRCM6 at reproducing the characteristics of the observed PL. In particular, the results were compared with Infra-Red satellite imagery and scatterometer wind estimates to verify whether the location and intensity of the PL were correctly simulated. The analysis of the simulated fields allows a better understanding of the relevance of the different physical mechanisms involved in the development of this PL.

Does increase in vapour pressure lead to high precipitation in Ny Ålesund?

Athulya R, National Centre for Polar and Ocean Research, Ministry of Earth Sciences, Government of India, Vasco-da-Gama, Goa India
Nuncio M, National Centre for Polar and Ocean Research, Ministry of Earth Sciences, Government of India, Vasco-da-Gama, Goa India

Keywords: Precipitation, Vapour Pressure, Arctic

It is widely accepted that the Arctic amplification has led to an increase in the water vapour pressure in the Arctic which can lead to a high rate of precipitation. The present study is an attempt to understand the variability in the precipitation associated with vapour pressure change in Ny Ålesund, Svalbard, using long-term homogenised radiosonde data and reanalysis data (ERA-5). A seasonal analysis was conducted on the events where vapour pressure exceeds saturation vapour pressure which is a condition for precipitation to occur. Later on, it was investigated whether precipitation happened at the ground level during these events. Over the study period of 27 years (1993-2020), a steep increase of 300(winter)events to 800(summer) events were observed after 2006, whereas the precipitation did not show any significant trend. In the summer of 2013, the count of such events was at the maximum without any notable increase in precipitation. By examining the specific humidity on a seasonal scale, it was realised that the moisture availability in Ny Ålesund has also increased noticeably in winter and fall seasons after 2006, but the available moisture was not getting precipitated as expected. This study points out that a complex mechanism is driving the precipitation events in the regional Arctic and its study is crucial in understanding the local climate dynamics of Ny Ålesund.

Observing water vapor in the Arctic from satellites: a multi-parameter retrieval

Janna E. Rückert, University of Bremen, Bremen, Germany
Raul Scarlat , University of Bremen, Bremen, Germany
Gunnar Spreen, University of Bremen, Bremen, Germany

Keywords: Water Vapor, Optimal Estimation Method, Remote Sensing, Microwave Radiometer

Water vapor is a significant component of the hydrological cycle as well the Earth's atmosphere, being a crucial greenhouse gas. However, obtaining a long-term dataset to monitor trends and variability of water vapor in the Arctic is hampered by the sparseness of in-situ measurements and the challenges for remote sensing retrievals. Space-borne microwave radiometers allow water vapor retrieval over the open ocean but over sea ice the retrievals are more challenging and have higher uncertainties due to high and variable sea-ice emissivity in the microwave domain. Here we present a comparison of a satellite-based water vapor retrieval to in-situ measurements, especially radiosondes, taken during the MOSAiC campaign (mosaic-expedition.org). The retrieval is based on an optimal estimation method to simultaneously retrieve integrated water vapor and six other geophysical parameters, including sea ice concentration, from passive microwave satellite radiometry (Scarlat et al., 2017, 2020). Overall the satellite retrieval can reproduce the temporal water vapor variability and also captures warm air intrusions. During certain periods significant biases are observed, which will be further explained. An improved water vapor dataset will help to quantify how the water vapor feedback contributes to Arctic amplification. Scarlat et al. (2017). IEEE J-STARS, 10, 3934–3947. doi:10.1109/jstars.2017.2739858 Scarlat et al. (2020). J. Geophys. Res. Oceans, 125(3). doi:10.1029/2019JC015749

Reproduction of early twentieth century Arctic warming by global climate models

Mikhail Latonin, Nansen International Environmental and Remote Sensing Centre; Saint Petersburg State University, Saint Petersburg, Russia
Igor Bashmachnikov, Saint Petersburg State University; Nansen International Environmental and Remote Sensing Centre, Saint Petersburg, Russia
Leonid Bobylev, Nansen International Environmental and Remote Sensing Centre, Saint Petersburg, Russia
Richard Davy, Nansen Environmental and Remote Sensing Center, Bergen, Norway

Keywords: Internal Variability, The Arctic, Global Climate Models, Arctic Amplification, Early Twentieth Century Warming

The surface air temperature (SAT) changes in the Arctic are stronger than in the lower latitudes because of the higher sensitivity of high-latitude climate to forcing. This study aims at assessing the performance of global climate models from the phases 5 and 6 of the Coupled Model Intercomparison Project (CMIP5 and CMIP6) in reproducing the observed Arctic warming and cooling periods. The Arctic amplification variability in the multi-model ensemble mean of the 9 models in the CMIP5 pre-industrial control experiment fluctuates around zero, suggesting a crucial role of external forcings in a stronger SAT increase in the Arctic compared to the Northern Hemisphere during the latest decades. The multi-model ensemble mean of the same models in the historical experiment shows a century-long upward trend and clearly reproduces the present-day Arctic amplification. However, there is no consistent response of increasing Arctic amplification in the early twentieth century warming period during the 1920s–1940s in the CMIP5 models. This indicates the 1920s–1940s Arctic warming was unlikely to happen due to external forcing. Using 108 ensemble members from 32 models in the historical experiment we show that the new generation of high-resolution CMIP6 models do not reproduce that warming either, thus posing questions how well the models capture internal climate variability and distinguish it from natural and anthropogenic forcings.

The role of the North Atlantic Oscillation over the Greenland Ice Sheet in a changing climate

Tiago Silva, Institute for Geography and Regional Sciences - University of Graz, Graz, Austria
Sonika Shahi, Institute for Geography and Regional Sciences - University of Graz, Graz, Austria
Jakob Abermann, Institute for Geography and Regional Sciences - University of Graz, Graz, Austria
Wolfgang Schöner, Institute for Geography and Regional Sciences - University of Graz, Graz, Austria

Keywords: Climate, Atmosphere-Surface interactions, GrIS, NAO, SEB

Atmospheric circulation patterns can partially explain the recent trends of mass loss over the Greenland Ice Sheet (GrIS). Understanding the role of climate variability under anthropogenic effects in such a sensible area of the globe is crucial to predict further potential risks worldwide (e.g. sea level rise and thereby increasing flooding of coastal areas). Therefore, it is primordial to investigate the influence of teleconnections on the surface energy budget (SEB) throughout the year over GrIS. After cross-checked with satellite and reanalysis products, 61-year (1959-2019) output of a high spatial resolution (5.5 km) regional climate model is used. Additionally, two periods ("past" and "recent" period) were defined and inter-seasonal variability was characterized based on opposed North Atlantic Oscillation (NAO) phases. The near-surface analysis of all variables contributing to SEB describes regional heterogeneity. Regardless of the season or NAO phase, for some SEB components positive anomalies are seen in the "recent" period with respect to the "past" period. These positive anomalies are likely to be promoting and to keep enhancing GrIS ablation rates in the near future. The magnitude of the anomalies vary geographically, being the northern Greenland region the most affected.

An analysis of surface and air temperature variability in a boreal wetland ecosystem, Whatì, Northwest Territories Canada

Scott Vegter, University of Lethbridge, Lethbridge, Canada

Keywords: Permafrost, Ground Surface Temperatures, Air Temperatures, TTOP, Ground temperature node

Within boreal wetland areas of the discontinuous permafrost zone, there can be high levels of thermal heterogeneity over small distances. Permafrost distribution in these areas has been shown to largely depend on three factors including vegetation type and stage of succession, substrate material, and topographic position index influencing snow and water accumulation. To effectively understand thermal heterogeneity and model it, an air and ground surface temperature network was established in and around the NWT community of Whatì. The objective of this study aims to compare and understand the degree of variability in air and ground surface temperatures in order to better model and predict thermal gradients across ecosystems in order to understand how they might be impacted by future warming. Air, ground surface, and depth temperature (seasonally frozen sites) were collected from 10 select locations around Whatì. Hourly data from September 2019 – August 2020 was analyzed indicating considerable variation over short horizontal distances in freezing and thawing degree-days. Variability illustrates that peat plateaus showed that these areas have the greatest amount of variation while mix-wooded forests that overlay more gravelly soil had the lowest variation in temperature between ground surface and air. These gradient calculations are crucial to modeling permafrost distribution on a large scale in this region. Addressing a large knowledge gap while assisting remote communities.

Anatomy of a Precipitation event in Arctic

M. Nuncio, National Centre for Polar and Ocean Research, Goa, India
K. Satheesan, Cochin University of Science and Technology, Kochi, india
Sourav Chatterjee, National Centre for Polar and Ocean Research, Goa, India
Asutosh Acharya , National Centre for Polar and Ocean Research, Goa, India
M.P. Subeesh , National Centre for Polar and Ocean Research, Goa, India

Keywords: Precipitation, Arctic, Clouds, Radiation

A precipitation event during March 2016 was studied at Ny Alesund Arctic. On 13 th March 2016 intense precipitation was noticed in the Micro rain radar. Coincidently, the atmospheric temperature profiles obtained from a profiling radiometer also showed an increase. The precipitation event during 2016 March 13 was due to two causes. The first one was a southerly wind event that brought heat and moisture to Svalbard. However, this was not sufficient to initiate a precipitation event. But the cloud formation associated with this process enhanced the net radiation warming the air column. The atmosphere over Svalbard experienced peak warming on 13 March between 05-09 UTC, the same time when the precipitation peaked. It is also noted that there was warm/cold advection present at the surface/aloft. However, the surface warm advection was small compared to radiative warming induced by the cloud formation associated with the southerly wind events. The warming resulted in an upward motion and increased the vapour pressure above the saturation vapour pressure resulting in intense precipitation. We also note that the intensity of precipitation was maximum at 200 m above the ground when the peak warming was noticed. Thus whether this suggests the clouds, though resulted in precipitation, has also sublimate a part of the precipitation before it reaches the ground by means of radiative heating need to be investigated more.

Evaporation over glacial lakes of the Schirmacher oasis, East Antarctica

Elena Shevnina, Finnish Meteorological Institute, Helsinki, Finland
Miguel Potes, University of Evora, Evora, Portugal
Margarita Choulga, European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom

Keywords: Glacial Lake, Climate Change, Water Balance, Antarctica

Antarctica is the continent consisting mostly of frozen water. Increasing of air temperature enhances a transition of water from solid to liquid phase (melting) over the margins of the continent ice-sheet. Melted water accumulates in populations of glacial lakes may connected by ephemeral streamflow network developed during warm seasons. Remote sensors and geophysical surveys report a great amount of the glacial lakes over the surface, on rock contact and inside the ice-sheet. Water cycle of the glacial lakes is not well studied, and this study contribute to better understanding of evaporation, which is among other components of water budget of lakes. We use meteorological observations and hydrological observations collected on glacial lakes located in the Schirmacher oasis in two field experiments in 2017–2018 and 2019–2020. The evaporation is evaluated with various methods including the eddy covariance, the semi-empirical equations and the energy budget. We found, that the evaporation over the surface is a significant term of water balance of the epiglacial lakes, and it exceeds the precipitation with a factor of ca 6–10 times. In the numerical experiments show that the evaporation is now underestimated by the modern weather and climate models.

Hydropower risks in rapidly warming Arctic: towards long term prediction of hydrological extremes

Elena Shevnina, Finnish Meteorological Institute, Helsinki, Finland
Timo Vihma, Finnish Meteorological Institute, Helsinki, Finland

Keywords: Climate Extremes, Risks, Hydropower, The Arctic

Due to the rapid climate and environmental change, societies in the Arctic and sub-Arctic are increasingly threatened by risks related to weather and climate extremes, such as floods, droughts, avalanches and storms. Probabilistic forecasts are needed for better awareness of the risks. In a probabilistic forecast, the value (e.g., air temperature, wind speed, river runoff, and snow depth) is given together with its exceedance probability, which allows evaluation of the extremes defined as events of rare occurrence that happens once per 10, 100, or 1000 years. The probabilistic form of the forecasts is particularly important for hydropower managers planning how to use terrestrial water resources in energy production. They also need to keep the hydraulic constructions safe to be able to resist floods. In our study, the probabilistic forecasts are provided for the period of 2020–2050 based on the method of advanced frequency analysis. The probabilistic forecast are given for annual river runoff and spring floods. The estimations are based on hydrological observations on 173 rivers located in Finland, Sweden, Norway, the Russian Federation, Canada and the United States. To estimate the expected warming and precipitation patterns over the prediction period, climate projections available from meteorological models under three Representative Concentration Pathways were used. The strengths and weaknesses of the method of advanced frequency analysis are evaluated.

Methodology and preliminary assessment of changes in abiotic component of the Ob-Taz estuarian ecosystem due to natural and anthropogenic impacts

M.V. Tretiakov, Arctic and Antarctic Research Institute, St. Petersburg, Russia
A.I. Shiklomanov, University of New Hampshire, Durham, USA
L. Cai, Norce Norwegian Research Centre, and Bjerknes Centre for Climate Research, Bergen, Norway
V. Alexeev, University of Alaska, Fairbanks, USA

Keywords: The Ob'-Taz Gulf , Ecosystem, Natural And Anthropogenic Impacts

The Ob'-Taz gulf (OTG) is a very important natural and economic resource for the stable and sustainable development of the most economically and rapidly developing region of the Russian Arctic. Natural and anthropogenic changes in OTG drainage basin have an imminent impact on various hydrological processes in the gulf. Changes in abiotic estuarian processes, forming the position of the frontal zones, depth of the halocline location, depth of convection, ice phases and other characteristics affect both water management and the biotic component of the ecosystem effecting on related industries. To understand historical abiotic changes in OTG and quantify contributions of different factors to these changes we applied multi-model approach using atmospheric, watershed and estuarine models. ERA Interim Reanalysis fields provided boundary conditions to the Weather Research and Forecasting (WRF) model adapted for Arctic regions used to simulate detailed atmospheric characteristics for OTG watershed. Climate variables from WRF were used to drive the UNH Water Balance Model (WBM) with extensive modules designed to capture the influences of humans. Water and energy fluxes to OTG simulated with WBM along with climatic variables from WRF were used to run recently developed OTG hydrodynamic model. We present the preliminary results of our multi-model simulations for the study region over 1980-2018. This research was supported by RFBR grant 18-05-60192.

Precipitation types and winds in Ny Alesund

Naveen Nandanan, Cochin University of Science and Technology, Kochi, India
Nuncio Murukesh, National Centre for Polar and Ocean Research, Goa, India

Keywords: Precipitation, Precipitation Types, Atmospheric Circulation

Precipitation types with respect to wind direction are studied using the data from OTT PARSVEL 2 from December 2018-February 2019 at Ny-Ålesund in Svalbard archipelago- Arctic. Hail events were the least frequent ones however these less frequent hail events were the most intense events in the winter. In all three months, slight and moderate snow events were the most frequent events and the hail events were the most intense events. The second most intense events were heavy snow events. The most intense event, hail was associated with the south-westerlies. Intense precipitation events were associated with south-westerlies and frequent precipitation events were associated with south- easterlies, south-westerlies and north-westerlies. These results are further investigated w.r.t the atmospheric circulation patterns in the northern hemisphere. Most of the time, intense events are a part of southerly wind events associated with high-pressure systems over northern Europe. However, we note that the high-pressure systems displaced to the west are more efficient in forming precipitation events in Ny Alesund.

Temperature inversions in Zackenberg region, Northeast

Sonika Shahi, Department of Geography and Regional Science, University of Graz, Austria
Jakob Abermann, Department of Geography and Regional Science, University of Graz, Austria & Austrian Polar Research Center, Austria
Tiago Silva, Department of Geography and Regional Science, University of Graz, Austria
Georg Heinrich, Department of Geography and Regional Science, University of Graz, Austria
Kirsty Langley, Asiaq-Greenland Survey, Nuuk, Greenland
Signe Hillerup Larsen, Geological Survey of Denmark and Greenland, Denmark
Wolfgang Schöner, Department of Geography and Regional Science, University of Graz, Austria & Austrian Polar Research Center, Austria

Keywords: Inversions, Weather Patterns,Greenland

The Arctic planetary boundary layer provides a favorable condition for the formation of temperature inversions. The surface-based inversions (SBI) are frequent during the polar night, which strongly decouples the surface from the air above. Thus, better understanding spatial and temporal variability of SBI are crucial for studies on the variation of the Arctic biotic and abiotic environment such as vegetation, glaciers, or snow cover. Here, we explore the spatio-temporal variations of SBI in the Zackenberg region (Northeast Greenland). In total, we use the dataset from 9 automatic weather stations (AWS) distributed at different elevations and over different surface types: 4 AWS are located on local glaciers and icecaps; 5 AWS are over gravel or tundra surfaces. In this respect, we pursue the following objectives: to better understand the relevance of SBI for simulating the glacier melt, to quantify some of the physical mechanisms responsible for the variation of SBI, and to estimate the role of atmospheric circulation in controlling the change of air temperature distribution in the Zackenberg region, and hence SBI. The preliminary results show inter-annual variability in slope lapse rate, and thereby its varying effect on simulating the air temperature above the glacier. Furthermore, the SBI becomes weaker with increasing wind speed, because of turbulent mixing. Finally, we derive weather patterns for Greenland and estimate its role in controlling temperature distribution.

ID: 64 - Arctic clouds, aerosols and climate effects

Conveners

Claudia Mohr | Stockholm University

Paul Zieger | Stockholm University

Sophie Haslett | Stockholm University

Arctic Mixed-Phase Clouds: The NASCENT 5-Days Case Study with HoloBalloon

Julie Pasquier, Institute for Atmospheric and Climate Science, ETH Zurich, Switzerland
Jörg Wieder, Institute for Atmospheric and Climate Science, ETH Zurich, Switzerland
Guangyu Li, Institute for Atmospheric and Climate Science, ETH Zurich, Switzerland
Robert O. David, Department of Geosciences, University of Oslo, Norway
Tim Carlsen, Department of Geosciences, University of Oslo, Norway
Rosa Gierens, Institute for Geophysics and Meteorology, University of Cologne, Germany
Kerstin Ebell, Institute for Geophysics and Meteorology, University of Cologne, Germany
Marion Maturilli, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Roland Neuber, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Paul Zieger, Department of Environmental Science, Stockholm University, Sweden
Ulrike Lohmann, Institute for Atmospheric and Climate Science, ETH Zurich, Switzerland
Jan Henneberger, Institute for Atmospheric and Climate Science, ETH Zurich, Switzerland

Keywords: Arctic, Mixed-Phase Clouds, Secondary Ice Production, INP

In-situ cloud microphysical measurements were conducted in Ny-Ålesund, Svalbard, in autumn 2019 as part of the NASCENT campaign. We used a holographic cloud probe imaging cloud droplets and ice crystals mounted on a tethered balloon system. Additionally, ambient ice nucleating particles and cloud condensation nuclei were quantified, remote sensing instruments were profiling the troposphere, and radiosondes were launched. We will present the cloud microphysical properties of mixed-phase clouds (MPCs) observed from November 8 to 12, 2019. During the two first days, a low-pressure system influenced the formation of the MPCs. On Nov. 10, despite temperatures below -15°C, the glaciation of the cloud was inhibited by the limited ambient INP concentration and the non-occurrence of secondary ice processes. Nov. 11 was characterised by microphysical variations in the MPCs. Some regions showed heavily rimed particles, some regions concentrations of elongated columns up to 150 L-1 and some regions frozen droplets, suggesting droplet fragmentation as an active secondary ice process. On Nov. 12, a MPC evolved gradually from a turbulent state, in which ice crystals grew through riming to a state where concentrations up to 90 L-1 of small pristine hollow columns were observed together with frozen droplets. This indicates droplet fragmentation and the subsequent growth of splinters to columns. These observations help quantifying the importance of processes relevant for ice crystal formation.

Colder summers and warmer winters: Role of sulfate aerosols in modulating Arctic climate

Asutosh Acharya, ESSO-National Centre for Polar and Ocean Research (NCPOR), Ministry of Earth Sciences, GOA, India
Suvarna Fadnavis, Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, Pune, India
Nuncio Murukesh, ESSO-National Centre for Polar and Ocean Research (NCPOR), Ministry of Earth Sciences, GOA, India

Keywords: Arctic Summer Cooling And Winter Warming, Cloud Radiative Forcing, Surface Temperature. Climate Change

The Arctic is warming as a consequence of human-induced greenhouse gas emissions play an essential role in climate change. Our study shows that local and global emission of sulfate aerosols, which offset the global warming signal, also produce a measurable impact on the climate of the Arctic. Here, using the Community Earth System Model (CAM5) experiments, with emission enhancement of sulfate (1) five-fold globally, (2) ten-times over Asia, and (3) ten-times over Europe, we show that emission enhancement modulates the Arctic climate via cloud radiative forcing. The enhancement of sulfate emission, globally or regionally, induces colder summers and warmer winters in the Arctic. However, global and European emissions play a dominant role in cooling (0.6 K) while Asian emissions in warming (1K) the Arctic surface temperature. The cooling/warming is associated with negative/positive cloud radiative forcing. The summertime increase in low and mid-level clouds, induced by sulfate emission, favours the solar dimming effect that reduces the downwelling radiation to the surface leads to surface cooling. In contrast, warmer winters are associated with the high-level clouds that induce positive radiative forcing at the TOA. This study points to international strategies being implemented to control sulfate emission to combat Air Pollution will produce significant Climate Change in the Arctic

Elucidating Ice Nucleating Particle Concentrations in the Arctic: Investigating Predictability from Parameterizations and Fresh Snow Samples

Jörg Wieder, Institute for Atmospheric and Climate Science, ETH Zürich, Zurich, Switzerland
Guangyu Li, Institute for Atmospheric and Climate Science, ETH Zürich, Zurich, Switzerland
Julie Pasquier, Institute for Atmospheric and Climate Science, ETH Zürich, Zurich, Switzerland
Kerstin Ebell, Institute for Geophysics and Meteorology, University of Cologne, Cologne, Germany
Robert O. David, Department of Geophysics, University of Oslo, Oslo, Norway
Jan Henneberger, Institute for Atmospheric and Climate Science, ETH Zürich, Zurich, Switzerland
Ulrike Lohmann, Institute for Atmospheric and Climate Science, ETH Zürich, Zurich, Switzerland
Zamin A. Kanji, Institute for Atmospheric and Climate Science, ETH Zürich, Zurich, Switzerland

Keywords: INP, Aerosol, Clouds, Microphysics, Modelling

Climate change is most pronounced in the Arctic. Amongst other factors, climate feedbacks are linked to the ice-to-liquid ratio of hydrometeors in clouds. Primary ice crystals in Arctic mixed-phase clouds form on ice nucleating particles (INPs), which need to be accurately predicted to represent cloud phase feedbacks in the Arctic. Here we present a model to predict INP concentration (INPC) in the remote Arctic atmosphere, for which a parameterization does not yet exist. We also investigated how INPC can be estimated from analyzing fresh snow samples. In autumn 2019 and spring 2020, INPC were monitored in-situ at Ny-Ålesund (Svalbard, Norway) during two field campaigns in the framework of NASCENT. Combining offline drop-freezing technique and an online continuous flow diffusion chamber, INPC from 0 °C to -20 °C and at -30 °C respectively, were measured at high temporal resolution over a period of six weeks per season. While no seasonal differences in INPC were found in our study, two separate parameterizations developed for dust and marine rich air masses were able to predict 80% of the INPCs within a factor 10 for each season. Since neither of these parameterizations were developed for remote background conditions or Arctic haze aerosol, we present a new approach using the assumption of log-normally distributed INPC to predict ambient background INPC for the Arctic. With this we are able to predict over 90 % of the INPCs within a factor of 10 for both seasons. By comparing in-situ ambient INPCs in air to INPCs retrieved from fresh snow fall we showed that this method can be used to estimate INPC and benefits further from remotely retrieved cloud water content. We found that a median cloud water content of ~ 0.2 g/m3 was required to better predict INP concentrations from snow samples, which was similar to the value reported from cloud radar data.

Impact of warm air mass intrusions on atmospheric chemistry and microphysics – Observations during MOSAiC

Julia Schmale, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland
Lubna Dada, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland
Ivo Beck, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland
Tuija Jokinen, University of Helsinki, Helsinki, Finland
Lauriane Quéléver, University of Helsinki, Helsinki, Finland
Tiia Laurila, University of Helsinki, Helsinki, Finland

Keywords: MOSAiC, Aerosol, Trace Gases, Warm Air Mass Intrusion, Cloud Condensation Nuclei

The Arctic is warming twice as fast as the global average. The contribution of aerosol-cloud interactions is still uncertain. Globally, clouds have a cooling effect, because they reflect solar radiation over low albedo surfaces. Over the Arctic ocean, clouds have a net warming effect over the high albedo sea ice. To understand the radiative effect of clouds, their formation and optical properties need to be known. Those two aspects depend on aerosol particles, which serve as cloud condensation nuclei (CCN) or ice nucleating particles. The aerosol regime over the Arctic ocean features strong seasonal variability: The winter is dominated by Arctic haze and remote emissions, and the summer by low particle concentrations and local processes. Summertime measurements over the Arctic ocean have been carried out during a number of previous cruises. In winter, the haze situation is so widespread that much information is available from permanent land-based observatories. What is missing is a characterization of the aerosol regime during transition seasons. Here, we report preliminary results from aerosol and trace gas measurements during the MOSAiC expedition. Warm air mass intrusions from the North Atlantic were observed in April. They did not only lead to higher temperatures and moister air. But they also changed the trace gas and aerosol chemical composition as well as microphysical properties, such as the size distribution, drastically, with implications on the CCN availability.

Modeling marine biogenic aerosol precursors in the Arctic Ocean

Moritz Zeising, Alfred Wegener Institute Helmholtz Center for Polar and Marine Research, Bremerhaven, Germany
Judith Hauck, Alfred Wegener Institute Helmholtz Center for Polar and Marine Research, Bremerhaven, Germany
Bernd Heinold, Leibniz Institute for Tropospheric Research, Leipzig, Germany
Svetlana Losa, Alfred Wegener Institute Helmholtz Center for Polar and Marine Research, Bremerhaven, Germany
Silke Thoms, Alfred Wegener Institute Helmholtz Center for Polar and Marine Research, Bremerhaven, Germany
Sebastian Zeppenfeld, Leibniz Institute for Tropospheric Research, Leipzig, Germany
Astrid Bracher, Alfred Wegener Institute Helmholtz Center for Polar and Marine Research, Bremerhaven, Germany

Keywords: Arctic Ocean, Biogeochemical Model, Aerosol Precursor, TEP

The climate radiative effect of Arctic clouds depends on the presence of liquid or ice as cloud phase, which, among other things, is determined by the abundance of aerosols acting as cloud condensation or ice nuclei. Biogenic aerosols originate from local phytoplankton production in leads or open water. Based on recent publications, we choose acidic polysaccharides (PCHO) and transparent exopolymer particles (TEP) as tracers for biogenic aerosol precursors in the upper ocean layer. We incorporate processes of algal PCHO excretion, PCHO aggregation into TEP, as well as TEP degradation into the ecosystem model REcoM2 coupled to the finite-volume sea ice ocean circulation model FESOM2 with a resolution up to 4 km in the Arctic realm. REcoM2 describes the biogeochemical processes with two functional phytoplankton and one zooplankton class. Especially the ascending and enrichment of TEP to the surface microlayer, but also sinking of larger aggregates, are processes, which will be considered for model improvement. We are aiming at reproducing TEP distribution and seasonality patterns in the Arctic Ocean over two decades. Evaluation of the model results will be done using in-situ measurements (FRAM, MOSAiC). Ultimately, the modeled aerosol precursors will be used as an important input in an accompanied project, in which the net aerosol radiative effects will be quantified with an atmospheric aerosol-climate model. This work is part of the DFG TR 172 Arctic Amplification.

Molecular composition of semi-volatile aerosols in the summertime central Arctic Ocean using FIGAERO-CIMS

Karolina Siegel, Department of Meteorology/Department of Environmental Science, Stockholm University, Sweden
Linn Karlsson, Department of Environmental Science, Stockholm University, Sweden
Paul Zieger, Department of Environmental Science, Stockholm University, Sweden
Andrea Baccarini, Laboratory of Atmospheric Chemistry, Paul Scherrer Institute, Villigen PSI, Switzerland
Julia Schmale, Laboratory of Atmospheric Chemistry, Paul Scherrer Institute, Villigen PSI/School of Architecture, Civil and Environmental Engineering, École Polytechnique Fédérale de Lausanne, Switzerland
Michael Lawler, Department of Chemistry, University of California, Irvine, United States
Matthew Salter, Department of Environmental Science, Stockholm University, Sweden
Caroline Leck, Department of Meteorology, Stockholm University, Sweden
Annica M. L. Ekman, Department of Meteorology, Stockholm University, Sweden
Ilona Riipinen, Department of Environmental Science, Stockholm University, Sweden
Claudia Mohr,Department of Environmental Science, Stockholm University, Sweden

Keywords: Aerosol Chemical Composition, Trace Gases, Aerosol-Cloud Interactions, Chemical Ionization Mass Spectrometry

The central Arctic Ocean in summer has a pristine atmosphere with very low aerosol particle concentrations. Still, large knowledge gaps remain regarding the sources and properties of Arctic aerosols and their effects on clouds and climate. We measured the molecular composition of semi-volatile compounds (= 200°C) in aerosol samples collected at 88.6-82.3°N in September 2018 during the Arctic Ocean 2018 expedition with the Swedish Icebreaker Oden. Analysis was performed using a High Resolution Time-of-Flight Chemical Ionization Mass Spectrometer with a Filter Inlet for Gases and AEROsols (FIGAERO-HRToF-CIMS). We found a significant signal from both organic and inorganic compounds, likely from primary and secondary marine sources, where fatty acids had a large contribution (12.5 ± 5.9%) to the sampled organic mass. As fatty acids are known to be surface active due to their highly polar structures, these compounds could be important for cloud formation and cloud droplet stability. Several of the sulfuric compounds are associated with the oxidation of dimethyl sulfide (DMS), a gas released by marine microorganisms. Non-sea-salt sulfate (nss-SO42-) aerosols at lower latitudes are also known to play a role in cloud formation due to their high hygroscopicity (water-attracting ability).This is the first time the FIGAERO-HRToF-CIMS has been used to investigate the composition of aerosols in the central Arctic, and our results further demonstrate its suitability for this purpose.

Aircraft measurements of ice-nucleating particles and aerosol size-resolved composition in the Western North American Arctic

Alberto Sanchez-Marroquin, School of Earth and Environment, University of Leeds, Woodhouse Lane, Leeds, LS2 9JT, UK
Sarah Barr, School of Earth and Environment, University of Leeds, Woodhouse Lane, Leeds, LS2 9JT, UK
Ian T. Burke, School of Earth and Environment, University of Leeds, Woodhouse Lane, Leeds, LS2 9JT, UK
James B. McQuaid, School of Earth and Environment, University of Leeds, Woodhouse Lane, Leeds, LS2 9JT, UK
Benjamin J. Murray, School of Earth and Environment, University of Leeds, Woodhouse Lane, Leeds, LS2 9JT, UK

Keywords: Ice-Nucleation, Dust, INP, Mixed-Phase Clouds

Ice-related processes in mixed phase clouds, such as heterogeneous ice formation in the presence of ice-nucleating particles (INPs), play an important role in the climate system. However, knowledge of the sources and concentrations of INPs, particularly for the Arctic region, is still insufficient. Previous studies suggest that dust from lower-latitude deserts or local sources, as well as marine organic material are the main contributors to the Arctic INP population. However, more research is necessary in order to elucidate the overall and relative importance of these sources. Here, we present a new dataset of aircraft based INP measurements and aerosol composition in the Western North American Arctic. Aerosol samples were collected on top of filters from the FAAM Bae-146 research aircraft. Samples were analysed using droplet-freezing assays to determine INP concentration and Scanning Electron Microscopy (SEM) to determine size-resolved composition. Measured INP and aerosol concentrations were low. SEM analysis indicates that our samples were dominated by sea spray aerosol and mineral dust. Further analysis shows that the mineral dust is the most important component for the ice-nucleating ability of our samples. These results suggest that dust is a relevant source of INPs in the Arctic. Given the sizes of the dust and the time of the year, it is likely that this dust was transported from lower-latitude deserts. However, we cannot rule out the possibility that closer sources of high-latitude dust contribute to the dust budget at the region. Hence, further work is necessary to investigate the contribution of the different dust sources to the Arctic INP population.

Clustering derived Black Carbon size distribution at Zeppelin station, Svalbard and investigating source contribution with airmass trajectories

Roxana S. Cremer, Stockholm University, Stockholm, Sweden
Peter Tunved, Stockholm University, Stockholm, Sweden
Johan Ström, Stockholm University, Stockholm, Sweden
Dan G. Partridge, Stockholm University, Stockholm, Sweden

Keywords: Black Carbon, Size Distribution, Trajectory, Source Contribution, Data Mining

Black carbon (BC) particles originate from incomplete combustion of biomass and fossil fuels. They are known to contribute to the warming of Earth's climate due to radiative effects and aerosol-cloud interactions. The lifetime of sub-micron BC in the troposphere is in the order of days-weeks. Through interaction with other airborne compounds, the hydrophobic nature of BC gradually becomes more hygroscopicity and thus available as CCN. An assessment of the large-scale impact on clouds and climate, requires detailed insights about the lifecycle of BC in the atmosphere, understanding sources for BC, transport, transformation, and removal processes are. All these processes are tightly linked to particle size, making knowledge regarding how BC distributes over a given size range substantial. In a previous study we explored statistical methods to attribute BC mass according to particle size (in review). Combining these results with cluster analysis of long term record of aerosol number size distribution (NSD) observations from Zeppelin Observatory it was shown that the method produced reasonable results for a majority of observations. However, the cluster characteristic of NSD associated with high level of pollution (mainly springtime), presented additional challenges as the methodological approach gave an average BC size distribution that was unrealistic. In the current study we focus on these inconsistencies; additional analytical methods are introduced to resolve source-receptor relationships and defining transport characteristics using extensive trajectory analysis. The analysis provides insides of the processes along the travel path to the receptor location and resolving key transport routes for the BC fraction to the Arctic.

Comparison of characteristics of the new particle formation (NPF) event in the Arctic, urban, and agricultural environments

Haebum Lee, Gwangju Institute of Science and Technology (GIST), Gwangju, Korea.
Kihong Park, Gwangju Institute of Science and Technology (GIST), Gwangju, Korea.

Keywords: Aerosol, Nano-Particles, New Particle Formation

New particle formation (NPF), which significantly increases the number of sub-micrometer particles in the ambient atmosphere, has been observed in various environments. The newly formed nanoparticles have the potential to form CCN affecting cloud formation. It has been reported that the NPF was affected by preexisting aerosols, RH, precursor gases. The sulfuric acid (H2SO4) which is one of the precursor gases plays a key role of nucleation and subsequent growth of particles with being formed as binary nucleation (H2SO4-H2O), ternary nucleation (H2O-H2SO4-NH3). The NPF event has been reported regardless of pollution levels. This study compared the characteristics of NPF events at the Arctic (Ny-Alesund, Norway), urban (Gwangju, Korea), and agricultural (Gimje, Korea) sites by examining the NPF-related parameters (e.g. formation rate, growth rate). The NPF occurrence frequencies at Ny-Alesund, Gwangju, and Gimje sites for each measurement period were 23%, 42%, and 53% days, respectively. The NPF event at Gwangju site was observed frequently in spring, and at the Arctic site was observed frequently in summer. The NPF duration time was lowest at Gimje site, and highest at the Arctic site. The growth and formation rate during the NPF period were highest at Gimje site, and lowest at the Arctic site. The growth rates at Gwangju and Gimje sites were several times higher than at the Arctic site, and the formation rates were several tens of times higher.

Ice Formation Processes in climate models

Georgia Sotiropoulou, Stockholm University/ Ecole Polytechnique Federale de Lausanne, Stockholm, Sweden
Annica Ekman, Stockholm University, Stockholm, Sweden
Athanasios Nenes, Ecole Polytechnique Federale de Lausanne, Lausanne, Switzerland

Keywords: Arctic Clouds, Ice Microphysics, Secondary Ice Production, Climate Model

Mixed-phase clouds in polar regions play a crucial role in surface ice melting. To accurately predict their radiative impact in climate models, an accurate representation of their microphysical structure is required. However, cloud ice content is generally underpredicted in models, when primary ice nucleation is constrained with measurements. Apart from uncertainties in primary ice formation, another possible explanation for this discrepancy is that most models underestimate secondary ice production. In this study we implement missing secondary ice production mechanisms in the Norwegian Earth System Model version 2 and investigate their impact on the representation of Arctic clouds observed at Ny-Alesund.

One-year-long measurements of the chemical composition of aerosol particles and trace gases involved in cloud formation at the Zeppelin Observatory, Svalbard

Yvette Gramlich, Department of Environmental Science, Stockholm, Sweden
Sophie Haslett, Department of Environmental Science, Stockholm, Sweden
Karolina Siegel, Department of Environmental Science, Stockholm, Sweden
Radovan Krejci, Department of Environmental Science, Stockholm, Sweden
Paul Zieger, Department of Environmental Science, Stockholm, Sweden
Claudia Mohr, Department of Environmental Science, Stockholm, Sweden

Keywords: Aerosol-Cloud Interactions, Chemical Composition, Trace Gases, NASCENT, Zeppelin Observatory

Clouds play an important role in the amplified Arctic warming, with changes often being driven by aerosol particles acting as cloud condensation nuclei (CCN), or ice nucleating particles (INP). In addition, gaseous compounds can interact with hydrometeors and thereby influence cloud properties. This study aims to better understand the chemistry of aerosol-cloud interactions and hence the role of aerosols and clouds in the Arctic. During the course of a full year (fall 2019 – fall 2020), a filter inlet for gases and aerosols coupled to a high-resolution time-of-flight mass spectrometer (FIGAERO-CIMS) using iodide as reagent ion was deployed at the Zeppelin Observatory, Svalbard (480 MSL). The FIGAERO-CIMS was connected to an inlet switching between a whole air inlet and, during conditions when the station was engulfed in clouds, a counterflow virtual impactor inlet sampling cloud residual particles only. This setup allows for the investigation of the chemical properties of trace gases, aerosol particles and cloud residuals at the molecular level, with main focus on the organic fraction. First results show that during cloud events, some gaseous compounds are scavenged by the cloud particles whilst others are not. In this presentation we will discuss the chemical characteristics of the gases exhibiting different behavior during clear sky and cloudy conditions, and the implications for partitioning of organic compounds between the gas, aerosol particle and cloud hydrometeor phase.

Studying the role of bioaerosols in the formation of Arctic clouds

Gabriel P. Freitas, Stockholm University, Stockholm, Sweden
Radovan Krejci, Stockholm University, Stockholm, Sweden
Paul H. Kaye, University of Hertfordshire, Hatfield, United Kingdom
Warren Stanley, University of Hertfordshire, Hatfield, United Kingdom
Paul Zieger, Stockholm University, Stockholm, Sweden

Keywords: Bioaerosols, Fluorescence, Arctic, Clouds

Primary bioaerosols are regarded as excellent ice nucleating particles and as such influence cloud formation. In the Arctic, as climate change changes the sources of aerosols, bioaerosols might begin to play a bigger role. Within the Ny-Ålesund Aerosol Cloud Experiment (NASCENT) 2019-2020, we are determined to investigate how bioaerosols impact Arctic cloud formation. To do so, we deployed a Multiparameter Bioaerosol Spectrometer (MBS) at Zeppelin Observatory situated 480 meters above sea level in the Svalbard archipelago. The MBS is an instrument designed to assess the biological origin of coarse particles (size = 1 µm) by using a combination of scattering and fluorescence spectrometry techniques. The MBS is situated behind a ground-based Counterflow Virtual Impactor (gCVI) inlet, which is capable of aerodynamically sampling only cloud droplets or ice crystals removing interstitial aerosol. During clear conditions, the MBS is sampling from the standard whole-air inlet. This unique set-up allows to separately study the contribution of bioaerosols acting as cloud nuclei. Sampling has started in June 2019 and is still ongoing. Distinct events of potentially biological particles have been observed that originated from the marginal ice zone, which is known to be a biological active area. Other strong events originated from the Eurasian continent. Here we will present a first summary on the results of our long-term dataset of bioaerosols in the Arctic.

ID: 100 - Changing Arctic Coasts

Conveners

Bianca Perren | British Antarctic Survey

Kwangchul Jang | Division of Glacier Environment Research, Korea Polar Research Institute

Joshua Evans | U. of New-Brunswick – ArcTrain

Jennifer Wesselbaum | U. of New-Brunswick – ArcTrain

Holocene rise and fall of the North Water polynya: a climate-sensitive Arctic sea-ice ecosystem

Sofia Ribeiro, Geological Survey of Denmark and Greenland, Copenhagen, Denmark
Audrey Limoges, University of New Brunswick, Fredericton, Canada
William T. Colgan, Geological Survey of Denmark and Greenland, Copenhagen, Denmark
Kaarina Weckström, Geological Survey of Denmark and Greenland, Copenhagen, Denmark
Rebecca Jackson, Geological Survey of Denmark and Greenland, Copenhagen, Denmark
Guillaume Massé, Station Marine de Concarneau, Concarneau, France
Thomas A. Davidson, Aarhus University, Silkeborg, Denmark

Keywords: Arctic Sea Ice, Marine Ecosystems, Paleoceanography, Baffin Bay, Inuit

Polynyas are relatively ice-free areas surrounded by sea ice and sustained by atmospheric and oceanic forcing. These are hotspots for marine biological productivity and biodiversity, comparable to oases in terrestrial deserts. The North Water (NOW) or Pikialasorsuaq is the largest arctic polynya, situated between Greenland and Canada. It is historically one of most productive ecosystems of the Arctic Ocean, and its living resources have supported Pre-Inuit and Inuit groups for millennia. In order to achieve reliable future predictions, a thorough understanding of the response of this unique ecosystem to past climate fluctuations is required. Using proxy-methods applied to marine sediment cores, we reconstructed Holocene changes in sea ice and primary productivity in the NOW. Our results, alongside with paleolimnological studies on Little Auk colony dynamics, suggest a polynya onset at ca. 4.4 cal ky BP, coeval with the first arrival of humans in Greenland. Rapid ocean-atmosphere climate shifts during the late Holocene resulted in polynya instability from ca. 2.7 cal ky BP. The fact that Greenland was abandoned at this time (until the arrival of late Dorset groups from Canada ca. 900 years later) further supports the idea that it temporarily failed to act as a biological hotspot and reliable ice bridge. Temperatures in the High Arctic now exceed those of the mid-Holocene, and the demise of the NOW seems a plausible future scenario that calls for mitigation measures.

Genetic signatures from glass houses deposited millennia ago: applying a new biological lens to multi-proxy paleoenvironmental reconstructions in the North Water polynya (Pikialasorsuaq) with targeted sedaDNA metabarcoding of Arctic diatoms

Joshua R. Evans, University of New Brunswick, Fredericton, Canada
Gary W. Saunders, University of New Brunswick, Fredericton, Canada
Sofia Ribeiro, Geological Survey of Greenland and Denmark, Copenhagen, Denmark
Sara Harðardóttir, Université Laval, Québec, Canada
Audrey Limoges, University of New Brunswick, Fredericton, Canada

Keywords: North Water, Diatoms, DNA, Paleooceanography, Primary Production

The North Water (NOW) polynya (Pikialasorsuaq) is the largest polynya in the Arctic and reforms each year in northern Baffin Bay. The formation and stability of the NOW relies partly on the resilience of ice bridges that form in the Nares Strait during Arctic winter. Multiyear sea ice originating in the Arctic Ocean becomes congested in Nares Strait, and as the polynya forms downwind, new open waters provide optimal conditions for spring phytoplankton blooms that promote the regional biodiversity. Specifically, diatoms play a key role in this productivity and little is known regarding the response or potential adaptations of these organisms to large-scale climatic changes. Sedimentary ancient DNA (sedaDNA) is emerging as a powerful tool to increase the detection and resolution of taxa over long temporal periods. In this presentation, I will present preliminary results from bioinformatic and experimental data that highlight the potential utility of targeted sedaDNA metabarcoding to resolve temporal changes of diatom diversity in the NOW polynya during the last ~3800 years. The resulting long-term temporal dataset will be compared with existing multi-proxy datasets and it is expected these genetic data will help elucidate relationships between diatom species composition and inferred environmental conditions. Ultimately this work also will enable better predictions of Arctic diatom responses in a rapidly changing climate.

Northeast Greenland polynyas: a Holocene perspective from the Sirius Water

Rebecca Jackson, Geological Survey of Denmark and Greenland (GEUS), Copenhagen, Denmark
Anna Bang Kvorning, Geological Survey of Denmark and Greenland (GEUS), Copenhagen, Denmark
Marit-Solveig Seidenkrantz, Aarhus University, Aarhus, Denmark
Christof Pearce, Aarhus University, Aarhus, Denmark
Sofia Ribeiro, Geological Survey of Denmark and Greenland (GEUS), Copenhagen, Denmark

Keywords: Sirius Polynya, Greenland, Holocene, Foraminifera, Primary Production

Human occupation in the harsh northeast Greenland environment is intrinsically linked to the availability of natural resources. Polynyas, recurrent areas of open water that punctuate a coastline otherwise characterised by fast ice, are unique hotspots of marine primary production. Three recurrent polynyas form along the northeast Greenland coast; the North East Water, the Scoresby Sund and the Sirius Water (SIW). The presence of the SIW and the huge numbers of marine mammals that migrate there is key to the arrival of Pre-Inuit around 4,500 years ago and the islands that flank the polynya host the densest archaeological evidence from the Thule culture in northeast Greenland, present throughout the Little Ice Age. Aside from archaeological evidence and beyond the observational era however, the dynamics of the SIW are virtually unknown. We investigated a newly-recovered sediment core from the central region of the modern SIW, following a multi-proxy approach including foraminifera assemblages, sedimentology, and biogeochemical indicators. We will present the first data from this region on Holocene changes in primary production and bottom water conditions. Only with insights from this new record and others can the resilience of the northeast Greenland polynyas in the face of past rapid climate change be determined and their vulnerability to future changes assessed.

Tracking the Atlantic multidecadal oscillation with highly resolved paleoclimate records

Francois Lapointe, University of Massachusetts, Amherst, United States
Raymond S Bradley, University of Massachusetts, Amherst, United States
Michael Retelle, Bates College, Lewiston, United States

Keywords: Atlantic Multidecadal Oscillation, Arctic Varves, Large-Scale Teleconnections, Global Warming

The Atlantic multidecadal oscillation (AMO) plays an important role on temperature and precipitation anomalies in the Northern Hemisphere. Yet, its influence on Arctic regions remains poorly understood because of the scarcity of weather stations. Here, using well dated annually laminated sediment from lakes, we show that the imprint of the AMO can be uncovered in these highly resolved sedimentary archives. Two lakes located in the High-Arctic are discussed: Linnevatnet Lake on Svalbard, and South Sawtooth Lake (SSL) on Ellesmere Island, Canada. The latter lake revealed significant correlation with instrumental Atlantic sea surface temperatures (SSTs) allowing SSTs to be reconstructed for the past 2900 years. The reconstructed AMO highlights periods of high coherence with other subdecadal marine records in a wide swath of the Atlantic giving confidence in the reconstructed AMO. At Linnevatnet Lake in Svalbard, the record also shows a strong AMO signal, but the coherence with our reconstructed AMO at SSL is not strong. We discuss that the discrepancies among records may be related to the regional influence of atmospheric variability on these two distant regions, particularly associated with the polar vortex. In this case, the forcing of the Polar/Eurasian pattern is prevalent in Svalbard, while the North Atlantic Oscillation has a stronger influence in the Canadian Arctic.

Historical representations of winter on the coast of Nunatsiavut (Canada), from 1770 to 1950

Marie-Michèle Ouellet-Bernier, University of Quebec in Montreal, Montreal, Canada
Anne de Vernal, University of Quebec in Montreal, Montreal, Canada
Daniel Chartier, University of Quebec in Montreal, Montreal, Canada

Keywords: Historical Climatology, Sea-Ice, Documentary Sources, Discursive Sourcesnunatsiavut

Like many subarctic and arctic regions, the coast of Nunatsiavut is facing climatic changes that have major impacts on physical environment and on human livelihood. Recent sea ice lost limited people mobility and traditional activities, such as hunting and fishing. This study aims to document winter climate variations from 1770 to 1950 from a human perspective. An approach based on discursive, documentary and instrumental sources allows the presentation of a unique portrait of historical climate allowing to resolve season scale conditions. The first part of this research provides mentions of exceptional weather events in winter as extracted from discursive sources (e.g., life stories, novels, journals). Authors focus mostly on socio-economic vulnerabilities, such as delayed fishing and sailing seasons, difficulty of mobility on ice and material damages in storms. The second part shows the duration of sea-ice season based on winter freeze-up and summer break-up along the coast of Nunatsiavut based on documentary sources published by Moravian missionaries. The third part is a record of instrumental winter temperature collected by the First International Polar Year initiative that covered the period from 1880 to 1939. The data show a succession of colder and warmer winter conditions with frequency of 10-20 years during the 19th century. The overall data set suggests a relationship between unfavorable climate conditions at regional scale and the positive phases of the North Atlantic Oscillation in winter.

Marked 20th-century regional warming in the Hudson Bay Lowlands shown in a Holocene lake record

Kathryn E. Hargan, Memorial University of Newfoundland, St. John's, Canada
Kathleen M. Rühland, Queen's University, Kingston, Canada
Sarah A. Finkelstein, University of Toronto, Toronto, Canada
Andrew M. Paterson, Ontario Ministry of the Environment, Conservation and Parks, Dorset, Canada
April S. Dalton, Charles University, Prague, Czech Republic
Wendel Keller, Laurentian University, Sudbury, Canada
John P. Smol, Queen's University, Kingston, Canada

Keywords: Pollen, Chironomids, Diatoms, Hudson Bay Lowlands

In stark contrast to most of the circum-Arctic, the Hudson Bay Lowlands (HBL) of subarctic Canada has registered minimal 20th century warming, largely due to negative feedback mechanisms linked to persistent sea ice. Consequently, paleoecological profiles from the region have expressed little compositional change. However, since the mid-1990s, the HBL has crossed a climate tipping point, the pace and magnitude of which is exceptional even by Arctic standards. Within this short period of warming, striking algal changes from dated sediment cores are indicative of longer ice-free periods and the onset of thermal stratification in several HBL lakes. To assess whether these recent changes exceed the range of long-term natural variability, we examine a multi-proxy Holocene record from central HBL. The pollen record signifies a warm and moist mid-Holocene period starting ~6200 yr BP. Shifts in chironomid taxa at ~5000 yr BP are indicative of wet conditions and an expansion of littoral habitat. A modest decline in pollen-reconstructed temperatures and increased abundances of cold-stenothermal chironomid taxa signals a gradual transition into regional Neoglacial cooling. Marked changes occur in the mid-20th century with diatoms appearing in notable abundances for the first time in the lake's sedimentary record, increases in littoral chironomid taxa, and unprecedented increases in sedimentary chlorophyll a. Holocene pollen trends suggest slow centennial-scale changes in temperature and precipitation, whereas chironomid assemblages indicate abrupt mid-Holocene and 20th-century limnological changes, highlighting that biota in HBL lakes may experience further substantial changes under future global climate warming scenarios.

Structure of microbial communities in lake sediments of the High Arctic

Anne-Marie Lapointe, Université Laval, Québec, Canada
Yohanna Klanten, Université Laval, Québec, Canada
Alexander Culley, Université Laval, Québec, Canada
Catherine Girard, Université du Québec à Chicoutimi, Chicoutimi, Canada
Dermot Antoniades, Université Laval, Québec, Canada

Keywords: Paleolimnology, Bacterioplankton, Viruses, Metagenomics, Arctic

Stuckberry Valley, located on the north shore of Ellesmere Island (Nunavut), was impacted by significant climatic variability during the Holocene and is an environment currently undergoing a rapid transition due to rising temperatures. The retreat of the valley's main glacier resulted in the formation of four lakes. Lacustrine sediments of these lakes represent a treasure-trove of information about past changes in the Stuckberry Valley watershed and provide a "long-term memory" of how the lakes' responded to these changes. Microbes are the dominant form of life in this environment and thus understanding the diversity and distribution of microorganisms in the lakes' sediments is essential to better understanding the effects of climate change on episodic and interannual changes in the biology of this valley. The specific objective of the study is to characterize changes over time in the structure of microbial communities by comparing microbial diversity in sediment cores from the four Stuckberry lakes, based on amplicon sequencing of viruses and bacteria. We hypothesize that microbial diversity will vary over time and that these dynamics will reflect past environmental changes in the catchment. We will also assess the differences in microbial diversity between the sediments of the four lakes. These data will provide new insight into microbial community succession in a region that is on the frontline of climate change.

Application of neodymium isotopes for the reconstruction of glacial environmental changes in northern Svalbard over the last 16.5 kyr

Kwangchul Jang, Korea Polar Research Institute, Incheon, South Korea
Youngkyu Ahn, Korea Polar Research Institute, Incheon, South Korea
Young Jin Joe, Korea Polar Research Institute, Incheon, South Korea
Carmen A. Braun, UiT The Arctic University of Norway, Tromsø, Norway
Young Ji Joo, Pukyoung National University, Pusan, South Korea
Jung-Hyun Kim, Korea Polar Research Institute, Incheon, South Korea
Germain Bayon, IFREMER, Plouzané, France
Matthias Forwick, UiT The Arctic University of Norway, Tromsø, Norway
Christoph Vogt, University of Bremen, Bremen, Germany
Seung-Il Nam, Korea Polar Research Institute, Incheon, South Korea

Keywords: Neodymium Isotopes, Svalbard, Weathering, Svalbard Barents Sea Ice Sheet

Authigenic neodymium isotope (143Nd/144Nd, eNd) has been widely used as a tracer of seawater circulation. This application is based on negligible isotopic decoupling between dissolved and particulate Nd during the continental weathering process, but recent studies suggest that this assumption is not always correct. Indeed, the preferential chemical weathering can occur within the mineral scale in response to the change in weathering regime, which may result in Nd isotopic decoupling. Assuming that the change in weathering regime was closely related to glacier behavior, here we analyzed the detrital and authigenic Nd isotopes to reconstruct the glacier variability in the northern continental shelf off Svalbard. The detrital and authigenic eNd showed a strong correlation, implying a strong influence of continental weathering materials. Aside from the overall similarity between authigenic eNd and detrital eNd, abrupt increases in authigenic eNd at 15.2 and 14.1 ka BP indicate that the Svalbard-Barents Sea Ice Sheet (SBIS) occupied on northern Svalbard experienced at least two re-advances. Enhanced glacial erosion from SBIS advance probably supplied freshly exposed rock/sediment substrates, which resulted in an intensified preferential chemical weathering process and consequent release of radiogenic dissolved Nd.

Climate-related sedimentary changes of Wijdefjorden, northern Svalbard, since the last deglaciation

Youngkyu Ahn, Korea Polar Reseach Institute & Inha University, Incheon, Republic of Korea
Young Jin Joe, Korea Polar Research Institute, Incheon, Republic of Korea
Kwangchul Jang, Korea Polar Research Institute, Incheon, Republic of Korea
Young Ji Joo, Pukyoung National University, Busan, Republic of Korea
Yeong Ju Son, Korea Polar Research Institute, Incheon, Republic of Korea
Matthias Forwick, UiT The Arctic University of Norway, Tromsø, Norway
Sungmin Hong, Inha University, Incheon, Republic of Korea
Seung-Il Nam, Korea Polar Research Institute, Incheon, Republic of Korea

Keywords: Northern Svalbard, Wijdefjorden, Tidewater Glacier, Sedimentary Processes, End-Member Analysis Of Grain-Size Distribution

Tidewater glaciers of Svalbard fjords have undergone repeated advances and retreats since the last deglaciation. Hence, Svalbard fjords are suitable for investigating sedimentary processes and their environmental changes related to tidewater glacier dynamics. We applied end-member analysis (EMA) of grain-size distribution combined with other lithological proxy studies using six sediment cores to reconstruct temporal and spatial changes in northern Svalbard's sedimentary processes, recovered along the transect of Wijdefjorden. Four end-members are classified based on the characteristics of grain-size distribution curves, including mode and skewness. The distribution of major end-members reflects climate-related changes of the sedimentary environment, such as strength and continuity of meltwater discharge and the range of drifting icebergs. At the Younger Dryas cooling event(ca. 12.9-11.7 ka BP), the main mode of the major end-member becomes fine, indicating that the tidewater glacier retreated slowly. During Glacier Minimum (ca. 9-4.5 ka BP), the coarse-skewed major end-member is predominant even in the inner fjord, representing the sediment supply meltwater was rare. Our results may offer new perspectives for understanding glacier-induced sedimentary processes and their environmental changes in northern Svalbard since the last deglaciation. We suggest that EMA applied in this study can be used as a proxy for understanding changes in sediment processes in Arctic fjords.

Source of sedimentary organic carbon in Wijdefjorden in the Svalbard Archipelago

Dahae Kim, Korea Polar Research Institute
Jung-Hyun Kim, Korea Polar Research Institute
Seung-Il Nam, Korea Polar Research Institute

Keywords: Svalbard, Wijdefjorden, Surface Sediment, Organic Matter, Glacial Discharge,

Recent Arctic warming accelerate the release of vast amounts of organic carbon (OC) from land to the Arctic Ocean. In order to understand the Arctic carbon cycle, knowledge of OC dynamics with various regional characteristics is essential. Wijdefjorden is the longest fjord in the Svalbard archipelago, located in the northern portion of the island of Spitsbergen, which supplies glacigenic terrestrial material through glacial discharges. In this study, we investigated six surface sediments collected along Wijdefjorden during the expedition of the R/V Helmer Hanssen (HH17 in 2017). We analyzed the samples for bulk (grain size, major element, TOC, TON, d13Corg, and ?14Corg) and molecular (n-alkanes and sterols) parameters to assess the source of sedimentary OC. Our results provide information on the land-ocean terrestrial OC transfer in the Arctic fjords.

Environmental changes and depositional processes in Woodfjorden of northern Svalbard since the last deglaciation

Young Ji Joo, Department of Earth and Environmental Sciences, Pukyong National University, Busan, Republic of Korea
Trude Hansen, Department of Geosciences, UiT The Arctic University of Norway, Tromsø, Norway
Matthias Forwick, Department of Geosciences, UiT The Arctic University of Norway, Tromsø, Norway
Seung-Il Nam, Division of Glacial Environmental Research, Korea Polar Research Institute, Incheon, Republic of Korea

Keywords: Holocene, Svalbard, Fjord, Sediment

The Svalbard Archipelago underwent dramatic environmental changes since the deglaciation of the Svalbard-Barents Sea Ice Sheet. Partial break-up and complete retreat of glaciers that once occupied the fjords on Svalbard, followed by the Holocene climate variations, affected the relative sea level, calving rate of tidewater glaciers, extent of sea ice, meltwater discharge, and sediment provenance. The Holocene environmental developments in Spitsbergen, the largest island of the archipelago, have received significant attention, and sediment cores collected from the fjords have provided excellent high-resolution data. This study investigates the depositional processes and environmental conditions in Woodfjorden of northern Spitsbergen based on multi-proxy analyses of post-Weichselian sediment deposited in the fjord via meltwater plumes, icebergs, and sea ice. While the sediment texture, granulometry and ice-rafted debris (IRD) contents reflect the main modes of deposition, the mineralogy, lithology of IRD, and geochemistry mirror shifts in the main sediment source. In combination with previously published data, our results allow us to reconstruct the variations in depositional processes in the fjord driven by the Holocene climate changes. This study provides additional information about the post-glacial environmental fluctuations in northern Spitsbergen, the area less extensively studied compared to the western part of the island.

Post-Yonger Dryas depositional environment of the Little-Storfjorden in the southern Spitsbergen, Svalbard

Young Jin Joe, KOPRI, Incheon, South Korea

Keywords: Little-Storfjorden, Yonger Dryas, Deglaciation

Storfjorden is the largest fjord located in the southeastern Spitsbergen, Svalbard. The fjord is divided by a north-south striking submarine ridge (the Mid-ridge) into a narrow western trough (Little-Storfjorden) and a broader eastern trough. Previously reported sediment records and geophysical data provided detailed information for the eastern trough's glacial history during the last deglaciation. On the other hand, the glacial history of the Little-Storfjoden is poorly understood. Hence, to reconstruct glacial history in the Little Storfjorden during the last deglaciation, our research focuses on the Hambergbukta fjord in the east coast of southern Spitsbergen and the outer basin extending to the Little Storfjorden. For this, we used detailed seafloor bathymetry, high-resolution subbottom profiles, and three sediment cores. Based on 14C age data, lithological changes combined with other proxies, we reconstruct changes in glacigenic depositional environments related to glacier behaviors in the Little Storfjorden since the Younger Dryas.

Northern biome changes synthesized from taxonomically harmonized and temporally standardized fossil pollen record since the Last Glacial Maximum in comparison to GCM simulations

Chenzhi Li, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Polar Terrestrial Environmental Systems, Potsdam, Germany; Institute of Environmental Science and Geography, University of Potsdam, Potsdam, Germany
Anne Dallmeyer, Max Planck Institute for Meteorology, Hamburg, Germany
Xianyong Cao, Key Laboratory of Alpine Ecology, Institute of Tibetan Plateau Research, CAS Center for Excellence in Tibetan Plateau Earth Sciences, Chinese Academy of Sciences (CAS), Beijing, China
Andrej Andreev, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Polar Terrestrial Environmental Systems, Potsdam, Germany
Thomas Böhmer, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Polar Terrestrial Environmental Systems, Potsdam, Germany
Alexander Karl Postl, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Polar Terrestrial Environmental Systems, Potsdam, Germany; Institute of Geosciences, University of Potsdam, Potsdam, Germany
Mareike Wieczorek, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Polar Terrestrial Environmental Systems, Potsdam, Germany
Ulrike Herzsch, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Polar Terrestrial Environmental Systems, Potsdam, Germany; Institute of Environmental Science and Geography, University of Potsdam, Potsdam, Germany; Institute of Biochemistry and Biology, University of Potsdam, Potsdam, Germany

Keywords: Fossil pollen dataset, Biomization, Last Glacial Maximum, Northern Hemisphere

Fossil pollen datasets can help to understand the temporal and spatial distribution patterns and driving forces of the past terrestrial biomes in high northern latitudes. However, the existing databases deal with several problems, such as lack of reliable chronologies and harmonized taxonomy. Here we present a taxonomically harmonized and temporally standardized pollen data set since the Last Glacial Maximum that was used for biomization. All terrestrial pollen taxa were taxonomically harmonized on genus (woody taxa) or family level (herb taxa), and temporally standardized by using a defined parameter setting for Bayesian age-depth modelling based on 14C dating. Biomized results were compared to outputs from a transient run of an Earth system model.

Spatial distribution of microcharcoal and black carbon on the Greenland ice sheet

Sandra O. Brugger, Division of Hydrologic Sciences, Desert Research Institute, Reno, Nevada, USA
Nathan J. Chellman, Division of Hydrologic Sciences, Desert Research Institute, Reno, Nevada, USA
Callie McConnell, U.S. Forest Service, WO Detached Unit, Corvallis, Oregon, USA
Joseph R. McConnell, Division of Hydrologic Sciences, Desert Research Institute, Reno, Nevada, USA

Keywords: Ice palynology, Refractory black carbon (rBC), Microscopic charcoal, Spheroidal carbonaceous particles (SCP), Fire history

Temperatures in high latitudes are icreasing twice as fast as the global mean, which affect sensitive boreal forests and Arctic ecosystems. Dark particles from biomass and fossil fuel combustion in lower latitudes, such as microscopic charcoal, spheroidal carbonaceous particles (SCP), and the smaller black carbon fraction in surface snow on the Greenland ice sheet directly change the surface albedo, potentially contributing to accelerating climate change. Over time, these particles are incorporated into growing layers of ice thereby preserving records of past environmental changes. Recent methodological advances permit extraction of microfossils from remote polar ice cores in sufficient numbers to achieve continuous environmental records, and combined with continuous refractory black carbon measurements, provide a powerful record of past burning history. We present preliminary results from the Basin ice cores (an array of 7 sites from Southern to Central Greenland) to examine the spatial variability of burning tracers spanning 1970-2000 AD – a period that experienced dramatic environmental change in response to global warming. The combination of the unspecific burning tracer black carbon with the specific microfossil tracers for biomass (microcharcoal) and fossil-fuel (SCP) burning gives unique insights into the burning sources. Our study provides essential knowledge transferable to other remote ice records including glaciers in the mid-latitudes and the tropics.

Limnological responses to anthropogenic climate forcing across the Arctic

Bianca Perren, British Antarctic Survey
John Smol, Queen's University
Kathleen Rühland, Queen's University

Keywords: Paleolimnology, Paleoecology, Paleoclimatology, Circumpolar, Climate Change

Since the publication of the Smol et al. PNAS paper in 2005, there has been a rapid expansion of published paleolimnological records across the circumpolar north and major advances in methodologies used to document recent environmental change. Here we present a review of recent advances in our understanding of 20thand 21stC limnological change in the Arctic, taking into account new sites, new proxies, and larger ecosystem-wide changes. Our efforts will focus on: 1) identifying the signature and timing of anthropogenic climate forcing in Arctic lakes; 2) what changes have taken place in Arctic lakes since 2005; 3) how our understanding of these changes has developed since the initial Smol et al. publication, and 4) identifying knowledge gaps that currently exist and where we might concentrate future scientific efforts.

ID: 102 - Arctic Glaciers and Ice Sheets: Past, Present and Future

Conveners

Marc Oliva | University of Barcelona, Catalonia, Spain

David Palacios | Complutense University of Madrid, Spain

Samantha Buzzard | Georgia Tech, USA

Al. Ramanathan | Jawaharlal Nehru University, India

Alfred Wegener’s Greenland Expedition Revisited

Jakob Abermann, Graz University
Wolfgang Schöner, Graz University
Robert Fausto, GEUS
Baptiste Vandecrux, GEUS

Keywords: Greenland, Ablation, Historical Glaciology, Firn

The cryosphere in Greenland is currently undergoing strong changes. While remote sensing improves our understaning of spatial and temporal changes across scales, particularly the knowledge of changes during the pre-satellite era is scarce and thus valuable in a climate change perspective. At Graz University, the last work-place of Alfred Wegener we have access to the extensive expedition results from their epic 1929-1931 expedition to Greenland. This coincides with the warmest phase of the Arctic early 20th century warm period. We present an overview of the main findings of the Wegener expedition archive and set it into context with further monitoring activities that occurred since. While firn temperatures increased significantly, firn densities and surface snow densities decreased since. We compare the ablation rates with modern ablation rates along Greenland’s West coast and find them in the same order of magnitude, despite a clear latitudinal gradient. Local conditions at the Qaamarujup outlet however have changed dramatically with a length reduction of more than 2 km and a rise in terminus position by ca. 500 m. We assess the potential for using high quality historical meteorological and glaciological data together with reanalysis products and contemporary measurements in order to reconstruct glacier changes, meteorological conditions and to extract geometrical feedback processes.

Biological darkening of the Greenland Ice Sheet.

Martyn Tranter, Aarhus University, Roskilde, Denmark.

Keywords: Albedo Greenland Ice Sheet Microbes

Current understanding of how pigmented glacier ice algae darken the surface of the Greenland Ice Sheet on an annual basis is reviewed. The Dark Snow, Black and Bloom and Deep Purple projects have shown that the growth of glacier ice algae is a key determinant on both the extent of the Dark Zone, a band of dark ice ~10-30 km in width which grows annually down the western margin of the ice sheet during the melt season. The reduction in surface albedo that the glacier ice algae produce is no longer contested. However, the factors which initiate and limit the growth of the glacier ice algae, and the consequent albedo reduction, are in need of urgent investigation if the process-oriented parameterisations of ice surface albedo required for predictive models of future ice sheet melt are to be realised. Interdisciplinary field and laboratory work to date is beginning to reveal the external, bottom up and top down controls on glacier ice algae growth. These factors include nutrient limitation, biomining of particulate nutrients, antecedent winter snow conditions, ablation season climatology and meteorology, and the development of the weathering crust, the heterogeneous living skin of the melting ice sheet. Glacier ice algae are widely distributed across the Greenland Ice Sheet, so an understanding of the controls that limit their growth is also needed to assess the likelihood of extensive ice sheet darkening beyond the current Dark Zone in an ever warming 21st century.

Fluctuations of Tungnahryggsjökull glacier (Tröllaskagi Peninsula, Northern Iceland) since the Neoglaciation: a multiple-dating approach

José M. Fernández-Fernández, Instituto de Geografia e Ordenamento do Território (IGOT), Universidade de Lisboa, Lisbon, Portugal
Nuria Andrés, High Mountain Physical Geography Research Group, Department of Geography, Univesidad Complutense de Madrid, Madrid, Spain
David Palacios, High Mountain Physical Geography Research Group, Department of Geography, Univesidad Complutense de Madrid, Madrid, Spain
Skafti Brynjólfsson, Faculty of Life and Environmental Sciences, University of Iceland, Reykjavík, Iceland
Þorsteinn Sæmundsson, Icelandic Institute of Natural History, Akureyri, Iceland
Irene Schimmelpfennig, Centre de Recherché et d'Ensenginement des Géosciences de l'Environnement (CEREGE), CNRS, Aix-Marseille Université, Aix-en-Provence, France

Keywords: Neoglacial, Little Ice Age, Cosmic-Ray Exposure dating, Tröllaskagi, Iceland

The Tröllaskagi peninsula (Northern Iceland) is a natural laboratory where the widespread geomorphic evidence shows the dynamic landscape evolution since the last deglaciation. The Vesturdalur and Austurdalur valleys show a wealthy of well-preserved moraine ridges close to the glacier termini, indicating their climatic sensitivity. By means of Cosmic-Ray Exposure (CRE) dating, lichenometry and historical aerial photos, we have reconstructed the Late Holocene fluctuations of the Tungnahryggsjökull glacier. CRE dating results revealed major Neoglacial culminations at 1.6 and 1.3 ka and between the 15th and 17th centuries (Little Ice Age, LIA). These dates indicates significant glacier expansions during Neoglacial and early LIA, which seems to have been of similar importance as generally considered Late Holocene maximum glacier conditions during the late LIA. The joint use of lichenometry based on the species Rhizocarpon geographicum and Porpidia cf. soredizodes and historical aerial photos demonstrated lichen colonization lags of 15-20 and 10-15 yrs, respectively. This technique allowed to date several glacier advances or standstills during the 19th century (1800s, 1830s, 1840s, 1860s and 1890s), in good agreement with previous results reported from nearby valleys, and with cold episodes of the late-LIA. During the 20th century, glaciers underwent a retreating trend only interrupted by several advances at 1910s, 1950s and from the mid-1980s to the mid-1990s.

Preliminary studies on MassBalance in VestreBroggerbreen and Feiringbreen glaciers in Svalbard

AL Ramanathan, Parmanand Sharma, Raaj Ramsankaran, Kalyan Biswal, Arindan Mandal,Mohd Soheb, Sarvagya Vatsal, Naveen Pandey, Shyam Ranjan

Keywords: Vestrebroggerbreen , Feiringbreen Glaciers, Mass Balance, Snow Pack, Temeperature

Arctic glaciers are experiencing a negative mass balance in the last few decades.From 1950s various organisations carried out regular MB studies in Svalbard .Most observations show an increment sea-level proportional to high rate of glacier mass wastage post twentieth century. In 2011 under Indian Arctic Expedition, we have started our first field based survey on Vestre Broggerbreen glacier and later extended to Feiringbreen glacier .Our observation shows that Vestre Broggerbreen?glacier experienced a negative mass balance with an annual average of -0.69mw.e.a?-1 and cumulative loss of more than 5 m w.e.for the period 2011-2019. Feiring breen glacier also face mass loss of 0.51 m w.e from 2018-2019.The intensity of precipitated snow during winter seasons and near by ocean-atmospheric circulation are dominating factors controlling glacier mass balance in the region. In VestreBroggerbreen glacier, a constant reduction in snow water equivalent was also observed with significant positive correlation(R=0.7) with mass balance .Liquid precipitation during winter seasons are mostly triggered by inflow of warm and moist southerly winds.That reduced the cold content of the snow pack but also reduced snow water equivalent contributing whcih leads to more negative mass balance over the years.Thus, it is very essential to continue our investigations in future in order to monitor such changes and fulfill data gaps related to glacier mass balance studies in Svalbard.

Rapid and complex recent evolution of a glacier: Héðinsdalsjökull (Norhern Iceland)

Manuel Rodríguez-Mena, High Mountain Physical Geography Research Group, Department of Geography, Universidad Complutense de Madrid, Madrid, Spain
José M. Fernández-Fernández, Instituto de Geografia e Ordenamento do Território (IGOT), Universidade de Lisboa, Lisbon, Portugal
Luis M. Tanarro, High Mountain Physical Geography Research Group, Department of Geography, Universidad Complutense de Madrid, Madrid, Spain
José J. Zamorano, Instituto de Geografía, Universidad Nacional Autónoma de México, Mexico DF, Mexico
David Palacios, High Mountain Physical Geography Research Group, Department of Geography, Universidad Complutense de Madrid, Madrid, Spain

Keywords: Debris-covered glacier, Rock glacier, Geomorphological mapping, Cosmic-Ray Exposure dating, Iceland

The Héðinsdalsjökull glacier is located at the headwall of the Héðinsdalur valley (65°39 'N, 18°55' W), in the western sector of Tröllaskagi peninsula (northern Iceland). A detailed geomorphological map of its foreland, supported on fieldwork and historical aerial photographs (1946-2019) has been produced. Based on this map, 11 different evolutionary stages of the glacier have been identified. Timing of the oldest phases (prior to 1946) and their glacial and periglacial landforms has been approached through the cosmonuclide 36Cl and lichenometric dating. The results of both methods reveal that the glacier remained debris-free until 7-6 ka. Subsequently, the lower frontal sector became debris-covered while the higher one evolved into a rock glacier. Although this rock glacier still preserves the ice core, its front stabilized shortly after forming. The lower sector of the debris-covered glacier (<800 m a.s.l.) collapsed at ~3 ka, while the rest is still active today. During the Little Ice Age, the upper part of the glacier advanced as a debris-free one, overlapping the active debris-covered glacier and leaving a series of frontal moraines on it. Since then, the debris-free glacier has undergone an intense retreat while the active debris-covered glacier has been affected by an intense subsidence even evolving into incipient rock glacier in a small sector. This case is an exceptional example of the complex evolution that a glacier can undergo.

The deglaciation of the Zackenberg Valley (NE Greenland)

Julia Garcia-Oteyza, Department of Geography, Universitat de Barcelona, Catalonia, Spain
Marc Oliva, Department of Geography, Universitat de Barcelona, Catalonia, Spain
David Palacios,Complutense University of Madrid, Madrid, Spain
Jose Maria Fernández-Fernández, Centre for Geographical Studies, IGOT, Universidade de Lisboa, Lisbon, Portugal
Irene Schimmelpfennig, Aix-Marseille Université, CNRS, IRD, INRAE, Coll. France, UM 34 CEREGE, Aix-en-Provence, France
Nuria Andrés, Department of Geography, Complutense University of Madrid, Madrid, Spain
Dermot Antoniades, Department of Geography & Centre for Northern Studies, Université Laval, Quebec, Canada
Hanne Hvidtfeldt Christiansen, Arctic Geology Department, University Centre in Svalbard, Longyearbyen, Norway
Jesus Ruiz-Fernández, Department of Geography, University of Oviedo, Asturias, Spain.
Vincent Jomelli, Aix-Marseille Université, CNRS, IRD, INRAE, Coll. France, UM 34 CEREGE, Aix-en-Provence, France
ASTER Team, Aix-Marseille Université, CNRS, IRD, INRAE, Coll. France, UM 34 CEREGE, Aix-en-Provence, France. Consortium: Georges Aumaître, Didier Bourlès, Karim Keddadouche

Keywords: NE Greenland; Zackenberg; Deglaciation; Geomorphology; Cosmic-Ray Exposure

The Greenland Ice Sheet (GrIS) plays a key role in the global climate system. However, our current knowledge of the spatio-temporal oscillations of the GrIS margins since the Last Glacial Cycle is still incomplete. Here, we present new records of the past GRIS extent and the deglaciation process in the Zackenberg Valley (74ºN, 20ºE), NE Greenland, based on geomorphological mapping combined with a new dataset of 39 10Be cosmic-ray exposure (CRE) ages. Geomorphic evidence at the summit surfaces reveal that glaciers were significantly thicker (>800 m) at ca. 80 ka. The Zackenberg outlet must have been slightly smaller during the Last Glacial Maximum, although no glacial records were found. A rapid and massive deglaciation of the highest and intermediate Zackenberg Valley slopes started by ca. 15 ka, during the Bølling-Allerød. At the end of the Younger Dryas, by ca. 12 ka, a readvance favoured the development of the lowest moraine ridges of the slopes, connected with the outermost moraine system existing in the valley floor. Within the limits of this moraine, a debris-covered glacier formed due to the intense paraglacial readjustment of the rock slopes and moraines triggered by glacier thinning. By 10.5 ka, the last remnants of glacial ice disappeared from the Zackenberg Valley floor. This chronology of the deglaciation is broadly similar to that observed in other sites across NE Greenland.

Melting glaciers in the Arctic

Victoria Ivanova, Murmansk Arctic State University (MASU), Murmansk, Russia

Keywords: Arctic, Glacier, Ground Ice, Climate Change

For over more than 100 years the rise of CO2 emissions has been causing annual temperature increase, what is due to the thawing of Arctic permafrost. In the Russian Arctic icebergs are mostly common in the Barents Sea, the Kara Sea and in the Sea of Laptev. They are situated near each glacier near the Franz Josef Land. Glacier islands can be divided into two types: the first type of islands are completely glacierized, such as Bruce Island in Franz Josef Land. The second type of islands have ground surface above the ice. For examples, Belyi Island and Victoria Island situated between Spitsbergen and Franz Josef Land. Another problem that is caused by the temperature increase is the melting ground ice. In the lowest layer of the ground ice large caves are being formed and the shores of such islands have ice grounds. Now the ground ice is melting fast in the Arctic what provokes coastline retreat and changes the Benthal.

Recent characteristics of surface energy balance observed at the SIGMA-A site on the northwest Greenland Ice Sheet

Teruo Aoki, National Institute of Polar Research, Tachikawa, Japan
Satoshi Hirose, New Chitose Aviation Weather Station, Japan Meteorological Agency, Chitose, Japan
Masashi Niwano, Meteorological Research Institute, Japan Meteorological Agency, Tsukuba, Japan
Sumito Matoba, Institute of Low Temperature Science, Hokkaido University, Sapporo, Japan
Tomonori Tanikawa, Meteorological Research Institute, Japan Meteorological Agency, Tsukuba, Japan
Satoru Yamaguchi, Snow and Ice Research Center, National Research Institute for Earth Science and Disaster Prevention, Nagaoka, Japan
Yamasaki Tetsuhide, Avangnaq Arctic Environmental Research Activity Project Osaka, Japan

Keywords: Greenland Ice Sheet, Surface Energy Balance, Albedo, Surface Melting, North Atlantic Oscillation

The drastic surface melting of the Greenland Ice Sheet (GrIS) occurs after the middle of the 1990s. To clarify the contributing factors of surface melting, we installed an automatic weather station (AWS) in June 2012 at the SIGMA-A site (78°N, 67°W, 1490 m a.s.l.) on the northwest GrIS and have monitored the meteorological and snow variables. Using these data, the surface energy balance is analyzed, by which the surface melting amount is estimated for the period from 2012 to 2019. The results show that the amount of surface melting increased in the warm summers of 2012, 2015, and 2019, in which the sensible heat transport and the net shortwave radiation increased. In those three years, the near-infrared (NIR) albedos measured in July decreased the values less than 0.63 compared to the mean value of 0.69 in July for the other years. The NIR albedo depends on snow grain size when snow impurity concentration is low in an accumulation zone such as SIGMA-A. This means that the positive feedback effect by snow grain growth on the NIR albedo reduction played an important role in the melting process. We also examined the relationship between the North Atlantic Oscillation index and surface melt flux. It is found that July 2012 was an extraordinary year with a significant increase in surface melting. Then, the increase in downward longwave radiation from the lower clouds suppressed the net longwave cooling in addition to the increase in sensible heat and net shortwave radiation.

The deglaciation of the Tröllaskagi valleys (Northern Iceland) according to 36Cl Cosmic-Ray Exposure dating

José M. Fernández-Fernández, Instituto de Geografia e Ordenamento do Território (IGOT), Universidade de Lisboa, Lisbon, Portugal
Nuria Andrés, High Mountain Physical Geography Research Group, Department of Geography, Univesidad Complutense de Madrid, Madrid, Spain
Luis M. Tanarro, High Mountain Physical Geography Research Group, Department of Geography, Univesidad Complutense de Madrid, Madrid, Spain
Þorsteinn Sæmundsson, Faculty of Life and Environmental Sciences, University of Iceland, Reykjavík, Iceland
Skafti Brynjólfsson, Icelandic Institute of Natural History, Akureyri, Iceland
David Palacios, High Mountain Physical Geography Research Group, Department of Geography, Univesidad Complutense de Madrid, Madrid, Spain
Irene Schimmelpfennig, Centre de Recherché et d'Ensenginement des Géosciences de l'Environnement (CEREGE), CNRS, Aix-Marseille Université, Aix-en-Provence, France

Keywords: Deglaciation, Rock glaciers, Debris-covered glaciers, Cosmic-Ray Exposure dating, Iceland

The Tröllaskagi Peninsula (65º49N, 18º47'W) is located in Central North Iceland, between Skagafjörður and Eyjafjörður fjords. The Peninsula consists of Miocene basaltic lavas culminating at a plateau on which several valleys of steep slopes are embedded, hosting over 160 glaciers in their headwalls. In the last years, new datasets of 36Cl exposure ages of moraines, rock glaciers and polished surfaces have been obtained. During fieldwork no glacial landforms were observed on the summits of Tröllaskagi; thus whether or not the Icelandic Ice Sheet (IIS) covered these areas during the Last Glacial Cycle is still under debate. However, there is clear evidence supporting that the main fjords and valleys in Central North Iceland were occupied by IIS outlet glaciers and ice streams. Culminating sectors of tributary valleys were deglaciated at 16 ka, and the ice had retreated considerably by 12 ka. Both IIS glacier outlets and the alpine glaciers of the interior of the Tröllaskagi rapidly retreated by 11 ka. Studies show that at the head of at least 5 interior valleys, moraines and erratic boulders, located close to the current glacier fronts were deposited at 11 ka. During the deglaciation, rock glaciers formed in several valleys, whose fronts collapsed at 9 ka. At present, active debris-covered glaciers and rock glaciers coexist in most of the studied valley heads, but their current dynamics are associated to subsidence. Dating of these formations showed their stagnation at 5-7 ka.

Theme D: The Changing Terrestrial Environments Dynamics and Impacts

ID: 30 - Permafrost thaw effects to the Arctic nature and society

Conveners

Moritz Langer | Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research (AWI), Germany

Lei Cai | NORCE Norwegian Research Centre, Bjerknes Centre for Climate Research, Norway

Yes Anna Liljedahl | Woods Hole Research Center, USA

Analysis of the stability of pipelines in Western Siberia in a changing climate

Fedor Iurov, Lomonosov Moscow State University, Moscow, Russia
Ivan Ilyushin, Lomonosov Moscow State University, Moscow, Russia
Valery Grebenets, Lomonosov Moscow State University, Moscow, Russia

Keywords: Arctic, Permafrost, Pipelines, Climate Change

The north of Western Siberia is a promising region for development; this territory contains large oil and gas fields, the functioning of which is impossible without trunk and infield pipelines. However, the problem of ensuring the stability of these objects is complicated by a number of factors. The north of Western Siberia is characterized by complex permafrost-lithological conditions, highly differentiated in various types of landscapes. In addition, the impact of climate change is very noticeable here: an increase in the temperature of frozen soils, in the thickness of the active layer. These changes lead to a decrease in the strength properties of soils. For a number of "reference" regions of Western Siberia, on the basis of existing trends to climate warming, a numerical simulation of the temperature field of frozen soils at the base of pipeline systems was carried out. A change in the bearing capacity of frozen-in pipeline supports, a change in the tangential forces of frost heaving and freezing forces of supports were predicted. Calculations have shown that by 2050, a significant decrease in the stability of pipeline systems will occur in a number of regions under study. For example, on the «Vankor-Purpe» oil pipeline, the most vulnerable to climatic changes are loamy soils, which, according to calculations, showed the least resistance to a decrease in bearing capacity (up to 10% in 10 years). This work was supported by RFBR grants 18-05-60080 and 20-35-90009.

Basic vs. applied science for effective climate adaptation - narrowing the gap

Soňa Tomaškovičová, Technical University of Denmark, Kongens Lyngby, Denmark
Johanna Scheer, Technical University of Denmark, Kongens Lyngby, Denmark
Thomas Ingeman-Nielsen, Technical University of Denmark, Kongens Lyngby, Denmark

Keywords: Permafrost, Infrastructure Development, Climate Adaptation, Applied Science

Available modeling predictions for Ilulissat (Greenland) forecast that permafrost in the sediments will thaw within the next forty years. Permafrost in the area is both ice-rich and saline, depending on the depth in the soil profile. Permafrost degradation will drastically alter such landscape: surface deformation following the ground volume changes will affect built structures; mobilization of salts dissolved in the pore water risks to contaminate surface water sources. We combine scientific findings with input from local stakeholders to discuss whether this knowledge plays role in community development plans. As the community is running out of the “safe ground” (bedrock) to build on, one of the main issues for town planners is to know what and how can be built on the sensitive terrain with high risk of ground settlement. We also reflect on how can science contribute to climate adaptation in face of ongoing changes and the pervading need to “build things fast”.

Classification of permafrost-ecosystem dynamics to assess thermokarst susceptibility in Yukon, Canada

Oliver K. Kienzle, University of Lethbridge, Lethbridge, AB, Canada
Philip P. Bonnaventure, University of Lethbridge, Lethbridge, AB, Canada

Keywords: Permafrost, Ecosystems, Thermokarst, Modelling, Climate Change

Permafrost is primarily a climatological phenomenon; connectivity between air and ground temperatures causes perennially frozen ground to develop in sufficiently cold climates. However, climate is not the only variable controlling permafrost presence or attributes. Vegetation can modify the connectivity between air and ground temperatures in areas where recent warming has occurred, sometimes permitting permafrost to remain in climates outside the aggregational limit (>0°C). It is important to understand and to quantify these interactions in the context of permafrost degradation, as these patches of ecosystem-protected permafrost show that ecosystem change can sometimes be more significant than climate change in predicting permafrost thaw. This study used a dataset of over 800 permafrost ground truthing points supplemented by a series of boreholes, in combination with land cover and mean annual air temperature to delineate zones where permafrost is possibly ecosystem-protected, ecosystem-modified, or climate-driven for the southern 2/3rds of Yukon. A multinomial logistic regression was used to determine the extent to which different land covers were predictors of permafrost presence in different climates across the territory. Initial results show that there is spatial variation in permafrost-ecosystem dynamics within Yukon. This analysis is important in order to predict the spatial extent of permafrost thaw and is being used in a thermokarst susceptibility analysis for Yukon.

How is your life affected by permafrost thaw?

Justine Ramage, Nordregio, Stockholm, Sweden
Leneisja Jungsberg, Nordregio, Stockholm, Sweden
Alexandra Meyer, University of Vienna, Vienna, Austria
Susanna Gartler, University of Vienna, Vienna, Austria

Keywords: Impact, Permafrost Thaw, Ecosystem-Services, Subsistence Activities, Communities

Permafrost environments provide many Arctic coastal communities with the basis for their everyday lives – such as food security, recreation, and culture. However, these environments are strongly impacted by climate changes, among which permafrost thaw features prominently. The consequences of permafrost thaw on ecosystems vary across the Arctic and can significantly affect the lives of coastal community members, including their subsistence. In our research, we asked community members of Aklavik (NWT/Canada), Qeqertarsuak (Greenland), and Longyearbyen (Svalbard/Norway) how permafrost thaw was impacting their daily lives. We will present the results from the survey, highlighting differences and similarities in the way community members are affected in these three coastal communities. A total of 237 people answered the survey on the impact of permafrost thaw on their subsistence activities. The twenty-five survey questions were grouped into six themes identifying 1) the share of country food in the diet and related changes, 2) involvement in subsistence activities, 3) the type of food hunted or fished, 4) source and storage of country food, 5) perceived impacts of permafrost thaw, and 6) health and well-being.

Meaningful research for meaningful impact: Arctic researchers and indigenous communities working together to combat global climate change

Darcy L. Peter, Woodwell Climate Research Center, USA

Keywords: Permafrost, Thaw, Environmental Change, Guidelines, Traditional Knowledge, Education.

The Arctic is warming at twice the rate of anywhere else in the world. As a result, Arctic inhabitants' cultures, ways of life, and entire future is in jeopardy. Over the past decade, there have been significant advances made by the scientific community to monitor and predict the state of the rapidly changing Arctic. Information gained from these scientific studies could greatly benefit local and Indigenous communities in the Arctic. At the same time, the local knowledge of Arctic inhabitants could advance scientific understanding and guide relevant research outcomes. But how can local Arctic communities and researchers work together? How can scientific research outcomes positively impact the lives of Arctic residents? Scientific research, if shared and communicated properly, could greatly benefit Arctic communities who are dealing with the impacts of a changing climate on a daily basis. This communication between scientists and Arctic communities will be most effective if it is approached with open-mindedness, flexibility, willingness to collaborate, and respect. Building from generations of local community knowledge, I will first present observations of a changing Arctic climate through the lens of Indigenous Knowledge, a framework for observing and living in the natural world that has been passed from generation to generation. I will then provide specific guidelines for researchers working in the Arctic who aim to conduct ethical and meaningful research on traditional indigenous land. Finally, I will connect indigenous knowledge with western science, to shed light on how the two can work hand in hand to both advance scientific discovery and positively impact the lives of Arctic inhabitants.

Modelling consequences of permafrost degradation for Arctic infrastructure and related risks to the environment and society

Thomas Schneider von Deimling, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Thomas Ingeman-Nielsen, Technical University of Denmark, Lyngby, Denmark
Hanna Lee, NORCE Norwegian Research Centre, Bergen, Norway
Sebastian Westermann, University of Oslo, Oslo, Norway
Erin Trochim, University of Alaska Fairbanks, Fairbanks, USA
Jan Nitzbon, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany,
Moritz Langer, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany

Keywords: Permafrost Degradation, Infrastructure Failure, Modelling, Hazardous Waste, Risk Assessment

The fate of infrastructure in the Arctic is heavily depending on the stability of frozen ground which it is built on. Climate change and consequent degradation of permafrost will negatively affect various infrastructure types and can cause ultimate failure. Comprehensive pan-Arctic assessments are urgently needed to better quantify environmental, economic and societal risks and to help adaptation planning. The use of physical models can be a powerful tool for risk evaluation, but modelling challenges remain with respect to resolving construction details at infrastructure scales together with decadal-scale climate change impacts. Here we used the dynamic permafrost land-surface model CryoGrid3 to capture both - the effects from the interaction of small-scale infrastructure with permafrost and large-scale climate change effects evolving in the 21century under an extensive warming scenario. We discuss how infrastructure can affect ground temperatures, and how climate change increases the risk of future infrastructure failure. We modelled two exemplary cases of permafrost-affected infrastructure: a gravel road on continuous permafrost at Prudhoe Bay (Alaska), and the case of a diesel tank facility at Norilsk (Siberia) placed on permafrost already subject to degradation under present day climate. We use the latter example to discuss environmental risks from contamination of hazardous legacy waste stored on and in permafrostand discuss the urgency for near-term policy strategies.

Browning of northern surface waters: Implication on the microbiological quality of drinking water

Marie-Ange Moisan, Institut national de la recherche scientifique, Québec, Canada
Jérôme Comte, Institut national de la recherche scientifique, Québec, Canada
Alexander I. Culley, Université Laval, Québec, Canada
François Guillemette, Université du Québec à Trois-Rivières, Trois-Rivières, Canada
Stéphanie Guilherme, Université d'Ottawa, Ottawa, Canada
Manuel Rodriguez, Université Laval, Québec, Canada
Camilo A. Herrera, Institut national de la recherche scientifique, Québec, Canada
Isabelle Laurion, Institut national de la recherche scientifique, Québec, Canada

Keywords: Climate Change, First Nations, Nordic Water Browning, Drinking Water, Microbial Ecology

Northern water browning is caused by the increasing addition of terrestrial organic matter in aquatic ecosystems through hydrological intensification, changes in terrestrial productivity, and permafrost thawing. Browning and warming of surface waters can cause major changes in the functioning of aquatic ecosystems and may favor certain microorganisms such as toxic cyanobacteria. Thawing permafrost may also release microbes and pathogens previously trapped in soils into aquatic ecosystems. Collectively, these changes represent risks for drinking water quality in northern communities. We aim to evaluate the implications of browning on drinking water quality by assessing the microbial composition (virus and bacteria) along the drinking water supply system (from source to tap) and explore its relationship with dissolved organic matter. The project aims to identify environmental conditions leading to water quality issues and eventually forecast future changes in order to support northern communities in adapting to the impacts of climate change. Microbial composition analyses will allow identifying if any threatening microorganisms is present along the supply system. Preliminary results indicate cases where a large reduction of bacterial abundance occurs between source and tap water, while other cases show similar bacterial abundance along the supply system, or even an increase in household cisterns. Ongoing molecular analyses will identify the microbial taxa detected in the water.

Multi-disciplinary hazard mapping framework for critical infrastructure on permafrost, Ilulissat, West-Greenland

Johanna Scheer, Department of Civil Engineering, Technical University of Denmark, Kongens Lyngby, Denmark
Thomas Ingeman-Nielsen, Department of Civil Engineering, Technical University of Denmark, Kongens Lyngby, Denmark
Soňa Tomaškovičová, Department of Civil Engineering, Technical University of Denmark, Kongens Lyngby, Denmark

Keywords: Arctic infrastructure, Risk assessment, Permafrost modeling

In the face of climate change, degrading permafrost threaten the integrity of infrastructures, and Arctic communities become vulnerable and exposed to hazards. The implementation of adaptation strategies integrating future climate scenarios is fundamental to guide settlement expansions. In order to provide reliable decision support tools to local governments, hazard and risk assessments resulting from collaborative science and multi-disciplinary approaches have the potential to address stakeholder's needs, while taking account of societal/environmental settings, local resources and data availability. The growing settlement of Ilulissat, West-Greenland, experiencing such challenges, was chosen to develop and implement a community-scale risk assessment framework, whose steps and preliminary results are presented here. Based on the methodology deployed in the Canadian Arctic (Allard et al., 2012), the core of the approach consists in characterizing surficial geology, topography, and ground ice distribution from field measurements and remote-sensing products. In our case, a distributed permafrost model is additionally used to forecast permafrost degradation rate under conceivable climate scenarios, with a specific focus on salinity and snow accumulation effects. The suitability of the terrain for construction is expected to be assessed by combining model outputs with hazard mapping, and risk zonation products will be provided to stakeholders along with mitigation solutions.

Permafrost Carbon Feedback Including Terrestrial and Aquatic Dynamics in Long-Term Cycle

Deniz Vural, Polar Research Institute, The Scientific and Technological Research Council of Turkey, Istanbul, Turkey
E. Vural Yavuz, Faculty of Engineering, Turkish-German University, Istanbul, Turkey
Naki Akçar, Institute of Geological Sciences, University of Bern, Bern, Switzerland

Keywords: Permafrost Thawing, Climate Change, Carbon Feedback, Terrestrial and Aquatic Factors, Carbon Budget

Permafrost is a frozen ground that takes at least 2 consecutive years to form below 0°C. As one of the important characteristics of Periglacial environments, permafrost underlies almost a quarter portion of the Northern Hemisphere and twofold amount of carbon compared to the atmosphere can be found as frozen in permafrost. When frozen permafrost becomes thawed, it will release carbon which increases atmospheric CO2 and CH4 concentrations and amplifies surface warming that triggers positive carbon feedback in changing climate. In addition, microbial decomposition of previously frozen organic carbon is another result of this thawing which has significant potential feedback from terrestrial ecosystems to the atmosphere. Even though other dynamics such as growing season length, the rates of plant growth and species composition, as well as ecosystem energy exchange can be altered permafrost-carbon cycle, these processes are not able to offset C release from thawing permafrost. Particularly, extensive permafrost thaws within the last decades due to abrupt changes, methane emissions from thermokarst lakes have expanded in the past 60 years which directly increase the mass proportion of soil carbon inputs to the lakes from erosion of permafrost thawing. All in all, this study will focus on permafrost thawing to better understand both organic carbon exposed by microbial decomposition as well as changing carbon budget to the atmosphere by other factors along with climate change.

Permafrost Thaw in three Arctic Focal Areas: Risks and Responses

Susanna Gartler, University of Vienna, Austrian Polar Research Institute
Alexandra Meyer, University of Vienna, Austrian Polar Research Institute
Leneisja Jungberg, Nordregio
Justine Ramage, Nordregio
Peter Schweitzer, University of Vienna, Austrian Polar Research Institute
Olga Povoroznyuk, University of Vienna, Austrian Polar Research Institute
Joan Nymand Larsen, Stefansson Arctic Institute
Jean-Paul Vanderlinden, Université Paris-Saclay/Université de Versailles Saint-Quentin-en-Yvelines
Brenda Natalia Doloisio, Université Paris-Saclay/Université de Versailles Saint-Quentin-en-Yvelines

Keywords: Permafrost Thaw, Perception, Human-Environment Interaction, Climate Change

"Nunataryuk" is a multi-disciplinary research consortium, examining permafrost thaw (PFT) in Arctic coastal areas from multiple perspectives. This poster presents outcomes from fieldwork conducted between 2018 and 2020 in Longyearbyen on Svalbard (Norway), Tiksi and Bykovskiy in Yakutiya (Russia), in Ilulissat, Qeqertarsuaq and Qanaaq (Greenland) and in Aklavik, Inuvik and Tuktoyaktuk in the Northwest Territories (Canada). We analyze the entanglement between social and environmental change and address perceptions of impacts of PFT, as well as responses to these impacts. Changes affecting these different communities as well as responses vary, depending on physical factors such as the type of permafrost and substrate in the areas as well as on socio-cultural, historic, economic and political factors, significantly influencing the way local people interact with their environment. Here we highlight cross-cutting themes relevant in all study sites, such as the fact that socio-economic problems overshadow perception of risk as well as adaptation and responses to PFT in many of the study sites. These problems often stem from diverse colonial settings and histories in Greenland, Canada, Svalbard and East Siberia. Other dominant issues relate to infrastructure (including heritage sites), subsistence & food security, and a focus on adaptation instead of mitigation. Lastly, we examine what factors perception of PFT is influenced by in the three focal areas of the project.

Pocket fluorometers to assess the presence of disinfection by-products and cyanobacteria in northern drinking water

Camilo Herrera, Institut national de la recherche scientifique, Quebec , Canada
Isabelle Laurion, Institut national de la recherche scientifique, Quebec, Canada
François Guillemette, Université du Québec à Trois-Rivières, Quebec, Canada
Stéphanie Guilherme, Université d'Ottawa, Ontario, Canada
Manuel Rodriguez, Université Laval, Quebec, Canada
Marie-Ange Moisan, Institut national de la recherche scientifique, Quebec , Canada
Jérôme Comte, Institut national de la recherche scientifique, Quebec , Canada

Keywords: Pocket Fluorometers, Desinfection By-Products, Cyanobacteria, Dissolved Organic Matter

Permafrost thaw and plant growth are causing an increase in dissolved organic matter (DOM) in northern aquatic ecosystems. Water browning affects surface water temperature, mixing regime and light availability. These changes could lead to an increasing occurrence of harmful cyanobacteria and impact potable water treatment. Adding chlorine to drinking water for the removal of fecal bacteria can react with DOM to generate disinfection by-products (DBPs), which presence is regulated in many countries. The study objectives are to develop early warning tools to quantify DOM, cyanobacteria and DBPs in drinking water used by communities in Nunavut, Nunavik and the Northwest Territories. Pocket fluorometers (AquaFluor) are promising and accessible tools that could be used to identify critical periods when DOM and phytoplankton biomass are increasing in source water. Preliminary results indicate that DOM was high enough in source water (DOC < 6 mg L-1) to generate DBP concentrations near or slightly above Health Canada guidelines in some communities (haloacetic acids up to 95 µg L-1, trihalomethanes up to 100 µg L-1). Phytoplankton biomass was too low in sampled waters to properly test the fluorometer, but a significant correlation was found between AquaFluor readings (FDOM) and DOC ($r=0.96$, $p<0.001$). In upcoming months, we will test the interference on fluorometer assessments, and the potential to use differential fluorescence as a first estimation of DBP concentrations using permafrost core leachates.

Project Introduction: Impact of rapid degradation of terrestrial cryosphere on the material cycle and the dynamics of environmental pollutants

Tetsuo Sueyoshi, National Institute of Polar Research (NIPR), Tokyo, Japan
Osamu Nagafuchi, Fukuoka Institute of Technology, Fukuoka, Japan
Koyomi Nakazawa, Fukuoka Institute of Technology, Fukuoka, Japan
Keiko Konya, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokohama, Japan
Tomoaki Morishita, Forestry and Forest Products Research Institute, Morioka, Japan
Go Iwahana, University of Alaska Fairbanks (UAF), Fairbanks, USA
Hotaek Park, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokohama, Japan
Koichiro Harada, Miyagi University, Sendai, Japan

Keywords: Warming, Permafrost, Mercury, Greenhouse Gas

This presentation aims to introduce a project "Impact of rapid degradation of terrestrial cryosphere on the material cycle and the dynamics of environmental pollutants", started in 2020, as a part of Japan's national Arctic research program ArCS II. Motivated by the recent works, the project focuses on the content and release of mercury in rapidly thawing permafrost and the release of greenhouse gases at the glacier terminal area. We would like to share the aim and the plan of the project and seek possible collaborations. As field measurements and sample analysis were planned as the main works of the project, the project is facing difficulties with the situation of the COVID-19 pandemic. The authors is examining the available options and th eway of collaborations to work under this situation, which will be included in the discussion as well.

Quantification of Ancient Microbes from Permafrost and their potential risk: A Simulation Study

Akhil Prakash E., Department of Marine Biology, Microbiology and Biochemistry, Cochin University of Science and Technology, Kochi, India.
Midhun Shah Hussan, Department of Marine Biology, Microbiology and Biochemistry, Cochin University of Science and Technology, Kochi, India.
Krishnan, K.P., National Centre for Polar and Ocean Research, Ministry of Earth Sciences, Goa, India, CUSAT-NCPOR Centre for Polar Sciences, Kochi, India.
Mohamed Hatha A. A., Department of Marine Biology, Microbiology and Biochemistry, Cochin University of Science and Technology, Kochi, India, CUSAT-NCPOR Centre for Polar Sciences, Kochi, India.

Keywords: Arctic, Climate change, Permafrost thawing, Ancient microbes, Antibiotic resistance

The rapid melting of glaciers and permafrost in the Arctic and Antarctic has made these locations a climate change hotspot. The rising temperature in the Arctic Circle which is warming at twice that of global average is leading to melting of the permafrost soil that has been frozen for thousands of years. Thawing of permafrost is expected to cause great variability in the current distribution and diversity of microbes. Studies reveal that ice cores from permafrost in Arctic and Antarctic showed the presence of giant viruses and very old bacterial species. The ancient microbes were found to be more resistant to certain antibiotics widely used in the past than the modern populations, whereas the permafrost isolates also show resistance to several next generation antibiotics. Studies also reveal the presence of all types of mobile genetic elements among these ancient bacteria which could facilitate horizontal gene transfer among mixed populations. The current study focuses on the possible impact caused by release of ancient microbes buried in different time scales by using permafrost/glacier melting models on spatio-temporal boundary parameters with the help of R programming language along with biophysical interactions in the system. The antibiotic resistance data and antibiotic usage indices are incorporated for assessing the extent of impact on the human population residing within the Arctic Circle. Auxiliary antibiotic resistance drivers are also incorporated in this study.

Remote sensing and geophysical techniques to detect and map ice-wedges

Samuel Gagnon, Centre d'études nordiques / Université de Montréal, Montréal, Canada
Daniel Fortier, Université de Montréal, Montréal, Canada
Isabelle de Grandpré, Université de Montréal, Montréal, Canada
François Cavayas, Université de Montréal, Montréal, Canada
Jane Dawson, DMT Group
Arianne Deshaies, Université de Montréal, Montréal, Canada
Katerine Grandmont, Université de Montréal, Montréal, Canada
Antoni Lewkowicz, University of Ottawa, Ottawa, Canada
Benoit Loranger, Université Laval, Québec, Canada
Julie Talbot, Université de Montréal, Montréal, Canada
Olivier Piraux, Stantec, Montréal, Canada
Megan Wolfe, DMT Group

Keywords: Permafrost, Ice Wedge, Infrastructure, Remote Sensing, Geophysics

Transportation infrastructure is essential for the economic and social development of the Canadian North. Ice wedges are particularly problematic because their degradation can cause thaw settlement, water ponding and rapid linear erosion with collapses, which in turn can affect the structural integrity of roads and airstrips. Therefore, detecting and mapping ice wedges has become essential to build sustainable transportation infrastructure and implement the appropriate mitigation techniques. To better understand the limitations and applicability of different techniques to map and characterize ice wedges, this study investigated three remote sensing techniques (LiDAR, multispectral satellite imagery, photogrammetry by drone) and four geophysical techniques (GPR, CCR, ERT, microgravimetry). The results of the techniques were compared and calibrated with field measurements made in three study sites with different permafrost conditions near highways in north-western Canada. Remote sensing techniques were particularly useful when working over large areas, while geophysical techniques were more effective for precise localization of ice wedges and for road design purposes. Almost all techniques proved to be effective to detect ice wedges and results were improved when techniques were combined. We conclude that the applicability of each technique depends on the objective and the scale of interest.

ID: 34 - Implications of permafrost thaw at multiple scales: effects on hydrology and biogeochemistry

Conveners

Lara Hughes-Allen | Université Paris Saclay

Frédéric Bouchard | Université Paris Saclay

Ylva Sjöberg | University of Copenhagen

Importance of Dissolved Organic Matter (DOM) Characterization From Permafrost Thermokarst Lakes

Diogo Folhas, Centro de Química Estrutural - Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal
Armando C. Duarte, Department of Chemistry & CESAM, University of Aveiro, Aveiro, Portugal
Martin Pilote, Environment and Climate Change Canada, Aquatic Contaminants Research Division, Montreal, QC, Canada
Warwick F. Vincent, Département de biologie, Université Laval, Quebec City, QC, Canada
Pedro Freitas, Centro de Estudos Geográficos - Instituto de Geografia e Ordenamento do Território, Universidade de Lisboa, Lisboa, Portugal
Gonçalo Vieira, Centro de Estudos Geográficos - Instituto de Geografia e Ordenamento do Território, Universidade de Lisboa, Lisboa, Portugal
Artur M. S. Silva, Department of Chemistry & QOPNA and LAQV-REQUIMTE, University of Aveiro, Aveiro, Portugal
Regina M. B. O. Duarte, Department of Chemistry & CESAM, University of Aveiro, Aveiro, Portugal
João Canário, Centro de Química Estrutural - Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal

Keywords: Permafrost, Thermokarst, Peatlands, DOM, Carbon Cycle

Thermokarst lakes result from the thawing of ice-rich permafrost and are widespread across northern landscapes. Thaw lakes are strong emitters of methane, especially in permafrost peatland regions, where high concentrations of dissolved organic matter (DOM) are common. In the present study, we have characterized DOM from a set of peatland thermokarst lakes, systems associated with intense microbial decomposition and methane emission. Sampling was conducted at different depths from three thaw lakes in the Sasapimakwananisikw (SAS) River valley, near Kuujjuarapik–Whapmagoostui (Nunavik, Canada). Characterization of DOM was conducted through spectrofluorometry, Fourier-transform infrared spectroscopy (FTIR), nuclear magnetic resonance spectroscopy (NMR), and elemental analysis. Fluorescence analyses indicated a presence of autochthonous DOM in the surface waters of SAS 1A, indicating a strong bioavailability of labile DOM, and thus, a greater methanogenic potential. The three lakes differed in their chemical composition and diversity, suggesting various DOM transformations phenomena. The importance of complementary analytical approaches to characterize the complex mixture of DOM in permafrost peatland waters cannot be overlooked, since it can provide a vital perspective on the occurring biogeochemical processes and greenhouse gas production within these thaw lakes. This represents a first step towards greater comprehension of organic geochemistry in permafrost thermokarst lakes.

Annual ecosystem carbon budgets across an abrupt permafrost thaw gradient in Northern Norway

Inge Althuizen, NORCE Norwegian Research Centre, Bjerknes Centre for Climate Research, Bergen, Norway
Casper Christiansen, NORCE Norwegian Research Centre, Bjerknes Centre for Climate Research, Bergen, Norway; Center for Permafrost (CENPERM), Department of Geocience and Natural Resource Management, University of Copenhagen, Copenhagen, Denmark
Anders Michelsen, University of Copenhagen, Center for Permafrost (CENPERM), Copenhagen, Denmark
Sebastian Westermann, Department of Geosciences, University of Oslo, Oslo, Norway
Norbert Pirk, Department of Geosciences, University of Oslo, Oslo, Norway
David Risk, Earth Sciences, St. Francis Xavier University, Antigonish, NS, Canada
Hanna Lee, NORCE Norwegian Research Centre, Bjerknes Centre for Climate Research, Bergen, Norway

Keywords: Climate Change, Arctic, Palsa Mire, Carbon Flux, Methane

Global scale warming leads to permafrost thaw and the release of large amount of carbon to the atmosphere as CO2 and CH4, potentially accelerating global warming. However, there are large uncertainties concerning permafrost thaw and related carbon emissions as changes in soil hydrology associated with permafrost thaw affect the mechanisms controlling carbon mineralization. In 2017 we established a field site in northern Norway, where recent degradation of permafrost created thaw ponds in palsa-mire ecosystems. The site exhibits a natural gradient of permafrost thaw, which also corresponds to a local hydrological gradient. To gain process understanding of how changes in local hydrology affects CO2 and CH4 release from permafrost soils we set up six transects along permafrost degradation gradients. We used a range of manual and automated techniques to measure changes in soil and water microclimate, biogeochemistry, and soil CO2 and CH4 concentrations and efflux across the permafrost thaw gradient. We also installed open top chambers along each of the gradients, except for thaw ponds, to study the effect of enhanced warming on the different permafrost degradation states. Our observations show that permafrost thaw and landscape subsidence – both permafrost slumping and pond formation – increase annual net carbon loss. These increases relate to enhanced CO2 emissions in thaw slumps and a large release of CH4 – calculated as CO2 equivalents – for thaw ponds.

Quantifying and characterising organic carbon in newly-developed soils following glacier retreat in northern latitudes

Saule Akhmetkaliyeva, Manchester Metropolitan University, Manchester, UK
Robert Sparkes, Manchester Metropolitan University, Manchester, UK
Leon Clarke, Manchester Metropolitan University, Manchester, UK
Andrew Dean, Manchester Metropolitan University, Manchester, UK
Simon Cook, University of Dundee, Manchester, UK

Keywords: Organic Carbon, Biomarkers, Bhps, R'soil Index

Arctic and sub-arctic regions contain a globally significant reservoir of easily degradable glacial organic carbon (GOC). 21st century warming will result in glacier retreat with the potential to expose and release GOC, degradation of which can produce CO2 and/or CH4 through physical, chemical or biological processes. Newly-exposed nutrient rich glacial landscapes may develop soils and ecosystems. However, current understanding of the nature of glacial carbon cycling is very weak. Soil development was characterised in three contrasting glacial systems (Oræfajökull ice cap in Iceland, Tarfala in Sweden and Zackenberg in Greenland) in order to understand the main source of OC in soils exposed after glacier retreat and soil development along downstream transects from the glacier front. Soil and sediment samples were analysed for organic carbon and nitrogen concentrations, bacteriohopanepolyol biomarkers (BHPs), DNA sequencing and major elements (using ICP-OES and IC). Soil samples from moraines showed highest OC concentrations (up to 5.5% in Iceland), while fluvial sediment samples from all study areas had low to no OC. Both total BHP concentration and R'soil index (up to 50.5 µg/g SBHPs in 200-400-year-old and 0.41 R'soil in a 2500-year-old Icelandic moraines) show development of soils over time along the downstream transect from the glacier front. Particulate OC concentration in glacial meltwater streams and proglacial lakes was low (up to 0.03 mg/L), perhaps due to the high total suspended sediment concentrations (up to 0.96 mg/L) in most of the streams. Water chemistry analyses showed significant Ca, S, Na, Fe, Mg and Al concentrations, that potentially would fertilise the Arctic ocean. Based on these preliminary data, it can be concluded that direct glacial output of organic carbon is low, but soil and ecosystem development in front of retreating glaciers leads to the build-up of new terrestrial OC stores. Erosion of OC from these pro-glacial landscapes by glacial meltwater might highly affect estimates of GOC. Future glacier retreat in deglaciating systems in the Arctic and sub-arctic regions might increase terrestrial OC productivity and carbon export.

Degradation of particulate organic carbon in the Kolyma River

Kirsi Keskitalo, Vrije Universiteit Amsterdam, Amsterdam, the Netherlands
Lisa Bröder, Swiss Federal Institute of Technology, Zürich, Switzerland
Dirk Jong, Vrije Universiteit Amsterdam, Amsterdam, the Netherlands
Nikita Zimov, Northeast Science Station, Pacific Geographical Institute, Russian Academy of Sciences, Cherskiy, Russia
Anya Davydova, Northeast Science Station, Pacific Geographical Institute, Russian Academy of Sciences, Cherskiy, Russia
Sergey Davydov, Northeast Science Station, Pacific Geographical Institute, Russian Academy of Sciences, Cherskiy, Russia
Tommaso Tesi, National Research Council, Institute of Polar Sciences, Bologna, Italy
Paul Mann, Northumbria University, Newcastle, United Kingdom
Negar Haghipour, Laboratory of Ion Beam Physics, Swiss Federal Institute of Technology, Zürich, Switzerland
Timothy Eglinton, Swiss Federal Institute of Technology, Zürich, Switzerland
Jorien Vonk, Vrije Universiteit Amsterdam, Amsterdam, the Netherlands

Keywords: POC, Kolyma River, Degradation, Permafrost, Carbon Isotopes

Arctic permafrost thaw releases organic carbon (OC) that had been freeze-locked since the Last Glaciation. Thawed permafrost can be released and remineralized in aquatic ecosystems, acting as a potential feedback to climate warming. However, the susceptibility and rate of OC loss during transport, specifically in the particulate OC fraction is uncertain. We focus on quantifying the degradation of POC mobilized from the banks of the Kolyma River. We incubated whole-water samples for 9-15 days (dark, ambient temperature) and quantified POC loss over time both during the spring freshet (2019) and late summer (2018). We tracked changes in POC composition with carbon isotopes (d13C-OC, d13C-DIC, ?14C-OC). Results from summer 2018 show a decrease in POC concentrations of up to 30% while those of dissolved OC decrease by up to 11%. Isotopic shifts suggest that these losses are likely driven by consumption of fresh organic matter while permafrost OC appears mineral-bound and, thus, less degradable. During the freshet, flocculation of DOC increases POC concentrations, whereas total OC decrease 3-12%. These first estimates suggest that POC degrades during transport in the Kolyma River, and that seasonal variability, POC composition, and interactions between DOC and POC are important factors affecting POC dynamics. A better understanding of POC degradation along lateral flow paths is important for improving our knowledge of permafrost thaw and its possible climate impacts in the future.

Nitrogen sources and dynamics in high-Arctic streams

Ada Pastor, Aarhus University, Aarhus, Denmark
Tenna Riis, Aarhus University, Aarhus, Denmark

Keywords: Nitrogen, Freshwaters, Terrestrial-Aquatic Linkages, Ecosystem Productivity, , Greenland

The Arctic is warming at over six times the global average rate, causing permafrost thaw through the gradual deepening of the active layer and increasing soil mass wasting processes. These climate-driven changes will affect the hydrological and hydrochemical fluxes reaching aquatic ecosystems. Nitrogen (N) availability defines structure and function of ecosystems and its low availability is one of the reasons of the limited productivity across the Arctic. However, it is unclear how N sources will change in high-latitude running waters, and thereby the ecological consequences for these ecosystems. In this talk, we will present some of our previous results in NE Greenland placed into the Arctic context. We will focus on (i) the N sources reaching into streams, (ii) the variability of stream N concentrations, and (iii) the effects for aquatic productivity. Our results showed that Arctic riparian soils have general low N available for hydrological export because of the efficient soil microbial N uptake. This is consistent with the prevalence of low N concentrations in stream water, which limits aquatic production. However, we also observed high variability of N concentrations along the fluvial networks, revealing strong controls of the watershed typology and in-stream N biological demand. Our studies indicates that N exports and ecological effects depend on the geomorphological features, vegetation and erosion in the watershed, which are extremely vulnerable to climate change.

A 14,000- year record of permafrost and carbon dynamics from Lake Malaya Chabyda, central Yakutia (eastern Siberia)

Lara Hughes-Allen, Université Paris Saclay, Orsay, France, Alfred Wegener Institute, Potsdam Germany
Frédéric Bouchard, Université Paris Saclay, Orsay, France, Centre d'études nordiques (CEN), Université Laval, Québec, Canada
Christine Hatté, Laboratoire des Sciences du Climat et de l'Environnement (LSCE), Université Paris Saclay, Saint-Aubin, France
Hanno Meyer, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Lyudmila Pestryakova, North-Eastern Federal University of Yakutsk, Russia
Bernhard Diekmann, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Dmitry Subetto, Herzen State Pedagogical University of Russia, St. Petersburg, Russia, Institute for Water and Environmental Problems, Siberian Branch of the Russian Academy of Sciences, Barnaul, Russia

Keywords: Paleolimnology, Permafrost, Sediment Core, Climate Change

A multi-proxy paleolimnological analysis of a sediment core sequence from Lake Malaya Chabyda in central Yakutia (eastern Siberia, Russia) was conducted in order to investigate changes in lake processes within the context of Holocene climate change. Age-depth modelling with 14C indicates that the maximum age of the sediment core is approximately 14,000 cal BP. This includes the end of the late glacial period, spans the Pleistocene-Holocene transition, and encompasses the entire Holocene Epoch. Three distinct units and corresponding thermokarst stages have been identified within the sediment core. Sedimentological and geochemical properties in the deepest section of the core (14,000-12,500 cal BP) suggests a predominately terrestrial environment. The middle section of the core (12,500 9,500 cal BP) is characterized by distinctly lacustrine conditions, while conditions in the upper section of the core (9,500–0 cal BP) suggest a mature lake stage. The transition from terrestrial to lacustrine conditions within the sediment core corresponds to the Holocene Thermal Maximum (9,000-5,000 cal BP) and suggests that thermokarst processes might have been triggered by increasing temperatures. The paleoenvironmental conditions during sediment deposition and soil formation affect the quantity and potential decomposability of sequestered organic material within permafrost and therefore the potential greenhouse gas production of these landscape units after thawing. Decomposability was determined from different geochemical proxies, including total organic carbon and the ratio of total organic carbon to total nitrogen. This study highlights the dramatic effects that increases in temperature can have on landscape dynamics, particularly the initiation of thermokarst processes, thawing of permafrost, and subsequent release of stored organic matter in the form of greenhouse gases.

Long-term hydrometeorological changes in basin underlain by continuous permafrost in the high Arctic (Brattegg river, SW Spitsbergen)

Łukasz Stachnik, University of Wroclaw, Wroclaw, Poland
Krzysztof Migała, University of Wroclaw, Wroclaw, Poland
Mirosław Wąsik, University of Wroclaw, Wroclaw, Poland
Henryk Marszałek, University of Wroclaw, Wroclaw, Poland
Marek Kasprzak, University of Wroclaw, Wroclaw, Poland
Aleksandra Wołoszyn, University of Wroclaw, Wroclaw, Poland
Elżbieta Łepkowska, University of Silesia, Katowice, Poland

Keywords: Base Flow, Permafrost Thaw, Long-Term Runoff, High Arctic, Climate Change

Permafrost thawing related to an increase in air temperature and precipitation affects the water balance, which is strongly enhanced in the high latitudes due to Arctic amplification. Despite it is suggested that peak and base flows increase as results of thawing permafrost, hydrological data used to draw these conclusions are sparse and short-term (< 5-year long dataset) in polar regions. Our study aims at determining the long-term influence of meteorological conditions on discharge in permafrost underlined catchment situated in the high Arctic (Svalbard). Our research was conducted in Brattegg river (area 7.25 km2), sparsely glacierised (0.37 km2) fluvial-lacustrine catchment underlined by continuous permafrost. We used long-term hydrological (discharge, water level, water temperature) and meteorological (air temperature, precipitation, total irradiance) data from 16 hydrologically active seasons from 1973-2019 (1972–73, 1975, 1983, 1985, 1998, 2004–2010, 2017–2019). Our results show a positive correlation between air temperature and discharge for both daily and monthly data. Also, these relationships are stronger for data from August and September as compared with for June and July. The monthly sum of precipitation shows a strong correlation with specific runoff for the former months than for the latter. Future increase in air temperature and precipitation likely lead to increase in base flow and high runoff in the late part of season.

Long-term warming & precipitation experiments in the high Arctic Canada

Ji Young Jung, Korea Polar Research Institute, Incheon, Republic of Korea
Min Jung Kwon, Korea Polar Research Institute, Incheon, Republic of Korea
Kyung-Soon Jang, Korea Basic Science Institute, Cheongju, Republic of Korea
Junhwa Chi, Korea Polar Research Institute, Incheon, Republic of Korea
Sungjin Nam, Korea Polar Research Institute, Incheon, Republic of Korea
Mincheol Kim, Korea Polar Research Institute, Incheon, Republic of Korea
Hojeong Kang, Yonsei University, Seoul, Republic of Korea
Juyoung Seo, Yonsei University, Seoul, Republic of Korea
Jeongeun Yun, Yonsei University, Seoul, Republic of Korea
Yoo Kyung Lee, Korea Polar Research Institute, Incheon, Republic of Korea

Keywords: Climate Manipulation, NDVI, CO2, DOC, FT-ICR/MS

Arctic environment is rapidly changing over the last few decades. Atmospheric temperature has been increasing with a rate of 2-3 times faster than the global average, and precipitation patterns are also changing with warming. Thus, we started a climate manipulation experiment to study ecosystem responses in Cambridge Bay (69° N, 105° W), Canada since 2012. We used Open Top Chambers (2-m diam.) to increase air temperature and added 2L/week of water manually. Several soil biogeochemical parameters were measured to understand carbon dynamics in this ecosystem during 2018-19. The atmospheric and soil temperature increased about 0.5°C in warming compared to control plots. As for plant responses, Normalized Difference Vegetation Index (NDVI) was consistently higher in warming plots than non-warming ones. With a manual chamber method, we measured net ecosystem exchange and ecosystem respiration. Although the amount of CO2 uptake was higher than production during growing season (mid July to mid August), there was no significant differences among treatments. Dissolved organic carbon (DOC) contents in warming plots was higher compared to non-warming plots at the end of growing season in both years despite no significant differences. DOC compositions using 15T FT-ICR/MS showed a decreasing trend of condensed aromatics and proteins with warming. The extracelluar enzyme activities (EEA) related to C and N cycling were also measured, but no significant relationship was found between EEA and other measured variables. After 7-8 years, increased precipitation had no effects on all measured variables. A low degree of warming induced a slight changes in vegetation and DOC contents and compositions, but many C related parameters remained the same in this ecosystem.

Comparing streamflow analysis and remote sensing observations to assess climate change impact on permafrost degradation

Flore Sergeant, Département géologie et génie géologique, Université Laval, Québec, Canada
René Therrien, Département géologie et génie géologique, Université Laval, Québec, Canada
Ludovic Oudin, Laboratoire METIS, Université Pierre et Marie Curie, Paris, France
Anne Jost, Laboratoire METIS, Université Pierre et Marie Curie, Paris, France
François Anctil, Département génie des eaux, Université Laval, Québec, Canada
Romain Jolivet Laboratoire de Géologie, École Normale Supérieure, Paris, France

Keywords: Climate Change, Permafrost Thawing, Storage-Discharge Dynamics, Ground Subsidence, Satellite Images

In many Arctic zones, the frequency of environmental disturbances caused by permafrost thawing increases so rapidly that maintaining an accurate inventory of the state of permafrost at a regional scale represents a great challenge. Moreover, depending on the study area and the permafrost ice content, the thawing rate can vary from millimetres to decimeters per year. Another current challenge is the limited availability of temporal and spatial data on permafrost thawing rates. To address the above challenges, two indirect methods are used: (1) Arctic river streamflow analysis method and (2) Ground settlement analysis method via satellite image observation. Both methods use free-access data that have an exceptionally large temporal and spatial coverage capacity for such a poorly instrumented region. The first method analyses the recession events' behavior of Arctic streams and relates those behaviors to changes in catchment-scale depth to permafrost that influences storage-discharge dynamics. The second method analyses satellite images of the Arctic ground and associates surface elevation change to long-term permafrost degradation due to climate change. Both methods have already been tested through multiple local investigations and gave promising results. However, no comparative study and no large-scale application have been conducted so far. Extending the analysis to hundreds of Arctic basins and comparing the resulting permafrost-thawing rate values from both methods constitute the innovative aspect of this project.

Hydrochemistry of the small streams in Arctic tundra

L.S. Lebedeva, Melnikov Permafrost Institute, Yakutsk
V.V. Shamov, Melnikov Permafrost Institute, Yakutsk & Pacific Institute of Geography, Vladivostok
A.M. Tarbeeva, Lomonosov Moscow State University
N.A. Pavlova, Melnikov Permafrost Institute, Yakutsk

Keywords: small streams, Arctic tundra, hydrochemistry

The aim of the study is to identify river sources and characterize the runoff formation at the small streams in Arctic tundra in the low Lena River basin, Eastern Siberia. In 2018-2020, new hydrochemical and hydrometeorological data were collected during the summer field campaigns at Samoylov research station in the Lena River Delta. The headwaters of tundra streams are ultra-fresh, cold and have a slightly acidic reaction. It indicates their formation in the organic part of the active layer at the contact with the permafrost. The stream waters enrich with dissolved solids where the channel is actively cut into the bedrock. Downstream, water warms up in the channel and ultra-fresh water flows from the slopes and dilute the stream water. The ground water of the active layer and low-mineralized tributaries of the small streams are formed due to the thawing of the ground ice in the active layer. Water isotopic composition suggests that liquid precipitation is a source of the ground ice in the active layer. Detailed field studies in the Arctic tundra are important for understanding of hydrochemistry and hydrology in intensively changing region with lack of any relevant observations at small streams. The research was funded by RFBR according to the projects ?20-35-70027 and 20-05-00840

Lena River biogeochemistry in a wet and a dry year

Pier Paul Overduin, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Bennet Juhls, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Anne Morgenstern, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany

Keywords: Arctic, Hydrology, Permafrost, Organic Carbon

River biogeochemistry integrates environmental processes over a definable upstream area of the river watershed. Therefore, variability of river water biogeochemistry can be a powerful indicator of the impacts of climate change. The current warming of the Siberian Arctic is changing atmospheric forcing, precipitation, subsurface water storage and runoff from rivers to the Arctic Ocean. Consequently, a number of studies predict an increase of organic carbon export by rivers into the Arctic Ocean with further warming of the Arctic. Major potential drivers for this are the increase in river discharge and permafrost thaw, which mobilizes previously frozen organic matter. Here, we present results of high frequency monitoring of the Lena River biogeochemistry close to the river mouth in the central Lena River Delta. The time series comprises two years covering from the spring of 2018 until spring 2020, which were characterized by extreme high and low summer discharges compared to the 94-year historical record. The biogeochemical response of the Lena River water to high and low runoff levels leads to insights into interannual differences in catchment processes, including permafrost thaw and the resulting mobilization of organic carbon, and how they depend on source water determined via end-member analysis. This monitoring program can serve as a baseline against which future change may be measured and as a training dataset to project changes with future climate scenarios.

Efficient representation of overwinter freeze-thaw events

Élise Devoie, University of Waterloo, Waterloo, Canada
Aaron Berg, University of Guelph, Guelph, Canada
James R. Craig, University of Waterloo, Waterloo, Canada
Renato Pardo, University of Guelph, Guelph, Canada
William L. Quinton, Wilfrid Laurier University, Waterloo, Canada

Keywords: Permafrost, Freeze-Thaw, Numerical Modelling, Active Layer, Hydrology

Anthropogenic climate change is responsible for widespread loss of permafrost and changes in active layer dynamics in cold regions. Climate change is also responsible for significant increases in climate variability, leading to an anticipated increase in the number of midwinter melt events in permafrost and permafrost free cold regions. Additional freeze-thaw cycling of the active layer can have important implications for biogeochemical cycling, and midwinter melt can lead to infiltration of meltwater and subsequent refreeze. Midwinter melt events are notoriously difficult to represent in hydrologic models and have serious implications for the hydrologic function of temperate regions, including flooding due to rain-on-snow events and limited soil infiltrability. This can alter the hydrology of the spring freshet which is the dominant hydrologic process in most cold regions. A numerically efficient, semi-analytical coupled thermal and mass transport model is presented that is capable of representing the ice content of near-surface soil. The model is capable of rapid and stable prediction of the infiltrability of the frozen or partially frozen soil without having to solve a discrete form of the coupled partial differential equations. The model tracks pore ice formation and soil cold content in terms of enthalpy. It is tested against data collected in Southern Saskatchewan and is shown to reproduce field observations. This model is efficient enough to be incorporated as a module into existing regional hydrologic models and is hoped to improve predictions of over-winter streamflow and flooding potential during the spring freshet. It may also inform biogeochemical cycling models to better understand the shifts in nutrient cycling due to changing freeze-thaw regimes.

Cold and colder: extreme seasonality in thermokarst lake viral communities

Valérie Langlois, Université Laval, Québec, Canada
Warwick F. Vincent, Université Laval, Québec, Canada
Alexander I. Culley, Université Laval, Québec, Canada

Keywords: Virus, Thermokarst, Metagenomic, Biogeochemical Cycles, Aquatic Microbial Ecology

Thawing of ice-rich permafrost can result in creation of thermokarst lakes and ponds. These aquatic ecosystems are rich in organic matter and shallow, yet during the summer, their water columns are highly stratified with a warm, well-oxygenated layer at the surface and a cool, anoxic layer at the bottom. During the winter, their water columns are isolated by snow and ice and become entirely anoxic, favouring the production of greenhouse gases. Through their wide-ranging impact on their host, viruses affect food chains, microbial population composition and biogeochemical cycles. However, viral diversity is still poorly understood, and the impact of viruses on northern ecosystems is still largely undocumented. The present study addresses the question: how depth-dependent and seasonal changes in the thermokarst pond environment affect viral diversity and community structure. We produced metagenomes from water samples in a thermokarst pond in northern Quebec. The resulting viral assemblages contained numerous, previously unknown strains, and we identified two distinct communities: a variable annual community found at the surface during summer and a perennial community found in the anoxic water layer. The communities were compared to other permafrost and northern lake metagenomes to assess their uniqueness. This is the most comprehensive portrait of viral diversity in thaw ponds to date and move us closer to the elucidation of viral ecology in this environment of global importance.

Ultra-high resolution assessment of potential impacts of vegetation shadows on satellite-derived spectral signals from small thermokarst lakes

Pedro Freitas, Centre of Geographical Studies, IGOT, Universidade de Lisboa, Portugal; Center for Northern Studies, Canada.
Gonçalo Vieira, Centre of Geographical Studies, IGOT, Universidade de Lisboa, Portugal.
Carla Mora, Centre of Geographical Studies, IGOT, Universidade de Lisboa, Portugal.
João Canário, Department of Chemical Engineering/Instituto Superior Técnico – Universidade de Lisboa, Portugal.
Diogo Folhas, Center for Northern Studies, Canada; Department of Chemical Engineering/Instituto Superior Técnico – Universidade de Lisboa, Portugal.
Warwick F. Vincent, Center for Northern Studies, Canada; Dépt de Biologie – Université Laval, Quebec QC, Canada.

Keywords: Thermokarst Lakes And Ponds, Remote Sensing, Drone, Spatial Analysis, Spectral Unmixing

In subarctic Canada, abrupt permafrost thaw is creating widespread thermokarst lakes. Little attention has been given to small waterbodies less than 10000 m2, yet these are biogeochemically more active than larger lakes. Additionally, the landscapes where they develop show intense shrubification and terrestrialization processes. Tall vegetation colonizing waterbody margins can project shadows that impact productivity, thermal regime and the water spectral signal, which in satellite data generates mixed signatures. We undertook unmanned aerial vehicle surveys using optical and multispectral sensors in the boreal forest-tundra transition zone of subarctic Canada. Ultra-high resolution digital surface models were produced to model shadowing at satellite overpass time (WorldView, PlanetScope and Sentinel-2). We then analyzed the impacts of surrounding vegetation and cast shadows on lake surface spectral reflectance derived from satellite imagery. Ultra-high resolution UAV data allows generating accurate shadow models and can be used to improve the assessment of errors and accuracy of satellite data. This research is funded by the Portuguese Foundation for Science and Technology (FCT) under the project THAWPOND (PROPOLAR), by the Centre of Geographical Studies (FCT I.P. UIDB/00295/2020 and UIDP/00295/2020), with additional support from ArcticNet (NCE), Sentinel North (CFREF) and CEN and is a contribution to T-MOSAiC. PF is funded by FCT (SFRH/BD/145278/2019).

Thawing permafrost: an overlooked source of seeds for Arctic cloud formation

Jessie Creamean, Colorado State University, Fort Collins, Colorado, USA
Thomas Hill, Colorado State University, Fort Collins, Colorado, USA
Paul DeMott, Colorado State University, Fort Collins, Colorado, USA
Jun Uetake, Colorado State University, Fort Collins, Colorado, USA
Sonia Kreidenweis, Colorado State University, Fort Collins, Colorado, USA
Thomas Douglas, U.S. Army Cold Regions Research and Engineering Laboratory, Fort Wainwright, Alaska, USA

Keywords: Arctic Aerosols, Ice Nucleating Particles, Permafrost Thaw

As the Arctic warms at more than twice the global rate, radiative feedbacks from clouds will lead to compounding impacts on glaciers, sea ice, and permafrost. However, the formation of Arctic clouds remain highly uncertain due to a limited understanding of ice nucleating particles (INPs). In particular, the sources and abundance of biologically-derived INPs are poorly characterized, yet they may be pivotal for cloud ice formation, especially at temperatures in which Arctic mixed-phase clouds (AMPCs) persist. Here, we show for the first time that permafrost is a remarkably rich source of biologically-derived INPs, both proteinaceous and biomolecular organic INPs. INP concentrations in up to 30,000 year old permafrost were comparable to the most active of other Arctic and midlatitude soils. We will also discuss ongoing laboratory work evaluating permafrost microbial emissions from freshwater and plans for a large-scale field deployment during summer 2021 in Northern Alaska. Thawing of permafrost—which promotes metabolic activity in microbes—and subsequent mobilization of those soils directly into the atmosphere or into lakes, rivers, and the ocean, suggests the intriguing possibility that increasing emissions of INPs from this hitherto overlooked reservoir could be widespread, and, in time, greatly impact Arctic cloud cloud glaciation and radiative properties. This discovery is timely given the rapidly-thawing permafrost in Alaska and across Earth's high latitudes.

Iron speciation at the permafrost-active layer boundary

Amanda Barker, US Army Cold Regions Research and Engineering Laboratory, Fairbanks, USA
Grace McInturff, U.S. Coast Guard, New London, USA
Robyn Snow, U.S. Coast Guard Academy, New London, USA
Thomas Douglas, US Army Cold Regions Research and Engineering Laboratory, Fairbanks, USA
Shawn Gallaher, U.S. Naval Academy, Annapolis, USA
Joseph Smith, U.S. Naval Academy, Annapolis, USA

Keywords: Permafrost, Iron, Speciation, Soil, Redox

In arctic regimes where permafrost accounts for a large portion of the soil environment, the unique interactions between the active layer (seasonally-thawed upper portion of soil) and permafrost (permanently frozen lower portion of soil) contribute an additional barrier to predicting surface water material flux. Permafrost contains a unique environmental interface at the active layer-permafrost transition zone characterized by a sharp redox gradient and a phase change from liquid water to frozen ice. As solid-phase water in permafrost thaws, a higher proportion of interfacial water may be present, disrupting the localized microenvironment of this transition zone. Previous work shows the interface represents a reducing zone that is highly susceptible to mass flushing of redox active elements (e.g. iron; Fe) if thawed and this mass flush will likely occur in late fall/early winter when the active layer is at its' deepest yearly extent. Our work shows bands of reduced Fe sit perched at the active layer permafrost boundary that partition to soil solution greater than the oxidized bands present at the surface of the soil column. Additionally, we observed high concentrations of Fe in the nearby surface water in late fall/early winter corresponding to when the soil surface is frozen, but the active layer is at its' deepest annual depth. As seasonal transitions become more intense in the arctic (winter to spring and fall to winter) and permafrost degradation accelerates, there will be rapid changes to the first 1-2 meters of the soil with potentially significant changes occurring at the permafrost-active layer interface, thus warranting further research.

Source-to-mainstem: geohydrochemical chain from catchment deposits to stream waters, Brøggerdalen, NW Spitsbergen

Zbigniew Zwoliński, Institute of Geoecology and Geoinformation, Adam Mickiewicz University in Poznań, Poland
Małgorzata Mazurek, Institute of Geoecology and Geoinformation, Adam Mickiewicz University in Poznań, Poland
Joanna Gudowicz, Institute of Geoecology and Geoinformation, Adam Mickiewicz University in Poznań, Poland
Przemysław Niedzielski, Department of Analytical Chemistry, Faculty of Chemistry, Adam Mickiewicz University in Poznań, Poland

Keywords: Paraglacial, Surface Water, Geohydrochemistry, Spatial Patterns, High Arctic

We examined the chemical properties of sediments and water flowing down the valley slopes to the valley floor, i.e. main stem of Brøggerelva. Hydrochemical transformations of fresh waters flowing in paraglacial watercourses on the background of the geochemical properties of the surface sediment covers became the main objective of the study. During the summer campaign of the project "Late-glacial and present landscape evolution following deglaciation in a climate sensitive High-Arctic region" we made field mapping. On the e-poster we present the results of field studies and the spatial patterns of hydrochemical properties of surface water. Four geochemical groups we distinguished based on the varying contents of 61 sediment elements. The geochemical features show differences in sedimentary environments and lithology of bedrock and superficial deposits. Six hydrochemical groups of surface waters we distinguished based on the varying contents of macro-elements. The hydrochemical features document differences in water circulation within deposits building the catchment. To identify sources supplying the chemical components in the water samples, factor analysis was conducted with the help of the principal components method. Despite the major relief changes in the valley of the Brøggerbreen contemporary hydrochemical transformations of surface waters with respect to surface sediment geochemistry do not stand up now too great diversity.

Carbon dioxide and methane fluxes measurement in the high Arctic tundra ecosystems in Cambridge Bay, Canada

Namyi Chae, Korea University, Seoul, South Korea
Juyeol Yun, Korea Atomic Energy Research Institute, Daejeon, South Korea
Taejin Choi, Korea Polar Research Institute, Incheon, South Korea
Johann Wanger, Polar Knowledge Canada, Cambridge Bay, Canada
Bang yong Lee, Korea Polar Research Institute, Incheon, South Korea

Keywords: Global Warming, Carbon Flux, Tundra Ecosystem, Carbon Cycle

Response of the Arctic to global warming has shown as a high-sensitivity indicator of climate change. Considering that 25% of Earth's terrestrial surface is underlay by permafrost, warming permafrost may play important roles in carbon cycle of the polar region. The carbon flux in tundra ecosystems should be monitor in order to evaluate the potential future sensitivity of the carbon cycle to climate change. In this study, CO2 and CH4 fluxes were measured in tundra ecosystem using eddy covariance methods and chamber systems during summer in 2019 in Canada. The study site is located on dry tundra with ponds in high-arctic near Cambridge Bay, Nunavut, Canada (69°7'47.7"N, 105°3'35.3"W). The dominant plant speciese are Carex spp. (C. scirpoidea, C. rupestris, C. fuliginosa, etc.) and Dryas integrifolia and the soil type is Orthic Eutric Turbic Cryosol. CO2 and CH4 fluxes near ponds in permafrost were examined to understand the mechanism of the carbon cycle over the tundra ecosystems.
This study was supported by a National Research Foundation of Korea grant from the Korean government (MSIP) (NRF-2016M1A5A1901790 and NRF-2015R1C1A1A02037763).

Environmental controls on organic carbon stocks stored in different tundra vegetation types in the High Arctic of Svalbard

Anna Zielonka, Institute of Geography and Spatial Management, Jagiellonian University, Cracow, Poland; Department of Environmental Sciences, Western Norway University of Applied Sciences, Sogndal, Norway
Jacob C. Yde, Department of Environmental Sciences, Western Norway University of Applied Sciences, Sogndal, Norway
Marek Drewnik, Institute of Geography and Spatial Management, Jagiellonian University, Cracow, Poland

Keywords: Organic Carbon, Aboveground Biomass, Belowground Biomass, Enviornmental Factors, Svalbard

Changes in climatic conditions in the High Arctic affect vegetation and soil development and permafrost thawing. Such acceleration in terrestrial ecosystem changes needs comprehensive examination of environmental controls by concurrent above- and below-ground soil and vegetation properties and their spatial distribution. This study assessed the relationship between aboveground and belowground biomass stocks with particular emphasis on the organic carbon stock and key environmental factors in two study areas in Spitsbergen. Fieldwork was conducted during the vegetation season 2018 (Adventdalen Valley) and 2019 (Brøgger Peninsula). Our results showed significant differences in organic carbon stocks between the two studied areas, with higher organic carbon stock at Adventdalen Valley. The highest organic carbon stock was measured at wet moss tundra sites both in terms of aboveground and belowground stocks. Interestingly, there was a significant amount of organic carbon stored in soils under initial developing tundra. We found substantial impact of abiotic factors on organic carbon stock, i.e. topographic wetness index and soil pH. Additionally, summer temperature and mean annual precipitation were significant controls at both study areas. Our findings suggest faster carbon sequestration in High Arctic soils due to tundra vegetation development than previously thought.

Hydrochemical features of thermokarst lakes of southern and central Yamal (Russian Arctic)

Irina Fedorova, Saint Petersburg State University, St. Petersburg, Russia
Roman Zdorovennov, Northern Water Problems Institute, Karelian Research Centre of Russian Academy of Sciences, Petrozavodsk, Russia
Valerii Kadutskii, Siberian Federal University, Krasnoyarsk, Russia

Keywords: Arctic Lakes, Hydrochemistry, Thermokarst

Arctic thermokarst lakes are sensitive and have regional specific. The major amplitude in ecosystem features could be noticed for Yamal – quite sensitive region according to close permafrost border and increasing human loads. During summer 2018-2020 several lakes of southern (valley of the Erkuta River) and central (Neitinskiye lakes) Yamal had been studied. Erkuta lakes have a medial depth 5 m and are formed on river and marine terraces that effect on hydrochemistry; water consumption by indigenous people can change ecosystem status as well. Thermokarst lake on riverine terrace has conductivity 43-798 µS/cm. The maximum of conductivity and water temperature (+23.5°?) was in a hot summer 2019. The lake on a marine terrace had a strong stratification with halo- and thermocline on 4 m depth with conductivity value from 42 µS/cm on surface to 1300 µS/cm on the bottom with declining water temperature from 20°? to 8°?. The dissolved oxygen (DO) values were 11-13 mg/l with neutral pH. Neitinskie lakes have a thermokarst origin formed due to melting out of the dead fossil glacier ice. Tangabteito Lake depth reaches 35 m, temperature decreases from 13°? on surface to 6°? on bottom. Electro conductivity, DO and pH do not change significantly: 38-85 µS/cm , 9.5-11.6 mg/l and neutral pH correspondingly. Hereby, Yamal thermokarst lakes have numerous hydrochemical parameters that affected by their origin, current loads and climatic parameters. Studies supported by RFBR 18-05-60291.

Low-molecular-weight organic acids of peat soils in the tundra zone of European North-East

Olesya Kubik, Institute of Biology Komi Science Center Russian Academy of Sciences
Elena Shamrikova, Institute of Biology Komi Science Center Russian Academy of Sciences
Alexander Pastukhov, Institute of Biology Komi Science Center Russian Academy of Sciences
Dmitriy Kaverin, Institute of Biology Komi Science Center Russian Academy of Sciences
Vasiliy Punegov, Institute of Biology Komi Science Center Russian Academy of Sciences

Keywords: Low-Molecular-Weight Organic Acids, Peat Soils, Active Layer, Permafrost

High-latitude ecosystems are most sensitive to global climate change. Among the features of the biogeochemical carbon cycle of tundra ecosystems is the formation of a significant number of labile organic compounds. As a result of our study, it was found that the content of low-molecular organic acids ranges from 10-450 mg/kg in the active layer (AL), and up to 10 mg/kg in the permafrost layer (PL) (which is ~ 5% and 1% of the total carbon of water extract, respectively). All soils contain the largest amounts of hydroxypropanoic (up to 40 %), glyceric, glycolic and erythric (on average up to 10% each) acids. The distribution of low-molecular organic substances in AL and PL as an indicator of the processes of modern and previous stages of soil genesis in the European Arctic sector and deserves special attention. This work was supported by the Russian Foundation for Basic Research (project nos. 20-34-70005 and 20-04-00445?).

Modelling pan-arctic lateral carbon transport from abrupt permafrost thaw

Philip Pika, Departement of Earth Sciences, Vrije Universiteit Amsterdam, Netherlands
Wim J. van Hoek, Department of Earth Sciences, Utrecht University, Utrecht, the Netherlands
Arthur H.W. Beusen, Department of Earth Sciences, Utrecht University, Utrecht, the Netherlands. & PBL Netherlands Environmental Assessment Agency, the Netherlands.
Alexander F. Bouwman, Department of Earth Sciences, Utrecht University, Utrecht, the Netherlands. & PBL Netherlands Environmental Assessment Agency, the Netherlands. & Laboratory of Marine Chemistry Theory and Technology, Ministry of Education, Ocean University of China, Qingdao, PR China.
Jack J. Middelburg, Department of Earth Sciences, Utrecht University, Utrecht, the Netherlands.
Jorien Vonk, Departement of Earth Sciences, Vrije Universiteit Amsterdam, Netherlands

Keywords: Permafrost, Modelling, Carbon, Thermokarst, Lateral Transport

The permafrost (PF) zone in the Arctic is experiencing rapid warming which exposes its large stock of soil carbon (C) to thaw and decomposition, prompting potential major changes in the global C cycle. Most large-scale models simulate gradual changes in PF thaw, thereby neglecting C release from abrupt thaw events. While only about 20% of the PF zone is vulnerable to abrupt thaw, these regions contain disproportionate amounts of C affecting half of the C stored in PF soils through abrupt and rapid landscape collapse. Our grasp of the source and fate of particulate and dissolved organic carbon (POC and DOC), released into inland waters from these thaw processes is improving, but little is still known about their lateral transport pathways and driving mechanisms on a pan-arctic scale. Here we implement the C release from abrupt thaw events into a process-based global model framework (IMAGE-DGNM CARBON-DISC) and investigate the lateral transport, transformation and burial of DOC and POC in the pan-arctic river network. Results in the Lena river basin show a positive influence of discharge on the export of POC originating from terrestrial and aquatic sources, while temperature drives in-stream POC, but decreases terrestrial POC. We aim to assess the fate of PF C from abrupt thaw along its riverine network towards the ocean, by quantifying the contribution of in-stream produced CO2 to the PF C feedback to climate warming and quantifying OC sequestration through burial.

Monitoring the optical properties of small thermokarst lakes through synergistic Unmanned Aerial Vehicle and satellite data analysis

Pedro Freitas, Centre of Geographical Studies, IGOT, Universidade de Lisboa, Portugal; Center for Northern Studies, Canada.
Gonçalo Vieira, Centre of Geographical Studies, IGOT, Universidade de Lisboa, Portugal.
Carla Mora, Centre of Geographical Studies, IGOT, Universidade de Lisboa, Portugal.
João Canário, Department of Chemical Engineering/Instituto Superior Técnico – Universidade de Lisboa, Portugal.
Diogo Folhas, Department of Chemical Engineering/Instituto Superior Técnico – Universidade de Lisboa, Portugal; Center for Northern Studies, Canada.
Warwick F. Vincent, Center for Northern Studies, Canada; Dépt de Biologie – Université Laval, Quebec QC, Canada.

Keywords: Thermokarst Lakes And Ponds, Remote Sensing, Drone, Spatial Analysis, Biogeochemistry

Abrupt permafrost thaw is creating widespread thermokarst lakes affecting greenhouse gas emissions to an extent that still needs to be fully integrated in Earth System Models. Scarce attention has been given to waterbodies smaller than 10,000 m2, yet these are biogeochemically more active than larger lakes. Changes in the morphological and optical properties of small thermokarst lakes can provide insight into their biogeochemical significance. Data acquisition using optical and multispectral sensors in unmanned aerial vehicles, along with water sampling are being conducted at long-term monitoring sites of the Centre d'Études Nordiques (CEN) in Subarctic Canada, from the discontinuous to the sporadic permafrost zones. This ultra-high-resolution data, together with field observations, enables a detailed spatial characterization of thermokarst lakes, allowing an improved understanding of microscale phenomena that impact on coarser spatial resolution satellite imagery. Here we describe new challenges and opportunities for remote sensing based on upscaling field observations and monitoring of small thermokarst lakes. This research is funded by the Portuguese Foundation for Science and Technology (FCT) under the project THAWPOND (PROPOLAR), by the Centre of Geographical Studies (FCT I.P. UIDB/00295/2020 and UIDP/00295/2020), with additional support from ArcticNet (NCE), Sentinel North (CFREF) and CEN, and is a contribution to T-MOSAiC. PF is funded by FCT (SFRH/BD/145278/2019).

Suprapermafrost taliks in the small river watershed in Eastern Siberia

L.S. Lebedeva, Melnikov Permafrost Institute, Yakutsk
V.S. Efremov, Melnikov Permafrost Institute, Yakutsk
N.E. Baishev, Melnikov Permafrost Institute, Yakutsk
V.V. Ogonerov, Melnikov Permafrost Institute, Yakutsk
K.I. Bazhin, Melnikov Permafrost Institute, Yakutsk
I.I. Khristoforov, Melnikov Permafrost Institute, Yakutsk

Keywords: Suprapermafrost Talik, Groundwater, Permafrost

The aim of the study was to characterize formation, distribution and dynamics of the suprapermafrost talik aquifers in the continuous permafrost of Central Yakutia with the example of the Shestakovka river watershed with an area of 170 sq.km. Fieldwork included drilling, geophysical profiling and collection of soil temperature, groundwater levels and meteorological data. It was found that approximately 20% of the Shestakovka watershed is covered by suprapermafrost water-bearing taliks of radiation-thermal type with a thickness of up to 20 m. They are located at sparse pine forests on well-drained sandy slopes. Taliks are characterized by presence of the seasonally frozen layer with thickness of 1.7–2.5 m; the depth of zero annual amplitudes is 5–6 m, and the temperature at a depth of zero annual amplitudes is 0 degrees. The seasonal dynamics of the spatial distribution of taliks is more pronounced than interannual changes. Relatively wide distribution of suprapermafrost taliks in continuous permafrost is novel result and has important implications for regional hydrology and hydrogeology. The research was funded by RFBR according to the projects ?? 20-35-70027 and 20-05-00670

The extent of Alaskan arctic coastal wetlands in response to changing sea level

Matthias Fuchs, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Claire Treat, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Guido Grosse, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Ingmar Nitze, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Miriam C. Jones, US Geological Survey, Reston, USA
Katey Walter Anthony, University of Alaska Fairbanks, Fairbanks, USA
Benjamin M. Jones, University of Alaska Fairbanks, Fairbanks, USA
Jonathan A. O`Donnell, National Park Service Alaska, Anchorage, USA
Steve Frolking, University of New Hampshire, Durham, USA

Keywords: Permafrost, Carbon, Coasts

Sea level rise inundated vast areas of the Alaskan coastal zone during the last deglaciation and led to a transformation of large terrestrial areas from organic-rich permafrost terrain to water logged coastal wetlands. This likely weakened the northern terrestrial carbon sink by converting a greater portion of the region into methane-emitting landscapes. In order to estimate the area affected by sea level rise and changing ecological conditions, we compiled a geospatial data set that maps the past (pre-deglaciation) and present extent of Alaskan coastal wetlands based on bathymetry (IBCAO, ARDEM), digital elevation models (ArcticDEM) and Alaskan wetland inventory maps (US Fish & Wildlife) including sea level rise scenarios (e.g., Keigwin et al. 2006). Based on these data sets, we can locate areas likely undergoing ecological changes in future (from dry to wet and water-logged soils) and are able to quantify the carbon stocks affected by previous and current sea level rise by including available soil information. Due to ongoing sea level rise, changing precipitation patterns and increasing river discharge, we expect an ongoing transition from terrestrial permafrost landscapes towards coastal wetlands in future and our data set will help project and understand changes occurring at this land-ocean interface in the Arctic.

Transcriptional response of methanogenic communities to permafrost thaw

Nu Ri Myeong, Korea Polar Research Institute, Incheon, Republic of Korea
Mincheol Kim, Korea Polar Research Institute, Incheon, Republic of Korea

Keywords: Active layer, Permafrost, Methane, Climate change, Metatranscriptome

Thawing permafrost promotes microbial respiration and microbial degradation of organic carbon in permafrost-affected soils, leading to the biogenic production of greenhouse gases such as carbon dioxide and methane. However, the mechanistic understanding of the responses of methane dynamics and microbial processes to permafrost thaw has not been well elucidated. We performed a 336-day laboratory incubation experiment using active layer and permafrost soils under anaerobic condition at three different temperatures (5?, 15?, and 25?), and examined the temporal dynamics of active methanogenic communities using metatranscriptome analysis. Methane production was sensitive to temperature difference, with a greater amount of methane being generated at higher temperatures in both soil layers. Interestingly, the permafrost layer showed a relatively lagged response of methane production but the methane concentrations at later incubation stages were almost two times higher than those of the active layer, which corresponds well with the transcript abundance of methanogens. The dominant methanogens also shifted from 'Ca. Methanoflorens' to Methanosarcina with the increase of the incubation temperature. Our results suggest the possibility that climate change prompts the release of vast amounts of methane to the atmosphere from thawing permafrost since permafrost contains the potential of excessive methanogenic activities in higher temperature although it has lower organic carbon content.

ID: 53 - Earth surface processes in a warmer and wetter Arctic

Conveners

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Changes in the flow regime in the four High Arctic catchments with a different stage of catchment glaciation

Marzena Osuch, Institute of Geophysics Polish Academy of Sciences, Warsaw, Poland
Tomasz Wawrzyniak, Institute of Geophysics Polish Academy of Sciences, Warsaw, Poland
Marta Majerska, Institute of Geophysics Polish Academy of Sciences, Warsaw, Poland
Dariusz Ignatiuk, University of Silesia in Katowice Institute of Earth Sciences, Sosnowiec, Poland
Elżbieta Łepkowska, University of Silesia in Katowice Institute of Earth Sciences, Sosnowiec, Poland
Krzysztof Migała, Department of Physical Geography University of Wrocław, Wroclaw, Poland
Piotr Modzel, Department of Physical Geography, University of Wroclaw, Wrocław, Poland
Łukasz Stachnik, Department of Physical Geography, University of Wroclaw, Wrocław, Poland

Keywords: Hydrological Regime, High Arctic Catchments, Hornsund, Svalbard

The increase in air temperature, the change of annual precipitation run, the higher share of liquid precipitation, the decrease in snow cover duration and the shortening of the snow cover observed recently in the Arctic are reflected in catchment hydrology. Due to the complexity of hydrological systems in cold regions, a catchment response can vary depending not only on climate forcing but also on catchment properties. One of the most important factors influencing the hydrological regime and, so far, poorly recognized is the degree of glacial coverage. This study aims at the analysis of the effect of the level of catchment glaciation on the discharge pattern, based on hydrometeorological data. The study area covers four basins with different glacial coverage located in SW Spitsbergen: Fuglebekken (non-glaciated), Bratteggelva and Ariedalen (glaciers covering 5.9% and 11.5% of the catchment area respectively), and Werenskioldbreen (highly glaciated catchment 61%). For this purpose, an ensemble of hydrological models was applied. Firstly, the models were calibrated and validated using available daily discharge data. In the second step, the flow regime in the period 1979-2020 was reconstructed using calibrated models and meteorological observations from the Hornsund station. The changes in the flow regime were analysed by comparing model results for catchments investigated.

Detecting changes in the high-latitude carbon seasonal cycle with a multi-model approach

Aleya Kaushik, GML NOAA/CU CIRES, Boulder, USA
Lei Hu, GML NOAACU CIRES, Boulder, USA
Luke Schiferl, Harvard University, USA
Roisin Commane, Columbia University, USA
Katherine Haynes, Colorado State University, Fort Collins, USA
Ian Baker, CIRA/Colorado State University, Fort Collins, USA
Arlyn Andrews, GML NOAA, Boulder, USA

Keywords: Carbon-Cycle, Ecosystem, Model, Biosphere, Atmosphere

High-latitude CO2 seasonal cycle amplification has been well documented in long-term atmospheric observations since the 1960s. Explanations include warming-induced earlier onset and enhancement of vegetation growth, increased carbon releases in the fall, and mid-latitude transport. To quantify contributions of gross primary productivity (GPP) and ecosystem respiration (ER) separately to the Arctic CO2 seasonal cycle, we use state-of-the-science process-based, empirical and inverse models to partition net ecosystem exchange (NEE) into GPP and ER for 2000-2020. The process-based Simple Biosphere Model (SiB4) tracks mechanisms controlling phenological plant responses to climate variables, e.g. temperature and moisture. An empirical framework with the Polar Vegetation Photosynthesis and Respiration Model (Polar-VPRM) uses reanalysis climatology from ERA5, satellite-based solar-induced fluorescence and eddy covariance (EC) flux tower measurements to estimate parameters corresponding to specific vegetation types. Polar-VPRM was also tuned with atmospheric inversion model-derived NEE fluxes, constrained by thousands of NOAA in situ atmospheric CO2 observations with larger footprints than EC towers. Our results show (1) the Eurasian boreal region contributes more to the Arctic carbon budget, with higher inter-annual variability, but (2) the only significant trend is increasing GPP in the North American boreal region. Finally, partitioning is compared to FLUXSAT and FLUXCOM products.

Groundwater flow in the marginal zone of the Werenkiold Glcier in southern Svalbard

Katarzyna Stachniak, Silesia University in Katowice, Poland
Sławomir Sitek, Silesia University in Katowice, Poland
Dariusz Ignatiuk, Silesia University in Katowice & SIOS Knowledge Centre, Svalbard
Jacek Jania, Silesia University in Katowice, Poland

Keywords: Arctic, Proglacial Zone, Groundwater Flow, Hydrogeological Modelling

Significant recession of Arctic glaciers reflects climate warming and results in distinct increase of their marginal zones. Thus, significance of hydrologic processes in the proglacial zones is growing. In contrast to the superficial waters in such areas, a role groundwater in hydrological balance of Svalbard glacierized catchments is poorly recognized. Both, increasing of proglacial area and the active layer thickness influence groundwaters processes and their potential retentiveness. The main objective of the study was to recognize hydrogeological conditions of the active layer in the Werenskiold Glacier forefield. Groundwater flow and retention properties were investigated in the glacier sediments thanks to the field studies and by developing of a three-dimensional groundwater flow model for the ablation season in 2017. The main results of the study show components and characteristics of groundwater balance with the possibility of spatial analysis and share of the individual watercourses in underground drainage (for 85 day time period). The calculated runoff was 0.568% of the total runoff from the entire catchment and the volume of water retention in the sediments of marinal zone was 2%. The maximum potential free pore spaces that could be filled up by water was estimated as 3.68% of the total runoff from the entire catchment. Additionaly, results of the spatial analysis of the distribution of the groundwater table depth and identification of zones and boundaries and the directions of groundwater flow are presented. Reported here detailed studies on the hydrogeological aspect of a glacierized catchment is one of very rare in Svalbard and similarly, modeling with use of the FEFLOW software seems to be the first for a proglacial zone in Svalbard.

Holocene chloroplast genetic variation of shrubs (Alnus alnobetula, Betula nana, Salix sp.) at the Siberian tundra-taiga ecotone inferred from modern chloroplast genome assembly and sedimentary ancient DNA analyses

Stefano Meucci, Polar Terrestrial Environmental Systems Research Group, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany.
Luise Schulte, Polar Terrestrial Environmental Systems Research Group, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany.
Heike H. Zimmermann, Polar Terrestrial Environmental Systems Research Group, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany.
Kathleen R. Stoof-Leichsenring, Polar Terrestrial Environmental Systems Research Group, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany.
Laura Epp, Department of Biology, University of Konstanz, Konstanz, Germany.
Pernille Bronken Eidesen, The University Centre in Svalbard, Longyearbyen, Norway.
Ulrike Herzschuh, Polar Terrestrial Environmental Systems Research Group, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany.

Keywords: Chloroplast Genome, Genetic Variation, Sedimentary Ancient DNA (Sedadna), Hybridization Capture, Lake Sediments

Climate warming alters plant composition and population dynamics of arctic ecosystems. In particular, an increase in relative abundance and cover of deciduous shrub species has been recorded. We inferred genetic variation of common shrub species through time. Chloroplast genomes were assembled from modern plants from the Siberian forest-tundra ecotone and sedimentary ancient DNA (sedaDNA) from a lake on the southern Taymyr Peninsula was analyzed by metagenomics shotgun sequencing and hybridization capture approach. For A. alnobetula, analyses of modern DNA showed low intra-species genetic variability and a clear geographical structure in haplotype distribution. In contrast, B. nana showed high intra-species genetic diversity and weak geographical structure. Analyses of sedaDNA revealed a decreasing relative abundance of Alnus since 5400 cal yr BP, whereas Betula and Salix increased. A comparison between genetic variations identified in modern DNA and sedaDNA showed that Alnus variants were maintained over the last 6700 years in the Taymyr region, while Betula and Salix sedaDNA showed higher genetic diversity. Overall, our results suggest that shrubification has species-specific trajectories. The low genetic diversity in A. alnobetula suggests a local population recruitment and growth response of the already present communities, whereas the higher genetic variability and lack of geographical structure in B. nana may indicate a recruitment from different populations.

Integrated geomorphological mapping of an Arctic shoreline: The case of Qaanaaq, North Greenland

Thomas Guldborg Petersen
Niels Foged
Thomas Ingeman-Nielsen
Soňa Tomaškovičová

Keywords: Geomorphology, Quaternary geology, Holocene, Mapping

Due to the highly dynamic evolution during the Pleistocene, a large degree of lateral variability of the near surface, coastal geology is expected with great implications for the integrity and longevity of constructions, as sensitivity to frost heave or lowering of the permafrost table are both dependant on the soil type. The complex sequence of deposition in the Qaanaaq area includes marine, glacial and meltwater deposits. Especially areas with predominantly fine-grained, marine deposits at the surface pose significant risk for civil works, as these are both sensitive to frost heave as well as increased depth to the permafrost. Areas covered with coarse-grained meltwater material is however less sensitive to these factors. We describe the morphology of the Qaanaaq area as dominated by raised marine terraces, intersected by meltwater outwash fans. This is good agreement with the borehole data, which show the presence of fine-grained marine material, overlain by meltwater sand and gravel in the outwash fan areas. The thickness of the coarse-grained material ranges from 0 to ca. 25 m across the town of Qaanaaq, which has significant implications for foundation design. C-14 dating of shells recovered from the boreholes indicate that the nearby fiords where at least occasionally ice free during the last glacial maximum, as shells in reworked material show ages of ca. 42 Ka BP. We also constrain the deglaciation to a period between 9,2-7,9 Ka BP based on in-situ marine shells

The impact of precipitation regime on the CO2 emission rates in pine forests of Central Siberia

Anastasia V. Makhnykina, Siberian Federal University, Krasnoyarsk, Russia
Anatoly S. Prokushkin, VV.N.Sukachev Institute of Forest SB RAS, Krasnoyarsk, Russia
Nataly N. Koshurnikova, Siberian Federal University, Krasnoyarsk, Russia
Eugene A. Vaganov, Siberian Federal University, Krasnoyarsk, Russia

Keywords: Soil Emission, Boreal Forest, Carbon Sink, Precipitation, Pulse Response

The soil emission is highly sensitive to changes in climatic variables and relatively small changes there may have a major influence on the magnitude of soil efflux. On a seasonal scale, soil CO2 efflux is strongly correlated with changes in soil temperature when water is not a limiting factor. Strong inhibition of flux rates was observed at low water content in the soil, which is mainly due to a decrease in degradation due to microbial activity. However, how elevated soil water content is reflected remains a matter of debate. In addition, the seasonal dependence of soil CO2 emissions on precipitation events such as rains is still poorly understood, since it area-specific process and sometimes observes the pulse response – the fast and strong increase in emission rates. In this study, we consider the response of soil CO2 emission rates on the rain events during the summer season. We found that the emission after the rain events which is more than 10 mm a day rose up 8-10 times compared to the emission rates before the rain.

Detecting spatiotemporal ecosystem change with remote sensing across the Arctic

Stefano Potter, Woodwell Climate Research Center

Keywords: Trends, Climate Change, Hotspot Analysis

The Arctic is warming faster than any other region on Earth, at a rate nearly twice the global average, and this warming is expected to have consequences for vegetation, hydrology and terrain thaw. One of the most important global threats from the Arctic is permafrost, which stores a vast amount of carbon that, if thawed, threatens to amplify global warming through decomposition and release of carbon dioxide and methane into the atmosphere. Despite the potential consequences associated with these threats, there is a currently a limited understanding of these processes which makes it difficult to project or manage associated risks. Here we propose to establish a monitoring system which will detect landscape changes in the Arctic using a suite of Visible, Near-Infrared and Thermal Infrared (VIS-NIR-TIR) and microwave remote sensing time series that provide ecological indicators for landscape freeze/thaw status, ecosystem water stress and vegetation state. More specifically, we examine trends in the timing of the annual start and end of the growing season, the surface freeze/thaw/transitional status, surface soil moisture, temperature, precipitation, and changes in vegetation health. We will then combine these separate indicators to create maps which highlight “hotspots” of ecosystem change, and examine regional case studies across a variety of ecosystems showing both consistent and anomalous change patterns.

ID: 59 - Permafrost and periglacial processes in cold climatic areas

Conveners

Hanne H. Christiansen | The University Centre in Svalbard, UNIS, Norway

Michael Krautblatter | Technical University Munich, Germany

An analysis of near-surface temperature inversion characteristics on permafrost in dissimilar valleys, Yukon Canada

Nick C. Noad, University of Lethbridge, Lethbridge, Canada
Philip P. Bonnaventure, University of Lethbridge, Lethbridge, Canada

Keywords: Surface-Based Temperature Inversions, Permafrost, Climate Reanalysis, High-Latitude Mountains, Dissimilar Valleys

Perhaps the largest difference in permafrost distribution in lower-latitude mountains and those in high-latitude continental areas involves the interfingering of latitudinal and elevationally controlled permafrost. This has been shown to be related to the occurrence of Surface Based Temperature Inversions (SBI) which influence Mean Annual Air Temperatures (MAAT) and Surface Lapse Rate (SLR) across the landscape on an annual scale. Study objectives seek to identify and quantify patterns of SBI characteristics in two proximal yet dissimilar valleys of Central Yukon, Canada. Investigation centres on elevational transects examining near-surface air temperature in the two valleys. On-site investigation is critical for analysis of SLR as considerable elevational heterogeneity commonly deems coarse resolution climate reanalysis products to be of limited use in complex areas. Secondarily, field-based SLR data is compared to SLRs calculated from coarse resolution climate reanalysis models (ERA5, MERRA, and JRA55) in areas of strong persistent SBIs. Measured SLRs in each valley indicate there is significant inter-valley differences in SLR patters and subsequent MAAT. These SBI differences contribute substantially to variable permafrost attributes which climate reanalysis products grossly under predict. Hyper-inverted SLR observed from valley bottom up surrounding slopes influencing the value of MAAT in the valley bottom by up to 3°C. Findings suggest that there is significant error in predicting MAAT across the landscape associated with the variable impact of SBI, thereby suggesting error in predicting current and future permafrost in these high-latitude mountainous areas.

An aerial inventory of rock glacier distribution and activity level assessment in Banff and Jasper National Parks, Alberta, Canada

Mishélle A.E. Wehbe, University of Lethbridge, Lethbridge, Canada
Philip P. Bonnaventure, University of Lethbridge, Lethbridge, Canada
Robert G. Way, Queen's University, Kingston, Canada

Keywords: Rock Glacier, Inventory, DEM, Rocky Mountains, Canada,

Rock glaciers are frozen masses of ice and debris that creep downslope under the weight of gravity. These features are often tongue-shaped, lobate landforms containing longitudinal or transverse flow structures, with a surface that consists of poorly sorted, angular, rock debris. Although rock glaciers are abundant geomorphological features in the alpine of the Alberta Rocky Mountains, their spatial distribution and characteristics are largely unknown. Over 875 intact (active/inactive) rock glaciers were identified within the study area, as well as over 115 features requiring further validation of surface kinematics and morphometric quantification. Aspect was found to be a topographic parameter that strongly influences rock glacier distribution in this region, as most features were found to occur on the North and Northeastern facing slopes. The manual inventorying of these features was done using high-resolution imagery available through ArcGIS Online and Google Earth. As rock glaciers contain frozen fresh water and can be potential geohazards, inventories are crucial in the assessment of the activity status of these landforms. The derived rock glacier classification method developed a proof of concept within a small area that verifies the applicability of this method at a regional scale. This work evaluates the suitability to detect rock glaciers using this method. Which can then be applied in various regions to determine further methodological improvements, as well as the identification of other variables that attribute to rock glacier formation/occurrence. The inventories completed with this initiative will be given to the International Permafrost Associations international rock glacier inventorying action group.

Does global warming stabilize or destabilize permafrost landforms? Decadal-scale monitoring in Svalbard

Norikazu Matsuoka, University of Tsukuba, Tsukuba, Japan
Tatsuya Watanabe, Kitami Institute of Technology, Kitami, Japan
Hanne H. Christiansen,University Centre in Svalbard, Longyearbyen, Norway

Keywords: Permafrost, Ice wedge, Rock glacier, Monitoring, Global warming

Decadal-scale monitoring of rock-glacier movement and ice-wedge cracking in Svalbard highlights the influences of climate changes on the activities of the two permafrost landforms. Thirteen years (2006–2019) of dynamics of a small valley-side rock glacier were studied by (1) continuous monitoring of ground temperature and internal deformation in a 15-m deep borehole and (2) annual GPS surveys of 13 surface benchmarks. Annual mean shallow permafrost temperatures fluctuated between -2 and -4°C with an overall warming rate of about 0.1°C/yr. The GPS surveys indicated downslope displacement at rates of 2.4–4.6 cm/yr and subsurface inclinometers steadily tilted, both showing interannual fluctuation with overall slow acceleration that correlated with annual mean permafrost temperatures. Our monitoring predicts that the surface velocity could rise by two times in the next 10–20 years. Monitoring of three ice-wedge troughs for 13 years (2005–2018) documented widening and cracking of the troughs and ground thermal regime down to the topmost permafrost. In winter, rapid cooling spells triggered temporary widening and cracking of troughs by thermal contraction when the ground surface was cooled below -20°C and thermal gradient exceeded 10°C m-1, regardless of annual or winter mean ground temperatures. The primary control on cracking is rapid cooling in excess of the critical condition, suggesting that despite ongoing warming crack activity may not necessarily decline in the next few decades.

Overwiev of diversity and ecological functions of biological soil crusts in High Arctic ecosystems (Billefjorden, Central Svalbard)

Ekaterina Pushkareva, Univeristy of South Bohemia, Ceske Budejovice, Czech Republic, and Department of Applied Ecology and Phycology, University of Rostock, Rostock, Germany
Jana Kviderova, Univeristy of South Bohemia, Ceske Budejovice, and Institute of Botany, CAS, Trebon, Czech Republic
Miloslav Simek, Univeristy of South Bohemia, and Biology Centre, Institute of Soil Biology, CAS, Ceske Budejovice, Czech Republic
Kamil Laska, Faculty of Science, Masaryk University, Brno, Czech Republic
Igor S. Pessi, InBios-Centre for Protein Engineering, University of Liège, Belgium, and Department of Microbiology, University of Helsinki, Helsinki, Finland
Yannick Lara, InBios-Centre for Protein Engineering, University of Liège, Belgium
David Baurain, InBios-Centre for Protein Engineering, University of Liège, Belgium
Annick Wilmotte, InBios-Centre for Protein Engineering, University of Liège, Belgium
Josef Elster, Univeristy of South Bohemia, Ceske Budejovice, and Institute of Botany, CAS, Trebon, Czech Republic

Keywords: Diversity, Ecological Functions, Soil Biological Crusts, High Arctic

The most important biological communities in periglacial terrestrial semi-arid and arid deserts areas in the High Arctic are Biological Soil Crusts (BSCs). Mainly mosses, lichens, fungi, cyanobacteria and eukaryotic microalgae, compose them. With climate changes, the BSCs are predicted to facilitate the “greening” of the Arctic, a phenomenon associated with increased biomass coverage by BSCs and the subsequent succession by shrub tundra, responsible for an increase of carbon sink. Microalgae (prokaryotic cyanobacteria and eukaryotic algae) are keystone microbial species of the BSCs, being significant primary producers, fixing atmospheric nitrogen and producing polysaccharides that bind soil aggregates together. In the last few years, we have studied the cyanobacteria and microalgae of BSCs to characterizetheir diversity and ecological functions (photosynthesis and nitrogen fixation) in Billefjorden, central Svalbard. The diversity of cyanobacteria and microalgae in different stages of development of the BSCs was analysed; a) using morphological (cell biovolume - stereomicroscopy - light microscopy) and molecular methods (NGS amplicon sequencing of cyanobacterial 16S RNA and eukaryotic 18S rRNA sequences of isolates), b) diurnal courses of photosynthetic and nitrogenase activity and, c) microclimatic and soil chemical conditions. The results showed that cyanobacteria prevailed in most barren soil types, dominated by filamentous cyanobacteria Leptolyngbya spp. In contrast, microalgae (green and yellow-green algae) were more abundant in frequently disturbed vegetated soils. Nitrogenase activity decreased from poorly to more developed soil crust types. Temperature was the main factor influencing photosynthetic activity of BSCs soil crusts. Higher temperatures led to inhibition of photosynthetic activity and increased energy dissipation, indicating acclimation of the soil crust photosynthetic microorganisms to cold environment.

Mountain permafrost in Sismiut, Greenland: an assessment based on temperature monitoring, geophysics and modelling

Marco Marcer, DTU BYG, Sisimiut, Greenland
Pierre-Allain Duvillard, EDYTEM, Chambéry, France
Thomas Ingemann-Nielsen, DTU BYG, Kgs. Lyngby, Denmark
André Revil, EDYTEM, Chambéry, France
Sona Tomaskovicova, DTU BYG, Kgs. Lyngby, Denmark

Keywords: Mountain Permafrost, Greenland, Geophysics, Modelling

Mountain permafrost assessment is included in hazard identification strategies in most of anthropized mountain areas across the globe. However, this is not the case for Greenland yet, despite mountains are a prevalent feature and involve hazards that already threatened the population in the recent past. Here, permafrost distribution is described only by large scale models not designed to capture the high spatial variability and steep terrain characterizing mountains. The reliability of these models is unknown, and the lack of in situ data prevents validation efforts. As result, stakeholders seldom consider permafrost in hazard assessment. In this context, we propose a comprehensive assessment of mountain permafrost in the Sismiut municipality, West Greenland. The project started in September 2020, when we installed a network of 38 ground temperature loggers in various ground and topographic settings in the mountains near town. In October 2020 we conducted ERT and IP surveys on two rockwall ridges, capturing ground geoelectrical characteristics and linking them to ground temperature through a series of laboratory experiences. We then set up a modelling procedure to estimate bedrock temperatures on the same ridges, based on ERA5 climatic database, surface energy balance and 2D heat transfer. Our results provide a first estimation of mountain permafrost for the Sisimiut area and a reference for mountain permafrost assessment at the regional scale for Greenland.

"Living Permafrost": Man and the Environment

Irina Chesnokova, Water Problems Institute Russian Academy of Sciences (WPI RAS), Moscow, Russia
Dmitry Sergeev, Institute of Environmental Geoscience, Russian Academy of Sciences (IEG RAS), Moscow, Russia

Keywords: Permafrost, Human Life, Permafrost Processes, Russia

Public opinion and widespread knowledge include permafrost in the geological environment, suggesting slow changes in comparison with the duration of human life. However, modernity testifies to dramatic changes in this "little changing" part of the natural environment. Signs of these changes can be recorded visually due to the interconnections of different components of the landscape The scientific novelty of our research lies in the description of these features in the original photographs of the participants of the expeditions taken in different years in different sectors of the Arctic. Special emphasis is placed on the beauty of the occurrence of underground ice, photographs of the same place at different times with the identification of the result of natural processes, examples of deformations of engineering structures as a result of climate change and geocryological conditions. The aim of the research project was to popularize knowledge about the meaning of permafrost for residents and nature users. The main tasks were: 1. Preparation of a photo album layout based on the signs of the impact of permafrost processes on infrastructure and landscapes. The layout includes color photographs with detailed comments, grouped by types of permafrost processes and the results of their impact on human activity and landscapes. 2. Preparation of an Internet version of the exposition demonstrating the importance of permafrost for humans and the environment. 3. Preparation of methodological material for teachers on the organization of school monitoring of permafrost, which is a step-by-step guide in pdf format, revealing the method of visual and instrumental observations of the state of permafrost. The effect of the project is to popularize permafrost as a geographic miracle of Russia. The publication was carried out with the financial support of the Russian Geographical Society, project no 22/2020-?.

Environmental controls on permafrost and ground temperature regimes and distribution in Barton Peninsula (King George Island, Antarctic)

Joana Baptista, CEG/IGOT, University of Lisbon, Lisbon, Portugal
Gonçalo Vieira, CEG/IGOT, University of Lisbon, Lisbon, Portugal
Pedro Ferreira, LNEG, Lisbon, Portugal
Daniel Vonder Mühll, ETH, Zurich, Switzerland
António Correia, University of Évora, Évora, Portugal
Soon Gyu Hong, Korea Polar Research Institute, South Korea, Incheon, South Korea
Hyoungseok Lee, Korea Polar Research Institute, South Korea, Incheon, South Korea

Keywords: Permafrost, Temperature, Monitoring; GTN-P, Antarctic Peninsula

Permafrost temperatures have been shown to be close to 0 ºC at the South Shetlands, which indicates a sensitive area to permafrost degradation. With the aim to better characterize the permafrost conditions in King George Island a new borehole was drilled in 2019 in Barton Peninsula at 128 m asl reaching a depth of 13.2 m (KSS). The borehole is integrated in the PERMANTAR network and in GTN-P and is equipped with 15 temperature sensors at different depths, recording at an 1-hour interval. The first full-year data set was collected in March 2020. To analyze the ground surface temperature (GST) regimes and their geographical controls, 20 miniloggers were installed in different terrain settings recording at an interval of 3 hours. In this presentation, we discuss the thermal regime of KSS and of the 20 GST monitoring sites and their implications for understanding the spatial distribution of permafrost in Barton Peninsula. KSS showed a mean permafrost temperature at 13 m of -1.5 ºC, an active layer depth of c. 2 m in 2019 and a thaw depth of 3 m in March 2020, a value which was possibly surpassed. One-Way ANOVA showed a prevailing control of elevation in GST distribution in Barton Peninsula, with significant spatial differences. The Freezing Degree Days varied from 438 to 1041 ºC during winter, with n-factors showing values between 0.6 and 1. Research funded by the Portuguese Polar Program of FCT through the project PERMANTAR, SWISS GCOS and CEG through FCT I.P.: UIDB/00295/2020.

Permafrost temperature reconstruction on James Ross Island (Antarctic Peninsula) in the period 2004-2017

Lucia Pastirikova, Department of Geography, Faculty of Science, Masaryk University, Brno, Czech Republic
Filip Hrbacek, Department of Geography, Faculty of Science, Masaryk University, Brno, Czech Republic
Kamil Laska, Department of Geography, Faculty of Science, Masaryk University, Brno, Czech Republic

Keywords: Permafrost Temperature Modelling, TTOP Model, Ground Thermal Regime, Antarctica, Climate Change

Permafrost temperature is one of the most important parameters describing the state of the terrestrial environments of the polar areas. The temperature in the topmost part of the permafrost reacts very sensitively to climate variability and is a suitable indicator of the climate change effect. Yet, only little is known about the long-term variability of the permafrost temperature in the Antarctic region due to generally short datasets. Therefore, one of the possible approach is the permafrost temperature reconstruction using air temperature data which cover the period since the 1950s. In this study, we present the first approach of the permafrost reconstruction using the Temperature at the Top of Permafrost model (TTOP) on the study site located near to Johann Gregor Mendel station on James Ross Island (Eastern Antarctic Peninsula) in the period 2004-2017. The reconstruction is based on air temperature data. The modelled results are validated against ground temperatures at a depth of 75 cm measured from 2011, which represent the topmost part of the permafrost. The TTOP validation showed a strong correlation ($R2=0.96$) and RMSE of 0.64. TTOP reconstructed mean temperature of -5.4 °C in the period 2004-2017 which was 1.2 °C higher then air temperature mean. The TTOP followed a trend of -0.06°C/decade whereas the air temperature had a trend of 0.03°C/decade, both non-significant at $p<0.05$.

Assesment of snow cover effect on active layer thermal regime and thickness, CALM-S JGM, James Ross Island

Filip Hrbacek, Department of Geography, Masaryk University, Czech Republic
Zbynek Engel, Department of Physical Geography and Geoecology, Faculty of Science, Charles University, Prague, Czech Republic
Michaela Knazkova, Department of Geography, Masaryk University, Czech Republic
Jana Smolikova, Department of Physical Geography and Geoecology, Faculty of Science, Charles University, Prague, Czech Republi

Keywords: Active Layer Thickness, Snow Cover, Antarctica, Ground Thermal Regime

This study assesses the effect of unusual presence of snow cover during high summer 2018 on thermal regime and thickness of active layer on James Ross Island, Eastern Antarctic Peninsula. The area of interest is typical for the irregular presence of snow cover during winter months and consequently its limited effect on ground thermal conditions. This is contrasting in comparison with the sites in the Western Antarctic Peninsula, where snow effect on active layer and permafrost is much significant. This case study brings observation of snow depth, spatial extension, the ground thermal regime at two profiles and active layer thaw depth on the CALM-S site JGM located in the northern part of James Ross Island. We observed a snowpack of a maximum depth of 25 cm, which covers >60 % of the CALM-S area (80 to 70 m). Multiple GPR measurements (850 MHz antenna) of the thaw depth in parallel profiles of CALM-S and evaluating of ground thermal parameters from both monitoring profiles showed the following results: The ten day of snowpack presence on the CALM-S area led to a decrease of the thawing degree days by ca. 10 % compared to the typical seasonal values. Further, active layer thaw depth was reduced by 5-10 cm in the parts covered by snow compared to previous snow-free summer seasons. We found, that even short-term occurrence of snow cover during high summer can significantly affect ground thermal regime as well as thaw depth.

Assessment of the spatial relationship between sorted stone circles and vegetation in Maritime Antarctica

Marta Almeida, CERENA/IST-Univ. LIsboa, Lisboa, Portugal
Pedro Pina, CERENA/IST-Univ. LIsboa, Lisboa, Portugal
Sandra Heleno, CERENA/IST-Univ. LIsboa, Lisboa, Portugal
Gonçalo Vieira, CEG/IGOT-Univ. LIsboa, Lisboa, Portugal

Keywords: Antarctica, Patterned Ground, Vegetation, UAV

Stone circles are a type of patterned ground formed in periglacial environments and whose relation to permafrost conditions make them very helpful for better understanding past climates. Their characterization and monitoring have been mostly made in the field by analysing few individuals. To allow a more detailed morphometric characterization of the circles, to assess their spatial variability and to understand how they relate to vegetation covers, we have established a methodology based on ultra-high resolution remote sensing. For that purpose, we have developed unmanned aerial vehicles (UAV) or drone surveys in different locations of Barton Peninsula in King George Island (62ºS), one of the terrestrial regions of Antarctica where these patterns are more ubiquitous. The use of both image mosaics and digital elevation models, highly detailed products of mm-cm resolutions built after structure-from-motion techniques, allow delineating accurately each sorted stone circle, from which a set of 2D and 3D morphometric features are extracted. Detailed maps of the main communities of vegetation (lichens and mosses) on the same locations are also obtained after the automatic classification of the image mosaics with machine learning methods. The morphometric characteristics of the about 3000 circles analysed along an altitudinal gradient in the peninsula (from 65 to 245 m asl) and their relation to the vegetation are presented and discussed.

Aufeis resources of the North-East of Russia

Natalia Nesterova, North-Eastern Permafrost Station of Melnikov Permafrost Institute, Magadan, Russia
Olga Makarieva, North-Eastern Permafrost Station of Melnikov Permafrost Institute, Magadan, Russia
Anastasia Zemlianskova, North-Eastern Permafrost Station of Melnikov Permafrost Institute, Magadan, Russia

Keywords: Aufeis Resources, The North-East Of Russia, Climate Change, Hydrological Cycle

On the territory of the North-East of Russia there are more than 7 thousand aufeis, which are located in the basins of the large rivers Yana, Indigirka, Kolyma, rivers of the Chukotka Peninsula and the sea of Okhotsk basin. The Indigirka river is the world's champion for aufeis among major Arctic rivers, the aufeis cover about 0.55 % of its territory. Currently, the hydrological cycle of the region has been changing, winter river flow is increasing. In this paper, the analysis of modern aufeis resources is performed for the first time in the last 60-70 years. Preliminary results indicate that there has been a significant decrease in the aufeis resources of the North-East. For example, in the work (Koreisha, 1981), the total aufeis reserves of the North-East are estimated as 17 km3. According to modern assessment performed based on satellite images data, they amount to at least 10.6 km3 or 5 mm of aufeis runoff. In the context of climate change, the continuation of research on the patterns, dynamics of aufeis formation and their resource potential, both in the fundamental plan of studying the natural phenomena of the cryolithozone, and for practical purposes of ensuring sustainable and safe development of the region, is extremely relevant and timely.

Comparison of Ground Surface Freezing-thawing Conditions in Discontinuous Permafrost Regions between Alaska and the Qinghai-Tibet Plateau

Tonghua Wu,State Key Laboratory of Cryospheric Science, Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences, Lanzhou, China
Bob Bolton,International Arctic Research Center, University of Alaska Fairbanks, USA
Bob Busey,International Arctic Research Center, University of Alaska Fairbanks, USA
Xiaodong Wu,State Key Laboratory of Cryospheric Science, Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences, Lanzhou, China

Keywords: Permafrost; Climate change; Freezing-thawing condition; Arctic; Qinghai-Tibet Plateau

The land surface and subsurface processes and their complex interactions are of great importance to improve the performance of Earth System Models in cold regions including the high-altitude and high-latitude regions. The in-situ observations for those processes are especially important for cold regions ecosystems where topography, permafrost, hydrology, vegetation, and biogeochemistry are inextricably linked. The implications of such linkages include permafrost thaw and deepening of the active layer, changing productivity, and watershed-scale changes in ground surface. In order to compare the difference of ground thermal regimes between the third pole regions and the Arctic regions, in September of 2018, an integrated automatic weather station was set up through collaboration of SKLCS and IARC at Teller site of Nome, Alaska. At the same time, the active layer monitoring site to measure soil temperatures at five levels has been deployed. Until the September of 2019, the air temperature, the ground surface temperature, and soil temperature data have been collected for a whole freezing-thawing period. In this study, the ground surface freezing-thawing condition has been analyzed to identify the different impact factors of meteorological and local parameters between both sites. The result will enhance our understanding the energy and water exchange mechanism between atmosphere and ground surface in the discontinuous permafrost regions.

Growth of permafrost within peatlands during warm climate period

Yana Tikhonravova, Melnikov Permafrost Institute, SB RAS, Yakutsk, Russia

Keywords: Permafrost, Arctic Peatland, Thermokarst, Ground Ice

The polygon peatland was studied at drained lake on the Pur-Taz interfluves (the North of West Siberia). It locates between the road and a small lake. The peatland's apparent thickness is 2.4 m. The ice wedges (> 4 m length and 3 m wide), ice lenses and closed-cavity ice were discovered in cross section of the icy peatland. Thermal erosion on ice wedge was produced by drainage construction and direction of flow under the road. The ice wedges thawing led to gullies formation on polygon troughs. This gullies' bottoms are water filled. This syngenetic ice wedges grew due to thermal contraction cracking during the Holocene and the present. However, local thermokarst process participated in the ice wedges formation. When the climate fluctuates, the thermokarst produces to a cavity, filled water, on the ice wedge at summer periods. And other genetic types of ice build up to the ice wedge at winter periods. Also, the thermokarst produces ice lenses formation, that to safe peatland permafrost. It was established that the big ice lenses formed by lake water infiltration and accumulation within peat layer under lowered top of permafrost. Ice segregation released from this flooded peat layer during seasonal freezing. This big ice lenses save a peatland from degradation. The permafrost top lowered down due to the thawing effect of the watered peat layer during the ice lenses formation. After its formation, active layer thickness decreased because more energy necessary to thawing this ice lenses. Increase of summer temperatures causes to increase of plants growing. The plants increase causes to raise of surface and conservation of the ice lens. And increase of wetting peatlands provides to grow permafrost. The reported study was funded by RFBR, project N 19-45-890011.

Holocene vegetation of Coles valley, Spitsbergen island

Diana Soloveva, Arctic and Antarctic Research Institute; St. Petersburg State University, St. Petersburg, Russia
Larisa Savelieva, St. Petersburg State University, St. Petersburg, Russia

Keywords: Svalbard, Holocene, Vegetation, Pollen Analysis

The pollen and radiocarbon data newly obtained for three peat sequences from the Coles valley (Spitsbergen Archipelago) allow us to reveal several stages of vegetation development during the Holocene. A comparison of these data with our previous data from Grendalen valley and published data from north cost of Nordenskiöld Land shows the asynchronous of vegetation development on these area from ~10000 to ~2500 yrs ago. Probably this event is connected with the orographic features and distance far from the ocean. The model of vegetation changes for the north part of Nordenskiöld Land on the basis of pollen and radiocarbon data will be presented.

Paleogeography of the Pleistocene-Holocene environment in Central Yakutia

Anna Kut', Melnikov Permafrost Institute SB RAS, Yakutsk, Russia
Valentin Spector, Melnikov Permafrost Institute SB RAS, Yakutsk, Russia

Keywords: Paleogeography, Pleistocene, Holocene, Sedimentation Environment

In paper results of quartz grain's micromorphological analysis adduced. It was conducted for the Bestyakh floodplain terrace in Central Yakutia. The aim is paleogeographical environment studying in Pleistocene and Holocene in view of sediment genesis disambiguate. Sand complex of the Bestyakh terrace was referred to us river derived fluvioglacial sediment (S. Biske), ancient alluvium of Lena (P. Soloviev, M. Alekseev, M. Ivanov) and buried middle-quaternary aeolian dunes (V. Kolpakov). 64,5 meter's profile of the borehole 19/1 drilled in 2019, was studied for reconstruction of sedimentation environmnet. Roundness degree and frosting of quartz grains, its genetic classes distribution and texture manifestation on quartz grains points to fluvial and aeolian processes involvement under upper part of terrace formation. Sediments were transported in aqueous processing with saltation and suspension.

Satellite based mapping of vegetation in Antarctica guided by UAV surveys based on machine learning

Vasco Miranda, CERENA/IST, Lisboa, Portugal
Sandra Heleno, CERENA/IST, Lisboa, Portugal
Gabriel Goyanes, CERENA/IST, Lisboa, Portugal
Gonçalo Vieira, CEG/IGOT, Lisboa, Portugal
Pedro Pina, CERENA/IST, Lisboa, Portugal

Keywords: Lichen, Moss, UAV, Satellite, Machine Learning

Vegetation in Antarctica, associated to the active layer and the underlying permafrost, is a key environmental element of their terrestrial ecosystems. Their extended multitemporal mapping can only be performed through spaceborne datasets. But the nature of occurrence of the main types of vegetation (lichens and mosses) in relatively small and sparse patches, frequently below the detection resolution limit of most satellite images, makes their identification very challenging. To create reliable vegetation maps we propose a methodology that integrates remote sensing imagery in multiple spatial scales: 5 cm (UAV), 2 m (WorldView or similar), 10 m (Sentinel-2) and 30m (Landsat). The controlled understanding of the increase of spectral mixing with the decrease in resolution along the multiscale datasets in the same date, allows designing and calibrating robust machine learning models to perform the classifications with high performances on the datasets of lower resolution (Landsat), the only ones which cover the whole terrestrial regions of Antarctica for more than 4 decades. Results about the vegetation mapping are presented, focusing on multitemporal changes detected, for different terrestrial areas of the South Shetlands where we have been conducting UAV surveys.

Theme E: Unravelling Arctic Ecosystem Dynamics

ID: 06 - Arctic ecosystem changes, pollutant issues and their impact on wildlife and northern communities

Conveners

Martin Pilote | Environment and Climate Change Canada, Aquatic Contaminants Research Division, Montreal, Canada & Centre for Northern Studies

Martin Jusek | Centro de Química Estrutural, Instituto Superior Técnico, University of Lisbon, Lisbon, Portugal

João Canário | Centro de Química Estrutural, Instituto Superior Técnico, University of Lisbon, Lisbon, Portugal

Advancing models to link changes in dissolved organic carbon with PAR and UV light attenuation and the ecosystem responses in browning lakes

Rachel M. Pilla, Miami University, Oxford, OH, United States
Raoul-Marie Couture, Center for northern studies (CEN), Takuvik Joint International Laboratory and Department of Chemistry, Université Laval, Quebec City, QC, Canada

Keywords: Process-Based Model, Light Attenuation, Dissolved Organic Carbon, Photosynthetically Active Radiation, Ultraviolet Light

Climate change-induced thawing of permafrost and changing precipitation patterns have added to existing anthropogenic stressors, leading to increasing dissolved organic carbon (DOC) in aquatic ecosystems throughout many parts of the northern hemisphere. These increases in DOC fundamentally alter the light and heat distribution in lake ecosystems, and in turn affect the water transparency and vertical structure of lakes. In many northern clearwater lakes, small changes in DOC can result in rapid changes to both photosynthetically active radiation (PAR) and ultraviolet (UV) light penetration in lakes. We present and evaluate an update to the process-based lake model MyLake that includes a dynamic linkage between light attenuation of PAR and UV to changes in DOC concentration. This is the first dynamic modelling of UV attenuation in lakes, which is of particular importance in northern latitudes with high incident UV that can be selectively absorbed by DOC in lakes. We use this model update to test the responses of PAR and UV attenuation to short-term fluctuations in DOC and with a test case of long-term increases in DOC at Lake Giles (Pennsylvania, USA). We found that the model performance improved by 16% and 52% for long-term trends in PAR and UV attenuation, respectively, when these coefficients respond directly to in-lake DOC concentrations. Further, empirical long-term trends in vertical thermal structure and deepwater oxygen depletion in Lake Giles were better captured by the model with this update compared to the previous version. This dynamically-responsive link between DOC and light attenuation in lake models is key to understanding both short-term and long-term changes in DOC, relevant mechanisms, and ecological consequences.

Who is methylating Mercury in Permafrost Thaw Lakes?

Martin Jusek, Centro de Química Estrutural, Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal
Holger Hintelmann, Water Quality Centre, Trent University, 1600 West Bank Drive, Peterborough, ON, Canada
Martin Pilote, Environment and Climate Change Canada, Aquatic Contaminants Research Division, Montreal, QC, Canada
Jérôme Comte, Institut National de la Recherche Scientifique, Centre – Eau Terre Environment, Québec, QC, Canada
João Canário, Centro de Química Estrutural, Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal

Keywords: Mercury, Monomethylmercury, Mercury Methylation; Demethylation, Permafrost thaw lakes, Subarctic

In the Arctic, permafrost degradation led to the formation of thermokarst lake among other features. As a consequence, toxic mercury and monomethylmercury are being mobilized. Thus, the study of the mercury cycle in these systems is crucial to better understand the consequences and impacts to the arctic ecosystems. Mercury and monomethylmercury levels and mercury methylation and monomethylmercury demethylation rates from sediments and bottom water from two permafrost thaw lakes (SAS-1A and SAS-2A) in the sub-arctic region of Nunavik (Canada) in a sporadic permafrost area were determined using Hg stable isotope techniques. Enrichments were made to study the influence of known mercury methylators, iron-reducing bacteria, sulphate-reducing bacteria and methanogens, in these concentrations and rates. Results showed that the concentrations of both Hg species were higher in lake SAS-1A (SAS-1AUp 346 ng/g), than in SAS-2A (SAS-2AUp 53 ng/g). Sediment mercury methylation rates appear to be influenced by the Hg content and by organic matter content and quality. Microbial diversity plays a major role in mercury methylation, sulfate-reducing bacteria and methanogens were shown to be largely involved and differences between both lakes were clear pointed, however, their influence in monomethylmercury demethylation was not clear.

Influence of thawing permafrost on the fate of Hg and trace metals in thermokarst ponds, eastern Canadian subarctic region (Nunavik)

Martin Pilote, Université Laval, Québec, Canada
João Canário, Instituto Superior Técnico, University of Lisbon, Portugal
Patrice Turcotte, Environment and Climate Change Canada, Montreal, Canada
Christian Gaggnon, Environment and Climate Change Canada, Montreal, Canada
Daniel Houle, Environment and Climate Change Canada, Montreal, Canada

Keywords: Fate, Mercury, Thermokarst Pond, Freshwater System, Subarctic Region

Recent findings suggested that a globally significant amount of carbon (C) and mercury (Hg) might be contained in permafrost and estimated at about 800 Gg of Hg in the Northern Hemisphere. Thawing permafrost has the potential to release a large proportion of historically stored C, Hg and trace metals that could alter biogeochemical processes and increase the export of contaminants to freshwater ecosystems. Changes in redox conditions in thaw lakes may consequently enhance the production of higher toxic chemical species such as methylmercury (MeHg). The main objective of this study is to evaluate the fate of Hg and trace metals in thermokarst ponds, to compare the biogeochemical processes involved between seasons, and to assess the potential transport towards the aquatic ecosystem. More specifically, the study compared the influence of thawing permafrost in subarctic sporadic permafrost (thaw lakes formed by the collapsed of peat mounds / palsas) and discontinuous permafrost (circular or crest thaw lakes formed by the collapse of frozen silt-clay mounds / lithalsas). The palsa sites showed higher dissolved organic carbon (DOC) and Hg, while lithalsa sites showed higher variability. The Hg and trace metals, as well as biogeochemical processes varied between sites and seasons, showing a strong relationship with oxygen level, organic matter and the geomorphology of the surrounding landscape. While Hg export occurred potentially and predominantly by diffusion in palsas and by land subsidence in lithalsas area. Quantifying Hg and trace metals originating from perennial frozen soil and thawing permafrost that can cause a potential risk to native communities in polar regions is crucial of interest for the scientific community and policy makers.

Microplastic pollution estimation in the surface water of the Barents and Norwegian Seas in Norwegian and Russian marine expeditions

Svetlana Pakhomova, NIVA, Oslo, Norway; SIO RAS, Moscow, Russia
Evgeny Yakushev, NIVA, Oslo, Norway; SIO RAS, Moscow, Russia
Sørensen Kai, NIVA, Oslo, Norway
Eduard Spivak, POI, Vladivostok, Russia
Amy Lusher, NIVA, Oslo, Norway, Oslo, Norway
Bert van Bavel, NIVA, Oslo, Norway, Oslo, Norway

Keywords: Microplastics, subsurface waters, Barents Sea, Norwegian Sea

Contamination of the World Ocean by synthetic non-biodegradable material has become a high profile environmental concern. Standardized field methods and methods of plastic identification should be developed so that results can be fed into international monitoring strategies to map plastic distribution worldwide. Here we present results of studies carried out on a transect along the Kola peninsula and Scandinavian peninsula coast and on a transect between Tromsø-Svalbard performed with the same procedure for microplastics sampling in subsurface waters during three Norwegian and Russian expeditions in 2019. Microplastics sampling was carried out using a filtering system. Water passed through the system and SPM was collected on a metal mesh screens. All potential plastic particles and fibers were checked for polymeric identification using a PerkinElmer Spotlight ATR-FTIR. The level of confirmed microplastics abundance ranged from 0 to 1.1 items/m3 (0.4 items/m3 in average) along the Kola peninsula and Scandinavian peninsula coast and from 0 to 1.9 items/m3 (0.7 items/m3 in average) on a transect Tromsø-Svalbard.

Distribution of floating marine macro-litter in relation to oceanographic characteristics in the Russian Arctic Seas in October 2020

Maria Pogojeva, Shirshov Institute of Oceanology RAS, Moscow, Russia; N.N.Zubov State Oceanographic Institute, Roshydromet, Moscow, Russia
Igor Zhdanov, Shirshov Institute of Oceanology RAS, Moscow, Russia
Anfisa Berezina, Shirshov Institute of Oceanology RAS, Moscow, Russia; St.Petersburg State University, St.Petersburg, Russia
Artem Lapenkov, Institute of Limnology RAS, St.Petersburg, Russia
Denis Kosmach, V.I. Il'ichev Pacific Oceanological Institute FEB RAS, Vladivostok, Russia
Alexander Osadchiev, Shirshov Institute of Oceanology RAS, Moscow, Russia
Georg Hanke, European Commission Joint Research Centre, Ispra, Italy
Igor Semiletov, V.I. Il'ichev Pacific Oceanological Institute FEB RAS, Vladivostok, Russia; Institute of Ecology, Higher School of Economics, Moscow, Russia
Evgeniy Yakushev, Shirshov Institute of Oceanology RAS, Moscow, Russia; Norwegian Institute for Water Research, Oslo, Norway

Keywords: Marine Pollution, Marine Floating Macro Litter, Arctic, Marine Environmental Monitoring

The main objectives of this work was the acquisition of new data on floating marine macro litter (FMML) and natural floating objects in the Arctic seas, an initial assessment of the level of pollution by FMML and an analysis of potential sources. The results of this study present the first data on FMML distribution in Russian Arctic shelf seas in relation to oceanographic conditions (i.e. position of water masses of different origin as described by temperature, salinity, dissolved oxygen and pH). The main finding of this study is that FMML was found only in the water of Atlantic origin, inflowing from the Barents Sea, where FMML average density on the observed transects was 0.92 items/ km2. Eastern parts of the study, Kara Sea, Laptev Sea and East Siberian Sea were practically free from FMML. The input from rivers appears to be negligible, at least in autumn.

Anti-biotic resistance genes in arctic aquatic environments

Mary Thaler, Université Laval, Québec, Canada
Juliette Provencher, Université Laval, Québec, Canada
Alex Culley, Université Laval, Québec, Canada

Keywords: Antibiotic Resistance, Horizontal Gene Transfer, Lakes, Bacteria, Metagenome

Antibiotic Resistance Genes (ARG) are a worldwide threat to human health. They proliferate as a result of human antibiotic use, but also occur naturally in bacterial communities, including in the Arctic. The bacterial capacity for horizontal gene transfer allows human pathogens to access the wild ARG genetic space, meaning that even remote Arctic regions may be part of this global “resistome”, with implications for human health. On the one hand, anthropogenic ARGs may arrive in the Arctic via long-distance airborne transport of microbes, or because of human impacts in areas surrounding Arctic towns. Conversely, melting cryo-environments resulting from climate change have the potential to increase aerosolisation and transport of Arctic microbes, thereby adding novel ARGs to the global resistome. The extent of this genetic exchange remains unknown because of a lack of knowledge of the Arctic ARG inventory. We used standard curated databases to screen assembled metagenome data from two High Arctic lakes, one remote and receiving near-zero human impacts, the other with heavy impacts from a nearby town. We established criteria to distinguish anthropogenic and naturally occurring ARGs, paying particular attention to potential mobile genetic elements which could facilitate the spread of ARGs between bacterial taxa. To our knowledge, this is the first inventory of ARGs to focus on Arctic aquatic environments, and has implications for human health risks in the Arctic and worldwide.

Comparison of ion runoff during the ice-covered period and summer according to actual data and long-term change in ion runoff of Lena river delta

Natalia Alekseeva, Arctic and Antarctic Research Institute, Saint-Petersburg, Russia and The Trofimuk Institute of Petroleum Geology and Geophysics, Siberian Branch of the Russian Academy of Science, Novosibirsk, Russia
Irina Fedorova, Saint-Petersburg State University, Saint-Petersburg, Russia
Denis Aibulatov, Moscow State University, Moscow, Russia
Aleksandra Shadrina, Saint-Petersburg State University, Saint-Petersburg, Russia
Miron Makushin,State Company «Mineral» Saint-Petersburg, Russia
Anastasia Kirillova, Arctic and Antarctic Research Institute, Russian State Hydrometeorological University, Saint-Petersburg, RussiaSaint-Petersburg, Russia

Keywords: Ions Runoff, Hydrology, Lena River Delta.

Ion runoff is the most important geochemical characteristic describing erosion and accumulation processes on the earth's surface.The cold climate and the distribution of permafrost are determining factors in the ion runoff formation of arctic rivers. The study reported here was conducted on the channels of the Lena River delta in ice-covering and summer periods. The water discharge, velocity of streams, ionic composition, pH and conductivity were measured on the main river branches in years 2016 and 2017. The studied channels differ in water content of river, hydrodynamic conditions, of solid runoff characteristics, hydrochemical runoff and the nature of sediments (Fedorovaet al., 2014). The Lena delta branches are characterized by a wide variety of water discharge values and hydrodynamic conditions. It has been revealed that the hydrochemical composition of the delta is specific due to the dominance of hydrocarbonates and calcium ions. (Chetverova et al, 2017). The field materials obtained made it possible to calculate the ion runoff in the channels and to compare with long-term data. The quantitative and qualitative of anions and cations distributions along the river branches and the downstream cross section are analyzed. The reported study was funded by This work was supported by the RFBR (project no. 18-05-60291). We thank Dmitriy Bolshiyanov for assistance with winter field work and Stepan Romanov for assistance in the field and laboratory.

Modeling the influence of biogeochemical and ecosystem processes on microplastic transport in the Arctic seas on the example of Oslofjord

Anfisa Berezina, St. Petersburg State University, St. Petersburg, Russia
Evgeniy Yakushev, Norwegian Institute for Water Research (NIVA), Oslo, Norway

Keywords: Microplastic, Mathematical Modelling, Arctic Seas, Biogeochemical Processes, Biofouling

Currently, all natural environments, including the and Arcric seas, are contaminated by microplastics (MP, plastic fragments less than 5 mm). Biogeochemical processes significantly affect the physical properties of MP, primarily its density due to biofouling. The aim of this work is to develop a numerical model for assessing the fate of MP in the marine environment under the influence of natural biogeochemical cycles in the Arctic seas on the example of Oslofjord.

The biogeochemical model OxyDep (E.V. Yakushev et al., 2011) was used to reproduce the temporal variability of the phyto- and zooplankton, dissolved and particulate organic matter. The two-dimensional 2D benthic-pelagic transport model (2DBP), which considers the processes in the water column and bottom sediments together, is used as a hydrophysical model. The separate module which describes the transformation of the MP under biogeochemical processes was developed. The biogeochemical and MP modules were coupled with the transport model using the Framework for Aquatic Biogeochemical Modeling (FABM) (Bruggeman & Bolding, 2014). The results show, that there would be a decrease in the MP content in the surface layer in summer period due to the ingestion by zooplankton and its transfer to the sediments. Based on the obtained patterns, it is possible to predict zones of accumulation of MP for a specific water area, depending on the local ecosystem. Funding: The reported study was funded by RFBR, project number 20-35-90056.

ID: 44 - Effect of environmental parameters on polar terrestrial microbial communities

Conveners

Laura Zucconi | University of Tuscia

Fabiana Canini | University of Tuscia

Glacier retreat in the High Arctic: Opportunity or threat for ectomycorrhizal diversity?

Sunil Mundra, Section for Genetics and evolutionary biology (EVOGENE), Department of Biosciences, University of Oslo, Blindern, Oslo, Norway. Department of Biology, College of Science, United Arab Emirates University, Al-Ain, UAE
Synnøve S. Botnen, Section for Genetics and evolutionary biology (EVOGENE), Department of Biosciences, University of Oslo, Blindern, Oslo, Norway
Håvard Kauserud, Section for Genetics and evolutionary biology (EVOGENE), Department of Biosciences, University of Oslo, Blindern, Oslo, Norway
Pernille B. Eidesen, The University Centre in Svalbard, Longyearbyen, Norway

Keywords: Arctic, Early Colonizing Fungi, Ectomycorrhiza, Glacier Foreland, Climate Change, DNA Metabarcoding

Climate change causes the Arctic glaciers to retreat at high pace, exposing new areas for colonization of biota. Several pioneer plants likely to colonize these recent deglaciated, nutrient-poor areas are dependent on fungal partners for successful establishment. Little is known about these facilitating fungal pioneers in high arctic areas; who are they and what are driving their richness and community composition? The High Arctic Archipelago Svalbard represent an excellent study system to address these questions, as glaciers are currently covering about 60% of the land surface, but recent estimations have shown at least 7 % reduction of glacier area since 1960s. Roots of two ectomycorrhizal (ECM) plants (Salix polaris and Bistorta vivipara) were sampled in eight glacier forelands. The associated ECM fungi were assessed using DNA metabarcoding. A large part of the diversity could not be determined at a high taxonomical resolution, indicating presence of undescribed species. Seven genera dominated based on richness and abundance, but showed different habitat preferences. The genus Geopora showed surprisingly high richness and abundance, particularly in dry, nutrient-poor forelands – a habitat expected to diminish in the future, due to plant succession followed by climax vegetation. With continued climate change we are likely to lose unknown fungal diversity, without knowing their identity or importance for the ecosystem.

Tundra type drives distinct trajectories of functional and taxonomic composition of arctic fungal communities in response to climate change – results from long-term experimental summer warming and increased snow depth

József Geml, MTA-EKE Lendület Environmental Microbiome Research Group, Eszterházy Károly University, Eger, Hungary
Luis N. Morgado, Department of Biosciences, University of Oslo, Oslo, Norway
Tatiana A. Semenova-Nelsen, Naturalis Biodiversity Center, Leiden, The Netherlands

Keywords: Climate Change, Fungal Ecology, ITEX, Metabarcoding, Tundra

The arctic tundra is undergoing climate-driven changes and there are serious concerns related to the future of arctic biodiversity and altered ecological processes under possible climate change scenarios. Arctic land surface temperatures and precipitation are predicted to increase further, likely causing major transformation in terrestrial ecosystems. As a response to increasing temperatures, shifts in vegetation and soil fungal communities have already been observed. Little is known, however, how long-term experimental warming coupled with increased snow depth influence the trajectories of soil fungal communities in different tundra types. We compared fungal community composition in experimental plots simulating the expected increase in summer warming and winter snow depth, based on DNA metabarcoding data. Fungal communities in the sampled dry and moist acidic tundra communities differed greatly, with tundra type explaining ca. one-third of compositional variation. Also, dry and moist tundra showed different trajectories in response to climate change. While both warming and increased snow depth had significant effects on fungal community composition in dry tundra, the effect of increased snow was greater. In most tundra, fungal communities mainly were affected by summer warming, while increased snow depth had a smaller effect and only on some functional groups. In dry tundra, microorganisms generally are limited by moisture in the summer and extremely low temperatures in winter, which is in agreement with the stronger effect of increased snow depth relative to warming. On the contrary, moist tundra soils generally are saturated with water and show small fluctuations in temperature, which is conducive to the greater effect of warming on resident microbes.

Spatial scale structure soil bacterial communities across an Arctic landscape

Lucie A. Malard, Faculty of Health and Life Sciences, Northumbria University, Newcastle-upon-Tyne, United Kingdom, Department of Ecology and Evolution, University of Lausanne, Lausanne, Switzerland
Muhammad Z. Anwar, Department of Environmental Sciences, Aarhus University, Roskilde, Denmark; Department of Pathology and Laboratory Medicine, University of British Columbia, Wesbrook Mall, Vancouver, British Columbia, Canada
Carsten S. Jacobsen, Department of Environmental Sciences, Aarhus University, Roskilde, Denmark
David A. Pearce, Faculty of Health and Life Sciences, Northumbria University, Newcastle-upon-Tyne, United Kingdom

Keywords: Arctic Soil, Bacterial Communities, Dispersal Limitation, Environmental Factors,

Bacterial community composition is largely influenced by environmental factors, and this applies to the Arctic region. However, little is known about the role of spatial factors in structuring such communities. In this study, we evaluated the influence of spatial scale on bacterial community structure across an Arctic landscape. Our results showed that spatial factors accounted for approximately 10 % of the variation at the landscape scale, equivalent to observations across the whole Arctic region, suggesting that while the role and magnitude of other processes involved in community structure may vary, the role of dispersal may be stable globally in the region. We assessed dispersal limitation by identifying the spatial autocorrelation distance, standing at approximately 60 m, which would be required in order to obtain fully independent samples and may inform future sampling strategies in the region. Finally, indicator taxa with strong statistical correlations with environment variables were identified. However, we showed that these strong taxa-environment associations may not always be reflected in the geographical distribution of these taxa.

Structural and functional characteristics of high alpine soil communities

Federica D'Alò, University of Tuscia, Viterbo, Italy

Keywords: Alpine soils, Metatranscriptome, Metagenome, Warming effect, Decomposition, Vegetation shift

Arctic and alpine ecosystems cover about 2% of the Earth's land surface. They are critical reservoirs in the global C cycle, as almost 50% of the global belowground C pool is stored in organic soils. Rising temperatures are causing an increased melting of glacial ice and shrub expansion. These changes may induce changes in soil microbial diversity and function, and on biogeochemical processes, including nutrient cycling and C fluxes and storage. We analysed how microbial diversity and communities structure and function change along altitudinal gradients under different vegetation coverages. Soils were collected in alpine, inside and outside Open Top Chambers (OTC), and subalpine sites at Stelvio Pass, Italian Alps, with the aims to i) determine the potential effect of upward subalpine vegetation shift, ii) assess the impact of short-term warming mediated by OTCs. Soils were analysed for their physicochemical properties, microbial biomass, and metagenomic and metatranscriptomic. Alpine and subalpine soils were characterized by significant differences of community and functioning composition. Subalpine regions showed higher abundances of fungal taxa and ligninolytic activity, suggesting a greater decomposition of recalcitrant carbon. An increase of nitrifying and denitrifying enzymes inside the OTCs at the higher altitude suggested a potential positive feedback of nitrous oxide emissions. These results suggest that climate change may promote a rise of greenhouse gas emissions.

Antarctic Dry Valley Refugia

Abigail Jackson, Brigham Young University, Provo, Utah, USA

Keywords: Antarctica, Nematode, Refugia

Limited research has identified potential refugia in the Antarctic Dry Valleys. Living conditions in the Dry Valleys of Antarctica are extreme. Mean annual temperatures of -14°C to -30°C and limited precipitation, restrict life to soil microorganisms well adapted to the freezing temperatures and harsh soil conditions. The only form of life besides the transient McMurdo Research Station scientists are endemic soil microbial communities. These communities only exist where precise soil conditions are met. On top of these restricting conditions to life, much of the Dry Valleys were inundated by glaciers during the Last Glacial Maximum, wiping out all existing life. Refugia would have preserved endemic microorganisms in the Dry Valleys and provided a source for dispersal across other valleys after glaciation retreat. This research focuses on identifying a potential refugia population of microorganisms that avoided inundation during the LGM. Using sanger sequence analysis of the soil nematode, Scottnema, this research will analyze the population structure between potential source populations from the refugia to potential sink populations of nearby valleys. This data will model for identifying refugia of the Dry Valleys and indicate areas of conservation. Further research avenues should explore if historical Antarctic refugia will serve the same purpose in anthropogenic driven warming.

Finding Snowball Earth: a multidisciplinary study of Arctic and Antarctic Cryogenian analogues

Jaz Millar, Cardiff University, Cardiff, UK
Elizabeth Bagshaw, Cardiff University, Cardiff, UK
Anne Jungblut, The Natural History Museum, London, UK
Arwyn Edwards, Aberystwyth University, UK

Keywords: Cryoconite, Cryogenian, DNA Sequencing, Microbiology

Between 720 and 635 million years ago the Earth was frozen in ice, in a period known as the Cryogenian Snowball Earth. During this time life not only survived but diversified, staging the conditions for the development of animals in the subsequent Ediacaran period. This presentation describes the first microbiological study on how and where microorganisms survived during Snowball Earth. We focus on cryoconite holes, supraglacial meltwater habitats whose biodiversity and robustness make them ecosystems of particular relevance to Cryogenian studies. Next generation sequencing allowed us to analyse cryoconite eDNA across both poles to higher resolution than ever before. The Arctic and Antarctic cryoconite holes harbour distinct microbial communities, but the various biotic niches (grazer, predator, photoautotroph, chemotroph), are filled in every location. Cryoconites of interest were incubated under "Snowball Earth" experimental conditions, and showed a strong resilience to these variations in environment. In addition, we are carrying out ongoing investigation into the physical and ecological connections between cryoconite and the surrounding connected niches. Through this combination of eDNA analysis, ex situ monitoring and in situ observation of modern analogue glacial communities, we outline a paradigm for Cryogenian ecosystems in which interconnected glacial surface ecosystems provide "diversity hotspots" for key crown groups of microorganisms.

Cooperative communities at both poles: From explorative studies to comprehensive theory

Jesse Jorna, Brigham Young University, Provo, Utah
Byron Adams, Brigham Young University and Monte L. Bean Life Science Museum, Provo, Utah

Keywords: Microbial communities, Soil metazoans, Biodiversity, Facilitation, Metabarcoding

Decades of research on facilitative relationships between organisms have exposed a trend of increased dependence on mutually beneficial interactions in more extreme environments. However, in the most extreme water-limited ecosystems on earth and amongst those organisms with the most extreme distribution evidence for this hypothesis is scarce. Metabarcoding approaches are a cheap and accessible way to gain information about the presence and absence of microbial and metazoan life in both Arctic and Antarctic soils, allowing comparisons between ecosystems on a local, regional and even global scale. Utilizing genetic data further allows for phylogenetic comparisons between co-occurring organisms in soils to strengthen inferences on the strength and direction of interactions between soil organisms. Using these techniques we can construct a pipeline from sampling to ecologically relevant results about biotic interactions between organisms amongst different environmental gradients. Polar soils thus serve to observe an increase in the dependency on positive biotic interactions under increasing resource limitation, temperature stress or in the presence and absence of different types of vegetation. These would not only be the first findings to support the existence of strong facilitative interactions in a both respective ecosystems, but also the first field experiment to provide evidence for the stress gradient hypothesis in microscopic ecosystems.

Interplay between fungal and bacterial communities in soils with different vegetation coverage in Western Greenland

Fabiana Canini, University of Tuscia, Viterbo, Italy
Laura Zucconi, University of Tuscia, Viterbo, Italy

Keywords: Soil Communities, Shrub Expansion, Physicochemical Parameters, Fungi, Bacteria

Climate warming is resulting in the expansion of shrub vegetation across wide areas of Arctic tundra. In these cold and nutrient-poor terrestrial environments, soil microbial communities play key roles as plant symbionts, pathogens and decomposers and thus can mediate plants adaptation. Additionally, soil fungi and bacteria have a major role in biogeochemical cycles of global importance, mediating the release of carbon from polar soils. Despite some studies addressed the interactions between vegetation and soil fungi and bacteria in arctic environments, most of them ignore the potential role of interactions between these two groups. With the aim to give some insights on the effect of this interplay on the above vegetation shifts, the fungal and bacterial communities of soils characterized by increasing vegetation coverages, previously analysed independently, have been compared. Samples corresponding to 9 soil plots covered by vascular vegetation (VV) (Betula, Salix, Vaccinium, Empetrum), 6 of biological soil crusts (BSCs) with mosses and lichens, and 5 of bare grounds (BG) were collected in Kobbefjord. Fungal and bacterial communities have been characterized through the metabarcoding sequencing of the ITS1 and 16S rRNA genes, respectively. The correlations between the abundance and diversity of different fungal and bacterial groups and the co-occurrence of specific taxa have been studied and related to different above vegetation coverage and soil physicochemical parameters.

Microbial response to anthropogenic pollutants in Polar lakes

Maria Papale, Istituto di Scienze Polari, Consiglio Nazionale delle Ricerche (CNR-ISP), Messina, Italy
Maurizio Azzaro, Istituto di Scienze Polari, Consiglio Nazionale delle Ricerche (CNR-ISP), Messina, Italy
Filomena De Leo, Dipartimento di Scienze Chimiche, Biologiche, Farmaceutiche ed Ambientali, Università di Messina, Italy
Stefania Giannarelli, Dipartimento di Chimica e Chimica Industriale, Università di Pisa, Pisa, Italy and the MicroPolArS Team

Keywords: Prokaryotes, Eukaryotes, Contaminants, Svalbard Islands, Byers Peninsula

Major contaminant transport routes to polar regions include atmospheric and oceanic transport. Contaminants can be incorporated in drifting ice in the oceanic surface microlayer, and accumulated on the snow and ice surface from the atmosphere. Lakes are widely reported as very sensitive ecosystems to environmental change. This is particularly true in the case of small lakes and ponds that occur extensively in the Arctic and Antarctic regions. Small variations in the dynamics and duration of their snow and ice covers or the deposition of contaminants can have a noticeable effect on lake ecological variables. Microbial communities promptly respond to environmental perturbations by the activation/deactivation of genes involved in the resistance or biodegradation processes. Thus, the evaluation of microbial genetic regulation and expression could provide essential and sensitive information related to the potential application of microbes (both prokaryotes and eukaryotes) as biosensors or in the bioremediation of cold contaminated areas. In this context, our attention is addressed to microbial communities from water and sediment of lakes located in the Ny-Alesund (Svalbard Islands, Norwegian Arctic) and Byers Peninsula (Livingston Island, South Shetland Islands, Antarctica) areas. The study is supported by grants from the Programma Nazionane di Ricerche in Antartide (Project MicroPolArS; grant n. PNRA18_00194).

ID: 57 - Light as a structuring mechanism in the Arctic – from physics to biology

Conveners

Nicholas Per Huffeldt | Greenland Institute of Natural Resources & Aarhus University, Denmark

Finlo Cottier | The Scottish Association of Marine Science, United Kingdom & UiT The Arctic University of Norway

Laura Hobbs | The Scottish Association of Marine Science, United Kingdom & The University of Strathclyde, United Kingdom

Light and energetics at seasonal extremes limit poleward range shifts

Tom Langbehn, Department of Biological Sciences - University of Bergen, Bergen, Norway
Gabriella Ljungström, Department of Biological Sciences - University of Bergen, Bergen, Norway
Christian Jørgensen, Department of Biological Sciences - University of Bergen, Bergen, Norway

Keywords: Photoperiod Constraint Hypothesis, Photic Barrier, Range Shifts, Visual Foraging, Species Interactions

In response to climate warming, species globally are on the move. The general direction of observed movement is poleward, and in marine systems the highest species turnover, invasion intensities and increases in maximum (fisheries) catch potential are predicted for high-latitude regions (>60°N/60°S). These predictions stem from a group of statistical models that assume a fixed relation between species distributions and temperature. But temperature is not the only factor that restricts species' distributions. Light is a crucial but often neglected factor that strongly influences energy acquisition and survival prospects in visual foragers. Seasonality in light becomes progressively extreme at high latitudes, in terms of the diel light dark cycle and the duration of light summers and dark winters. In contrast to temperature, this latitudinal gradient in light seasonality is not affected by climate change. Here, we use two mechanistic models that explicitly link light-dependent encounters and temperature-dependent physiology for two widespread planktivorous fish types, along a latitudinal gradient in the North Atlantic to predict where populations survive and acquire resources to reproduce, and where they demise. We find that not only does seasonality in light constitute a stronger barrier to poleward distribution than cold temperatures, but counterintuitively we identify two processes that at high-latitudes could lead to equatorward distribution shifts under climate warming: faster depletion of energy stores in winter and higher foraging-related predation mortality in summer.

Oscillating circadian clock genes and widely rhythmic transcriptome in Calanus finmarchicus during the high Arctic summer solstice

Laura Payton: Institute for Chemistry and Biology of the Marine Environment, Carl von Ossietzky University of Oldenburg, Oldenburg, Germany; Section Polar Biological Oceanography, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
Lukas Hüppe, Institute for Chemistry and Biology of the Marine Environment, Carl von Ossietzky University of Oldenburg, Oldenburg, Germany; Section Polar Biological Oceanography, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany; Helmholtz Institute for Functional Marine Biodiversity (HIFMB) at the University of Oldenburg, Oldenburg, Germany
Céline Noirot, Plateforme bio-informatique GenoToul, MIAT, INRAE, Mathématiques et Informatique Appliquées Toulouse, Castanet-Tolosan, France
Claire Hoede, Plateforme bio-informatique GenoToul, MIAT, INRAE, Mathématiques et Informatique Appliquées Toulouse, Castanet-Tolosan, France
Kim S. Last, Scottish Association for Marine Science, Oban, Argyll, UK
David Wilcockson, Institute of Biological, Environmental, and Rural Sciences, Aberystwyth University, Aberystwyth, UK
Elizaveta Ershova, Department for Arctic and Marine Biology, Faculty for Biosciences, Fisheries and Economics, UiT The Arctic University of Norway, Tromsø, Norway; Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russian Federation
Sophie Valière, Plateforme Génomique, INRAE US GeT-PlaGe, Centre INRAE de Toulouse Occitanie, 24 Chemin de Borde Rouge - Auzeville, Castanet-Tolosan cedex, France
Bettina Meyer, Institute for Chemistry and Biology of the Marine Environment, Carl von Ossietzky University of Oldenburg, Oldenburg, Germany; Section Polar Biological Oceanography, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany; Helmholtz Institute for Functional Marine Biodiversity (HIFMB) at the University of Oldenburg, Oldenburg, Germany

Keywords: Arctic, Midnight Sun, Copepod, Circadian Clock, Transcriptome

Solar light/dark cycles and seasonal photoperiods underpin daily and annual rhythms of life on Earth. Yet, the Arctic is characterized by several months of permanent illumination (“midnight sun”). To determine the persistence of 24h rhythms during the midnight sun, we investigated circadian clock gene expression and whole transcriptomic dynamics in the copepod Calanus finmarchicus during the summer solstice in the Arctic, with the lowest diel oscillation and the highest altitude of the sun’s position (Payton et al., 2020a). First, we reveal circadian clock gene oscillations, showing that the core molecular clockwork remains synchronized at this time (Hüppe et al., 2020). Then we reveal that in these extreme photic conditions, a widely rhythmic daily transcriptome exists, showing that very weak solar cues are sufficient to entrain organisms (Payton et al. 2020b). Furthermore, at extremely high latitudes and under sea-ice, gene oscillations become reorganized to include <24h rhythms, corroborating with the bimodal oscillations of circadian clock gene transcripts. Environmental synchronization may therefore be modulated to include non-photic signals (i.e. tidal cycles). The ability of zooplankton to be synchronized by extremely weak diel and potentially tidal cycles, may confer an adaptive temporal reorganization of biological processes at high latitudes.

High latitude photoperiodism in the copepod Calanus finmarchicus

Kim S. Last, Scottish Association for Marine Science, Oban, Argyll, UK.
Jonathan Cohen, University of Delaware, Lewes DE USA.
Jordan Grigor, Scottish Association for Marine Science, Oban, Argyll, UK.
Jørgen Berge, UiT, The Arctic University of Norway, Faculty for Biosciences, Fisheries and Economics, Department for Arctic and Marine Biology, Tromsø, Norway. University Centre in Svalbard, Longyearbyen, Norway.
Estelle Coguiec, UiT, The Arctic University of Norway, Faculty for Biosciences, Fisheries and Economics, Department for Arctic and Marine Biology, Tromsø, Norway.
Finlo Cottier, cottish Association for Marine Science, Oban, Argyll, UK.
Malin Daase, UiT, The Arctic University of Norway, Faculty for Biosciences, Fisheries and Economics, Department for Arctic and Marine Biology, Tromsø, Norway.
Jennifer Freer, British Antarctic Survey, High Cross, Madingley Road, Cambridge, UK.
Sören N. Häfker, Max Perutz Labs, University of Vienna, Dr. Bohr-Gasse 9/4, 1030 Vienna, Austria.
Lukas Hüppe, Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Am Handelshafen 12, Bremerhaven, Germany. Helmholtz Institute for Functional Marine Biodiversity at the University of Oldenburg, Oldenburg, Germany.
Laura Payton, Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Am Handelshafen 12, Bremerhaven, Germany.
Laura Hobbs, Scottish Association for Marine Science, Oban, Argyll, UK. Department of Mathematics and Statistics, University of Strathclyde, Glasgow, UK.
David Pond, Faculty of Natural Sciences, University of Stirling, UK.
Janne Søreide, University Centre in Svalbard, Longyearbyen, Norway.
Geraint A. Tarling, British Antarctic Survey, High Cross, Madingley Road, Cambridge, UK.
David Wilcockson, Institute of Biological, Environmental and Rural Sciences, Aberystwyth University, Penglais, Aberystwyth, Ceredigion, UK.
Bettina Meyer, Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Am Handelshafen 12, Bremerhaven, Germany. Helmholtz Institute for Functional Marine Biodiversity at the University of Oldenburg, Oldenburg, Germany. Institute for Chemistry and Biology of the Marine Environment, Carl von Ossietzky Universität Oldenburg, Carl von Ossietzky Straße 9-11, Oldenburg, Germany.

Keywords: Photoperiod, Calanus Finmarchicus, Behaviour, Circadian Clock

The Arctic is changing rapidly with sea-ice retreat resulting in a warmer, fresher and lighter oceans. This is leading to the earlier arrival of the spring bloom and delayed autumn freeze, with an extension of the annual growing season. Such climate change effects are driving marine zooplankton to extend their habitat ranges polewards1 resulting in exposure to new and more extreme day-lengths (photoperiods) with unknown consequences2. Using the copepod Calanus finmarchicus, a centrally important species in structuring North Atlantic predator/prey interactions and biogeochemical cycling3, we present behavioural and physiological data revealing unexpected individual variability within and across habitats in response to photoperiod. Expression of photoperiodically driven swimming behaviour and overall activity amplitude decrease with increasing latitudes (56 - 83oN). Furthermore, a recent daily transcriptome analysis of C. finmarchicus during the midnight sun period has shown a disconnect between swimming behaviour and overt circadian clock gene expression cycles4 when compared with lower latitudes5, suggesting that adaptation potential of these animals to very high latitudes may be limited or modified to accommodate other, non-photic environmental selective pressures.

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5 Häfker NS., Meyer B., Last KS., Pond DW., Hüppe L., Teschke M.

Do physiology and behavior track time of day under the continuous light of polar summer in a seabird?

Nicholas P. Huffeldt, Greenland Institute of Natural Resources, Nuuk, Greenland; Aarhus University, Roskilde, Denmark; & Wake Forest University, Winston-Salem, NC, USA
Anna Tigano, University of New Hampshire, Durham, NH, USA
Kjell Einar Erikstad, Norwegian Institute for Nature Research, Tromsø, Norway & Norwegian University of Science and Technology, Trondheim, Norway
Wolfgang Goymann, Max-Planck-Institut für Ornithologie, Seewiesen, Germany
Susanne Jenni-Eiermann, Swiss Ornithological Institute, Sempach, Switzerland
Truls Moum, Nord University, Bodø, Norway
Tone Kristin Reiertsen, Norwegian Institute for Nature Research, Tromsø, Norway

Keywords: Behavior, Melatonin, Midnight Sun, Physiology, Seabird

The predictable cycling between the light of day and the dark of night is a powerful selective force that has resulted in anticipatory mechanisms in nearly all taxa. At polar latitude, however, the difference in light intensity between "day" and "night" decreases dramatically during the continuous light of summer. A general understanding of whether the diel change in light intensity structures animal physiology and behavior under these conditions is poorly understood. We investigated diel variation in colony-attendance behavior and two hormones generally associated with diel timekeeping, melatonin and corticosterone, in the common murre (a seabird, Uria aalge) at Hornøya, Norway (70.39 °N). The common murres did not schedule their colony-attendance behavior by time of day, yet they had higher concentrations of melatonin and, to a lesser extent, corticosterone during night than day. Despite the continuous light of polar summer, the common murres can use melatonin as a physiological signal to track the 24-h day, while the murre's less variable corticosterone profile aligns with results from other polar-adapted birds and mammals. Thus, the polar light can have contrasting associations with daily behavior and physiology of species residing at high latitude.

Does climate change lead to timelapse versions of spring bloom scenarios in Arctic fjords?

Eva Leu, Akvaplan-niva, Oslo, Norway
Laura Hobbes, Scottish Association for Marine Science, Oban, UK
Dirk Notz, University of Hamburg, Hamburg, Germany
Janne Søreide, UNIS - The University Centre in Svalbard, Longyearbyen, Norway
Jozef Wiktor, Institute of Oceanology, Polish Academy of Science, Sopot, Poland
Clara J M Hoppe, Alfred-Wegener-Institute, Helmholtz-Centre for Polar and Marine Research, Bremerhaven, Germany
Jørgen Berge, UiT - The Arctic University of Norway, Tromsø, Norway
Finlo Cottier, Scottish Association for Marine Science, Oban, UK

Keywords: Spring Bloom, Ice Algae, Phytoplankton, Arctic, Climate Change

Light availability controls primary production in polar marine ecosystems. In ice-covered fjords, the first algal bloom in spring occurs inside the ice by ice algae adapted to grow under very dim light. Once enough light is transmitted through sea ice, phytoplankton starts growing in surface waters. 15 years of studies in various fjords in Svalbard document an astonishing variability of bloom timing. For some years, more in-depth documentation of ice algal and pelagic blooms exists. Based on a comparison of two fjords studied in detail in 2007 and 2017, respectively, we postulate that the ongoing changes in ice coverage alter the relative timing of ice algal and phytoplankton spring blooms. While ice algal growth commences in April (or earlier), the pelagic bloom in Rijpfjorden peaks often only around 1st of July. In late April/early May 2017 in Van Mijenfjorden, we found a pelagic bloom that peaked almost simultaneously with the sea ice bloom. In years with less sea ice cover in Rijpfjorden, pelagic blooms peak earlier, too. Thus, climate change seems to move pelagic blooms earlier. Concomitantly, earlier onset of terrestrial melt and runoff leads to increased turbidity in the fjords extending the second period of light limitation during the ice-free summer months. We suggest that favourable conditions for new production in these coastal systems are becoming shorter and blooms will be progressing faster than previously, with cascading effects on higher trophic levels.

Arctic zooplankton and the Lightscape of Fear: Behavioural Responses to Light Buffer Diel and Seasonal Changes in Visual Predation Risk

Laura Hobbs, University of Strathclyde, Glasgow, UK and Scottish Association for Marine Science, Oban, UK
Neil S. Banas, University of Strathclyde, Glasgow, UK
Jonathan Cohen, University of Delaware, Lewes, DE, United States
Øystein Varpe, University of Bergen, Bergen, Norway and Norwegian Institute for Nature Research, Bergen, Norway
Jørgen Berge, UiT The Arctic University of Norway, Tromsø, Norway and and University Centre in Svalbard, Longyearbyen, Norway and Centre of Autonomous Marine Operations and Systems, Norwegian University of Science and Technology, Trondheim, Norway
Kim S. Last, Scottish Association for Marine Science, Oban, UK
David McKee, University of Strathclyde, Glasgow, UK
Stacey Connan, University of Strathclyde, Glasgow, UK
Finlo R. Cottier, Scottish Association for Marine Science, Oban, UK and UiT The Arctic University of Norway, Tromsø, Norway

Keywords: Zooplankton, Light, Sea Ice, Isolume, Predation

Light plays a critical role in zooplankton ecology, with brighter conditions making individuals more vulnerable to visual predators. Consequently, avoidance of light is a central driver in behavioural responses. The high Arctic experiences extreme seasonality in the light environment, from 24-hour light to 24-hour darkness, and therefore provides a natural laboratory for studying light and predation risk over diel to seasonal timescales. Here we show that zooplankton (observed using acoustics) position themselves vertically in relation to light. We find that the upper edge of zooplankton vertical distribution follows a specific isolume (the value of which is comparable to the visual detection limits of Arctic Calanus spp.) across diel and seasonal time scales, suggesting that the light-mediated predation risk is kept constant by zooplankton at all times. The depth of the isolume is altered by the shading effects of sea ice and phytoplankton. We use data from similar latitudes in an open water and ice-covered environment as a comparative study, and evaluate the various ways in which phytoplankton can affect zooplankton behaviours: as both a prey source and as a shading factor. Changing light fields (through populations moving north and sea-ice loss) have been suggested to affect zooplankton predation. Here we suggest that zooplankton might already follow a foraging strategy that will keep visual predation risk roughly constant under changing light conditions, such as those caused by the reduction of sea ice, but likely with energetic costs such as lost feeding opportunities due to altered habitat use.

Arctic twilight entrains visual sensitivity and behavioral rhythms in krill

Jonathan H. Cohen, University of Delaware, Lewes, USA
Kim S. Last, Scottish Association for Marine Science, Oban, UK
Corie L. Charpentier, Stetson University, DeLand, USA
Finlo Cottier, Scottish Association for Marine Science, Oban, UK
Malin Daase, UiT, The Arctic University of Norway, Tromsø, Norway
Laura J. Hobbs, Scottish Association for Marine Science, Oban, UK
Geir Johnsen, Norwegian Univ. of Science and Technology, Trondheim, Norway
Jørgen Berge, UiT, The Arctic University of Norway, Tromsø, Norway

Keywords: Euphausiid, Electroretinogram, DVM, Polar Night, Circadian Clock

Light plays a fundamental role in the ecology of organisms in nearly all habitats on Earth, and is central for processes such as vision and the entrainment of biological clocks. The poles represent extreme light regimes with an annual light cycle including periods of Midnight Sun and Polar Night, where the sun remains above and below the horizon, respectively, for up to 6 months. The Arctic stands apart in that the ocean extends to the North Pole, and marine light extremes reach their maximum extent. Here, we characterize light across a latitudinal gradient (76.5° N to 81° N) during Polar Night in January. Our hyperspectral measurements demonstrate that the classical solar photoperiod dominant at lower latitudes is highly influenced by lunar and auroral components. We therefore ask, is this particular ambient light environment relevant to behavioral and visual processes? We reveal from field observations that the zooplankton community are undergoing diel vertical migrations (DVM), and furthermore the main migratory species, Arctic krill (Thysanoessa inermis) display endogenous nocturnal circadian swimming activity in the laboratory. Using electroretinogram recording under constant darkness, we show increases in visual sensitivity during subjective night, irrespective of latitude. We conclude that the extremely weak light regime experienced by krill at high latitudes during the darkest parts of the year has ecological relevance in structuring DVM and predator / prey interactions by non-classical photoperiod entrainment of biological rhythms.

Behavioral response of marine fish and zooplankton exposed to artificial light during the Arctic polar night

Maxime Geoffroy, Fisheries and Marine Institute of Memorial University of Newfoundland, St. John's, Canada
Tom Langbehn, University of Bergen, Bergen, Norway
Øystein Varpe, University of Bergen, Bergen, Norway
Jonathan H. Cohen, University of Delaware, Newark, USA
Finlo Cottier, Scottish Association of Marine Sciences, Oban, UK
Kim S. Last, Scottish Association of Marine Sciences, Oban, UK
Geir Johnsen, Norwegian University of Science and Technology, Trondheim, Norway
David McKee, University of Strathclyde, Glasgow, UK
Malin Daase, UiT The Arctic University of Norway, Tromsø, Norway
Emlyn J. Davies, SINTEF, Trondheim, Norway
Jørgen Berge, UiT The Arctic University of Norway, Tromsø, Norway

Keywords: Artificial Light, Fish, Zooplankton, Distribution, Abundance

Almost all biological samples taken at sea during the night, including the polar night, are sampled with artificial light. Working light from a research ship can impact fish and zooplankton behaviour down to at least 200 m depth. A detailed understanding of these responses is required to quantify biases resulting from sampling fish and zooplankton from illuminated ships. In January 2020, during the polar night, we conducted in situ experiments in Svalbard by turning lights from a research ship on and off and deploying an acoustic probe equipped with light sources of different colours. When exposed to white, blue, or red light, zooplankton and fish avoided the first 23 m to 118 m from the light source. Individual fish and zooplankton slowly returned into the light field after a few minutes and a portion of the population reoccupied its initial distribution after 2 hours of continuous light exposure, while another part of the population remained deeper. At one location, fish and zooplankton abundance was >2.5-fold lower when measured from a ship cruising at 10 knots with navigation lights and search beams on compared to all lights off. This study suggests that: 1) pelagic organisms avoid optical instruments using high-intensity visible light; 2) the most severe biases on biological sampling conducted from a lit ship persist at least hours after arriving on station; and 3) marine organisms can avoid ships during acoustic-based stock assessment surveys.

Changes in the solar partitioning of the sea ice cover during summer in the Arctic Ocean

Gaëlle Veyssière, British Antarctic Survey (BAS), Cambridge, United Kingdom
Giulia Castellani, Alfred Wegener Institute (AWI), Bremerhaven, Germany
Jeremy P. Wilkinson, BAS, Cambridge, United Kingdom
Michael Karcher, AWI, Bremerhaven and Ocean Atmosphere Systems GmbH, Hamburg, Germany
Alexander Hayward, National Institute of Water and Atmospheric Research, Wellington, New-Zealand
Julienne C. Stroeve, University College London, United Kingdom; University of Manitoba, Winnipeg, Canada; National Snow and Ice Data Centre, Boulder, USA
Marcel Nicolaus, AWI, Bremerhaven, Germany
Joo-Hong Kim, Korean Polar Research Institute (KOPRI), Incheon, South Korea
Eun-Jin Yang, KOPRI, Incheon, South Korea
Lovro Valcic, Bruncin, Zagreb, Croatia
Frank Kauker, AWI, Bremerhaven and Ocean Atmosphere Systems GmbH, Hamburg, Germany
Alia L. Khan, Western Washington University, Bellingham, USA

Keywords: Light, Sea Ice, Summer, First Year Ice

A changing light field under the sea ice is one of the main drivers that will affect large-scale ecosystem structure and biogeochemical functioning of the Arctic marine environment. Sea ice and snow, which are major factors impacting the light field, are changing: sea ice is melting earlier and forming later. In fact, the Arctic is no longer a region dominated by a thick multi-year ice (MYI), but it is moving into a regime controlled by thinner, more dynamic first year ice (FYI). This shift from MYI to FYI has consequences on the radiative transfer, as well as for the ecosystem dynamics. To better understand the biological response to this changing Arctic, we need to better describe the complexity of the coupled physical-biological system. In this study, we describe recent in situ measurements of light penetration through different types of sea ice performed during two expeditions to the Chukchi Sea in August 2018 and 2019 and during the leg 4 of the Multidisciplinary drifting Observatory for the study of Arctic Climate (MOSAiC) expedition in the Central Arctic Ocean (June and July 2020). The purpose of our study is to link under-ice light measurements to different sea ice types and conditions that characterize the summer season with the aim to improve our understanding of the optical properties of sea ice and how these are described in numerical models. Among our key findings, the observation of two types of FYI in late summer with different physical and optical properties.

Light permits continued near-bottom chlorophyll fluorescence on a shallow Arctic shelf, the eastern Chukchi Sea

Michael F. Sigler, NOAA Alaska Fisheries Science Center, Juneau, Alaska USA
Phyllis J. Stabeno, NOAA Pacific Marine Environmental Laboratory, Seattle, Washington,USA
Calvin W. Mordy, University of Washington, Seattle, Washington USA
Chelsea W. Koch, University of Maryland, Solomons, Maryland USA

Keywords: Chukchi Sea, Ice Algae

The Chukchi Sea consists of a broad, shallow (<45 m) shelf that is seasonally (November–July) covered by sea ice. This study characterizes the seasonal patterns of near-bottom primary production using moored instruments measuring chlorophyll fluorescence, oxygen, nitrate, and photosynthetically active radiation during 2010-2018. The intensity of light at the seafloor (~40 m deep) was similar to levels observed under 1–2 m thick ice floes in the spring/early summer, and was sufficient to support photosynthesis near the seafloor, utilizing nitrate and producing oxygen. We hypothesize that the near bottom bloom originated from aggregates of ice algae that sank during ice retreat. This conclusion is consistent with moored sediment traps which identified disassociated ice algae species together with chlorophyll fluorescence for several months at the seafloor. As a consequence of climate warming and earlier ice retreat, we predict that the near-bottom bloom onset will occur earlier, but the timing of the end of the near-bottom bloom will remain the same pending a sufficient nutrient supply. The Chukchi Sea is highly productive even though the growing season is short. This production is promoted by a shallow seafloor, which allows multiple production layers (surface open water, bottom of the mixed layer, under-ice algae, and disassociated ice algae which settles near the seafloor). We term this the Multiple Production Layers (MPL) hypothesis.

Different responses to photoperiod in boreal and sub-Arctic Calanus population: a seasonal study of individual cyclic activity

Estelle Coguiec , UiT the Arctic university of Norway, Tromsø, Norway
Malin Daase, UiT the Arctic university of Norway, Tromsø, Norway
Kim Last, The Scottish Association for Marine Science, Oban, Scotlland
Jonathan Cohen, University of Delaware, United States of America
Jordan Grigor, The Scottish Association for Marine Science, Oban, Scotland
Laura Hobbs, The scottish Association for Marine Science, Oban, Scotland and University of Strathclyde, Glasgow, Scotland
Marvin Choquet, Nord University, Bodø, Norway
Jørgen Berge, UiT the Arctic university of Norway, Tromsø, Norway, The university centre in Svalbard, Longyearbyen, Norway and Norwegian University of Science and Technology, Trondheim, Norway

Keywords: Photoperiod, Latitude, Zooplankton, Calanus, Activity

Biogeographical shifts in zooplankton species distribution are expected due to climate warming, particularly at high latitudes. A northward shift will expose populations to stronger seasonal fluctuations in light intensity and daylength (photoperiod). Such changes in light climate may trigger behavioural and physiological responses that can affect survival and productivity. To document such effects, we need a better understanding of behavioural swimming patterns and how they are controlled by photoperiod. Here we used an experimental approach to study seasonal changes in swimming activity in copepods of the genus Calanus finmarchicus and Calanus glacialis, key species in boreal and Arctic marine ecosystems. Those species are found across a wide latitudinal and photoperiodic range, from the North Atlantic to the Arctic Ocean. We conducted monthly sampling of Calanus from Loch Etive, Scotland (56°N) where C. finmarchicus resides under a boreal seasonal light cycle, and Ramfjord, Norway (69°N) with a mix of C. finmarchicus and C. glacialis under extreme seasonal photoperiods with two months of polar night and midnight sun. The activity patterns of individual Calanus subjected to the local photoperiod were monitored in the lab using modified Trikinetics Locomotor Activity Monitors (LAM). We found high individual variations in behaviour in both locations, with a part of the population exhibiting no diel cycle of activity, while others were rhythmic. The degree of cyclic activity in the population changes with season and photoperiod, with an increase in cyclic activity with increasing day length in the high latitude population. Our results show high individual variability in behaviour that may indicate high potential for adaptation to changing photoperiod.

ID: 54 - Fjords ecosystems in a global perspective – similarities and special features

Conveners

Ingrid Wiedmann | UiT The Arctic University of Norway

Angelika H. H. Renner | Institute of Marine Research, Norway

Maeve McGovern | Norwegian Institute for Water Research, UiT The Arctic University of Norway

Perspective on fjord dynamics in a changing Arctic

Karley Campbell, UiT The Arctic University of Norway, Tromsø, Norway
Sünnje Basedow, UiT The Arctic University of Norway, Tromsø, Norway
Rolf Gradinger, UiT The Arctic University of Norway, Tromsø, Norway
Paul Wassmann, UiT The Arctic University of Norway, Tromsø, Norway
Marit Reigstad, UiT The Arctic University of Norway, Tromsø, Norway
Jørgen Berge, UiT The Arctic University of Norway, Tromsø, Norway

Keywords: Fjord Systems, Climate Change, Production, Marine, Sea Ice

Fjords are dynamic coastal environments where marine, freshwater and cryosphere systems converge. The biological productivity within them reflects this complexity, which combined with their potential sensitivity to ongoing environmental change, has made them a topic of focus in the study of ocean biogeochemistry and food web interactions. Their physical-biological characteristics can vary widely across the Arctic as a result of differences in local geography (e.g. catchment size and type of glaciation) and our vision of Arctic fjords is thus strongly dominated by the localities in which studies has been carried out. In this work, we build off of successes at the 2019 ARCTOS (Arctic Marine Ecosystem Research Network) fjord workshop, Tromsø, Norway, to synthesize our current knowledge on fjord biogeochemistry and productivity in the Arctic. We will thus try to achieve a vision that develops from a singular fjord to the fjords as a collective. Our work will include but not be limited to an analysis of primary and secondary production in fjords across regions of the Arctic (e.g. Greenland vs. Norway). We will make use of sympagic and pelagic-focused datasets in our assessment and will conclude by identifying critical ways forward in their study, and within the context of climate change. This work represents a collective research initiative of the Arctic Science Partnership (ASP) and is a precursor to an ASP-ARCTOS fjord-focused workshop to be held in Tromsø, fall 2022.

Seasonal plankton trends in Kongsfjorden, Svalbard, during 2019

Philipp Assmy, Norwegian Polar Institute, Tromsø, Norway
Ane Cecilie Kvernvik, Norwegian Polar Institute, Tromsø, Norway and The University Centre in Svalbard, Longyearbyen, Norway
Allison Bailey, Norwegian Polar Institute, Tromsø, Norway
Pedro Duarte, Norwegian Polar Institute, Tromsø, Norway
Haakon Hop, Norwegian Polar Institute, Tromsø, Norway
Clara J. M. Hoppe, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
Amalia Keck Al-Habahbeh, Norwegian Polar Institute, Tromsø, Norway
Sławomir Kwaśniewski, Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland
Weronika Patula, Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland
Harald Steen, Norwegian Polar Institute, Tromsø, Norway
Agnieszka Tatarek, Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland
Jozef M. Wiktor, Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland
Anette Wold, Norwegian Polar Institute, Tromsø, Norway

Keywords: Kongsfjorden, Phytoplankton, Zooplankton, Seasonal, Environmental Drivers

We present seasonal plankton time-series data from a glacial fjord in the Arctic: Kongsfjorden on the west coast of Spitsbergen (79°N). It integrates inputs from Atlantic and Arctic waters, and glacier run-off, and is thus a prime location to study key environmental drivers that are relevant across the Arctic. Despite the extensive research in Kongsfjorden over the last decades, seasonally resolved data are largely missing. From April to September 2019, we conducted field sampling at weekly resolution investigating the environmental drivers of phyto- and zooplankton phenology. The phytoplankton spring bloom was dominated by the algae Phaeocystis pouchetii while the typical spring bloom diatoms played a minor role. The early feeding stages of the dominant Calanus copepods coincided with the spring bloom, suggesting good conditions for growth. Following the rapid collapse of the spring bloom phytoplankton in late May biomass levels increased again and remained elevated during summer and early autumn, coinciding with the peak glacier run-off season. The summer and autumn phytoplankton communities were co-dominated by diatoms and phototrophic dinoflagellates and resembled autumn bloom communities of lower latitudes. Our seasonal data provide a first glimpse into the environmental drivers of plankton phenology, but high-resolution monitoring over many annual cycles is required to resolve the ephemeral variations of plankton populations against the backdrop of climate change.

Biogeochemistry of an Arctic fjord under high-resolution lens

Archana Singh, National Center for Polar and Ocean Research, Ministry of Earth Sciences, Goa, India
Divya David T., National Center for Polar and Ocean Research, Ministry of Earth Sciences, Goa, India
Subeesh M.P., National Center for Polar and Ocean Research, Ministry of Earth Sciences, Goa, India

Keywords: Biogeochemical, Chlorophyll a, High resolution, Nitrate, Time series

With an understanding of the annual pattern and seasonal variability of the biogeochemical parameters along with their interactions with the physical parameters in Kongsfjorden- an Arctic fjord in Svalbard (Singh et al., 2020), we now zoom in to the intraseasonal and other smaller time scale variations. We are investigating a 3-year (July 2015-Oct 2018) biogeochemical time series recorded at sub-surface by the Indian mooring in the fjord. For these three years, the spring bloom timing was quite consistent. Roughly, the bloom started in April and peaked in May. The summer of 2017 was observed with a spurt in nitrate values at 45 m (~10-15µM), and sometimes attained values as high as the winter values. The wind and current data showed the presence of high-frequency baroclinic currents in summer 2017 that coincided with strong winds in the fjord. Richardson number showed that even though the summer stratification was strong, the shear induced by the baroclinic currents was sufficient to mix the water column. Hence, the nitrate variability here appears strongly influenced by the vertical water column mixing due to the high-frequency oscillations. Another anomalous observation was that nitrate at 45m in 2018 was never less than 4µM, while it was <2µM in 2016 and 2017 autumn. With more questions than answers from the present 3-year time series, we try to explain and gain an understanding of some high-resolution variabilities in the fjord biogeochemistry.

15 years of observatory data from two Arctic fjords as open access

Jørgen Berge, UiT The Arctic University of Tromsø, Tromsø, Norway
Finlo Cottier, Scottish Association for Marine Science, Oban, Scotland
Tomasz Kopec, UiT The Arctic University of Tromsø, Tromsø, Norway
Estelle Dumont, Scottish Association for Marine Science, Oban, Scotland
Emily Venables, UiT The Arctic University of Tromsø, Tromsø, Norway,
Malin Daase, UiT The Arctic University of Tromsø, Tromsø, Norway,
Jon Beaton, Scottish Association for Marine Science, Oban, Scotland
Daniel Vogedes, UiT The Arctic University of Tromsø, Tromsø, Norway

Keywords: Biogeophysical Data, Marine Observatory, Svalbard, Long-Term Monitoring

The collection of oceanographic data over long periods of time is of great importance for the understanding of marine ecosystems, as well as for monitoring the effects of a changing climate on local environments. In a cooperation between UiT The Arctic University of Tromsø, the Scottish Association for Marine Science and the University Centre in Svalbard, we operate two long-term marine observatories in two fjords of the archipelago of Svalbard. In Kongsfjorden, a fjord influenced by Atlantic water, moored instrumentation has been in place since 2002 recording biogeophysical properties throughout the water column. Similar observations have been made in Rijpfjorden, influenced by Arctic water, since 2006. Along with an overview of the last 15 years of data, we present a new online visualisation portal through which all these data will be made open and freely accessible.

Biogeochemical regime of Templefjord (Spitsbergen) influenced by coastal runoff and glacial melting

M. Pogojeva, Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia; N.N.Zubov's State Oceanographic Institute, Roshydromet, Moscow, Russia
A. Polukhin, Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia
P.N. Makkaveev, Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia
A. Staalstrøm, Norwegian Institute for Water Research, Oslo, Norway
A. Berezina, Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia; St. Petersburg State University, Saint Petersburg, Russia
E. Yakushev, Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia; Norwegian Institute for Water Research, Oslo, Norway

Keywords: Sea Water Biogeochemistry, Arctic Ocean, Glaciers, Coastal Runoff, Acidification

Observations and predictions show that climate warming consequences such as declining summer sea ice cover, melting glaciers, thawing permafrost, increased river runoff to the Arctic Ocean will likely modify the processes relevant for the freshwater and carbon budget which in turn also affect the high latitude marine ecosystems. The aim of this work was to assess the current biogeochemical regime of coastal waters exposed to coastal runoff and glacial melting and discuss the possible consequences connected with the climate warming. We used data of 5 expeditions to the Templefjord, Spitsbergen, obtained in different seasons. In all the expeditions the distributions of dissolved oxygen, nutrients, carbonate system parameters in the water column were studied. The principal environmental media, i.e.: sea water, bottom sediments, river water, sea ice, river ice, glacier ice and snow were sampled. The collected data allowed to describe seasonal dynamics in the water column and to estimate the content of the parameters under study in different environmental media. Our observations revealed the glacial and river footprints in the water column biogeochemistry, the glacial influence can be traced as in summer and in winter season. The results demonstrated the significant influence of coastal runoff and melted glacier water on the carbonate system and nutrients regime in the Tempelfjord allowing to extrapolate the findings to other Arctic regions.

Glacial meltwater determines the balance between autotrophic and heterotrophic processes in a Greenland fjord

Mikael Sejr, Aarhus University, Denmark
Annette Bruhn, Aarhus University, Denmark
Tage Dalsgaard, Unisense A/S, Denmark
Thomas Juul-Pedersen, Greenland Institute of Natural Resources, Greenland
Colin Stedmon, Technical University of Denmark, Denmark
Martin Blicher, Greenland Institute of Natural Resources, Greenland
Lorenz Meire, Greenland Institute of Natural Resources, Greenland

Keywords: Greenland, Meltwater, Pelagic Ecosystem, Heterotrophy

Global warming accelerates melting of glaciers and ice sheets resulting in increased input of meltwater and associated inorganic particles, nutrients and organic matter to coastal seas. However, the impacts on marine carbon cycling remains poorly quantified. One potential impact could be that meltwater reduce light and nutrient availability for primary producers while supplying allochthonous carbon for heterotrophic processes, thereby tipping the net community metabolism towards heterotrophy. To test this hypothesis, we determined key physical and biogeochemical parameters along a 110 km fjord transect in Young Sound, NE Greenland impacted by glacial meltwater from the Greenland Ice Sheet. Meltwater was mainly delivered to the inner parts of the fjord creating a gradient in salinity and turbidity along the length of the fjord. The planktonic community in the innermost part was dominated by small ciliates, whereas larger diatoms dominated the outer fjord while primary production was low, 20-45 mg C m-2 d-1, in the more turbid inner half of the fjord increasing ten-fold to around 350 mg C m-2 d-1 near the Greenland Sea. Community metabolism was measured at three stations, and displayed a transition from a net heterotrophic community in the inner to a net autotrophic on the coastal shelf. Respiration was significantly correlated to turbidity, with a 10-fold increase in the inner turbid part of the fjord. The results highlight the importance of run-off for influencing carbon cycling in Arctic coastal waters. In fjords dominated by run-off from land-terminating glaciers, predicted future increases in glacial meltwater run-off and greening of catchments may reduce light availability, limit vertical mixing of nutrients for primary producers and provide allochthonous carbon for heterotrophic organisms.

Contrasting patterns of benthic biomass and response to climate warming in Antarctic versus Arctic subpolar fjords

Craig R. Smith, University of Hawaii, Honolulu, USA
Andrew K. Sweetman, Heriot-Watt University, Edinburgh, UK
McKenna Lewis, University of Hawaii, Honolulu, USA
Clifton Nunnally, Louisiana Universities Marine Consortium, Chauvin, USA
Maria Vernet, Scripps Institution of Oceanography, La Jolla, CA
Emily Eidam, University of North Carolina, Chapel Hill, USA
Amanda Ziegler, The Arctic University of Norway, Tromsø, Norway
Øyvind Lundesgaard, Norwegian Polar Institute, Tromsø, Norway

Keywords: Fjord, Benthos, Climate Warming, Antarctic, Arctic

Rapidly-warming West Antarctic Peninsula (WAP) fjords with tidewater glaciers are hotspots of biomass and biodiversity, but have remained poorly studied. Our FjordEco Project integrated field/modeling studies in Andvord Bay, WAP, to explore (1) how glacial/oceanographic processes enhance fjord productivity, and (2) how climate warming may alter these productive ecosystems. Field studies in Andvord Bay from Dec 2015 to Apr 2017 indicated intermittently high primary production throughout the fjord. Benthic ecosystem parameters integrated summer seafloor POC flux and identified fjord areas of high benthic food input. Sediment Chl-a and seafloor respiration were low throughout the fjord in Dec, but much greater in Apr, with highest levels in the inner fjord near fast-flowing glaciers. Benthic faunal biomass matched patterns of food input, with peaks in the inner fjord. Sedimentation rates were low throughout the fjord (< 0.7 cm/y) even within 1 km of glaciers. These patterns of high benthic biomass with limited burial disturbance in inner Andvord Bay contrast sharply with Arctic subpolar fjords with tidewater glaciers (e.g., Konsgfjorden), where high sedimentation (~9 cm/y) yields depauperate inner-fjord communities. We present a conceptual model describing how climate warming of the WAP will enhance meltwater/sediment input near glaciers and snuff out inner-fjord hotspots of productivity; i.e., warming effects in contrast to predictions for many subpolar Arctic fjords.

Ability of sediment bound heterotrophic bacteria from Kongsfjorden and Krossfjorden, Arctic to degrade structurally stable polysaccharides

Vishnupriya. S, Department of Marine Biology, Microbiology and Biochemistry ,Cochin University of Science and Technology, Cochin, India
K. P. Krishnan, National Centre for Polar and Ocean Research, Vasco-da-Gama, Goa. CUSAT-NCPOR Centre for Polar Sciences, Cochin
A. A. Mohamed Hatha, Department of Marine Biology, Microbiology and Biochemistry Cochin University of Science and Technology, Cochin, India, CUSAT-NCPOR Centre for Polar Sciences, Cochin

Keywords: Polysaccharides, Arctic fjords, Heterotrophic bacteria, Glycosidases

Carbohydrates constitute the largest fraction of marine dissolved organic matter, derived mostly from phytoplankton blooms. Marine polysaccharides have been found as the major structural constituent of the seaweed cell wall and exoskeleton of crustaceans. Since polysaccharides cannot be easily utilized by marine bacterioplankton, degradation of the same using glycosidic enzymes produced by the bacterial community are important to make available for their utilization. The primary objective of this study is to find out the capability of heterotrophic bacterial isolates from the sediments of Kongsfjorden and Krossfjorden to degrade structurally stable polysaccharides. We have isolated a total of 237 cold adapted bacteria from Kongsfjorden and Krossfjorden sediments and tested their ability to degrade the complex polysaccharides by using the plate assay method. Bacterial isolates were spot inoculated in the modified basal medium supplemented with structurally stable polysaccharides such as Xylan, Laminarin, Alginic acid, Agar, Carboxy methylcellulose, Chitin and incubated at 20o C for 7 days. Results indicated that one third of the isolates were capable of utilizing agar (33.75%) followed by chitin (30.80%), alginic acid (29.95%) and laminarin (28.69%), Xylan (18.56%) and carboxy methyl cellulose (15.61%).These results revealed the significant role of sediment bound bacteria in the degradation of complex polysaccharides in the Arctic fjord sediments and thereby carbon cycling.

Macrobenthic communities of deep sub-Arctic fjords

Valentin Kokarev, Nord University, Bodø, Norway
Henning Reiss, Nord University, Bodø, Norway

Keywords: Infauna, Community Structure, Norwegian Coast, Vestfjord

Macrobenthic communities are an important component of marine habitats, which are often used as indicators of ecosystem responses to various impacts, including climate change and human activities. However, before any change can be detected, baseline knowledge about the composition of macrofauna and factors affecting its distribution is required. There is a lack of such understanding for sub-Arctic fjords, which were shown to play an important role in carbon cycling and sequestration in coastal habitats. We studied eight deep (>290 m) sub-Arctic basins located in northern Norway to assess the community differentiation of neighbouring fjords. There was a significant difference in macrofaunal composition between shallow-silled and deep-silled fjords, which were characterised by different bottom-water masses. Moreover, further differentiation was observed among fjords with similar levels of water exchange with surrounding waters. We suggest that low connectivity among local communities and priority effects resulted in communities developing independently, which is reflected in distinct community structure for each basin. This natural variability in species composition and diversity on small spatial scales can be a distinguishing feature of the fjords when compared to the habitats offshore.

Effect of temperature and depth on ecosystem structure and properties of Arctic Norwegian fjords

Torstein Pedersen, UiT The Arctic University of Norway

Keywords: Ecosystem Modelling, Environmental Forcing, Climate Change, Ecosystem Structure

Arctic fjord ecosystems differ considerable with regard to ecosystem structure and environmental setting. Temperature and bottom depth are considered as major environmental factors affecting Arctic fjord ecosystems. In this study, it is tested if diverse Arctic fjord ecosystems may be represented by a general fjord mass-balance model forced by depth and temperature. Five published ecosystem models from various areas in the cold Porsangerfjord and two models from the warmer Ullsfjord-Sørfjord system are applied in the analysis. The fjord systems comprise ecological groups with arctic or boreal environmental tolerances. Temperature and depth responses functions for food consumption and growth for ecological model groups are reviewed and used as input to the general fjord model. To test possible future effects of warming on fjord ecosystem structure, scenarios with different increases in water temperature are run on the general fjord model.

Environmental and anthropological drivers of seasonal and diurnal material load patterns in north Norwegian fjords

Menno Blom, Institute of Marine Research/ University Centre of the Westfjords (Ísafjörður Iceland), Tromsø, Norway

Keywords: Subarctic, ADCP, Backscatter, Material load, Temporal patterns

In an effort to expand baseline knowledge of fjords in the subarctic region of northern Norway, anthropological and environmental drivers of material load patterns in two ice free fjords are investigated. This study uses ADCP backscatter in combination with long- and short term sediment trap data and other fjord parameters to identify drivers of material load patterns. Data gathered over a period of 6 to 10 months allows for temporal analysis of material load patterns. Preliminary results show diurnal patterns in the ADCP backscatter, and seasonal variability in backscatter and other fjord parameters such as hydrography, chlorophyll a distribution and vertical particle fluxes. Diurnal patterns are expected to be dominated by the diel vertical migration of zooplankton, variation of which potentially gives interesting clues to seasonal changes in ecological activity. We investigate environmental drivers of this seasonal variability including change of light - and meteorological conditions. The effect of human activities is highlighted in a comparison between aquaculture production, ADCP backscatter, TPM, chlorophyll a, and turbidity. Results are compared with findings at higher latitudes.

Glacial streams of the Novaya Zemlya as a source of nutrients for the Kara Sea fjords

Borisenko Gennady, IO RAS, Moscow, Russia
Alexander Polukhin IO RAS, Moscow, Russia
Fedulov Vadim IO RAS, Moscow, Russia
Stepanova Svetlana IO RAS, Moscow, Russia
Nedospasov Andrew IO RAS, Moscow, Russia
Khlebopashev Pavel IO RAS, Moscow, Russia

Keywords: Leaching, Biogeochemistry, Glacial Streams, Nutrient, Weathering

The Kara Sea belongs to the seas with low primary production (125mgC*m2/day) . This is due to the relatively low concentrations of nutrients in the water. In the framework of the Shirshov Institute of Oceanology Arctic programme ("Investigation of the Russian Arctic ecosystems") in 2007-2020, it was revealed that the concentration of nutrients (first of all, nitrates and silicate) in the bays of the Novaya Zemlya archipelago is higher than in the surrounding water area of the Kara Sea. Moreover, seasonal variability of the nutrient content in the water of glacial streams and archipelago fjords was revealed (PO43- 0.19 µM, SiO32- 29 µM, NO3- 9.4 µM). According to our assumptions, this is due to the leaching of nutrients from shale rocks. An experiment was carried out, which confirmed the possibility of leaching nutrients from the rock. The values of the runoff of nutrients into the waters of Novaya Zemlya bays were obtained. For total nitrogen and total inorganic carbon, the rates are 0.021–0.15 mmol / m2*day and 0.1–2.5 mmol / m2*day respectively. The results obtained in the course of the work can be useful in predicting the chemical composition of the ocean owing to climate changes which cause the melting of glaciers, which in turn could accelerates the weathering of rocks and increases the flow of nutrients into the ocean from the Arctic archipelagoes.

Mixed layer depth and its control on spring bloom dynamics in Kongsfjorden, Svalbard

Clara J M Hoppe, Alfred Wegener Institute, Helmholtzcenter, Bremerhaven, Germany
Klara K E Wolf, Alfred Wegener Institute, Helmholtzcenter, Bremerhaven, Germany
Finlo Cottier, SAMS, Oban, Scotland, UK
Eva Leu, Akvaplan Niva, Tromsø, Norway
Björn Rost, Alfred Wegener Institute, Helmholtzcenter, Bremerhaven, Germany

Keywords: Phaeocystis, Diatoms, Primary Production, Disturbance Recovery Hypothesis, Light

Especially in areas with strong seasonality such as the Arctic and Antarctic, the mass accumulation of phytoplankton biomass during the spring bloom plays a central role in sustaining marine food webs and strongly influences biogeochemical cycles. Traditionally, spring bloom initiation is often explained with the help of the 'Critical Depth Hypothesis', which assumes that the bloom is initiated once the mixed layer shoals enough for light to be sufficient for positive net phytoplankton growth. This view has been challenged by the 'Disturbance Recovery Hypothesis', which postulates that phytoplankton biomass changes when a disturbance de-couples phytoplankton growth from loss terms, the latter mainly due to grazing. According to this hypothesis, a deepening mixed layer can increase depth-integrated biomass due to its effects on grazer encounter rates. In this talk, a comprehensive dataset from three consecutive spring periods (2016-2018) from Kongsfjorden, Svalbard, with contrasting environmental conditions is used to investigate the controls of timing, composition and biogeochemical characteristics of Arctic spring blooms, with particular focus on the role of the mixed layer depth. The applicability of the above-mentioned hypotheses will be evaluated based on our data, and potential implications for future changes in spring bloom dynamics and fjord productivity will be discussed.

Modeling the impact of glacier run-off on plankton composition in West Spitsbergen fjord (Svalbard)

Marlena Szeligowska, Institute of Oceanology Polish Academy of Sciences, Sopot, Poland
Déborah Benkort, Institute of Coastal Research Helmholtz-Zentrum Geesthacht, Geesthacht, Germany
Emilia Trudnowska, Institute of Oceanology Polish Academy of Sciences, Sopot, Poland
Agnieszka Strzelewicz, Institute of Oceanology Polish Academy of Sciences, Sopot, Poland
Kirill Filchuk, Arctic and Antarctic Research Institute, Saint Petersburg, Russia
Katarzyna Błachowiak-Samołyk, Institute of Oceanology Polish Academy of Sciences, Sopot, Poland

Keywords: Glacier, Particles, Zooplankton, Protists, Modeling

Fjords located along the western coast of Spitsbergen (Svalbard) are affected by raising seawater temperatures and intensified advection of warm Atlantic Water. These processes accelerate the glaciers retreat and increase run-off of meltwater. Glaciers discharge freshwater with loads of suspended matter affecting living conditions for protists and zooplankton and producing steep horizontal gradients from glacier fronts to the outer parts of the fjords. In order to study the dynamics of the marine ecosystem in the West Spitsbergen fjords, we designed numerical experiments using the biogeochemical ECOSystem MOdel (ECOSMO) coupled with the General Ocean Turbulence Model (GOTM). ECOSMO structure was extended by implementing glacier run-off and meroplankton components. In this first attempt to investigate and solve scientific and technical challenges related to the coupling between the pelagic ecosystem and glacier run-off, the model was implemented in a 1D application. Extensive published and unpublished data, gathered from several monitoring programs of numerous institutes, including moorings, were used to create an idealized dataset of temperature and salinity profiles for one full year for locations influenced by glacier run-off and open waters. These datasets were necessary to run GOTM. Here, we present results from this numerical framework, aiming specifically at understanding the linkage between pelagic ecosystem and sediment discharge from glaciers.

Seasonality and variability of the circulation in a high-latitude fjord

Anna Nikolopoulos, Institute of Marine Research, Fram centre, Tromsø, Norway
Jofrid Skarðhamar, Institute of Marine Research, Fram centre, Tromsø, Norway
Angelika Renner, Institute of Marine Research, Fram centre, Tromsø, Norway
Qin Zhou, Akvaplan-niva, Fram centre, Tromsø, Norway

Keywords: Fjord-System, Oceanography, Seasonal Variability, Dynamics

The oceanographic conditions of a fjord system impact both pelagic and benthic biogeochemical components of its ecosystem. With increased human activity in the fjord environment it is crucial to improve our knowledge on the behaviour of these water bodies. We investigated the seasonal characteristics of water circulation and exchange in Kaldfjorden (69.7°N, 18.7°E), Northern Norway, based on observations in 2017-2018 and high-resolution hydrodynamic model simulations. Kaldfjorden is a small fjord (15 km long, 2-3 km wide and 230 m deep), dynamically connected with the coastal shelf area and the Norwegian Sea through two straits and the deeper trough Malangsdjupet. The interplay between the Norwegian Coastal Current and the North Atlantic Current, both flowing northward along the Norwegian coast, affects the hydrography in the fjord. We show that the general circulation in the fjord is more complex than classic-notion estuarine fjord circulation, with large horizontal gradients and high temporal variability throughout all seasons. The prominent circulation features, and the associated water exchange, are connected to both local and remote winds, as well as to the density-driven communication with the coastal shelf waters at intermediate depths. The present analysis makes it clear that a combination of extended observations and model simulations is not only preferable but rather necessary for catching the full dynamical functioning of a fjord system.

The Fate of Ice sheet Derived Organic Matter in Greenland Fjords

Johnna M. Holding, Aarhus University, Silkeborg, Denmark
Maria Lund Paulsen, Aarhus University, Silkeborg, Denmark
Katja Laufer, GEOMAR–Hemholtz Centre for Ocean Research–Kiel, Kiel, Germany
Ingrid Wiedmann, UiT–The Arctic University of Norway, Tromsø, Norway
Mie H.S. Winding, Greenland Climate Research Centre, Greenland Nature Institute, Nuuk, Greenland
Mikael K. Sejr, Aarhus University, Silkeborg, Denmark

Keywords: Greenland Ice Sheet, Carbon Cycling, Organic Matter, Biogeochemistry,

The Greenland Ice Sheet is melting rapidly, increasing freshwater run-off in the coastal ocean around Greenland. Ice sheet and glacial run-off have recently received a lot of attention, as it carries allochthonous material, such as nutrients and organic matter (OM) that have been suggested to have important consequences for coastal carbon cycling. However, there are few studies to date that follow allochthonous OM from its source in the Ice Sheet to its eventual fate in the marine coastal environment. This study takes a whole system approach, starting with land-sea interactions, but also focusing on the dynamics of allochthonous OM in the suspended, sinking and sediment compartments of the Tyrolerfjord-Young Sound System in East Greenland. From a marine perspective, there is relatively little organic carbon in Ice Sheet run-off in both the particulate (POC ~50µM) and dissolved fractions (DOC ~25µM), thus acting to dilute OM in the fjords. The POC that enters the marine system is sedimented out within the first few kms of the fjord. DOM from the Ice Sheet is rather labile (~55% bioavailable compared with 1-20% in the fjord) and is likely remineralized immediately upon entering the fjord. With this and future studies we hope to further elucidate the fate of Ice Sheet OM in Greenland fjords and its consequences for coastal carbon cycling.

Ocean temperature during summer in Kongsfjorden, an eastern Arctic fjord

Divya David T, NCPOR, Goa, India
Anju V .S, CUSAT, Kerala, India
Subeesh M. P, NCPOR, Goa, India
N. Anilkumar, NCPOR, Goa, India
M. Ravichandran, NCPOR, Goa, India

Keywords: Eastern Arctic, Fjord, Atlantification, Hydrography, Variability

Arctic fjords are ideal locations to study processes associated with atlantification and water column density modification due to brine ejection during sea-ice formation. Kongsfjorden in the west Spitsbergen shelf has high Atlantic water volume, compared to other southern fjords in Svalbard, due to its weaker frontal formation at the mouth, the wider-deeper trough connected to West Spitsbergen Current, and lesser freshwater content. A decade of summertime field surveys in Kongsfjorden from 2011 to 2020 showed an increase in the water column temperature embedded with an inter-annual variability. The mean water column temperature at the glacier side showed a 0.12oC/yr rate of increase. Meanwhile, the temperature in the upper water column, above 60 m, at the open ocean side showed an increase of 0.06oC/yr while the layer below showed an increase of 0.03 oC/yr, half the rate at which the upper layer warmed. More than the double the rate of increase in the mean water column temperature at the glacier side compared to that at the open ocean side explains the reported rise in basal glacial melting at the head of the eastern Arctic fjords over the last few decades, driven by increased Atlantic water near the glaciers. Besides the long term changes, the study focuses on explaining and quantifying the inter-annual summer temperature variability in Kongsfjorden against the atmospheric and oceanic fluxes over the period.

Sustainable Aquaculture in the North; Spatial response of hard and mixed-bottom epifauna to organic enrichment from salmon aquaculture in northern Norway

Katherine Dunlop, Institute of Marine Research, Tromsø, Norway
Nigel Keeley, Institute of Marine Research, Tromsø, Norway
Astrid Harendza, Akvaplan-niva, Tromsø, Norway
Raymond Bannister, Environment and Heritage, Hobart, Australia
Liv Plassen, Norwegian Geological Survey, Trondheim, Norway

Keywords: Benthic Fjord Megafauna, Coastal Aquaculture, Hard Substrates, Sponge Aggregation, Soft Corals, Ecological Environmental Assessment

Norwegian salmon aquaculture is expanding in northern fjords dominated by hard and mixed bottom substrates. Such habitats contain rich epifaunal communities, including sponges and soft corals, susceptible to the impacts of suspended particulate material released from finfish farms. Here conventional soft sediments sampling techniques are incompatible to discern the impacts of farm waste and new monitoring methods and indicator taxa must be identified. This study examines the impacts of particulate waste released from salmon farms on the density and structure of epifaunal assemblages on hard and mixed substrates in northern Norwegian fjords. Epifaunal communities were recorded in camera transects running from three salmon farms to ~ 800 m away in the primary current direction. The level of particulate material in the vicinity of these farms was a primary driver of epifauna community composition, as was the coverage of some key substrate types. The defecated mounds of lugworms and the seastar (Asterias rubens) were key components of communities receiving high waste input. Some sponge and soft coral species showed significant declines in density with increasing particulate material and were principal taxa in communities receiving relatively low waste levels. Results identify taxa with both positive and negative spatial association to farm waste and the potential to be suitable indicator taxa for monitoring aquaculture environmental impacts in hard bottom dominated fjords.

ID: 23 - The forgotten season – Arctic Winter Microbiology

Conveners

Riitta Nissinen | Department of Biological and Environmental Science, University of Jyväskylä, Finland

Shawn Brown | Department of Biological Sciences, The University of Memphis

Pernille Bronken Eidesen | The University Centre in Svalbard, Norway

Annual cycle of filamentous alga tribonema cf. Minus in hydro-terrestrial habitats in the high arctic

Matouš Jimel
Jana Kvíderová
Josef Elster

Keywords: Hydro-Terrestrial Habitats, Adaptation, Photosynthesis, Tribonema Cf. Minus, Vitality

Filamentous microalga Tribonema sp. (Stramenopiles, Xanthophyceae) play an important role in shallow polar (streams and seepages) as well as in seasonally cold habitats in temperate regions (ponds) where freezing and desiccation as well as freeze–thawing and drying–rewetting cycles are frequent. Here, they produce visible biomass and are important components of low temperature adapted communities. We characterized the annual cycles of a Tribonema cf. minus population in two habitats (seepage and stream) in the High Arctic, Svalbard. The season, locality and their combination (particular environmental conditions and their changes) together with cultivation conditions of strains significantly affected their morphological characteristics. Morphological changes following hardening processes related to preparation for the winter period (transition from vegetative cells to akinete and/or pre-akinete) were recorded. Over the year, positive water temperatures (warmest 13.3 °C) occurred for 5 months while negative (lowest temperature was – 17.4 °C) lasted for 7 months. In winter, there were two melt periods. Vitality staining protocol showed a high number of viable (77.4 and 53.8 %) and dormant cells (1.7 and 4.1 %) (capable of growth and reproduction once suitable conditions return) in the winter seepage and stream, respectively. NPQ and OJIP Chlorophyll fluorescence parameters revealed several hours recovery of photosynthesis (both field and control samples). During recovery, only minor or mild stress on photosynthesis was detected. FV/FM values (the photosynthetic efficiency of photosystem II in a dark-adapted state) in all field and control samples varied around 0.4. Tribonema cf. minus is capable of surviving winter Arctic conditions (perennial strategy).

Arctic spring awakening – reinitiation of photosynthetic activity at the winter-spring transition

Clara J M Hoppe, Alfred Wegener Institute, Helmholtzcenter, Bremerhaven, Germany
Ane Cecilie Kvernvik, Norwegian Poalr Institute, Tromsø, Norway
Allison A Fong, Alfred Wegener Institute, Helmholtzcenter, Bremerhaven, Germany
Anders Torstensson, Uppsala University, Uppsala, Sweden
Björn Rost, , Alfred Wegener Institute- Helmholtzcenter, Bremerhaven, Germany
Eva Leu, Akvaplan Niva, Tromsø, Norway
and the MOSAiC-ECO consortium

Keywords: Photosynthesis, Reillumination, Phytoplankton, Svalbard, MOSAiC

Microalgae as the base of the marine Arctic food web are traditionally thought to be mostly absent or inactive during the polar night. Our knowledge about overwintering strategies of phototrophic microalgae is still fragmentary, but vegetative cells and/or resting stages are found in various habitats, such as sea ice, water column, and surface sediments. To judge the relevance of different potential seeding populations, and to unravel the mechanisms triggering the very first initiation of algal growth during the winter-spring transition, it is essential to study the physiological characteristics of phototrophs at the end of the polar night as well as their abilities to initiate photosynthesis upon reillumination. Such knowledge is key for understanding and predicting the timing and composition of Arctic spring blooms with concurrent effects on ecosystems and biogeochemistry. Our recent findings suggest that Arctic microalgae can in fact remain active and possess largely functional photosystems throughout the winter, allowing them to reinitiate phototrophic growth as soon as the light returns. In this talk, experimental and observational results from several winter and early spring campaigns to Svalbard (79°N) will be combined with first insights on phototrophs from the winter-spring transition during the MOSAiC expedition to the central Arctic in 2019-2020.

Season strongly shapes bacterial but not fungal communities of subarctic plants

Suni Mathew, University of Jyväskylä, Jyväskylä, Finland
Cindy Given, University of Jyväskylä, Jyväskylä, Finland
Riitta Nissinen, University of Jyväskylä, Jyväskylä, Finland

Keywords: Plant Microbiomes, Endophytic Bacteria, Winter Microbiomes

Cold adaptation is one of the primary factors limiting geographical distribution of plant species. Cold growing season and long winter with freezing temperatures have strongly shaped arctic and cold climate vegetation. Plant associated microbes, including bacteria and fungi are known to contribute significantly to plant survival, growth and protection from environmental stresses. Yet, virtually nothing is known about plant microbiomes during arctic and boreal winters. We explored the leaf endophytic microbial communities in four subarctic plant species in nine sampling locations (60.1°N -69.1°N) over two seasons (August, February). Using 16S rRNA gene (bacteria) and ribosomal ITS (fungi) targeted sequencing and sequence analysis, we analyzed the influence of season, location and plant species (and overwintering strategy) on the composition of bacterial and fungal communities. Season had a significant impact on leaf bacterial communities, with distinct winter and summer community structures. Several season specific bacterial OTUs were detected. These season-specific OTUs were closely related to bacteria from other cold climate plants. In contrast, fungal communities were mainly shaped by plant species and sampling site, and to clearly lesser extent, season.

Ectomycorrhizal fungi: resilient to increased snow depth or a matter of experimental design?

Pernille Bronken Eidesen, The University Centre in Svalbard, Longyearbyen, Norway
Magdalena Wutkowska, The University Centre in Svalbard, Longyearbyen, Norway
Elisabeth Cooper, UiT The Arctic University of Norway, Tromsø, Norway
Sunil Mundra, United Arab Emirates University, Al Ain, United Arab Emirates
Anna Vader, The University Centre in Svalbard, Longyearbyen, Norway

Keywords: Snow-Depth, Root-Symbionts, Experimental Design

Snow depth and feedback loops linked to vegetation affect edaphic parameters and their soil-dwelling plant-symbionts. Direct effect of increased snow depth on the host plant, like a shorter growing season, may affect plant fitness and resource allocation (e.g. size of roots), which again can affect the carbon resources and physical space available for the symbionts. We investigated the effect of increased snow depth on diversity and composition of symbiotrophic associations in a widespread arctic herb, Bistorta vivipara in two different vegetation types (Cassiope heath and mesic meadow) using an experimental set-up of snow fences and high throughput sequencing. We found a clear differentiation among vegetation types, but a weak response to six years of experimentally increased snow depth. Our data suggest that arctic EcM communities are resilient to short term variation in snow cover. Alternatively, the lack of experimental response might be due to scale mismatch. Our study adds to a growing body of investigations of putative climate effect on fungal and bacterial communities utilizing experimental set-ups designed to study vegetation responses that clearly respond on very different spatial- and temporal scales than microbes. The implication of this is discussed, and some possible solutions suggested.

Nutrient cycles and gas exchange coupled to Microbial community diversity in Arctic permafrost

Lise Øvreås, Department of Biological Sciences, UiB and UNIS
Simone Lang, Department of Arctic Biology, UNIS

Keywords: Winter Temperature, Gas Exchange, Permafrost

The global warming is higher in the Arctic region than any other places on Earth. The temperature has increased with 4 degree Celsius during the last 40 years. This change has severe influences on the ecosystems and its biogeochemical processes. Understanding the role of microbial communities in cycling of carbon and regulation of greenhouse gas fluxes under these changing conditions is important to be able to realize its consequences. Although microbes are recognized as key players in these processes, their contribution is still poorly understood and incorporated into existing climate models. We have already a long experience in studying the microbial diversity in permafrost soils from Svalbard, and have tantalizing evidence that polar tundra represent a highly diverse and active ecosystem. We found that both active layer and permafrost layers have a quite high CO2 production potential upon the thaw of permafrost soils and that most of this comes from aerobic processes. We also found that the permafrost soils had increased number of stress response genes compared to the upper active layer that thaws every summer. Most of our studies are composed during summer season when the sampling sites are more easily accessible. We know that winter emissions contribute to only 1-2 % of the total annual production in Arctic tundra and that 90% of the annual variation of soil respiration is due to soil temperature. We therefore want to set up a long time monitoring system in Adventdalen covering the winter season for a more in-depth study on the winter processes.

Isolation and characterization of psychrotolerant arsenic-metabolizing microorganisms from a subarctic peatland used in treatment of mining-affected waters

Katharina Kujala, University of Oulu, Oulu, Finland
Aileen Ziegelhöfer, University of Applied Sciences FH Aachen, Jülich, Germany

Arsenic contamination of natural waters by mining activities is a major environmental concern. Thus mining-affected waters need to be treated prior to their release into downstream water bodies. Treatment peatlands are used in the polishing phase of water treatment, and peat microorganisms play a crucial role in arsenic removal. Pure cultures of arsenic-metabolizing microorganisms (arsenite oxidizers, arsenate respirers or arsenic tolerators) from peatlands can serve as model organisms to study microbial-assisted arsenic removal processes and could potentially be used in biotechnological applications. The present study used a dilution-to-extinction technique to isolate the above-mentioned groups from a peatland treating mine effluent waters of a gold mine in Finnish Lapland. 96-well plates were inoculated with different dilutions of peat suspension and incubated at 10°C. After = 3 transfers into new growth medium, 46, 76 and 117 potential isolates of arsenite oxidizers, arsenate respirers and arsenic tolerators were obtained and identified based on their 16S rRNA gene sequences. Physiological activity (i.e. arsenite oxidation or arsenate reduction) or growth in high-arsenic medium were tested at different temperatures ranging from 2 to 40°C. Most isolates showed maximal activity or growth at temperatures between 20-28°C. However, most also showed substantial activity at the lowest temperatures tested, while none showed activity at 40°C.

Capturing the unknown microbial players and genes involved in the cycling of arsenic and antimony in Northern peatland soils

Tiina Laamanen, University of Oulu, Finland
Stefan Lambert, University of Oulu, Finland
Katharina Kujala, University of Oulu, Finland

Keywords: Arsenic, Antimony, Treatment peatlands, Mine waters

Peatlands are used for treatment of mining affected waters in Finland. Wastewaters stemming from the ore beneficiation process or drain water pumped from underground mines are conducted onto treatment peatlands (TP) to remove contaminants before the waters get discharged into receiving water bodies. Those waters contain many metals, arsenic, antimony, nitrogen compounds, and sulfate. Peat microorganisms can oxidize or reduce arsenic and antimony species. Arsenic and Sb metabolizing microorganisms play a major role in peatlands with high As and/or Sb input. However, the microbial cycling of As and Sb in peat soils is only poorly studied to date, and many gaps in knowledge remain on what processes are occurring, which enzymatic pathways are involved, and who are the key players in microbial As and Sb transformation. Understanding the role of microorganisms in As and Sb cycling is crucial to the efficient use of peatlands in mine water treatment, and microorganisms isolated from As and Sb contaminated habitats can potentially be utilized in bioremediation.

ID: 26 - The Arctic Underground: Exploring root and rhizosphere processes in cold ecosystems

Conveners

Rebecca Hewitt | Center for Ecosystem Science and Society, Northern Arizona University

Michelle Mack | Center for Ecosystem Science and Society, Northern Arizona University

Can root-associated fungi mediate the impact of abiotic conditions on the growth of a High Arctic herb?

Magdalena Wutkowska, Department of Arctic Biology, The University Centre in Svalbard, Norway; Department of Arctic and Marine Biology, UiT – The Arctic University of Norway, Norway
Dorothee Ehrich, Department of Arctic and Marine Biology, UiT – The Arctic University of Norway, Norway
Sunil Mundra, Department of Arctic Biology, The University Centre in Svalbard, Norway; Department of Biosciences, University of Oslo, Norway; Department of Biology, College of Science, United Arab Emirates University, United Arab Emirates
Anna Vader, Department of Arctic Biology, The University Centre in Svalbard, Norway
Pernille Bronken Eidesen, Department of Arctic Biology, The University Centre in Svalbard, Norway

Keywords: Plant-Microbe Interaction, Plant Performance, Root-Associated Fungi, Arctic Soil Biology, Below-Ground Vegetation

Arctic plants are affected by many stressors. Root-associated fungi influence plant performance in stressful environmental conditions. However, the relationships are not well-known; do the number of fungal partners, their ecological functions and community composition mediate the impact of environmental conditions and/or influence host plant performance? To address these questions, we used a common arctic plant as a model system Bistorta vivipara. Whole plants with root systems were collected from 9 locations in Spitsbergen (n=214). Morphometric features were measured as a proxy for performance and combined with metabarcoding datasets of their root-associated fungi (amplicon sequence variants, ASVs), edaphic and meteorological variables. Seven biological hypotheses regarding fungal influence on plant measures were tested using structural equation modelling. The best-fitting model revealed that local temperature affected plants both directly (negatively aboveground and positively below-ground) and indirectly - mediated by fungal richness and ratio of symbio- and saprotrophs. The influence of temperature on host plants is therefore complex and should be examined further. Fungal community composition did not impact plant measurements and plant reproductive investment did not depend on any fungal parameters. The lack of impact of fungal community composition on plant performance suggests that the functional importance of fungi is more essential for the plant than their identity.

Fungi and plant co-variation in Arctic Siberia inferred from sedimentary ancient DNA metabarcoding during the last 50.000 years

Barbara von Hippel, Alfred Wegener Institute for Polar and Marine Research, Department of Polar Terrestrial Environmental Systems, Potsdam, Germany
Kathleen R. Stoof-Leichsenring, Alfred Wegener Institute for Polar and Marine Research, Department of Polar Terrestrial Environmental Systems, Potsdam, Germany
Luise Schulte, Alfred Wegener Institute for Polar and Marine Research, Department of Polar Terrestrial Environmental Systems, Potsdam, Germany
Peter Seeber, University of Konstanz, Limnological Institute, Konstanz, Germany
Laura S. Epp, University of Konstanz, Limnological Institute, Konstanz, Germany
Martin Melles, University of Cologne, Institute of Geology and Mineralogy, Cologne, Germany
Ulrike Herzschuh, Alfred Wegener Institute for Polar and Marine Research, Department of Polar Terrestrial Environmental Systems, Potsdam, Germany & University of Potsdam, Institute of Biochemistry and Biology, Potsdam, Germany

Keywords: Mycorrhizae, Ancient DNA, Metabarcoding, Fungi-Plant Co-Variation, Arctic Siberia

Climate change has a great impact on boreal ecosystems including Siberian larch forests. As a consequence of warming, larch grow is possible in areas where climate used to be too cold, leading to a shift of the tree line into more arctic regions. Most plants co-exist in symbiosis with heterotrophic organisms surrounding their root system. Mycorrhizal fungi are a prerequisite for plant establishment and survival, enabling nutrient uptake from nutrient-poor soils and maintaining the water supply. However, knowledge about the co-variation of vegetation and fungi is still poor. Certainly, the understanding of dynamic changes in biotic interactions is important to understand adaptation mechanisms of ecosystems to climate change. We investigated sedaDNA from Lake Levinson Lessing, Taymyr Peninsula, covering the last 50.000 years using ITS primers for fungi along with the chloroplast P6 loop marker for vegetation metabarcoding. The data shows that mycorrhizal fungi diversity was low during the glacial and highest between 10.000 and 5.000 BP, coinciding with the presence of conifers in the area. First evaluations of the fungi community indicate that Inocybaceae and Cortinariaceae are most common during the Holocene in the aforementioned time scale. In contrast, the saprotrophic Hyaloscyphaceae family shows high abundances between 35.000 and 25.000 BP when mycorrhizal fungi are rare. Network analyses will be implemented to investigate co-variations of plant and fungi communities.

Impact of short-term warming on nitrogen uptake and allocation by an arctic grass

Verity Salmon , Oak Ridge National Laboratory, Oak Ridge, TN, USA
Colleen Iversen, Oak Ridge National Laboratory, Oak Ridge, TN, USA
Joanne Childs, Oak Ridge National Laboratory, Oak Ridge, TN, USA
Alistair Rogers, Brookhaven National Laboratory, Upton, NY, USA
Kim Ely, Brookhaven National Laboratory, Upton, NY, USA
Shawn Serbin, Brookhaven National Laboratory, Upton, NY, USA
Stan Wullschleger, Oak Ridge National Laboratory, Oak Ridge, TN, USA

Keywords: Allocation, Nutrient, Nitrogen, Warming, Plant

To better understand the impact of rising temperatures on nutrient cycling in the tundra rhizosphere, we investigated the impact of a short-term warming treatment on soil nutrient availability, N uptake, and N allocation by the arctic grass Arctagrostis latifolia. The warming treatment was implemented for one growing season on the Northern Coastal Plain of Alaska at Utqiagvik. Zero Power Warming (ZPW) chambers elevated air temperatures by 4°C and warmed the top 5 cm of the soil profile by approximately 1°C (n=5). Ion-exchange resins were deployed from July-September to assess availability of inorganic N and P. In late July, an injection of 15N-NH4 was performed at 3 cm depth and left for one week (+200 mg N/ m2). Harvests of 9 × 9 cm squares of tundra were then performed. Resin data suggest P and NO3 availability in surface soils increased with warming (p=0.06 & p=0.01). Biomass of A. latifolia, above & belowground plant traits, and total N uptake were not impacted by the ZPW treatment. ZPW did, however, tend to increase the recovery of 15N in aboveground tissues and newly developing tillers (p=0.07). ZPW also significantly diminished the positive correlation between above:belowground biomass and N uptake (p=0.01). These findings suggest that a single growing season of elevated temperatures can increase soil nutrient availability, alter drivers of N uptake, and impact allocation to key plant tissues.

Reliance of subarctic fungal communities on recent photosynthate delivery revealed by a stem girdling experiment

Thomas C. Parker, University of Stirling, Stirling, UK
Karina E. Clemmensen, Swedish Agricultural University, Uppsala, Sweden
Björn D. Lindahl, Swedish Agricultural University, Uppsala, Sweden
Philip A. Wookey, University of Stirling, Stirling, UK

Keywords: Girdling, Shrubs, Rhizosphere, Mycorrhizal Fungi

Tundra plant communities are changing with deciduous shrubs becoming more dominant and treelines moving. Belowground, these changes will cause significant knock-on effects as these plants facilitate the introduction of novel microbial communities, particularly with regards to fungi. To test the influence of treeline species on the assemblage of fungal communities in the rhizosphere we conducted a girdling experiment on treeline birch forest and willow shrub patches in subarctic Sweden. We hypothesised that girdling would result in a shift from ectomycorrhizal fungi to saprotrophs as the primary autotrophic source of carbon for the community is lost. We sequenced soil fungal communities over three years and found that birch forest communities were surprisingly resistant to girdling with no significant change in community composition, despite significant reductions in soil respiration. Girdled willows saw significant reductions in ectomycorrhizal genera therefore showing that changes in aboveground activity of tundra shrubs can change the structure of belowground communities. The observed stability in the birch forest fungal community could be a result of high carbohydrate storage belowground, resulting from adaptation to defoliations by caterpillar outbreaks which are important in this region. Understanding the complexities in belowground ecology in the tundra as it relates to aboveground processes will be key to predicting whole ecosystem changes in the coming decades.

Rhizosphere and non-rhizosphere priming effects in the Arctic

Sylvain Monteux, Swedish University of Agricultural Sciences, Uppsala, Sweden - Stockholm University, Sweden
Frida Keuper, INRAE, Barenton-Bugny, France
Birgit Wild, Stockholm University, Sweden
Matti Kummu, Aalto University, Finland
Sébastien Fontaine, INRAE, Clermont-Ferrand, France
Eveline J. Krab, Swedish University of Agricultural Sciences, Uppsala, Sweden
James T. Weedon, Vrije Universiteit Amsterdam, The Netherlands
Ellen Dorrepaal, Umeå University, Abisko, Sweden

Keywords: Priming Effect, Rhizosphere, Microbial Community

Priming effects historically depict the increase in soil organic matter decomposition in response to substrate addition. Despite their ubiquity, their causes and mechanisms remain largely unexplained almost 70 years after their discovery. Rhizosphere priming effects (RPE) are probably the best-studied occurrences of priming in semi-natural settings, while substrate addition-induced priming effects are by far the subject of most studies. Here we summarize the first use of PrimeSCale, a depth-resolved spatially-explicit land surface model providing a first estimate of RPE on CO2 emissions in the circum-Arctic. We then discuss functional limitations in permafrost microbial communities, that is the absence of impairment of biogeochemical processes due to the absence of certain microbial taxa. Alleviating functional limitations accelerated or initiated C- and N-cycling processes, which can be considered as "non-rhizosphere" priming effects. Notably, a functional limitation of nitrification was observed in our study on Yedoma permafrost, and ammonium pools in permafrost are substantial, therefore non-rhizosphere priming of this N-cycling process could affect plant-microbial competition for nitrogen.

Rooting depth distribution of arctic vegetation on permafrost

Gesche Blume-Werry, Experimental Plant Ecology, Institute of Botany and Landscape Ecology, Greifswald University, Greifswald, Germany
Ellen Dorrepaal, Climate Impacts Research Centre, Department of Ecology and Environmental Science, Umeå University, Abisko, Sweden
Frida Keuper, BioEcoAgro Joint Research Unit, INRAE, Barenton-Bugny, France
Matti Kummu, Water and Development Research Group, Aalto University, Espoo, Finland
Birgit Wild, Department of Environmental Science, Stockholm University, Stockholm, Sweden
James Weedon, Systems Ecology, Department of Ecological Sciences, Vrije Universiteit Amsterdam, Amsterdam, the Netherlands

Keywords: Rooting Depth, Tundra, Shrubs, Graminoids, Permafrost

In arctic tundra, most of plant biomass is belowground. How this biomass is distributed within the soil profile affects not only plant performance but also the distribution of key nutrients and organic carbon in the soil. Permafrost restricts rooting depth in arctic tundra, but even if the active layer is relatively thick some plants root shallow and do not use all the available soil volume. The realized rooting depth distribution throughout the soil profile is thus likely a combination of species presence and site conditions, and observations usually suggest that graminoids root deeper than shrubs. If this is true on a biome scale, such general patterns of differences in rooting depth distribution between plant functional types would be important to implement in models. Indeed, including rooting depth can have stronger effects on modeled biogeochemical pools than the climate, but is thus far restrained by the lack of available and synthesized data. Here, we will present the results of a meta-analysis of published rooting depth profiles of arctic tundra vegetation on permafrost soils and their link to vegetation types and abiotic factors. In addition, we illustrate the influence of rooting depth distribution on carbon cycling through an analysis of the recently published PrimeSCale model.

Fine-root functional trait responses to experimental warming: A global meta-analysis

Jinsong Wang, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing, China
Camille Defrenne, Oak Ridge National Laboratory, TN, USA
M. Luke McCormack, The Morton Arboretum, IL, USA
Lu Yang, Beijing Forestry University, China
Dashuan Tian, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing, China
Yiqi Luo, Northern Arizona University, AZ, USA
Enqing Hou, Northern Arizona University, AZ, USA
Tao Yan, Lanzhou University, Lanzhou, China
Zhaolei Li, Shandong Agricultural University, Taian, China
Wensheng Bu, Jiangxi Agricultural University, Nanchang, China
Ye Chen, Northern Arizona University, AZ, USA
Shuli Niu, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing, China

Keywords: Fine Roots, Warming Magnitude, Warming Duration, Soil Depth, Functional Traits

Whether and how warming alters functional traits of absorptive plant roots remains to be answered across the globe. Tackling this question is crucial to better understand terrestrial responses to climate change as fine-root traits drive many ecosystem processes. We carried out a detailed synthesis of fine-root trait responses to experimental warming by performing a meta-analysis of 964 paired observations from 177 publications. Warming increased fine-root biomass, production, respiration and nitrogen concentration as well as decreased root carbon : nitrogen ratio and nonstructural carbohydrates. Surprisingly, warming effects on fine-root biomass decreased with greater warming magnitude, especially in short-term experiments. Furthermore, the positive effect of warming on fine-root biomass was strongest in deeper soil horizons and in colder and drier regions. Total fine-root length, morphology, mortality, lifespan, and turnover were unresponsive to warming. Our results highlight the significant changes in fine-root traits in response to warming as well as the importance of warming magnitude and duration in understanding fine-root responses. These changes have strong implications for global soil carbon stocks in a warmer world associated with increased root inputs into deeper soil horizonss and increases in fine-root respiration.

Impact of Increased Seasonal Snowpack on the Fine Root Dynamics of Treeline White Spruce (Picea glauca) in the Western Brooks Range, AK

Christina Minions, University of Alaska Anchorage, Anchorage AK, USA
Patrick F. Sullivan, University of Alaska Anchorage, Anchorage AK, USA

Keywords: Fine Root Dynamics, Minirhizotron, Treeline, Snow Depth, Arctic

Snow is a dominant feature of the Arctic landscape and acts as an important insulator of soils during winter. Changes in the timing and amount of snow could have significant impacts on fine root growth and/or mortality, which could alter aboveground growth and reproductive success of white spruce (Picea glauca). The main goal of this study is to investigate the impacts of experimentally increased snow depth on the fine root dynamics of treeline white spruce. We are using minirhizotrons to make direct measurement of root production, mortality, and decomposition rates at three treelines with varying hydrology (xeric, mesic, hydric) near the Agashashok River, in Noatak National Preserve, Alaska. At each site, snowfences were installed upwind of 8 trees in the fall of 2016. Measurements of fine root dynamics began in May of 2019, with images collected every other week during the growing season (late-May to early-September). The snowfence treatment produced mild (xeric) to strong differences (hydric, mesic) in snow depth and winter soil temperature between control and snowfence trees across study sites. Fine root measurements have been completed thus far for the xeric site and, consistent with the limited snowfence effect on snow depth and winter soil temperature, there is limited evidence of a snowfence effect on fine root dynamics.

Litter decomposition is moderated by below-ground micro-environmental variation in tundra ecosystems

Elise Gallois, School of GeoSciences, University of Edinburgh, Edinburgh, UK
Isla Myers-Smith, School of GeoSciences, University of Edinburgh, Edinburgh, UK
Haydn Thomas, School of GeoSciences, University of Edinburgh, Edinburgh, UK
Gergana Daskalova, School of GeoSciences, University of Edinburgh, Edinburgh, UK
Jeff Kerby, Aarhus Institute of Advanced Studies, Aarhus University, Aarhus, Denmark

Keywords: Microclimate, Tundra, Decomposition, Carbon Cycling, Remote Sensing

The Arctic tundra is one of the world's largest, yet most vulnerable, carbon stores. While climate warming is predicted to increase rates of global carbon cycling, we currently know very little about landscape-level controls of litter decomposition in tundra ecosystems. We examined how local topography, surface temperature, soil moisture and permafrost conditions influenced litter decomposition rates across a tundra landscape on Qikiqtaruk - Herschel Island (Yukon, Canada). We used the Tea Bag Index to derive decomposition metrics across environmental gradients, and compared decomposition rates with microclimate data derived from high-resolution drone data. We found that local decomposition rates were highest in wetter and warmer microsites, and that below-ground microenvironmental heterogeneity appears to control decomposition to a greater extent than above-ground microclimate conditions and topography. We also found that air temperature better explains variation in decomposition at larger spatial scales (>30 m) and soil moisture better explains decomposition at smaller spatial scales (<30 m). Quantifying microenvironmental controls on litter decomposition will improve projections of carbon cycling in a rapidly warming tundra biome.

Plant-Microbiome Interactions in Contaminated Soil in a Subarctic Mine Environment

Qinhong Cai, McGill University, Montreal, Canada
Katrina Callender, National Research Council, Montreal, Canada
Stephanie Pacheco, National Research Council, Montreal, Canada
Jessica Wasserscheid, National Research Council, Montreal, Canada
Martin Beaudoin Nadeau, Viridis Terra Innovations, Québec, Canada
Hugo Thibaudeau Robitaille, T2 Environnement, McMasterville, Canada
Daniel Tarte, T2 Environnement, McMasterville, Canada
Mariana Trindade, TATA Steel Minerals Corp., Montreal, Canada
Stéphane Boudreau, Université Laval, Québec, Canada
Damase Khasa, Université Laval, Québec, Canada
Charles W. Greer, National Research Council, Montreal, Canada

Keywords: Plant-microbiome, subarctic mine, 16S and ITS rRNA amplicon sequencing, metal contamination, rhizosphere and endophytic microbes

The plant-microbiome, including both rhizosphere and endophytic microorganisms, plays an important role in plant adaptation, growth and succession. Although significant progress in understanding plant-microbiome interactions has been made, complex environments like subarctic mine sites, remain largely unstudied. This study inventoried indigenous plants growing on a subarctic mining site and produced a taxonomic profile of both rhizosphere and endophyte microbes using 16S and ITS rRNA gene amplicon sequencing, and soil geochemistry data were employed to illustrate environmental drivers of plant-microbiome interactions. The results showed that both site characteristics and plant type had significant impacts on the composition and functions of the plant-microbiome. For example, the microbiome from Vaccinium uliginosum contributed to the concentration of Pb, Cr, Zn, Cu, and Ni from the surrounding soil. Rhizosphere microbes and endophytes had distinct community compositions and were heavily influenced by site characteristics and plant type, respectively, ultimately enabling the isolation of several plant-growth-promoting bacteria.

ID: 27 - Biodiversity and ecosystem functions in the New Arctic

Conveners

Gabriela Schaepman-Strub | University of Zurich

Cinzia Verde | National Research Council of Italy

Toke Thomas Høye | Aarhus University

A metagenomic view of microbial community, functional potential, and fishes in the central arctic ocean

Moritz Buck, Swedish University of Agricultural Sciences, Uppsala, Sweden
Stefan Bertilsson, Swedish University of Agricultural Sciences, Uppsala, Sweden
Pauline Snoeijs Leijonmalm, Stockholm University, Stockholm, Sweden

Keywords: Metagenomics, Diversity, Central Arctic Ocean, Cod, Microbes

The Central Arctic Ocean (CAO) is the extremely oligotrophic permanently ice-covered part of the Arctic Ocean roughly the size of India. Two prominent microbial habitats at the ocean surface in summer are the brackish melting water (ice-brine) in channels and cracks in the ice and the ice-water interface where melting water and seawater mix. We present the first shotgun metagenome of these two habitats, combined with biogeochemical measures. Twenty-two stations across the Eurasian basin of the CAO were sampled for DNA (in three size fractions). Metagenomes were assembled, binned, and annotated. The obtained bins were cluster into metagenomic Operational Taxonomic Units (mOTUs), species level clusters. Combining them with the annotations, we could predict species-defined functional potentials of the microbial communities of the surface of the central arctic ocean. Both the functional- and taxonomic-diversity was also quantified by mapping and correlated to biogeochemical data to predict drivers of these. Additionally, we could recover sufficient reads mapping to diverse arctic fish species which were used to analyse relative abundances of these along the cruise.

Adaptive mechanisms of phytoplankton in a changing Arctic: The hidden dynamics of intraspecific selection

Klara Wolf, AWI, Bremerhaven, Germany
Clara Hoppe, AWI, Bremerhaven, Germany
Florian Leese, Uni Duisburg-Essen, Essen, Germany
Björn Rost, AWI, Bremerhaven, Germany
Uwe John, AWI, Bremerhaven, Germany

Keywords: Arctic Phytoplankton, Intraspecific Selection, Populations, Adaptation

Progressing climate change poses large challenges of adaptation on Arctic organisms and ecosystems, including phytoplankton at the very base of the foodweb. Adaptation to a 'New Arctic' can be greatly influenced by an often overlooked mechanism: Intraspecific diversity and selection between genotypes, which can drive rapid evolutionary responses of species and thus productivity and resilience of entire communities. Intraspecific selective processes in phytoplankton, however, are methodologically still difficult to resolve, especially in diverse natural contexts and at temporal resolution. In this study, we investigate the role of intraspecific selection and population dynamics on an exemplary key species, the diatom Thalassiosira hyalina. We introduce new avenues for the use of microsatellites as an efficient population genetic tool, allowing the analysis of bulk community samples in experimental and natural contexts at close temporal resolution. Through our new method, Microsatellite PoolSeq Barcoding (MPB), we resolved detailed selection dynamics in simplified diatom populations, in experiments with natural populations and in field samples from two Svalbard spring blooms. We found surprising stability in the composition of diverse populations over time, but also sudden shifts of population structure under specific environmental conditions, hinting towards possible tipping points. Our results suggest that dynamics within populations are likely driven by more complex processes than clonal dominance in highly diverse phytoplankton populations and introduce a new tool to gain better understanding of such fundamental but often hidden mechanisms of adaptation.

Arctic Jellies: Investigating the impact of gelatinous zooplankton communities on changing Arctic ecosystems

Charlotte Havermans, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
Annkathrin Dischereit, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
Andrea Eschbach, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
Ayla Murray, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
Dmitrii Pantiukhin, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
Gerlien Verhaegen, Japan Agency for Marine-Earth Science Technology, Tokyo, Japan

Keywords: Gelatinous Zooplankton, Biodiversity, Range Shifts, Atlantification, Omics

Gelatinous zooplankton or “jellies” (ctenophores, cnidarians, tunicates) are known to be major drivers of ecosystem changes. Increases in jelly biomass, referred to as “jellification”, have been observed in several marine ecosystems, causing, amongst others, the collapse of major fisheries. For the Arctic region, abundance data on jellies are virtually non-existent, impeding our ability to detect changes of a similar magnitude. To better understand the role of jellies in the Arctic seas, the Helmholtz Young Investigator Group ARJEL (2019-2026), aims to combine the most recent technologies in optics, acoustics, and environmental DNA analyses. Based on data collected during recent international campaigns, we attempt to link distributional patterns of jellies to sea-ice and oceanographic features. Furthermore, we apply species distribution models to a broad set of archived data to understand observed species and community patterns and to predict changes under future climate-change scenarios. The role of jellies in the Arctic food web, their importance for planktonic predators and fish and their link to the sea-ice trophic pathway is assessed with molecular diet studies. Physiological and transcriptomic studies serve to predict range expansions, and the consequences of expansion will be predicted based on food web models. An overview of the project’s goals, methods and first results will be given. One of our first research highlights include the comparison of species composition and abundances of ctenophores and cnidarians in Arctic vs. Atlantic-influenced Svalbard fjords. We also demonstrate a seasonality in species composition of the gelatinous component of the zooplankton observed during the year-long expedition MOSAiC in the central-Arctic.

Range-wide ecological niche model of Calanus finmarchicus reveals possible drivers of Arctic 'Atlantification' by sub-Arctic zooplankton

Jennifer J. Freer, British Antarctic Survey, Cambridge, UK
Geraint A. Tarling, British Antarctic Survey, Cambridge, UK
David W. Pond, Institute of Aquaculture, University of Stirling, Stirling, UK

Keywords: Ecological Niche Modelling, Zooplankton, Atlantification, Calanus Finmarchicus, Range Shift

The copepod Calanus finmarchicus dominates zooplankton biomass in the northern North Atlantic. Climate-driven range shifts of C. finmarchicus and other boreal species into typically Arctic ecosystems are being documented yet it is unclear which environmental factors have facilitated this encroachment. To address this, we compiled over 80 datasets containing approx. 65,000 unique occurrence records of C. finmarchicus collected by both net-based surveys and the Continuous Plankton Recorder. These were matched to respective seasonal environmental data. The dataset was divided into two ~30 year eras, 1955-1984 and 1985-2017, and an optimised maxEnt ecological niche model was used to predict the seasonal distribution of C. finmarchicus's abiotic niche for both eras. Comparing distributions between eras reveals a recent northward advance of habitat suitability. This pattern of encroachment is within areas that have undergone a reduction in sea-ice cover and a shift in the timing of peak habitat suitability (occurring one season earlier). Model outputs show that this poleward shift is restricted to the Greenland Sea in late summer (July-September) but extends from the Labrador Sea to the Barents Sea outside these months. Our findings suggest that earlier food availability due to reduced sea-ice cover has played an important role in the poleward range expansion of C. finmarchicus and this is likely to continue. The implications of these shifts for the Arctic ecosystem are discussed.

Do interannual variations in environmental conditions affect the recruitment of adult Arctic cod

Jennifer Herbig, Fisheries and Marine Institute of Memorial University, Newfoundland, Canada
Caroline Bouchard, Greenland Institute of Natural Resources, Nuuk, Greenland
Mathieu LeBlanc, Université Laval, Quebec, Canada
Andrea Niemi, Fisheries and Oceans Canada, Winnipeg, Canada
Andrew Majewski, Fisheries and Oceans Canada, Winnipeg, Canada
Stephane Gauthier, Fisheries and Oceans Canada, BC, Canada
Jonathan Fisher, Fisheries and Marine Institute of Memorial University, Newfoundland, Canada
Maxime Geoffroy, Fisheries and Marine Institute of Memorial University, Newfoundland, Canada

Keywords: Arctic Cod, Hydroacoustics, Climate Change

Arctic cod (Boreogadus saida) is the most abundant forage fish species in Arctic seas and plays a pivotal role in energy transfer. Therefore, population dynamics of Arctic cod have cascading effects on the marine ecosystem. Climate change has already started to affect recruitment of age-0 Arctic cod in Canadian Arctic Seas. Earlier ice breakup, warmer surface temperatures, and enhanced plankton production improve larval survival by allowing age-0 Arctic cod to reach larger prewinter sizes. These conditions can result in more than a ten-fold increase in biomass of age-0 Arctic cod. It is unknown how enhanced larval survival affects the rest of the Arctic cod population and if it results in greater recruitment into the adult population. Greater larval recruitment may increase density dependent mortality due to increased competition for resources once juvenile fish leave the epipelagic layer to overwinter. Here, we test if ice breakup and freeze date, sea surface temperature, and zooplankton abundance during the larval phase affect the recruitment of adult Arctic cod. We use hydroacoustic surveys conducted from 2006-2019 to estimate Arctic cod biomass in the Canadian Arctic and on satellite measurements to document environmental variables. Preliminary results suggest that warming conditions favoring the survival of age-0 fish may result in a decline in the adult population due to warming surface temperatures, changing sea ice conditions, or increased competition for resources.

Competition among Arctic cephalopods: how do diet and life history traits in three sympatric Arctic Rossia spp. may reduce it?

Alexey V. Golikov, Department of Zoology, Kazan Federal University, Kazan, Russia
Filipe R. Ceia, University of Coimbra, Marine and Environmental Sciences Centre, Department of Life Sciences, Coimbra, Portugal
Rushan M. Sabirov, Department of Zoology, Kazan Federal University, Kazan, Russia
Georgii A. Batalin, Laboratory of Isotopic and Elemental Analysis, Kazan Federal University, Kazan, Russia
Martin E. Blicher, Greenland Climate Research Centre, Greenland Institute of Natural Resources, Nuuk, Greenland
Bulat I. Gareev, Laboratory of Isotopic and Elemental Analysis, Kazan Federal University, Kazan, Russia
Gudmundur Gudmundsson, Collections and Systematics Department, Icelandic Institute of Natural History, 210 Gardabaer, Iceland
Lis L. Jørgensen, Tromsø Branch, Institute of Marine Research, Tromsø, Norway
Gazinur Z. Mingazov, Laboratory of Isotopic and Elemental Analysis, Kazan Federal University, Kazan, Russia
Denis V. Zakharov, Laboratory of Hydrobiology, Polar Branch of All-Russian Research Institute of Fisheries and Oceanography, Murmansk, Russia and Laboratory of Zoobenthos, Murmansk Marine Biological Institute, Murmansk, Russia
José C. Xavier, University of Coimbra, Marine and Environmental Sciences Centre, Department of Life Sciences, Coimbra, Portugal and British Antarctic Survey, Natural Environment Research Council, CB3 0ET Cambridge, UK

Keywords: Competition, Climate Change, Arctic, Cephalopoda, Stable Isotope Analysis

Trophic niche and diet comparisons among closely sympatric marine species are important to understand complex food webs, particularly in regions most affected by climate change in the World, such as the Arctic region. Using stable isotope analyses of cephalopod beaks, all ontogenetic stages of three sympatric species of the genus Rossia (widespread boreal Arctic R. palpebrosa, high boreal R. megaptera and Arctic endemic R. moelleri) were studied to assess inter- and intraspecific competition with niche and diet overlap and partitioning in West Greenland and the Barents Sea. These species, which have similar sizes, hunting behaviour and share the same habitat to some extent (i.e. all studied species can be found in the same one trawl catch), were found to have seven traits related to resource and habitat utilization. However, no trait was shared by all three species. High boreal R. megaptera and Arctic endemic R. moelleri shared three traits with each other, while both R. megaptera and R. moelleri shared only two unique traits each with widespread boreal-Arctic R. palpebrosa. Thus, all traits formed fully uncrossing pattern with each species having unique strategy (i.e. a set of specific traits) of resource and habitat utilization. Predicted climate changes in the Arctic region would have an impact on competition among Rossia with one potential 'winner' (R. megaptera in the Barents Sea) but no potential 'loosers'.

Modelling of Arctic Gelatinous Zooplankton

Dmitrii Pantiukhin, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
Charlotte Havermans, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany

Keywords: Gelatinous Zooplankton, Seascape Ecology, Ecological Modelling, Ecological Forecasting

The profound environmental shifts in the Arctic region lead to far-reaching alterations of the composition and structure of marine populations and communities and cause pronounced changes in ecosystem functioning. The expected decline of the sea-ice is hypothesized to weaken pelagic-benthic coupling, result in a shift from benthic-dominated to zooplankton-dominated energy flow pathways. Such release of energy in the pelagic zone is assumed to be followed by fish communities. However, carnivorous "jellies" (gelatinous zooplankton) can radically affect such scenarios and outcompete fish communities. For this purpose, data on jellyfish species distributions for the entire Arctic Ocean and adjacent seas will be collected based on existing scientific literature and public databases. Based on this collection of historical data as well as the data of jelly species derived from newly obtained optical and/or acoustic datasets (incl. data from recent international campaigns), advanced spatial statistical techniques such as Species and Community Distribution Models (SDMs and CDMs) will be applied in order to understand current patterns of species distributions and their realized niche. Moreover, the implemented models coupled with climate change scenarios will allow us to forecast potential changes in ecosystems, predict future range-expansions and identify climate change winners and losers among the jelly species.

Arctic vs sub-Arctic pelagic amphipods: DNA reveals a different history and a different future in the face of climate change

Ayla Murray, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremen, Germany
Charlotte Havermans, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremen, Germany

Keywords: Themisto Amphipods, Connectivity, Phylogeography, Atlantification, Genetic Structure

Rapid warming in the Arctic is drastically impacting marine ecosystems; affecting species composition, distribution and food web structure. Themisto amphipods are a key link between secondary producers and marine vertebrates at higher trophic levels. Two co-existing species dominate in the region: Themisto libellula, considered an Arctic species and Themisto abyssorum, a sub-Arctic, boreal species. T. libellula is larger, feeds on herbivorous copepods and is crucial prey for seabirds, fish species and marine mammals. However T. abyssorum is smaller, feeds on carnivorous zooplankton and is considered an indicator of warmer water masses. Both species have already exhibited changes in abundance and range shifts, likely due to the Atlantification of the Arctic. Many aspects of the ecology and genetic structure of these two species are not well studied, despite their importance in the food web and biogeochemical cycles. Further understanding of phylogeography and distributional patterns is crucial to understanding how they will be affected by climate change and how this will impact the ecosystem. This study focuses on the genetic structure and connectivity of both Themisto species as well as their association with Arctic and Atlantic water masses. We do this by analysing and comparing mitochondrial cytochrome oxidase I gene sequences according to the geographic populations, from Svalbard fjord systems, the Fram Strait and Southern Greenland. Distributional data are statistically analysed in relation to hydrographic data. These data reveal a contrasting genetic structure, predicting T. libellula will be less able to cope with environmental changes than T. abyssorum.

Should we expect shift in beluga habitat use in the context of climate change – Case of inshore Mackenzie Estuary and Tarium Niryutait Marine Protected Area in Western Arctic Canada

Aurelie Noel, University of Manitoba, Winnipeg, Canada
John Iacozza, University of Manitoba, Winnipeg, Canada
Stephane McLachlan, University of Manitoba, Winnipeg, Canada
Emmanuel Devred, Fisheries and Oceans Canada, Halifax, Canada
Douglas Esagok, Inuvik Hunters and Trappers Committee, Inuvik, Canada
Lisa Loseto, Fisheries and Oceans Canada, Winnipeg, Canada

Keywords: Beaufort Sea, Beluga Whales, Inuvialuit Settlement Region, Climate Change

Qilalugaq – beluga whales, are an important resource for Indigenous communities in the Inuvialuit Settlement Region (Canada). Every summer, the Eastern Beaufort Sea beluga whale population forms large clusters inshore the Mackenzie Estuary and the Tarium Niryutait marine protected area. Belugas are usually found in shallow turbid water under low winds, low salinity and warm sea surface temperature, potentially using them for scraping off moulted skin, feeding and as a thermal advantage for calves. However, these areas are facing increasing biogeochemical and physical stress due to climate change, with unknown impact on summer beluga habitat and habitat use. This project, guided by ISR communities perspectives and supported by the Inuvik community, aims at providing a meaningful understanding of how belugas interact with their inshore summer environment. Following a knowledge co-production framework, traditional ecological and local knowledge (TE/LK) and western science will complement each other. Our hypothesis is that belugas use resources differently depending on habitat characteristics. A resource selection function (RSF) model has been chosen to measure habitat selection, to assess preferences and to provide relative probability of habitat use. The required inputs of the RSF are beluga observations collected from aerial surveys conducted in summer 2019 and concurrent satellite-derived surface seawater properties. Due to current pandemic restrictions, only secondary sources of TE/LK on beluga habitat have been explored to date. Nonetheless, co-interpretation of the RSF outputs with key Inuvik knowledge holders is anticipated to alleviate the model predictive capacity and to make a broader sense of the model outcomes.

Sympagic fauna in seasonal land fast ice in the White Sea

Anna I. Timchenko, Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia
Daria A. Portnova, Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia

Keywords: White Sea, Sea Ice Community, Nematodes, Meiofauna, Diversity

Ice-associated fauna has different dispersal route and various capabilities to colonize newly formed sea ice and further first-year ice. This study aimed to provide the abundance and composition of sympagic fauna occurring ranging from new ice to the first-year ice. The study was carried out in the White Sea Biological Station of Moscow State University. Sea-ice, sediments, plankton and algae adjacent to sea ice were sampled in January and February 2020. The samples were washed through a sieve with a 6 µm mesh, fixed in a DESS. In the laboratory all organisms were counted and sorted into major taxa. Nematodes (74%) were dominated in the sea ice, bottom sediments and algae, followed by harpacticoids (14.3%). Sea-ice community was represented by nematodes, copepods, amphipods, acoel flatworms, annelids, mollusks and ostracods. The total abundance of sympagic fauna varied from 245.3 to 21.098 ind/m2. Nematodes in the sea ice were represented by *Theristus melnikovi, Cryonema crassum, Hieminema obliquorum, Daptonema sp., Halomonhystera sp., Desmodora communis, Halalaimus sp. and Paracyatholaimus sp*. Sea-ice nematode H. *obliquorum* was found in the sediment for the first time. In the zooplankton samples copepods contributed 97.1% of total abundance, whereas nematodes (2.5%) and rotifers (0.4%) were rare. In the algae frozen in the sea ice were found nematodes, copepods, juvenile of annelids and mollusks, halacarid mites, acoel flatworms and tardigrades. Most sea-ice fauna was restricted to the bottom 5 cm of young ice and 15 cm of first-year ice. The abundance and composition of sympagic fauna increased with the thickness of the sea ice. Contribution to the sea-ice nematodes assemblages was given by communities of algae (53%) and sediments (18.3%). In coastal region the sea ice had close contact with the seabed, boulders and thalli. The area is susceptible to daily fluctuations in sea level, convection and active ice formation. All processes can support the penetration of marine organisms into seasonal sea ice in the study region.

Changing sea ice ecosystems and associated ecosystem services

Nadja Steiner, Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, BC, Canada
Jeff Bowman, Scripps Institution of Oceanography, UC San Diego, La Jolla, CA, USA
Karley Campbell, UiT The Arctic University of Norway, Tromsø, Norway
Eeva Eronen-Rasimus, University of Helsinki, Helsinki, Finland
Marianne Falardeau, Department of Preventive and Social Health, Université Laval
Hauke Flores, Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany
Agneta Fransson, Norwegian Polar Institute, Fram Centre, Tromsø, Norway;
Melissa Chierici, Institute of Marine Research, Fram Centre, Tromsø, Norway;
Helena Herr, Center of Natural History (CeNak), Universität Hamburg, Hamburg, Germany
Stephen J Insley, Wildlife Conservation Society Canada, Whitehorse, Yukon Territory, Canada
Hanna M. Kauko, Norwegian Polar Institute, Tromso, Norway
Delphine Lannuzel, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Australia
Lisa Loseto, Freshwater Institute, Fisheries and Oceans Canada
Amanda Lynnes, International Association of Antarctica Tour Operators (IAATO), USA
Andy Majewski, Freshwater Institute, Fisheries and Oceans Canada
Klaus M. Meiners, Australian Antarctic Division, Department of Agriculture, Water and the Environment, Tasmania, Australia
Lisa A. Miller, Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, BC, Canada
Loïc N. Michel, Ifremer, Centre de Bretagne, REM/EEP, Laboratoire Environnement Profond, Plouzané, France
Sebastien Moreau, Norwegian Polar Institute, Tromso, Norway
Melissa Nacke, Association of Arctic Expedition Cruise Operators, Tromsoe, Norway
Daiki Nomura, Hokkaido University, Hakodate and Sapporo, Hokkaido, Japan
Pat Wongpan, Australian Antarctic Program Partnership, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Australia
Letizia Tedesco, Finnish Environment Institute (SYKE), Marine Research Centre, Helsinki, Finland
Jan Andries van Franeker, Wageningen Marine Research, Den Helder, The Netherlands
Maria A van Leeuwe, University of Groningen, Groningen Institute for Evolutionary Life Sciences, Groningen, the Netherlands

Keywords: Sea-Ice Ecosystems, EBSA, MPA, Ecosystem Services

The sea-ice ecosystem supports all four key ecosystem services and therefore deserves specific attention in the evaluation of marine protected area planning. Supporting services are provided in the form of habitat, including feeding grounds and nurseries for microbes, meiofauna, fish, birds and mammals. The key species Arctic cod (Boreogadus saida) and Antarctic krill (Euphausia superba) are tightly linked to the sea-ice ecosystem and transfer carbon from sea-ice primary producers to higher trophic level fish, mammal species and humans.Through, harvesting and the supply of potential medicinal products and genetic resources, the system contributes to provisioning services. The sea-icescape and its biology provide a multitude of cultural services, such as inspiration and attraction for cultural activities, tourism and research, and provide the base for Indigenous and local knowledge systems, cultural identity and spirituality. In addition, the sea-ice ecosystem contributes to climate regulating services through light regulation, the production of biogenic aerosols, halogen oxidation and the release or uptake of greenhouse gases, such as carbon dioxide. The ongoing changes in the polar regions have large impacts on sea-ice ecosystems and the ecosystem services sea ice provides to society. While the response of sea-ice associated primary production to environmental change is regionally variable, the effect on ice-associated mammals and birds are predominantly negative, subsequently impacting human harvesting and cultural services in both polar regions. Conservation can help preserve important species. However, the key mitigation measure that can slow the transition to a strictly seasonal ice cover with climate change, reduce the overall loss of sea ice habitats from the ocean, and thus preserve the unique ecosystem services provided by sea ice and their contributions to human-well being is a reduction in carbon emissions.

Environmental status of Svalbard coastscapes and focal ecosystem components

Janne E. Søreide, University Centre in Svalbard, Longyearbyen, Norway
Vanessa Pitusi, University Centre in Svalbard, Longyearbyen, Norway
Anna Vader, University Centre in Svalbard, Longyearbyen, Norway
Børge Damsgård, University Centre in Svalbard, Longyearbyen, Norway
Frank Nilsen, University Centre in Svalbard, Longyearbyen, Norway
Ragnheid Skogseth, University Centre in Svalbard, Longyearbyen, Norway
Amanda Poste, Norwegian Institute for Water Research , Oslo, Norway
Allison Baily, Norwegian Polar Institute, Fram Centre, Tromsø, Norway
Kit Kovacs, Norwegian Polar Institute, Fram Centre, Tromsø, Norway
Christian Lydersen, Norwegian Polar Institute, Fram Centre, Tromsø, Norway
Sebastian Gerland, Norwegian Polar Institute, Fram Centre, Tromsø, Norway
Sébastien Descamps, Norwegian Polar Institute, Fram Centre, Tromsø, Norway
Hallvard Strøm, Norwegian Polar Institute, Fram Centre, Tromsø, Norway
Paul E. Renaud, Akvaplan-niva AS, Tromsø, Norway
Maria P. Arvnes, SALT Lofoten AS, Svolvær, Norway
Piotr Graczyk, NORCE Norwegian Research Centre AS, Bergen, Norway
Denis Moiseev, Murmansk Marine Biological Institute, Murmansk, Russia
Rakesh Kumar Singh, University of Quebec at Rimouski, Canada
Simon Bélanger, University of Quebec at Rimouski, Canada
Josef Elster, Centre for Polar Ecology, University of South Bohemia, České Budějovice, Czech Republic
Jacek Urbański, GIS Centre, University of Gdańsk, Poland
Mateusz Moskalik, Institute of Geophysics, Polish Academy of Sciences, Warsaw, Poland
Józef Wiktor, Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland
Jan Marcin Węsławski, Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland

Keywords: Climate Change, Sea Ice, Biodiversity, Productivity, Ecosystem Change

Coastal waters are among the most productive regions in the Arctic. These nearshore waters are critical breeding and foraging grounds for many invertebrates, fish, birds, and marine mammals and provide a host of ecosystem services, from recreation to large-scale tourism and fisheries. Arctic nature coast types (= coastscapes) and biodiversity are under growing pressure as climate change and human activities increase in the region. Svalbard is warming more rapidly than anywhere else in the Arctic, and globally the Arctic is warming at 2-3 times the rate of other areas. Svalbard experiences steep climate gradients due to being at the interface between warm Atlantic and cold Arctic waters. Warming is creating a huge potential for increased colonisation by boreal species, with potential negative impacts on “native” species assemblages and food webs. Changes in physical drivers and biodiversity patterns must be documented to predict upcoming challenges and opportunities as the Arctic changes. This synopsis is the first joint effort across nations, institutes, and disciplines to address gaps in knowledge and monitoring of Svalbard’s coast – a result of the work conducted during the international workshop Svalbard Sustainable Coasts in Longyearbyen, February 2020. Here we present the applicability and status of the defined coastscapes and biodiversity tools in the Arctic Coastal Monitoring plan, initiated by the Arctic Council’s Conservation of Arctic Flora and Fauna, for Svalbard.

Sympagic meiofaunal abundance and diversity with emphasis on the phenology of ice nematodes, in Van Mijenfjorden (Svalbard)

Vanessa Pitusi, The University Centre in Svalbard, Norway
Rolf Gradinger, University in Tromsø
Janne E. Søreide, The University Centre in Svalbard, Norway

Keywords: Landfast Ice, Nematodes, Sympagic Meiofauna, Phenology, Svalbard

Changes in sea ice cover over the past decades are undeniable. The Arctic is moving towards a regime where thick multi-year ice is being replaced by thinner sea ice. Much of this type of ice can be found in Arctic fjords, where it offers a temporary nursery, breeding and feeding ground to sympagic (=ice-associated) meiofauna (> 20 um) and ice algae. The in-ice fauna is usually identified very coarsely with little information provided on their life history and feeding ecology. One of the most dominant taxa group in the ice are nematodes. This is the first study that follows the phenology of ice nematodes on Svalbard, in addition to the development of the overall ice flora & fauna community. Their change in integrated abundance throughout the season was tracked (peak nematode abundance of approximately 18,000 individuals per m^-2) and their mode of reproduction was captured. The data were used to assess the potential effects of changing sea ice conditions on this seemingly ice-dependent taxa group.

Sympagic carbon: an important food source for benthos in a warming Arctic?

Ivan Cautain, Scottish Association for Marine Science, Dunstaffnage, United Kingdom
Bhavani Narayanaswamy, Scottish Association for Marine Science, Dunstaffnage, United Kingdom
Kim Last, Scottish Association for Marine Science, Dunstaffnage, United Kingdom
David McKee, University of Strathclyde, Glasgow, United Kingdom
Bodil Bluhm, Department of Arctic and Marine Biology UiT - The Arctic University of Norway, Tromsø, Norway
Paul Renaud, Akvaplan-niva, Tromsø, Norway & University Centre in Svalbard, Longyearbyen, Svalbard

Keywords: benthos, H-print, Diet Composition

The benthos is a key component of the carbon flow of Arctic shelves, as it is both the end point for much of the surface productivity, as well as a source of food for many higher trophic levels. It is therefore important, and the goal of this study, to understand the uptake and utilisation of organic carbon by benthic organisms. We focus on the rapidly changing Barents Sea seasonal ice where primary production occurs in the sympagic and pelagic realms, with differences in terms of timing, amount, quality and delivery to the seafloor resulting in differing contributions of these two sources of organic matter to the seafloor. Samples were collected in the winter and summer of 2018, across a latitudinal gradient, to make comparisons between seasons and different concentrations of sea ice. We use highly branched isoprenoids – lipid biomarkers produced with separate, distinct structures in sea ice and the water column – to estimate the ratio of sympagic-to-pelagic carbon utilised by various benthic feeding guilds. First results suggest that surface deposit feeders have a higher proportion of sympagic carbon in their diets than suspension feeders and predators. Strengthening knowledge around the importance of sea ice algae- and phytoplankton- derived carbon to the benthos will allow for a better understanding of how seafloor communities will functionally change in a future, virtually ice-free Barents Sea.

High Arctic ecosystem change over the last 50,000 years revealed by paleo-metagenomics analyses on a lake sediment core from Far Eastern Russia

Kathleen R. Stoof-Leichsenring, Polar Terrestrial Environmental Systems, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Sichao Huang, Polar Terrestrial Environmental Systems, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Luidmila A. Pestryakova, Department for Geography and Biology, North-Eastern Federal University of Yakutsk, Yakutsk, Russia
Boris K. Biskaborn, Polar Terrestrial Environmental Systems, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Ulrike Herzschuh, Polar Terrestrial Environmental Systems, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Further affiliations of Ulrike Herzschuh:
Institute of Environmental Sciences and Geography, University of Potsdam, Potsdam, Germany
Institute of Biochemistry and Biology, University of Potsdam, Potsdam, Germany

Keywords: Paleogenomics, Arctic, Lakes, Sediment cores, Ecosystem change

Arctic environments are threatened by recent warming and have experienced climate transitions in the past. Important climate archives in poorly studied Siberian regions are lake sediment cores. We retrieved a 10 m long sediment core from the Siberian Lake Ilirney located in Eastern Chukotka, which covers the last 50000 years of major climate transitions from the lake's development within a warmer period (MIS3) to conditions during the last glacial (MIS2) and again the warmer Holocene period. We used a specific DNA library protocol combined with Illumina shotgun sequencing of ancient sedimentary DNA gaining comprehensive paleo-metagenomic data from 17 time slices. We just received the DNA data and analyzed it according the bioinformatic pipeline which includes data filtering and k-mer based taxonomic classification against the nucleotide database. Our preliminary results indicate on average 65 million reads per sample. A minority (0.5–3%) of total reads per sample got taxonomically assigned, whereof about 30% are of bacterial origin and 5% belong to eukaryotes. The representation of plants among eukaryotes agrees with results of a parallel study on plant metabarcoding. Deeper analyses of the paleo-metagenomic data will uncover ecosystem level changes of key taxonomic groups including terrestrial plants and fungi and aquatic life (phytoplankton, zooplankton and fish) which will delight our understanding of Arctic ecosystem change across previous glacial and warming periods.

Investigation of East Siberian Pleistocene glacial and interglacial paleodiversity based on ancient DNA analyses of sediments from the Batagay Megaslump exposure – Providing picture of past ecosystems

Jérémy Courtin, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research - Polar Terrestrial Environmental Systems, Potsdam, Germany
Amedea Perfumo, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research - Polar Terrestrial Environmental Systems, Potsdam, Germany
Kathleen R. Stoof-Leichsenring, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research - Polar Terrestrial Environmental Systems, Potsdam, Germany
Ulrike Herzschuh, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research - Polar Terrestrial Environmental Systems, Potsdam, Germany ; Institute of Environmental Science and Geography - University of Potsdam, Potsdam-Golm, Germany ; Institute of Biology and Biochemistry - University of Potsdam, Potsdam-Golm, Germany

Keywords: Batagay, Sedimentary Ancient DNA, Metabarcoding, Shotgun Sequencing, Palaeoreconstruction

Amplified arctic warming causes northern boreal ecosystems to experience even stronger climate change than in the rest of Northern Hemisphere. Because of the intricate interactions between and within the abiotic and biotic components of the system, it is challenging to predict the dynamic of arctic ecosystems. The glacial and interglacial cycles during the Pleistocene, involved drastic changes in past ecosystems. Thus, investigating Quaternary records can strengthen the current methods to forecast the effects of global warming on ecosystems. The Batagay megaslump, in northern Yakutia, is the world's largest known retrospective thaw slump discontinuously exposing, Middle Pleistocene to Holocene permafrost formations. In 2019, 70 sediment samples were collected with the aim to characterise biodiversity changes between Quaternary glacials and interglacials in East Siberia. Using the ancient DNA extracted from these environmental samples, we performed a metabarcoding analysis (chloroplast trnL) to investigate past vegetation composition as well as a shotgun metagenomic analysis allowing us to access the entire biodiversity, from viruses to Mammoths. This approach makes possible not only to investigate and provide an entire picture of past biodiversity but also to infer on potential interactions across taxa and kingdoms. This work on, past and modern, biodiversity of permafrost regions has the potential to reveal new insights into the evolution of this fragile ecosystem.

On the interannual variability of sea ice in the Bering Sea and related changes in primary production and Cold Pool distribution

Jaclyn Clement Kinney, Naval Postgraduate School, Monterey, CA, USA
Wieslaw Maslowski, Naval Postgraduate School, Monterey, CA, USA
Robert Osinski, Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland
Younjoo Lee, Naval Postgraduate School, Monterey, CA, USA

Keywords: Bering Sea, Sea Ice, Phytoplankton, System Model, Biogeochemistry

The Bering Sea experiences a seasonal sea ice cover, which is important to the biophysical environment found there. A pool of cold bottom water (< 2oC) is formed each winter as a result of the predominately local sea ice growth on the shelf and associated vertical mixing due to brine rejection. The extent and distribution of this Cold Pool (CP) is largely controlled by the extent of sea ice in the Bering Sea, which in recent winters has been much lower than average. The cold bottom water of the CP is important because it delineates the boundary between arctic and subarctic demersal fish species. The presence or absence of sea ice is found to also affect the timing of the spring/early summer phytoplankton bloom. This timing of this bloom is important for the fate of the production; whether it is primarily consumed in the pelagic community or deposited to the benthos. We use the Regional Arctic System Model (RASM) to examine variability of the extent and distribution of the CP in the Bering Sea during the period 1980-2018 and its relation to change in the sea ice cover. RASM is a high-resolution, fully-coupled, regional biophysical model. Its domain encompasses the entire marine cryosphere of the Northern Hemisphere, including the major inflow and outflow pathways, with extensions into North Pacific and Atlantic oceans. The components of RASM include: atmosphere, land hydrology, sea ice, ocean and marine biogeochemistry (BGC). The ocean BGC component in RASM is a medium-complexity Nutrients-Phytoplankton-Zoo-plankton-Detritus (NPZD) model. RASM results confirm the direct correlation between the extent of sea ice and CP and show a smaller CP as a consequence of recent declines of the sea ice cover in the Bering Sea. RASM also shows that a reduced sea ice cover leads to a later phytoplankton bloom, while an extensive ice cover leads to an earlier phytoplankton bloom.

Investigating the prey spectrum of two co-occurring Themisto amphipod species in the Fram Strait using DNA metabarcoding

Annkathrin Dischereit, Alfred-Wegener-Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
Charlotte Havermans, Alfred-Wegener-Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany

Keywords: DNA-metabarcoding, Themisto Amphipods, Prey Spectrum

The pelagic amphipods Themisto libellula and T. abyssorum represent a key zooplankton group in the polar regions. These two hyperiid amphipods are an important food source for higher trophic levels, and being carnivores, they are able to control the zooplankton standing stock in some Arctic regions. T. abyssorum is a boreal species reaching the Arctic with incoming Atlantic water and is thus likely to benefit from the ongoing Atlantification of the Arctic Ocean, whereas it may heavily impact the genuine Arctic T. libellula. Since the Arctic is undergoing drastic changes in terms of warming and sea ice loss, it is crucial to gain knowledge about the prey spectrum of these two important amphipods to predict the future of the pelagic food web in a changing Arctic. In recent years, several studies were conducted concerning the diet of T. libellula and T. abyssroum. In those studies, mainly using biomarkers or stereomicroscopy, a diet consisting of the most abundant zooplankton species including calanoid copepods, euphausiids and chaetognaths, was suggested. T. abyssorum and T. libellula were also found to occupy distinct niches in the Arctic ecosystem. In this study, DNA metabarcoding was used to compare the species-level prey spectrum of the two Themisto amphipods and compare its regional variation. It was found that T. libellula feeds on larvae of fish like Boreogadus saida, while this was not found for T. abyssorum. The chaetognath Eukrohnia hamata was detected in most samples of T. abyssorum, as well as DNA of hydrozoans like Aglantha digitale or Nanomia cara, suggesting that gelatinous zooplankton represent a food source for those amphipods.

On the phylogeny of Nematoda in coastal sea ice on Svalbard (European Arctic)

Vanessa Pitusi, The University Centre in Svalbard, Norway
Janne E. Søreide, The University Centre in Svalbard, Norway
Brandon T. Hassett, University in Tromsø, Norway
Miriam Marquardt, University in Tromsø, Norway
Magnus Heide Andreasen, The University Centre in Svalbard, Norway

Keywords: Sympagic meiofauna, Theristus ,Cryonema ,Hieminema ,Sanger sequencing

Understanding the diversity and functioning of Arctic sea ice ecosystems is vital to understand and predict the impact of current and future climate change. In the microscopic communities inhabiting the brine channels inside sea ice, nematodes act as bacterivores and herbivores. Despite nematodes' great abundances and known ecological roles, molecular tools have not been applied to investigate their species diversity in the Arctic. We Sanger sequenced 75 specimens from four locations around Svalbard (European Arctic) using the 18S rRNA barcode. Currently available nucleotide reference databases are both underpopulated with representative marine nematode taxa and contain a substantial number of misidentified organisms. Phylogenetic analysis of our specimens resulted in the formation of two clades within the taxonomic class Monhysterida. While it is possible that these specimens can represent novel species, supplemental morphometric analysis suggests that our specimens are Theristus, Cryonema spp., and Hieminema sp.. We leverage the assignment of molecular information to robustly identify nematodes and provide the first insight into the diversity of sea ice nematodes in the European Arctic.

Unique genetic origin of an old biodiversity hot spot in Svalbard

Viktorie Brožová, Faculty of Science, University of South Bohemia in České Budějovice, České Budějovice, Czech Republic
Pernille Bronken Eidesen, The University Centre in Svalbard, Longyearbyen, Norway

Keywords: Svalbard, Phylogeography, Hot Spot, Colonization, Holocene

To understand recent colonization patterns under climate warming, we need to understand past colonization events. Svalbard, a high-Arctic archipelago, which during the Pleistocene was glaciated and became colonized by plants at the beginning of the Holocene, is an ideal model system to study such colonization events. With an average temperature 6°C warmer than today, early Holocene conditions enabled establishment of a rich and partly thermophilic vegetation in favourable localities. The thermophilic plants are rare nowadays, thus they can still reflect past colonization patterns. Taking the vegetation age of many Svalbard localities into account, we aim to investigate if the colonization of early-vegetated localities differs from later colonization events. We analyzed chloroplast haplotypes of the thermophilic and common plant species from the earliest-vegetated biodiversity hot spot (Ringhorndalen), from later-colonized localities in Svalbard, and from putative source regions outside Svalbard. Our results show that two currently rare and thermophilic species, Campanula uniflora and Vaccinium uliginosum, have established themselves in Svalbard at least twice, and from different source regions. The old Ringhorndalen locality hosts populations originating from source regions that differ from the later-colonized Svalbard localities. We can assume that Ringhorndalen was colonized under different conditions, therefore in different time period than the later-colonized localities.

Flora of mosses of the Franz Josef Land

Irina V. Czernyadjeva, Komarov Botanical Institute Rus. Acad. Sci., St. Petersburg, Russia,
Olga M. Afonina, Komarov Botanical Institute Rus. Acad. Sci., St. Petersburg, Russia,
Sergei S. Kholod, Komarov Botanical Institute Rus. Acad. Sci., St. Petersburg, Russia,

Keywords: Mosses, Flora, Arctic, Franz Josef Land

Mosses in the polar desert zone are the richest group of plants in terms of the species number after lichens. Moss flora of the Franz Josef Land Archipelago includes 155 species of mosses. The moss species richness of the archipelago is thus nearly three times that of vascular plants (57 taxa) and comprise 56 % of the total number of species of mosses (270) known for the polar desert zone. For comparison, 149 species of mosses were recorded for the bryophyte flora of Nordaustlandet, 135 species in the northern extremity of the Novaya Zemlya Archipelago, 165 species in the Severnaya Zemlya Archipelago. The conducted research revealed relatively high mosses diversity in the archipelago. The largest number of moss species was recorded for Hooker (101 species), Alexandra Land (73), Northbrook (62), Meibel (58), George Land (53), Alger (46), Jackson (44) islands. The families Polytrichaceae (13 species), Grimmiaceae (13), and Pottiaceae (8) dominate the moss flora of the archipelago. The genera Bryum (11 species), Pohlia (9), Schistidium (8) and Dicranum (7) are fairly well represented in the flora. Eighteen species are widely distributed and found on most islands, where they presented an important component of the vegetation cover in polar deserts – Aulacomnium turgidum, Brachythecium turgidum, Dicranum elongatum, Drepanocladus arcticus, Flexitrichum flexicaule, Racomitrium lanuginosum, Roaldia revoluta, Sanionia uncinata et al.

Integrating metabolomics and ecological niche modelling to predict plant climate change resilience at a permafrost anomaly on Cornwallis Island, Nunavut

Lauren Erland, Chemistry, University of British Columbia, Kelowna, Canada
Susan Murch, Chemistry, University of British Columbia, Kelowna, Canada

Keywords: Plant Climate Change Resilience, Metabolomics, Ecological Niche Modelling, Plant Science

Understanding physiological mechanisms of Northern plant species can predict their viability in the face of changing climates. We are using a novel approach, the integration of metabolomics tissue analysis with ecological niche modelling (ENM) to predict species capacity to adapt to changing temperatures. During a botanical field survey near Resolute in the Summer of 2019, we observed an anomaly in the permafrost with temperatures about 10 °C warmer than the surrounding tundra. The plants at the anomaly were different species than the surrounding plant communities. We hypothesized that this anomaly represents a small-scale model of the effects of warming on plant biodiversity. Our objectives were to: (1) Determine community composition at and adjacent to the anomaly; (2) Perform ENM of the species; (3) Chemically characterize the species by metabolomics and (4) Identify relationships between metabolomics data and plant communities. Plant species with higher kurtosis and more negative skew had highest abundance at the warmest points in the anomaly. Metabolomics analysis identified unique chemical fingerprints indicative of climate exposure. These results demonstrate the potential for identification of biomarkers of climate change vulnerability and resilience through integration of multidisciplinary approaches.

Modelling reindeer adaptability in a changing landscape and climate

Ilona Kater, University of Durham, Durham, UK
Simone Abram, University of Durham, Durham, UK
Robert Baxter, University of Durham, Durham, UK

Keywords: Reindeer, Climate, Industry, Grazing, Model

Many Arctic animals are adaptive in nature especially with regards to climate, this quality being an essential component of survival in the area. Examining what affects that adaptability, alongside the direct effects of climate change on these organisms, is important if we are to understanding how the animal populations, and the humans that rely on them, may be affected by climate change. It may also offer insights into how some of the negative effects of change can be mitigated. The Arctic is after all changing in multiple ways, with an altering climate often coinciding with increased industrialisation and anthropogenic activity. Reindeer (Rangifer Tarandus L.) have lived in northern Fennoscandia for thousands of years, successfully adapting to changes in the local climate. However, over the last century they have experienced a significant loss of undisturbed pasture due to human activity such as the construction of mines, roads and reservoirs at hydropower stations. These structures have removed portions of their forage, either physically or through causing avoidance behaviour in the animals. This affects both the reindeer and the reindeer herders in the area, who have strong connections with these semi-domesticated animals economically and culturally. In recent years herders have shown concern about the effect that industrialisation, in combination with a changing climate, is having on their reindeer's survival and ability to adapt, especially during winter which is the period of greatest food stress for the animals. This study aimed to examine the effects of increased industrialisation on the ability of reindeer to adapt to changes in climate, especially during the critical winter period. This was done using novel field data from Northern Sweden together with results from past studies to construct a model of reindeer survival in different ecosystem scenarios. The model includes climatic, biotic and abiotic, as well as spatial and temporal, aspects of the winter period. The various factors influencing reindeer survival were then compared and contrasted, which highlighted some of the inherent complexities these animals face in their ecosystem, and how some of their adaptive behaviours can no longer be carried out.

Food web approach to manage arctic wildlife populations in an era of rapid environmental change

Jarad Pope Mellard, University of Tromsø, The Arctic University of Norway, AMB, Tromsø, Norway
John-André Henden, University of Tromsø, The Arctic University of Norway, AMB, Tromsø, Norway
Åshild Ønvik Pedersen, Norwegian Polar Institute, Tromsø, Norway
Filippo Marolla, University of Tromsø, The Arctic University of Norway, AMB, Tromsø, Norway
Sandra Hamel, Départment de biologie, Université Laval, Québec, Canada
Nigel Gilles Yoccoz, University of Tromsø, The Arctic University of Norway, AMB, Tromsø, Norway
Rolf Anker Ims, University of Tromsø, The Arctic University of Norway, AMB, Tromsø, Norway

Keywords: Food Web, Monitoring, Management, Models

Arctic scientists and wildlife managers implementing adaptive monitoring and management are tasked with providing predictions of biodiversity responses to environmental changes- not only direct effects of climate, productivity, land use, or habitat degradation, but also changes in the food web, such as expanding/increasing species that are predators, prey, and competitors of populations of concern. We expected that explicitly considering food webs and their dynamics in more complex models would provide better predictions on future changes and assessments of management actions. In the development of the Climate-ecological Observatory of Arctic Tundra (COAT) we have conducted a set of case studies applying a food web approach to assess climate and harvest impacts and their implications for management. We found empirical support for many of our hypothesized food web effects and were able in some cases to short-term forecast with slightly lower prediction error when we took into account food web dynamics compared to simpler models. Predictions are the foundation of adaptive management. However, to evaluate predictions requires adequate and high-quality monitoring data. A combination of long-term food web monitoring and different types of study designs coupled with models of adequate complexity are likely required to better understand the pathways of climate and harvest and the consequences arctic wildlife due to continuing rapid environmental change.

Cold Mountain (Goltzy) Deserts in European Arctic: an Inventory of Flora, Vegetation, and Soils

Natalia Koroleva, Polar-Alpine Botanical Garden-Institute, Kola SC RAS, Kirovsk Russia
Mikhail Maslov, Lomonosov Moscow State University, Moscow, Russia
Alena Danilova, Polar-Alpine Botanical Garden-Institute, Kola SC RAS, Kirovsk, Russia
Alexander Novakovskiy, Institute of Biology, Komi SC RAS, Syktyvkar, Russia
Irina Zenkova, Institute of North Industrial Ecology Problems, Kola SC RAS,
Regina Shalygina, Institute of North Industrial Ecology Problems, Kola SC RAS

Keywords: Goltzy Deserts, Ecosystems, Khibiny Mountains

Ecosystems of the cold mountain deserts (goltzy) in the European Arctic are characterized, on the example of Khibiny Mts (Murmansk Region) as the case study. Vegetation and soils were described, soil invertebrates and algae were collected and identified.

The goltzy deserts occur at 900-1000 m a.s.l., the vegetation covers from less than 1% to 10% and the total number of species from 4 to 35 per sample plot. Three vegetation types were identified: moss (Racomitrium microcarpon)-dominated type, dwarf-moss-lichens- type, and moss-dwarf shrubs-sedges- type. NMS ordination (quality index Sorensen) and clustering (Bray index) supported the table grouping. The leading role of cryptogams in goltzy deserts is considered as the ancient trait of Arctic ecosystems. The actual cyclic dynamics of goltzy deserts mirrors the unstable and changing habitat environment, namely substrata cryoturbation. Soils (typical and humic petrozems) occur under moss and lichen cushions. The soil profile was weakly differentiated as to content of elements, with the exception of phosphorus, which is concentrated in organogenic horizons. In many chemical and physic-chemical properties, these soils are close to dry peaty podbures of the tundra zone. The biological activity of petrozems is lower or comparable with the soil of the mountain tundra. When the structure of the vegetation cover becomes more complex, the activity of microorganisms increases and the organic matter of the soil gets more stabilized.

Effects of warmer and rainier arctic winters on a widespread herb: Bistorta vivipara

Jan Detampel, Fu Berlin, Berlin, Germany and UNIS, Longyearbyen, Svalbard
Mathilde Le Moullec, NTNU, Trondheim, Norway
Brage B. Hansen, NTNU, Trondheim, Norway
Pernille Bronken Eidesen; UNIS, Longyearbyen, Norway

Keywords: Rain-On-Snow, Basal Ice, Plant Growth, Flowering

Climate change leads to higher frequencies of extreme weather events. Especially in the Arctic, rain on snow events (ROS) caused by warm weather spells can drastically change the snowpack. Basal ice formed during these events encases vegetation and eliminates its insulating capabilities. Ice encapsulated tundra can lead to decreased food plant availability impacting population dynamics of arctic herbivores. However, little is known how icing affects the vegetation itself. Bistorta vivipara, a perennial forb, is an important food source for arctic herbivores: i.e., ptarmigan chicks that depend on a plant protein rich diet. We investigated effects on the reproductive and vegetative traits of Bistorta vivipara in a randomized factorial experiment. Extreme snow on ice (icing) and thaw-freeze events were simulated by treating a total of 75 plots split in four sub squares during polar winter at a field site in Adventdalen, Svalbard. The experiment ran for two years (2019/2020). Plant growth and fitness indicators, such as leaf area, inflorescence/bulbils number and height were measured after the succeeding growing season. The collected data is analyzed with Glmm's in R-Studio. Showing weather icing, thaw-freeze treatments, or other factors like spring-onset impact plant performance. By recording the effects of the treatments on a widespread arctic herb, we aim to shed light on a species-specific response to the drastic changes, which are predicted for the arctic climate.

Polyploidy in Saxifraga oppositifolia: A shift in reproductive parameters as a result of environmental adaptations?

Ingrid Vesterdal Tjessem, Department of Biosciences, University of Oslo, Department of Arctic Biology, The University Centre in Svalbard, Norway
Pernille Bronken Eidesen, Department of Arctic Biology, The University Centre in Svalbard, Norway
Anne Krag Brysting, Department of Biosciences, University of Oslo, Norway

Keywords: Polyploidy, Reproduction, Adaptations, Vegetative Propagation, Environmental Stress

Polyploidy as an adaptive mechanism in plants is particularly important in stressful environments, especially the ability of polyploid linages to expand into new environments or adjust to changed conditions. It has been shown that environmental stress, such as extreme climatic conditions, may enhance the production of unreduced gametes, which is usually a prerequisite for polyploidisation to occur. In the Arctic, which is experiencing some of the most rapid and severe climatic changes on Earth, polyploidy might increase the potential for new adaptations, and thus the chance of survival. Although diploids might outcompete polyploids in well-established ecosystems, polyploids may have an advantage in changing environments.

Saxifraga oppositifolia (Saxifragaceae) is an arctic-alpine species with two main ploidy levels: diploids and tetraploids. It has different growth forms, which are partly connected to ploidy levels and habitat type (ridge, slope, riverbed). Resource allocation between flower production and vegetative growth clearly differs between habitats and growth forms, but how this varies between ploidy levels is still unclear. We will present data covering sexual reproduction and vegetative propagation, among different ploidy levels and between habitats, to address the following question: Have autopolyploidisation in S. oppositifolia created a shift in reproductive parameters?

Saxifraga oppositifolia: Conquering new niches in the High Arctic in a successful polyploidization event

Simen Salomonsen Hjelle
Pernille Broken Eidesen
Ingrid Vesterdal Tjessheim
Xurxo Gago

Keywords: Polyplodisation, Evolution, Botany, Biodiversity, Physiology

Polyploidization is a mechanism for rapid speciation, especially in plants. It is predicted to be the most common mode of speciation in a changing climate, but how successful polyploidization is in establishing new species is debated. Here, we examine the polyploids (triploid & tetraploid) of Saxifraga oppositifolia . They express different morphology and habitat preference from their progenitors. We investigated physiological and reproductive differences. We measured chlorophyll fluorescence (n=30), leaf structural traits from the field (n=127), and asexual reproductive success (n=307). We hypothesize polyploids showing a higher growth rate , while diploids must sacrifice growth for survival and sexual reproduction. Measurements of PSII yield under light conditions show tetraploids having higher photosynthetic capacity, lower specific leaf area (SLA), and are twice as likely to succeed vegetative reproduction . While SLA correlates positively with growth rate in plants on a large multi-species scale, this relationship might not be the same within the same species. Overall, we found several distinct differences between the polyploids and their progenitors. This implies a different strategy between them, meaning that tetraploids can avoid competitive exclusion, ensure future survival, and potentially establish themselves as a new species. Further measurements should be done to improve our knowledge about polyploidization effects and success to adapt to other environments.

Dark diversity in the tundra: the source of future plant biodiversity change?

Gergana N Daskalova, University of Edinburgh, Edinburgh, Scotland
Isla Myers-Smith, University of Edinburgh, Edinburgh, Scotland
Christian Rixen, WSL Institute for Snow and Avalanche Research SLF, Switzerland
Anne Bjorkman, University of Gothenburg, Sweden
Toke Høye, Aarhus University, Denmark
Mats Björkman, University of Gothenburg, Sweden
Ingibjörg Svala Jónsdóttir, University of Iceland, Iceland
Isabel Barrio, Agricultural University of Iceland, Iceland
Sonja Wipf, WSL Institute for Snow and Avalanche Research SLF, Switzerland
Greg Henry, University of British Columbia, Canada
Elise Gallois, University of Edinburgh, Edinburgh, Scotland
Zoe Panchen, University of British Columbia, Canada
Sofie Agger, University of British Columbia, Canada
Anne Tolvanen, Natural Resources Institute, Finland
Hans Cornelissen, Vrije Universiteit Amsterdam, Netherlands
Rien Aerts, Vrije Universiteit Amsterdam, Netherlands
Jake Harris, Grand Valley State University, USA
Nicoletta Cannone, Insubria University, Italy
Petr Macek, University of South Bohemia, Czech Republic
Francesco Malfasi, Insubria University, Italy
Signe Normand, Aarhus University, Denmark

Keywords: Plants, Biodiversity, Dark Diversity, Scale, Monitoring

Tundra plant communities are responding as the climate continues to warm, with widespread shifts in community composition and traits. However, from where across the landscape new species come and how the larger species pool influences local-scale biodiversity change remains unknown. Traditional plant surveys often capture scales of only several square meters, leaving many unmonitored species that by chance could be absent in small plots. This so-called “dark biodiversity” could be a hidden source of future plant biodiversity change. We bring together decades of monitoring observations and the International Tundra Experiment Species Pool Protocol to reveal the magnitude of dark biodiversity in tundra ecosystems and the links between local compositional changes and the larger species pool. Across 14 sites including 29 vegetation types, we found that on average there are 30 species present within 100 m radius of long-term monitoring plots, which have never been recorded inside the plots. The amount of dark diversity varied considerably among sites, as did the rate of species accumulation with distance across different landscapes. Understanding the relationships between the species pool, dark diversity and plot-scale diversity can help us find the hotspots of plant biodiversity across tundra landscapes and will improve predictions of future changes in the richness and composition of tundra ecosystems with warming.

Do traits explain tundra plant species range size and projected expansion with warming?

Mariana García Criado, The University of Edinburgh, Edinburgh, UK
Isla H. Myers-Smith, The University of Edinburgh, Edinburgh, UK
Anne D. Bjorkman, University of Gothenburg, Gothenburg, Sweden
Signe Normand, Aarhus University, Aarhus, Denmark
Anne Blach-Overgaard, Aarhus University, Aarhus, Denmark
Haydn Thomas, The University of Edinburgh, Edinburgh, UK

Keywords: Climate Change, Species Distributions, Functional Traits, Range Shifts

Climate change is leading to shrub species expanding into new areas across the Arctic. However, it is unclear whether plant traits can be used to predict species' range shifts for tundra 'winner' and 'loser' species. We combined 18,414 trait records with distribution data derived from Species Distribution Models projections for 62 shrub species across three continents. We found that greater variation in seed mass and Specific Leaf Area (SLA) were related to larger current ranges and greater projected range expansions. Additionally, 'winner' species experiencing increasing abundance were taller, and had greater SLA and seed mass values than species with 'stable' abundances and the 'loser' species that decreased in abundance. However, trait effects on range shifts were highly dependent on the climatic scenarios considered in range projections. We found no consistent relationships between traits and ranges, suggesting highly individualistic responses of tundra shrub species to warming.

Drivers of Spatial and Temporal Variability in Ecosystem Functional Diversity on the Yamal Peninsula, Siberia, Russia

Morgan Tassone, University of Virginia, Charlottesville, VA, USA
Howard Epstein, University of Virginia, Charlottesville, VA, USA
Amanda Armstrong, NASA GESTAR- GSFC, Greenbelt, MD, USA
Domingo Alacaraz-Segura, University of Granada, Granada, Spain

Keywords: Ecosystem Function, Functional Diversity, Vegetation Productivity, Yamal Peninsula

The seasonal dynamics of primary productivity can be used to define Ecosystem Functional Types (EFTs), patches of the landscape that function similarly and have potentially coordinated responses to environmental drivers. Ecosystem functional diversity, defined as the variation in the seasonal dynamics of primary productivity across a landscape, can be inferred from EFT richness (the number of EFTs within a defined area). Arctic functional diversity likely exhibits spatiotemporal variability due to interactions with environmental and anthropogenic drivers; however, the effects of these drivers on EFT distribution and functional diversity in the Arctic have yet to be resolved. This research aims to disentangle the effects of these drivers on EFT distribution and functional diversity of the Yamal Peninsula, a hotspot for change in the Arctic. This analysis used climatic, geologic, biological, and anthropogenic driver variables to determine the spatial and temporal controls of satellite-derived EFTs and EFT richness. The distribution of EFTs was controlled by climatic drivers through longer growing seasons in areas with high Summer Warmth Index, high growing season precipitation, and early snow-free period onset dates. Conversely, spatial and temporal variation in functional diversity was controlled by fine-scale differences in the landscape caused by geologic, biological, and anthropogenic drivers that mediate vegetation response to climatic drivers.

Macro versus microenvironmental controls on tundra vegetation change

Isla Myers-Smith, University of Edinburgh, Edinburgh, Scotland, UK
Anne Bjorkman, University of Gothenburg, Gothenburg, Sweden
Team Shrub, University of Edinburgh, Edinburgh, Scotland, UK

Keywords: Tundra, Biodiversity, Plants, Microenvironment, Microclimate

The Arctic is warming rapidly with far-reaching consequences for the Earth's climate. With warming, not only the macroclimate, but also the microenvironment could influence future tundra biodiversity change. As the tundra warms, plants are responding by leafing out earlier, growing taller and expanding in cover, influencing tundra carbon storage and climate feedbacks. Yet, questions remain about how tundra plant responses to warming are mediated by the microenvironment – the localised conditions in which plants grow. Climate change influences the microenvironment by altering snow melt, soil temperatures, permafrost thaw, soil moisture and hydrology. Plants in warmer and wetter microclimates could grow for longer periods of time resulting in increased plant productivity and those plants could in turn have different traits. If the microenvironment both above and belowground is a major driver of tundra plant responses to warming, we need additional landscape-level information to make accurate future projections of Arctic vegetation change. In this talk, I will summarise the current evidence and future research directions for the influence of macro versus microenvironmental controls on vegetation change including plant phenology, growth, traits and composition that together inform our predictions of future tundra biodiversity change.

Vegetation phenology and microclimate in a changing Arctic

Geerte E. de Jong, University of Gothenburg, Gothenburg, Sweden
Anne Bjorkman, University of Gothenburg, Gothenburg, Sweden
Wilhelm Osterman, University of Gothenburg, Gothenburg, Sweden
Katrin Björnsdottír, University of Gothenburg, Gothenburg, Sweden

Keywords: Phenology, Ecosystem Change, Tundra Ecology

As we observe increasing Arctic warming, we see that the Arctic is not only greening, but also locally browning due to the effects of global climate change. The heterogeneity in these processes is recognized but not fully understood. Arctic vegetation change occurs not only heterogeneous spatially, but also temporally in for instance changes to the growing season length and timing of plant growth. Vegetation community composition can change due to species responding differently to warming, potentially changing biodiversity at these extreme sites. Microclimatic differences have been raised as a potentially important driver to the complexity of Arctic greening. Here we developed a field study to investigate the effect of microclimate differences on phenology. At three Arctic sites in northern Sweden (Latnjajaure), Greenland (Blaesedalen) and Svalbard (Adventdalen) we will set up our experiment for multiple years to monitor both above and belowground microclimate and phenology. We use in-situ logger data, field observations, soil and vegetation samples, and pheno-cams to observe our plots. We use vegetation inventories and pheno-cam imagery to study the species-specific response to micro-climatic variation. Due to the global pandemic we were only able to start our study in northern Sweden in 2020. Here we present results and lessons learned from this first observed year.

Not all flowers are equal: The importance of microclimate for reproductive success in the arctic-alpine cushion plant Silene acaulis

Rebekka Eriksen Ween, The University Centre in Svalbard/UiT - The Arctic University of Norway, Tromsø, Norway
Maria Huntsaar, The University Centre in Svalbard/University of Aberdeen, Aberdeen, The United Kingdom
Toke Thomas Høye, Aarhus University, Aarhus, Denmark
Nigel Yoccoz, UiT - The Arctic University of Norway, Tromsø, Norway
Pernille Bronken Eidesen, The University Centre in Svalbard, Svalbard, Norway

Keywords: Microclimate, Phenology, Plant Reproduction, Cushion plants

Reproduction in the Arctic is a challenge. Small variations in microclimate can therefore be crucial for flower development. Many Arctic plants adapt to these challenging conditions by forming dense cushions. Due to their dome shape, sun angle influence local temperatures within a cushion. The northern side of the cushion usually receives solar radiation at a lower angle compared to the southern side, which results in colder microclimate and later flowering on the northern side. We used the arctic-alpine cushion plant Silene acaulis (L.) Jack. as a model species to investigate the relationship between radiation-induced microclimate, flowering time, and reproductive output. We compared data collected by data loggers and time-lapse imagery from two populations at different latitudes (10 cameras in Bjørndalen, Svalbard 78°N, and 10 cameras in Narsarsuaq, South Greenland 61°N). For each cushion, we registered individual flower stages every 12 hours throughout the growth season, resulting in 500 to 7500 stages recorded per time series. Our preliminary data show pronounced variation in microclimate within individual cushions and confirm that flowering is earlier on the southern side of the cushion compared to the northern side. In addition, fruit-set was more frequent among early blooming flowers than among late blooming flowers; a pattern that was particularly evident among individuals on Svalbard.

Biodiversity in the Old and the New Arctic - toward completion of the Arctic Vegetation Archive

Amy Breen, International Arctic Research Center, University of Alaska, Fairbanks, Alaska, United States
Gabriela Schaepman-Strub, Department of Evolutionary Biology and Environmental Studies, University of Zurich, Switzerland
Ksenia Ermokhina, A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Moscow, Russia
Nadezhda Matveyeva, Russian Academy of Sciences, Komarov Botanical Garden, St. Petersburg, Russia
Jozef Šibík, Slovak Academy of Science, Bratislava, Slovak Republic
William MacKenzie, Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Smithers, British Columbia, Canada
D.A. (Skip) Walker, Institute of Arctic Biology, University of Alaska, Fairbanks, Alaska United States
and the AVA team

Keywords: Biodiversity, Terrestrial Vegetation, Plot Database, Circumpolar

Efforts toward an Arctic Vegetation Archive (AVA) are underway to support several of the biodiversity activities of the Conservation of Arctic Flora and Fauna (CAFF) and circumpolar activities of the International Arctic Science Committee's Terrestrial Working Group (IASC TWG). The domain of the AVA includes the entire Arctic tundra biome, the first vegetation archive for any of the world's major biomes. This is achievable because the Arctic is the only biome that has species checklists developed by taxonomists of known vascular plants, bryophytes and lichens. The primary goal of the AVA is to gather legacy plot data that are in danger of being lost that are the baseline for understanding changes in the New Arctic. Approximately 31,000 historical vegetation plots have been identified and are being gathered using a standardized format for vegetation classification and analysis. The AVA initiative encourages each Arctic country to assemble its own archive with common protocols that will later allow the databases to be united into a single circumpolar AVA. The AVA will then be used to create an Arctic Vegetation Classification (AVC) and for other applications. Towards these ends, two workshops were organized in conjunction with the Arctic Science Summit Weeks in 2017 and 2019. A third online workshop will occur before Arctic Science Summit Week in 2021. We provide a summary of the results of the workshop and the status of regional archives in our poster.

Will Current Protected Areas Harbour Refugia for Threatened Arctic Vegetation Types until 2050?

Merin R. Chacko, Department of Evolutionary Biology and Environmental Studies, University of Zurich, Zurich, Switzerland
Ariane K.A. Goerens, Department of Evolutionary Biology and Environmental Studies, University of Zurich, Zurich, Switzerland
Jacqueline Oehri, Department of Evolutionary Biology and Environmental Studies, University of Zurich, Zurich, Switzerland
Elena Plekhanova, Department of Evolutionary Biology and Environmental Studies, University of Zurich, Zurich, Switzerland
Gabriela Schaepman-Strub, Department of Evolutionary Biology and Environmental Studies, University of Zurich, Zurich, Switzerland

Keywords: Global Change, Conservation, CAVM, Vegetation Shifts, Climate Change Refugia

Arctic vegetation types provide food and shelter for fauna, support Northern livelihoods, and are tightly linked to climate, land and sea dynamics. Despite its significant role, a comprehensive understanding of climate change effects on Arctic vegetation is lacking. We compare the 2003 baseline with existing 2050 predictions of circumpolar Arctic vegetation type distributions and demonstrate that abundant vegetation types with a proclivity for expansion contribute most to current protected areas. Applying IUCN criteria, we categorize five out of the eight assessed vegetation types as threatened by 2050. Our analyses show that current protected areas are insufficient for the mitigation of climate-imposed threats to these Arctic vegetation types. Therefore, we located potential climate change refugia, areas where vegetation may remain unchanged, at least until 2050, providing the highest potential for safeguarding threatened vegetation types. Our study provides an essential first step to assessing vegetation type vulnerability in the Arctic, but is based on predictions covering only 46% of Arctic landscapes. The co-development of new protective measures by policymakers and indigenous peoples at a pan-Arctic scale requires more robust and spatially complete vegetation predictions. This is essential as increasing pressures from resource exploration and rapid infrastructure development complicate the road to a sustainable development of the rapidly thawing and greening Arctic.

Monitoring and modelling of the critical balance of biomass vs biodiversity in the development of the northern treeline using drone monitoring and earth observation in Siberia (BioS)

Stefan Kruse, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Birgit Heim, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Ulrike Herzschuh, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany and Institute of Earth and Environmental Science, University of Potsdam, Potsdam-Golm, Germany
Michael Förster, Geoinformation for Environmental Planning Lab, Technical University of Berlin, Berlin
Birgit Kleinschmit, Geoinformation for Environmental Planning Lab, Technical University of Berlin, Berlin
Evgenii S Zakharov, Federal State Autonomous Educational Institution of Higher Education "M.K. Ammosov North-Eastern Federal University", Yakutsk, Russian Federation and Institute for Biological Problems of Cryolithozone Siberian Branch of RAS, Yakutsk, Russian Federation
Luidmila A Pestryakova, Federal State Autonomous Educational Institution of Higher Education "M.K. Ammosov North-Eastern Federal University", Yakutsk, Russian Federation

Keywords: Tundra-Taiga Transition, Siberia, UAV, Monitoring, Scaling

Within the new cooperation project BioS starting 2021 between the Technical University of Berlin and the Alfred Wegener Helmholtz Institute for Polar and Marine Science, we intend to build up boreal ecosystem monitoring and modelling to understand the critical balance of biomass vs. biodiversity in northern treeline dynamics in Siberia.

• We will establish UAV- and Earth Observation-based monitoring of vegetation structure and composition across the treeline in Eastern Siberia and assess above ground biomass, species composition and by this biodiversity. We will experimentally derive Essential BioVariables EBVs: Leaf Area Index (LAI), Primary Production (plant biomass), vegetation height, vegetation structure plus plant traits that partly overlap in providing Essential Climate Variables ECVs.

• We will upscale EBVs and ECVs using ESA and NASA passive optical and spaceborne lidar remote sensing products, also scaling to the landscape level using Sentinel-2 optical satellite data.

• We aim at predicting spatially explicit treeline dynamics with the individual-based vegetation model LAVESI. Parameterizing with the new data and forcing the model with climate pathway scenarios, we will be able to estimate the dynamics of forest expansion and identify areas where tundra is most threatened.

The project will enable us to address the relevant question whether rising biomass will cause a drop in biodiversity at the tundra-taiga interface in Eastern Siberia.

The hidden world: how plants shape belowground development of active layer depth in a high arctic environment

Sil Schuuring, University Centre in Svalbard/University in Oslo, Longyearbyen/Oslo, Norway
Simone Lang, University Centre in Svalbard, Longyearbyen, Norway
Pernille Bronken Eidensen, University Centre in Svalbard, Longyearbyen, Norway
Rune Halvorsen, University in Oslo, Oslo, Norway

Keywords: Vegetation, Active Layer, Permafrost

While climate change is warming the Arctic and degrading permafrost, plants could play a role in mediating the vicious cycle of permafrost degradation and release of greenhouse gasses in the Arctic. Shrubs have been found to fulfil this role in lower Arctic regions, but are sparse or absent in the High Arctic, where Bryophytes (mosses and liverworts) dominate. These have been shown to lower soil temperatures underneath, but their effect on active layer development and the permafrost underneath is still relatively unknown. Our aim is to unveil the spatial and temporal differences in active layer development under contrasting vegetation communities. We established frost tubes for season-long monitoring of active layer depth in 4 grids containing 20 plots each, with contrasting vegetation communities. Snow melt, soil moisture and -temperature in these plots will be monitored simultaneously with active layer depth. The project is planned for summer 2021.

ID: 12 - Microbiomes and biogeochemical processes along geographic and environmental gradients in the circumpolar North

Conveners

Anne D. Jungblut | Natural History Musuem, London, United Kingdom

Jérôme Comte | Institut national de la recherche scientifique, Quebec city, Canada

Klemens Weisleitner | University of Innsbruck, Innsbruck, Austria

A 20-year record that links the planktonic microbiome of Toolik Lake to seasonal cycles of stratification

Natasha R. Christman, Oregon State University, Corvallis OR, USA
George W. Kling, University of Michigan, Ann Arbor MI, USA
Jason A. Dobkowski, University of Michigan, Ann Arbor MI, USA
Byron C. Crump, Oregon State University, Corvallis OR, USA

Keywords: 16S rRNA, Limnology, Bacteria, North Slope, PCR

Arctic freshwater microbiomes perform critical ecosystem functions including carbon cycling during the short, ice-free summer period when conditions for microbial activity are controlled by seasonally-influenced environmental drivers. A 20-year record of the planktonic microbiome of Toolik Lake, a tundra lake in northern Alaska, reveals a remarkably consistent, recurring seasonal pattern of community composition coincident with the progression of water column stratification. Early summer features a highly diverse under-ice community that is homogeneous with depth. After ice-out, epilimnion and hypolimnion communities rapidly diverge as the lake thermally stratifies. When stratification peaks in mid-summer, alpha diversity reaches an annual low. In late summer and fall downward mixing causes deep communities to resemble surface communities. During this period, microbiome composition and secondary productivity change little despite a dramatic decrease in temperature. Seasonal variability exceeded interannual variability in microbiome composition, indicating these assemblages are seasonally dynamic yet highly persistent on longer time scales. Thus, temperature-mediated stratification dynamics of Arctic lake systems may be the primary determinant of microbiome composition and diversity during the ice-free season. These microbiomes may serve as sentinels of ecological modification as climate change alters the timing and magnitude of Arctic seasonality.

Microbial monitoring of a three-year permafrost collapse in Greenland

Maria Scheel, Aarhus University, Roskilde, Denmark
Athanasios Zervas, Aarhus University, Roskilde, Denmark
Carsten S. Jacobsen, Aarhus University, Roskilde, Denmark
Torben R. Christensen, Aarhus University, Roskilde, Denmark

Keywords: Amplicon, Permafrost Erosion, Thermokarst, Methanogens, Emissions

Northern permafrost soils store more than half of the global soil carbon with an estimated 1850 Gt C. Permafrost temperatures have been eroding with increasing with 0.4- 0.6 °C per decade. Active layers increase, soil ice destabilizes and particularly extremely warm growing seasons can trigger thermokarsts. These abrupt thaw events can affect 20 % of all permafrost areas, making permafrost C accessible for deeper rooting vegetation and microbial decomposition into greenhouse gases. In vicinity to the Zackenberg Station, NE Greenland, a thermokarst collapsed abruptly in summer 2018 after an intense snow melt. The soil eruption revealed an ice lens at 40 cm depth. Soil cores from this site of abrupt permafrost erosion were taken annually since then down to 100 cm depth. Soil organic matter content and radiocarbon dating indicated significantly different material of up to 26,500 years below the eventually thawed ice lens. The active layer increased from 40 cm to 70 cm to 90 cm in the three consecutive years. In order to investigate the taxonomic distribution along the depth gradient, as well as monitor the relative species abundance changes related to the proceeding thaw, prokaryotic 16S and fungal ITS gene region amplicons were sequenced and analyzed. This work is part of a project, describing both the taxonomic and metabolic in situ composition of this site, as well as simulating future warmer growing season in thermally controlled incubations linking CO2 and CH4 fluxes with of comparative gene expression and potential.

Microbial iron cycling detection, ecology, and role in the Arctic tundra

Alexander B. Michaud, Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA
Remi Masse, University of Michigan, Ann Arbor, MI, USA; Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA
Nicholas R. Record, Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA
David Emerson, Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA

Keywords: Arctic, Active Layer, Remote Sensing, Iron Cycling, Bacteria

The fate of thawed organic carbon (OC) from Arctic permafrost is a balance between the active microbial community and biogeochemical conditions present. Permafrost promotes the growth of iron oxidizing bacteria (FeOB) at the oxic-anoxic interface, which typically occurs at the surface of water-logged soils and shallow ponds. FeOB produce biogenic Fe mats as a byproduct of their respiration. The Alaskan North Slope lends itself to remote sensing of biogenic Fe mats because the oxic-anoxic interface is visible from above due to the lack of trees or other tall vegetation. The goal of this research was to establish a method to detect biogenic Fe mats using remote sensing techniques and estimate the distribution and abundance of the FeOB populations and microorganisms associated with the biogenic Fe mats. We coupled drone-based aerial imagery with ground-based sampling near Toolik Field Station. A redness index from imagery was optimized to detect biogenic Fe mats, which was ground-truthed against samples collected for extractable iron and molecular microbial community data. We found that biogenic Fe mats cover 2% of the terrestrial surface area and these mats contained a core community of taxa that includes FeOB populations and also taxa related to known iron reducing bacteria. Given their areal extent and the iron cycling microorganisms found within the biogenic Fe mats, these mats provide a favorable site for OC oxidation to CO2 rather than CH4 in the Alaskan tundra.

Species diversity of fungi in peat plateaus in mountainous landscapes of the Arctic

Kovaleva Vera A., Institute of Biology, Komi Science Center, Ural Branch of the Russian Academy of Sciences, Syktyvkar, Russia
Pastukhov Alexander V., Institute of Biology, Komi Science Center, Ural Branch of the Russian Academy of Sciences, Syktyvkar, Russia
Lapteva Elena M., Institute of Biology, Komi Science Center, Ural Branch of the Russian Academy of Sciences, Syktyvkar, Russia
Perminova Evgeniya M., Institute of Biology, Komi Science Center, Ural Branch of the Russian Academy of Sciences, Syktyvkar, Russia

Keywords: Microfungi, Peat Bogs, Subpolar Urals

Microfungi living in different Arctic environments are generally well adapted to high stress conditions such as low temperatures, wide thermal fluctuations, high UV irradiance, and low water and nutrients availability; for this reason they could be investigated in order to explore limits of microbial life. Indeed, their adaptive strategies could be crucial as predictive tools in study the limits of life. The distribution of the diversity of cultivated microscopic fungi in the profiles of soils of two bogs of the Subpolar Urals, the tundra zone of the European part of Russia. The objects of study are two flat-mound peat plateaus in the Balbanyu river basin, located at the foot of the mountain slope (65°10'20.8"N, 60°14'16.9"E) and on the river terrace above the floodplain (65°11'47.2"N, 60°13'31.8"E). The species composition of the cultivated microscopic fungi was determined on Czapek's medium. From a total of 241 isolates, 14 genera were identified: Absidia spp, Actinomucor spp., Aureobasidium spp., Geomyces spp., Geotrichum spp., Gliocladium spp., Monila spp., Mortierella spp., Mucor spp., Oidiodendron spp., Paecilomyces spp., Penicillium spp., Trichoderma spp., Umbelopsis spp. The most frequently isolated fungi were Penicillium spp. (39%) and Trichoderma spp. (15%).The most common types were Geomyces pannorum, Penicillium funiculosum, Penicillium spinulosum, Penicillium thomii, Umbelopsis vinacea. In the gray climatic conditions of the Arctic, sterile mycelium was dominant in the soils of peat plateaus in the Subpolar Urals. "Acknowledgments: The reported study was funded by RFBR, project number 20-34-70005" and "Research topic ????-?17-117122290011-5".

Hydroecological and biogeochemical assessments of rainfall washoff on retrogressive thaw slump scars along the soil-slump-lake continuum

Thomas Reid, Environment and Climate Change Canada, Burlington, Canada
Renee McFadyen, Environment and Climate Change Canada, Burlington, Canada
Peter DiCenzo, Environment and Climate Change Canada, Victoria, Canada
Joanne Parrot, Environment and Climate Change Canada, Burlington, Canada
Lee Grapentine, Environment and Climate Change Canada, Burlington, Canada
Jane Kirk, Environment and Climate Change Canada, Burlington, Canada
Ian G. Droppo, Environment and Climate Change Canada, Burlington, Canada

Keywords: Biogeochemistry, Washoff, Erosion, Sediment Dynamics, Microbiology

The thawing of subsurface permafrost has created an extremely dynamic thermokarst landscape in the arctic, with rapidly forming retrogressive thaw slumps (RTS) scaring the tundra ecosystem. Mass wasting and overland erosion from increasingly common rainfall events, introduce immense quantities of soils and sediments into adjacent aquatic ecosystems with clear ecological implications. Of lesser knowledge, however, is the degree to which the retrogressive thaw slumps scars (RTSS) can also contribute sediments and associated nutrients/contaminants to receiving water bodies via storm water runoff. The sediment erosion continuum from RTSS to lakebed depositional zones can still provide ecologically relevant concentrations of nutrients, metals (i.e. mercury), contaminants and sediments/particulates to the small rivers and lakes of the western Canadian Arctic, inevitably shifting the biogeochemical signature long after initial mass wasting events. Here, through novel rain simulation and annular flume representation of sediment transport dynamics in aquatic ecosystems, we characterize the biogeochemical, toxicology and potential mercury dynamics from RTSS wash-off events and the subsequent implications for ecological health. Results reveal clear ecosystem responses to RTSS washoff, suggesting a need for further characterizing the spatial and temporal characteristics of the RTSS in the Canadian Arctic.

Terrestrial Inputs Shape Coastal Microbial Communities in a High Arctic Fjord (Isfjorden, Svalbard)

Lisa-Marie Delpech, École Normale Supérieure de Lyon, Lyon, France; Department of Arctic Marine Biology, UiT The Arctic University of Norway, Tromsø, Norway; Norwegian Institute for Water Research (NIVA), Tromsø, Norway
Tobias R. Vonnahme, Department of Arctic Marine Biology, UiT The Arctic University of Norway, Tromsø, Norway
Maeve McGovern, Department of Arctic Marine Biology, UiT The Arctic University of Norway, Tromsø, Norway; Norwegian Institute for Water Research (NIVA), Tromsø, Norway
Rolf Gradinger, Department of Arctic Marine Biology, UiT The Arctic University of Norway, Tromsø, Norway
Kim Præbel, Norwegian College of Fishery Science, UiT The Arctic University of Norway, Tromsø, Norway
Amanda Poste, Norwegian Institute for Water Research (NIVA), Tromsø, Norway

Keywords: Microbial Communities, Freshwater Runoff, Melt Season, Land-Ocean Connectivity, Climate Change

The Arctic is experiencing dramatic changes resulting in increasing freshwater runoff from melting glaciers and increased precipitation. During the melt season, terrestrial runoff delivers carbon and nutrient-rich freshwater to Arctic coastal waters, with unknown consequences for microbial communities. We determined the impacts of runoff on coastal microbial communities. Amplicon sequences of the 16S rRNA gene were generated for water column, river and sediment samples collected along inner- to outer-fjord transects in Isfjorden (Svalbard) in June and August 2018. We identified temporal and spatial reorganizations in microbial community structure and composition during the melt season, in relation to environmental conditions. In June, waters enriched in dissolved organic carbon (DOC) provided a niche for copiotrophic taxa such as Sulfitobacter and Octadecabacter. In August, lower DOC concentrations and Atlantic water inflow favored a shift towards more cosmopolitan taxa such as the SAR11 Clade Ia and oligotrophic marine clades, while nutrient and particle-rich freshwater inputs also contributed to shaping structural and compositional changes. Sentinel taxa of this late summer environment included taxa of the class Verrucomicrobiae (Roseibacillus, Luteolibacter). Our study suggests a strong impact of terrestrial runoff on Arctic coastal microbial communities through changes in biogeochemical conditions, highlighting their susceptibility to climate change.

The biogeochemical variability of Arctic thermokarst ponds is reflected by stochastic and niche-driven microbial community assembly processes

Alizée Le Moigne, University of Zurich, Zurich, Switzerland
Maciej Bartosiewicz, University of Basel, Basel, Switzerland
Gabriela Schaepman-Strub, University of Zurich, Zurich, Switzerland
Samuel Abiven, Ecole Normale Superieure,PSL Research Univeristy, Paris, France
Jakob Pernthaler, University of Zurich, Zurich, Switzerland

Keywords: Thermokarst ponds, Microbial communities, Stochasticity,

Shallow thermokarst ponds are a conspicuous landscape element of the Arctic Siberian tundra with high biogeochemical variability. Little is known about how microbes from the regional species pool assemble into local pond communities and how the resulting patterns affect functional properties such as dissolved organic carbon (DOC) remineralization and greenhouse gas (GHG) turnover. We analysed the pelagic microbiomes of 20 ponds in north-eastern Siberia in the context of their physico-chemical properties. Ponds were categorized as polygonal or trough according to their geomorphological origin. The diversity of bacteria and eukaryotic microbes was assessed by ribosomal gene tag sequencing. Null model analysis revealed an important role of stochastic assembly processes within ponds of identical origin, in particular for genotypes only occurring in few systems. Nevertheless, the two pond types clearly represented distinct niches for both the bacterial and eukaryotic microbial communities. Carbon dioxide concentration, indicative of heterotrophic microbial processes, varied greatly, especially in the trough ponds. Methane concentrations were lower in polygonal ponds and were correlated with the estimated abundance of methanotrophs. Thus, the overall functional variability of Arctic ponds reflects the stochastic assembly of their microbial communities. Distinct functional subcommunities can, nevertheless, be related to GHG concentrations.

Functional vs. taxonomic microbial diversity along lake glacier chronosequences: what is the better predictor for greenhouse gas production?

Jing Wei, Centre for Biogeochemistry in the Anthropocene, Department of Biosciences, Section for Aquatic Biology and Toxicology, University of Oslo, Oslo, Norway
Laurent Fontaine, Centre for Biogeochemistry in the Anthropocene, Department of Biosciences, Section for Aquatic Biology and Toxicology, University of Oslo, Oslo, Norway
Nicolas Valiente, Centre for Biogeochemistry in the Anthropocene, Department of Biosciences, Section for Aquatic Biology and Toxicology, University of Oslo, Oslo, Norway
Peter Dörsch, Faculty of Environmental Sciences and Natural Resource Management, Norwegian University of Life Sciences, Ås, Norway
Dag O. Hessen, Centre for Biogeochemistry in the Anthropocene, Department of Biosciences, Section for Aquatic Biology and Toxicology, University of Oslo, Oslo, Norway
Alexander Eiler, Centre for Biogeochemistry in the Anthropocene, Department of Biosciences, Section for Aquatic Biology and Toxicology, University of Oslo, Oslo, Norway

Keywords: Functional Microbial Diversity, Taxonomic Diversity, Glacier Lake, Chronosequence, Greenhouse Gas

Climate change is leading to higher temperatures in the Arctic and northern latitudes. This rapid warming is driving massive loss of ice sheets and retreat of glaciers. Following glacial retreat, landscape changes lead to the development of new ecosystems like lakes and ponds. These environments are considered as good sentinels to study processes in primary ecological succession such as microbial activities, and how such activities are related to greenhouse gas emissions. In order to understand climate feedback processes in such aquatic ecosystems, we explored the taxonomic and functional diversity of aquatic microbial communities along Arctic and alpine transects. Water samples from five catchments were obtained from alpine Hardangerjøkulen (central-southern Norway), as well as from Isfjorden and Kongsfjorden (Spitsbergen, Norway), along transects from glacier fronts, representing chronosequences of glacier retreat. Nutrients and greenhouse gases (CO2, CH4 and N2O) were analyzed in the water samples, and further combined with SSU rRNA gene metabarcoding and shotgun metagenomic sequencing. Our results highlight how microbial diversity changes with increasing distance to the glaciers and changes of nutrient status, reflecting the outcomes of ecological succession. In addition, repeatable patterns in functional diversity are expected while taxonomic diversity are predicted to be catchment specific. This study contributes to our understanding of using taxonomic and functional diversity as predictors for greenhouse gas emissions.

Variations in cryoconite holes and phototrophs across an outlet glacier in southwest Greenland

Nozomu Takeuchi, Chiba University, Chiba, Japan
Koki Ishiwatari, Chiba University, Chiba, Japan
Akane Watanabe, Chiba University, Chiba, Japan
Takahiro Segawa, Yamanashi University, Kofu, Japan

Keywords: Cryoconite, Glacier Algae, Greenland Ice Sheet

Cryoconite holes are habitats of microbes growing on ablating glacier ice surface and their dynamics largely affect surface darkening and ecosystems of Greenland Ice Sheet. We investigated spatial variations in cryoconite holes and phototrophs along a transect across Issunguata Sermia Glacier in southwest Greenland. There is a distinctive surface topography along the transect: flat ice area in the central part and rough crevasse area near the margin of the glacier. Cryoconite holes showed distinctive morphology between the two areas: shallower in the crevasse area and deeper in the flat ice area. Organic contents and carbon stable isotope of cryoconite were significantly different between the two area: abundant organic contents and higher stable isotope values in the flat ice area. Phototrophs in cryoconite holes were dominated filamentous cyanobacteria and glacier algae and their species compositions were also distinctive between the two areas. Results suggest that presence of crevasse is likely to cause shallower cryoconite holes formed on the ice surface, which further affect community structure of phototrophs on the glacier.

Salinity and dissolved organic carbon drive microbial community structure in a subarctic river system and its transition zone to the sea

Marie-Amélie Blais, Département de biologie, Université Laval, Québec, Canada
Alex Matveev, Département de biologie, Université Laval, Québec, Canada
Connie Lovejoy, Département de biologie, Université Laval, Québec, Canada
Warwick F. Vincent, Département de biologie, Université Laval, Québec, Canada

Keywords: Microbiome, Rivers, Bacteria, Microbial Eukaryotes, Permafrost

Microbial communities play key roles in ecosystem functioning by their involvement in biogeochemical cycles and as biomass producers at the base of food webs. As northern ecosystems undergo rapid transformation, there is a need to improve our understanding of microbial communities of rivers that flow across the changing landscape. Combining amplicon sequencing and physicochemical measurements, we investigated the diversity and environmental drivers of pelagic bacteria and microbial eukaryotes across environmental gradients in a subarctic river discharging into southeastern Hudson Bay: the Great Whale River (GWR), including its plume into Hudson Bay, and two permafrost-influenced rivers. Salinity gradients in the fresh to marine transition zone influenced microbial community structure by changing the taxonomic composition, including decreased richness of eukaryotes. The two permafrost-influenced rivers were more strongly influenced by their watersheds, as indicated by optical analysis of dissolved organic carbon (DOC). This variation in DOC concentrations, along with salinity, were the main factors explaining community dissimilarities among sites. Finally, we identified a ubiquitous bacterial core community suggesting that most of the community consists of generalist taxa, potentially adaptable to different environmental conditions. Our findings provide an improved understanding of microbial diversity and associated drivers in northern rivers and their transition to the sea.

Insights into metal tolerant bacterial diversity associated with a glacio-marine system in Ny-Ålesund, Arctic

Femi Anna Thomas, Arctic Ecology and Biogeochemistry Division, National Centre for Polar and Ocean Research, Ministry of Earth Sciences (Govt of India), Vasco da Gama, Goa, India
K. P. Krishnan, Arctic Ecology and Biogeochemistry Division, National Centre for Polar and Ocean Research, Ministry of Earth Sciences (Govt of India), Vasco da Gama, Goa, India

Keywords: Metals, Retrievable Bacterial Count, Glacier, Fjord, Antibiotic Resistance

The long-range transport of pollutants especially metals, via atmospheric and oceanic circulation along with the localized anthropogenic influence have contributed to their release and accumulation in various Arctic ecosystems. In this study, we aim to understand the metal tolerant bacterial diversity associated with a glacio-marine system in Arctic by enrichment with different metals such as Hg, Cd, Pb, Ni, Co, Zn and Mn. The highest total retrievable bacterial count was noted for Ni and Mn amendments while the lowest count was noted for Hg amendments. 106 metal tolerant isolates identified belonged to 55 bacterial species representing the phylum Proteobacteria, Actinobacteria, Bacteroidetes and Firmicutes. Presence of metal-resistance genes belonging to czcA(6), czcC(25), czcD(5) and merA(11) category corresponding to Cd/Zn/Co efflux protein and mercuric reductase was noted. Maximum tolerable concentration for Hg was 10µM, Cd and Pb was 250 µM, Co, Ni, Zn was 1mM and Mn was 10 mM. Twenty multi-metal tolerant isolates were further investigated for their antibiotic resistance wherein 90% of the selected isolates showed resistance to 2 or more antibiotics. Multiple antibiotic resistance noted for the metal tolerant bacterial isolates suggests either cross- or co-resistance mechanisms in bacteria. Thus, our study reports the presence of bacteria having multi-stress tolerant potentials from the glacier and fjord systems in Arctic which can provide a baseline for future studies.

Rare bacterial taxa shape the bacterioplankton community structure in the fjords of west and northern Svalbard, Arctic

Siddarthan Venkatachalam, Arctic Ecology and Biogeochemistry Division, National Centre for Polar and Ocean Research, Ministry of Earth Sciences, Goa, India
K.P. Krishnan, Arctic Ecology and Biogeochemistry Division, National Centre for Polar and Ocean Research, Ministry of Earth Sciences, Goa, India

Keywords: Fjord ecosystem, 16S rRNA amplicon sequencing, bacterioplankton community structure,

The fjords of Svalbard, Arctic are highly dynamic due to the influence of distinct water masses viz. the warm Atlantic Water (AtW) advected to the western part of the island by West Spitsbergen Current and cold Arctic Water (ArW) steered along the South Eastern tip of Spitsbergen and further carried northward through nearshore coastal area by Sørkapp and East Spitsbergen Currents. Convergence and mixing of these two water masses (AtW and ArW) occur at the West Spitsbergen Shelf, which influence the hydrodynamics of the adjacent fjords. In addition, increased freshwater runoff due to rapid melting of glaciers are also known to influence the bacterioplankton community structure and its functions. However, majority of the past studies were very much limited to single fjord systems around this region, limiting intra fjord comparison on bacterioplankton diversity and distribution patterns. In the present study, we investigated, (1) the bacterial diversity and community composition across three Arctic fjords located in the western and northern region of Svalbard, (2) the influence of environmental variables on the relationship between community assembly and distribution-dispersal patterns and (3) performed comparative meta-analysis along with the Kongsfjorden system. Our observations show that the bacterial community structure varied significantly between the fjords of western and northern Svalbard, and taxa belonging to rare bacterial groups mainly contributed to these differences.

Degradation of terrigenous dissolved organic matter in Arctic coastal waters: importance of the priming effect and identification of microbial actors

Lucas Tisserand, Laboratoire d'Océanographie Microbienne UMR7621 CNRS-SU, Banyuls sur Mer, France
Fabien Joux, Laboratoire d'Océanographie Microbienne UMR7621 CNRS-SU, Banyuls sur Mer, France

Keywords: Biodegradation, Permafrost, Microbial Communities, Priming Effect, Arctic

Up to 33% of the DOM in the Arctic Ocean is of terrestrial origin (tDOM), and a large fraction of this DOM comes from carbon-rich soils and peat bogs. Permafrost contains twice as much carbon as the earth's atmosphere. Because of global warming, the tDOM accumulated in the permafrost is being released from the ice and brought to the sea. The dissolved organic carbon (DOC) can then serve as an organic substrate for microorganisms and be metabolized during its transfer to the Arctic Ocean, releasing CO2 or methane. Some recent studies show that DOC from melting permafrost is more labile than previously admitted to being refractory to microbial degradation. In this context, we performed biodegradation experiments at three stations in the Mackenzie Delta region (from fluvial to marine water) to study the degradation of natural DOM (nDOM), nDOM with permafrost, nDOM with diatom exudates, nDOM with permafrost and diatom exudates. DOC degradation was followed in parallel to the analysis of microbial (bacteria and fungi) communities composition by Illumina sequencing. The data produced will improve our understanding of the degradation processes of the tDOM released during the melting of Arctic permafrost and the responses of microbial communities to current environmental changes, as well as test the priming effect hypothesis (labile organic carbon might trigger the degradation of previously unreactive organic matter).

Seasonal shifts in microbial dormancy and activity in Beaufort Sea coastal lagoons

Natasha A. Griffin, Oregon State University, Corvallis, USA
Kristina D. Baker, Oregon State University, Corvallis, USA
James W. McClelland, University of Texas Marine Science Institiute, Port Aransas, USA
Byron C. Crump, Oregon State University, Corvallis, USA

Keywords: Beaufort, Lagoons, Microbial, Dormancy, Seasons

Microbial communities in Arctic coastal lagoons persist through extreme seasonal fluctuations as they process massive terrestrial inputs during the spring freshet, and then adjust to severe resource depletion during the ice-covered winter. Recent work identified high seasonal turnover of taxa and genes in Arctic lagoon waters, but sediment community composition was surprisingly stable. Some microbial taxa likely survive seasonal shifts by entering a low-activity dormant state until conditions become more favorable. Understanding patterns of microbial dormancy provides crucial context for lagoon ecosystem processes, but the degree to which lagoon microbial communities are dormant or active across seasons remains undetermined. To identify active and dormant microbial communities, we collected water and sediment samples from six lagoons spanning the Alaskan Beaufort Sea coast in April, June, and August of 2019. Bacterial and eukaryotic communities were profiled using rRNA gene amplicon sequencing. We defined dormant taxa as those identified via DNA but not RNA sequences, while active taxa were identified using RNA. To assess potential environmental drivers of microbial activity, we also measured nutrient concentrations and physicochemical parameters. We hypothesized that low residence times and high resources would promote more active water column communities in spring, while winter communities would host more dormant taxa responding to resource depletion and stress.

Antibiotic resistance in cryosheric habitats

Daniel Gattinger, University of Innsbruck, Institute of Ecology, Innsbruck, Austria
Klemens Weisleitner, University of Innsbruck, Institute of Ecology, Innsbruck, Austria
Birgit Sattler, University of Innsbruck, Institute of Ecology, Innsbruck, Austria

Keywords: Antibiotic Resistance, Cryosphere, Polar, Alpine

In recent years, antibiotic (AB)-resistances are attracting attention more and more concentrating mostly on the anthropogenic impact on the rise of (multi-)resistant microorganisms. Only a few studies focus on natural habitats of which mainly terrestrial environments harbor the majority of antibiotic substances and hence also the coexisting microorganisms. This work provides a detailed report about the status of antibiotic-resistances in the cryosphere of polar and alpine regions and sets the focus on the identification of culturable resistant psychrophilic and psychrotolerant bacteria. To evaluate AB-resistance, agar-plates were mixed with six different antibiotics (natural, semi-synthetic and synthetic) to culture previously isolated bacteria from snow, ice, and air samples and checked for growth. With this method, out of 62 isolates, 61 could be identified as resistant whereby 50% of all bacteria could not be inhibited in growth by at least five antibiotics. Even though more research like broth dilution and molecular screening for antibiotic-resistance-genes needs to be done to gather more information about natural resistance mechanisms, the results of this work clearly show that AB-resistances are a global phenomenon and also present in anthropogenically relatively unaffected environment due to intrinsic resistance mechanisms and the global distribution via different vehicles.

Repertoire of membrane transporters encoded in the Arctic picophytoplankton Micromonas Polaris (Mamiellophyceae, Chlorophya) genomes

Margot Tragin, Living System Institute, University of Exeter, Exeter, United Kingdom
Victoria Jackson, Living System Institute, University of Exeter, Exeter, United Kingdom
Connie Lovejoy, Institut de biologie Intégrative et des systèmes, Université Laval, Québec, Canada
Adam Monier, Living System Institute, University of Exeter, Exeter, United Kingdom

Keywords: Arctic Microalgae, Micromonas Polaris, Comparative Genomics, Membrane Transporters

Micromonas is a ubiquitous genus of marine green pico-sized algae that can dominate temperate coastal waters, but also polar waters. Morphologically, Micromonas is a naked monoflagellated pico-algae; its plasma membrane is therefore the first exchange interface with marine waters. Putative transmembrane proteins, a subset of which could be membrane transporters, from 10 newly sequenced and de novo assembled using both Nanopore long and Illumina short reads M. polaris genomes and the already public M. commoda and M. pusilla genomes were predicted using hidden Markov models. The genes coding for proteins with at least one membrane domains predicted were extracted from the genomes. These subsets of genes predicted to code for transmembrane proteins represented around 18% of complete genomes. These genes were carefully functionnally annotated and classified. Their putative role in biological pathways as well as their evolutionnary history were investigated using phylogenetic analysis programs. Then, the gene subsets of each Micromonas strain were compared. These comparisons allowed to estimate the individual and intra-species varibility of M. polaris strains. Investiating putative transporters in M. polaris gave a valuable insight into the physiological adaptation of Micromonas to polar waters in comparison to a temperate Micromonas species.

Diversity and metabolic profiles of prokaryotic communities in extra-terrestrial analogues on Earth: perennially ice-covered Antarctic lake brines

Papale Maria, Institute of Polar Sciences, National Research Council (CNR-ISP), Messina, Italy
Angelina Lo Giudice, Institute of Polar Sciences, National Research Council (CNR ISP), Messina, Italy
Carmen Rizzo, Stazione Zoologica Anton Dohrn , National Institute of Biology, Department of Marine Biotechnology, Messina, Italy
Maurizio Azzaro, Institute of Polar Sciences, National Research Council (CNR ISP), Messina, Italy
Gabriella Caruso, Institute of Polar Sciences, National Research Council (CNR ISP), Messina, Italy
Giovanna Maimone, Institute of Polar Sciences, National Research Council (CNR ISP), Messina, Italy
Mauro Guglielmin, Department of Theoretical and Applied Sciences, University of Insubria, Varese, Italy

Keywords: Prokaryotic Communities, Metabolic Profiles, Brines, NGS, Antarctica

Several polar environments encapsulate brine pools characterized by a unique combination of extreme conditions, mainly in terms of high salinity and low temperature. To explore the biodiversity and ecological role of prokaryotes in terrestrial cryosystems, brine pockets from three lakes in the Northern Victoria Land (lying in the Tarn Flat, TF, and Boulder Clay, BC, areas) were analysed by NGS (including the predictive functional analysis on 16S rRNA gene data), extracellular enzyme activities and microbial abundances. The analysed cryo-environments were different in terms of prokaryotic diversity, abundance and retrieved metabolic pathways. By the analysis of DNA sequences, common operational taxonomic units were in the range 2.2-22.0%. The bacterial community was dominated by Bacteroidetes. In both BC and TF brines, sequences of the most thermally tolerant and methanogenic Archaea were detected, some of them related to hyperthermophiles. The prediction analysis of metabolic functions highlighted that prokaryotic communities were involved in methane metabolism, aromatic compounds biodegradation and organic compound (proteins, polysaccharides, phosphates) decomposition. The influence exerted by environmental parameters on the community composition and activities is discussed. Our findings indicate perennially ice-covered Antarctic lake brines as plausible terrestrial candidates for the study of the potential for extant life on different bodies of our Solar system.

In-silico analysis of functional annotations in cold active BgalEL from an Arctic psychrotrophic bacterium Enterobacter ludwigii

Aneesa P A, Department of Marine Biology, Microbiology and Biochemistry, CUSAT, Cochin-682016, Department of Biochemistry, SSC, Kalady-683574
Jesmi Yousuf, Department of Marine Biology, Microbiology and Biochemistry, CUSAT, Cochin-682016.
K P Krishnan, National Centre for Polar and Ocean Research, MoES, Vasco-da-Gama, Goa
A A M Hatha, CUSAT-NCPOR Centre for Polar Sciences, School of Marine Sciences, CUSAT, Cochin – 682016

Keywords: Active Site, Cold Active B-Galactosidase, Functional Annotations, Glycosyl Hydrolases

Reliable prediction of the structure of a protein from its sequence using functional annotation systems could add well-grounded information to protein function. In-silico analysis of BgalEL sequence, a cold active hydrolase from GH 2 family, in Pfam database revealed the presence of five distinct functional domains, GH family 2 N sugar binding domain, GH family 2 C domain, TIM barrel domain, DUF domain and Bgal_small_N domain. A comparison of topology of Pfam domains demonstrated similarity to the topology of ß-galactosidase from Pseudoalteromonas sp.BgalEL shared sequence homology with the acid/base catalytic sites in the vicinity of catalytic glutamic acid residues and also with the consensus nucleophilic regions of all other known cold active ß-galactosidases. I-Tasser analysis predicted Glu462 and Glu538 in the active cluster as the catalytic residues of cold active BgalEL.

Arctic tundra microbiomes in relation to relative humidity and soil properties

Lotte De Maeyer, Laboratory of Protistology and Aquatic Ecology, Ghent University, Krijgslaan 281 S8, 9000 Ghent, Belgium
Christophe V.W. Seppey, Department of Arctic and Marine Biology, UiT The Arctic University of Norway, Framstredet 39, 9037 Tromsø, Norway
Bjorn Tytgat, Laboratory of Protistology and Aquatic Ecology, Ghent University, Krijgslaan 281 S8, 9000 Ghent, Belgium
Mette M. Svenning, Department of Arctic and Marine Biology, UiT The Arctic University of Norway, Framstredet 39, 9037 Tromsø, Norway
Elie Verleyen, Laboratory of Protistology and Aquatic Ecology, Ghent University, Krijgslaan 281 S8, 9000 Ghent, Belgium

Keywords: High-Arctic Tundra Soil, Microorganisms, Moisture Availability, Global Climate Change, Surface And Subsoil Community Structure

High-Arctic tundra soils are major carbon reservoirs expected to increasingly impact the global climate through microbial climate change responses. The effects of predicted changing precipitation regimes on Arctic soil microbiomes are poorly understood. We studied surface and subsoil microbial communities along 2 moisture gradients in Kongsfjorden (79° N, Svalbard) using HT- sequencing of the bacterial 16S and eukaryotic 18S rRNA genes. Relative humidity (RH) was the most important factor structuring the surface communities of Bacteria and Eukarya significantly explaining 14.2 and 13.9% of the variation in their respective composition. Total C significantly contributed to the community structure of Eukarya in the soil surface, while total N significantly co-structured bacterial communities, albeit both to a lower degree than RH. Both subsoil communities were also significantly impacted by RH, albeit to a lower degree compared to surface soils. The CN ratio and silt content structured the subsoil bacterial and eukaryotic communities, in general more or equally compared to RH in both communities respectively. Total N also had a significant impact on subsoil eukaryotic structure. We conclude that RH and other abiotic factors have different effects on the top and subsoil microbial communities in tundra soils. The potential impact of climate change through i.a. shifting moisture availability will likely result in contrasting effects between top and subsoil microbial communities.

Changes in microbial diversity and ecology in Arctic freshwater biofilms across a broad latitudinal gradient (56-83 °N)

Patrick M. Hooper, Natural History Museum, London, United Kingdom
Christopher J. Owen, UCL Genetics Institute, University College London, London, United Kingdom
David Bass, International Centre of Excellence for Aquatic Animal Health, Cefas, Weymouth, United Kingdom
Edward J. Feil, Milner Centre for Evolution, University of Bath, United Kingdom,
Warwick F. Vincent, Centre for Northern Studies (CEN), Laval University, Quebec City, Canada
Anne D. Jungblut, Natural History Museum, London, United Kingdom

Keywords: Microbial Ecology, Freshwater, Amplicon Sequencing,

Diverse freshwater ecosystems, ranging from permafrost thaw ponds to ice-covered lakes and melt pools, span northern latitudes from the Subarctic to High Arctic, and commonly contain cyanobacteria-based microbial mat communities. An established concept in macroorganismal ecology is the latitudinal diversity gradient (LDG). However, investigations of LDG in microbial ecology have been limited. In this investigation, samples were taken from Arctic freshwater ecosystems across a latitudinal gradient (56-83°N). Arctic freshwater ecosystems pose an exciting environment in which to test this ecological theory, due to the diversity of aquatic habitats and simplified food-web structure relative to temperate latitudes. Developments in environmental DNA sequencing have revolutionised our ability to understand microbial ecology. By utilising small-subunit 16S and 18S rRNA gene-targeted amplicon sequencing, we aim to describe community assemblages and identify changes in bacterial and eukaryotic diversity, and ecological function in Arctic freshwater ecosystems. Furthermore, studying Arctic microbiomes across a latitudinal gradient provides opportunities to help understand microbial biogeography and the vulnerability of high-latitude aquatic ecosystems to rapid climate change.

ID: 71 - Biodiversity at Northern Latitudes: a Focus on Wetland and Freshwater Ecological Connectivity

Conveners

Skúli Skúlason | Hólar University, Iceland

Jennifer Lento | University of New Brunswick, Canada

Camille Leblanc | Hólar University, Iceland

Exploring biological diversity of Arctic freshwater organisms: Do conservation goals change when looking at structural versus functional diversity?

Brianna Levenstein, University of New Brunswick, Fredericton, Canada
Jennifer Lento, University of New Brunswick, Fredericton, Canada
Daniel Bogan, Alaska Center for Conservation Science, University of Alaska Anchorage, Anchorage, United States
Joseph Culp, Wilfrid Laurier University, Waterloo, Canada
Willem Goedkoop, Swedish University of Agricultural Sciences, Uppsala, Sweden
Mariah Kahlert, Swedish University of Agricultural Sciences, Uppsala, Sweden
Isabelle Lavoie, INRS - ETE, Quebec City, Canada
Jordan Musetta-Lambert, Environment and Climate Change Canada, Waterloo, Canada
Rebecca Shaftel, Alaska Center for Conservation Science, University of Alaska Anchorage, Anchorage, United States

Keywords: Circumpolar, Rivers, Lakes, Diatoms, Macroinvertebrates

Most assessments of diversity in Arctic freshwaters focus on structural diversity, i.e., the number and composition of taxa at local or regional scales. But changes in community structure may not result in alterations to ecosystem function if there is strong niche overlap among taxa, leading to functional redundancy. In Arctic freshwaters, where the number of taxa is often limited due to the exceedance of environmental tolerance thresholds, functional diversity and redundancy have not been widely studied, despite the importance of understanding how ecosystem function may change with continued warming. Furthermore, northward range expansion may alter functional composition of these systems as taxa that occupy a different functional niche are introduced. In this presentation, we will provide an overview of the approach that is being taken in the ARCTIC-BIODIVER project to quantify functional diversity of Arctic freshwaters across the circumpolar region, including compilation of circumpolar trait data, selection of relevant traits, and preliminary patterns of trait distribution along latitudinal gradients.

Indigenous partnered research to address biodiversity knowledge gaps and community ecological concerns: a case study from the lower Mackenzie Watershed, Canada

Jordan Musetta-Lambert, Environment and Climate Change Canada
Joseph Culp, Wilfrid Laurier University
Kirt Ruben, Joint Secretariat - Inuvialuit Settlement Region

Keywords: Indigenous-Partnerships, Aquatic Macroinvertebrates, Biodiversity, Decomposition

Anthropogenically driven climate change poses a risk to structural and functional biodiversity in Canada's Arctic freshwaters. In lakes and streams along the Dempster and Inuvik-Tuktoyaktuk highways in the Mackenzie River watershed of northern Canada, ecological impacts of road development may be exacerbated by climate change through increased sediment inputs caused by road erosion, permafrost slumping, and changes in hydrology. The impacts of road development on ecosystem services provided by the freshwaters in the region is of concern to the local communities that use this land. To study the effects of road development in an area of abrupt climate change, we collaborated with the Indigenous-led Imaryuk Monitors in the Inuvialuit Settlement Region to collect data through a combination of direct biodiversity observation of aquatic macroinvertebrates and the use of decomposition bioassays as a measure of ecosystem function. There currently exists a paucity of spatial and temporal biodiversity data related to freshwater biota in the lower Mackenzie River watershed and throughout much of Canada's Arctic freshwaters despite this region being vulnerable to climate stress and future development. This presentation will give an overview of how research opportunities can be developed to address the environmental concerns of local northern communities that has the added benefit of filling spatial and temporal knowledge gaps in biodiversity data.

Recent Trends in Nest Densities of Arctic Birds in Chaun Delta, Chukotka, Russia, as Related to the Climate Change

Diana V Solovyeva, Institute of Biological Problems of the North, Magadan, Russia
Daria A Barykina, Institute of Biological Problems of the North, Magadan, Russia

Keywords: Arctic Birds, Climate Change, Russian Arctic, Biodiversity

Recent climate warming is pronounced in Beringia and effects tundra habitats on both sides of Bering Strait. There are a very few camps that are conducting long-term monitoring of Arctic nesting birds in Western Beringia on the Russian side of the strait. Nest densities of all bird species have been monitored at lowland wet tundra of Chaun delta, Western Chukotka, between 2011 and 2018. Nesting density of “large” birds (all but shorebirds and passerines) was estimated for nine 1 km2 plots (9 km2 in total) and nesting density of shorebirds was estimated for five 16 ha plots (80 ha in total). Two searches by 2 people for all large bird nests was made in early June – mid July each year. Shorebird plots were searched two to four times each using single person nest search and rope-dragging by 3-4 people. Gull colonies were estimated by visual counts of nests. We found the density of Long-tailed duck and Arctic tern, despite being “large” bird species, were better estimated on small shorebird plots, searched more intensively than large plots. Arctic birds, associated with Bering Sea during the non-breeding period, showed pronounced decline in nest density in Chaun delta, as follows Glaucous gull, Spectacled eider and Red-necked phalarope; Red phalarope had declined previously before our study. We reported decreasing of Sabine’s gull colonies to almost disappearance from Chaun delta. Vega gull and Pacific loon density was stabilized after increase in 1980th-2000th probably resulted from favorable food situation on breeding and wintering grounds related to the climate. Long-tailed duck had stable nest density. Bewick’s swan density was declining after 10-fold increase and we attribute this decline to density-dependent autoregulation; this decline reduced competition to geese species that appeared on nesting in Chaun delta in small number during last years. Warming didn’t affect densities of the most common shorebirds (Dunlin, Temminck’s stint and Ruff) in Chaun delta; density of Pectoral sandpiper increased.

Temperature and spatial connectivity limit benthic macroinvertebrate biodiversity across Arctic lakes and rivers

Jennifer Lento, Canadian Rivers Institute and University of New Brunswick, Fredericton, Canada
Joseph M. Culp, Environment and Climate Change Canada and Wilfrid Laurier University, Cold Regions Research Centre, Waterloo, Canada
Brianna Levenstein, Canadian Rivers Institute and University of New Brunswick, Fredericton, Canada
Jukka Aroviita, Freshwater Centre, Finnish Environment Institute, Oulu, Finland
Maria A. Baturina, Institute of Biology, Komi Scientific Centre of the Ural Branch of the Russian Academy of Sciences, Syktyvkar, Russia
Daniel Bogan, Alaska Center for Conservation Science, University of Alaska Anchorage, Anchorage, USA
John E. Brittain, Norwegian Water Resources and Energy Directorate and Natural History Museum, University of Oslo, Oslo, Norway
Krista Chin, Cumulative Impact Monitoring Program, Government of the Northwest Territories, Yellowknife, Canada
Catherine Docherty, School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham, UK
Arni Einarsson, Mývatn Research Station, Myvatn, Iceland
Nikolai Friberg, Norwegian Institute for Water Research, Oslo, Norway and Freshwater Biological Section, University of Copenhagen, Copenhagen, Denmark
Jani Heino, Freshwater Centre, Finnish Environment Institute, Oulu, Finland
Finnur Ingimarsson, Natural History Museum of Kópavogur, Kopavogur, Iceland
Dean Jacobsen, Freshwater Biological Section, University of Copenhagen, Copenhagen, Denmark
Danny Chun Pong Lau, Climate Impacts Research Centre, Department of Ecology and Environmental Science, Umeå University, Abisko, Sweden
Olga A. Loskutova, Institute of Biology, Komi Scientific Centre of the Ural Branch of the Russian Academy of Sciences, Syktyvkar, Russia
Alexander Milner, School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham, UK
Heikki Mykrä, Freshwater Centre, Finnish Environment Institute, Oulu, Finland
Anna A. Novichkova, Department of Ecology and Hydrobiology, Biological Faculty, Moscow State University, Moscow, Russia
Jón S. Ólafsson, Marine and Freshwater Research Institute, Reykjavík, Iceland
Ann Kristin Schartau, Norwegian Institute for Nature Research, Oslo, Norway
Rebecca Shaftel, Alaska Center for Conservation Science, University of Alaska Anchorage, Anchorage, USA
Willem Goedkoop, Department of Aquatic Sciences and Assessment, Swedish University of Agricultural Sciences, Uppsala, Sweden

Keywords: Benthic Macroinvertebrate, Freshwater, Diversity, Temperature, Connectivity

Climate change is causing unprecedented changes to Arctic freshwater ecosystems through alterations to thermal and hydrologic regimes, which are predicted to have a significant effect on freshwater biodiversity. Temperature increases in the Arctic will allow for northward range expansion of southern species, but these distributional shifts will depend in part on spatial connectivity, with delays in biodiversity change likely on Arctic islands. To investigate trade-offs between temperature change and connectivity, we examined spatial patterns in macroinvertebrate diversity using a circumpolar dataset of > 1500 Arctic lake and river sites.

Alpha diversity was strongly related to temperature for both lakes and rivers, with the lowest diversity at the coldest sites. Alpha diversity declined with increasing latitude, reflecting latitudinal temperature gradients, though the pattern for lakes was stronger in mainland regions than on islands. Diversity declined sharply above approximately 65-68°N, corresponding to the northern border of mainland regions in the Arctic. Furthermore, beta diversity was highest when mainland regions were compared with island regions, which indicated that differences in connectivity led to strong compositional differences. With continued warming, diversity in lakes and rivers is expected to increase as less cold-tolerant taxa move north, but current patterns of diversity indicate that connectivity will limit the rate at which northward migrations occur.

Using bacterial diversity to predict greenhouse gas emissions from boreal lakes

Nicolas Valiente, Centre for Biogeochemistry in the Anthropocene, Department of Biosciences, University of Oslo, Oslo, Norway
Laurent Fontaine, Centre for Biogeochemistry in the Anthropocene, Department of Biosciences, University of Oslo, Oslo, Norway
Jing Wei, Centre for Biogeochemistry in the Anthropocene, Department of Biosciences, University of Oslo, Oslo, Norway
Camille Crapart, Centre for Biogeochemistry in the Anthropocene, Department of Chemistry, University of Oslo, Oslo, Norway
Peter Dörsch, Faculty of Environmental Sciences and Natural Resource Management, Norwegian University of Life Sciences, Ås, Norway
Alexander Eiler, Centre for Biogeochemistry in the Anthropocene, Department of Biosciences, University of Oslo, Oslo, Norway
Dag O. Hessen, Centre for Biogeochemistry in the Anthropocene, Department of Biosciences, University of Oslo, Oslo, Norway

Keywords: Boreal Lakes, Greenhouse Gases, 16S Metabarcoding, Bacterial Diversity, Browning

The Northern latitudes contain the highest density of inland water bodies on Earth. Among them, boreal lakes are most abundant. Due to climate change, catchment changes and other drivers, increased fluxes of organic carbon are causing a widespread "browning" of these ecosystems, affecting community composition, diversity and ecosystem processes such as productivity and greenhouse gas (GHG) emissions. Boreal lakes are important sources of GHG, and lake browning is a positive feedback loop since microbial conversion or organic C to GHGs promotes further climate warming. To understand this climate feedback loop, we studied a gradient of boreal lakes (n=73) with different organic matter inputs and catchment characteristics. By analyzing eDNA we gain information about biodiversity across phyla and taxa which is stored for later processing and analysis. We specifically test the hypothesis that bacterial diversity may be a relevant indicator for GHG emissions, as bacteria play a key role in controlling food web processes and biogeochemical cycles in such ecosystems. Nutrients and GHG (CO2, CH4 and N2O) were analyzed in the water samples, and further combined with 16S rRNA gene metabarcoding. While bacterial taxonomic diversity is predicted to be catchment specific, our findings suggest that community composition can be also used as a proxy for GHG emissions in boreal lakes. This study provides a better understanding about the potential of bacterial diversity to predict GHG fluxes.

Climate-change induced landscape alterations causes severe lake oligotrophication in Northern Scandinavia

Willem Goedkoop, Dept Aquatic Sciences and Assessment, Swedish University of Agricultural Sciences (SLU), Uppsala, Sweden
Sven Adler, Dept Forest Resource Management, SLU, Umeå, Sweden
Martyn Futter, Dept Aquatic Sciences and Assessment, SLU, Uppsala, Sweden
Brian Huser, Dept Aquatic Sciences and Assessment, SLU, Uppsala, Sweden
Hans Gardfjell, Dept Forest Resource Management, SLU, Umeå, Sweden

Keywords: Land-Water Interactions, Lake Oligotrophication, Landscape Greening, Total Phosphorus

Long-term monitoring has shown that many lakes in the Arctic/alpine ecoregion of Sweden have experienced dramatic declines (3–4% per y) in total-phosphorus (TP) concentrations since the late 1980s, forcing these lakes into ultraoligotrophic conditions. We hypothesized that the increased greening of catchments, due to increased vegetation growth in the region (i.e. greening), can explain a large share of the observed declines in surface water TP concentrations. We used two approaches to test this: (1) quantify the greening of these landscapes and the onset/duration of the growth season using remote sensing data (NDVI), and (2) process-based and empirical modeling to calculate the increase in TP-retention in these landscapes. Results show that there is a strong correlation between the loss of surface water TP and the greening of catchments. This shows that the climate-induced effects on landscape processes are already leading to the redistribution of nutrients between terrestrial and aquatic habitats. The ongoing severe oligotrophication of these lakes will negatively affect the production of algae, invertebrate consumers, and ultimately fish. Indeed, phytoplankton data show a shift in community composition towards a larger share of mixotrophs, suggesting an adaptation to more nutrient-poor conditions. Our findings also stress the need for monitoring to detect these changes and suggest that surface water oligotrophication may be going on in large parts of a greening Arctic.

Freshwater zoobenthos of the Severnaya Zemlya Archipelago

Andrey B. Krasheninnikov, Institute of Biological Problems of the North Far East Branch of the Russian Academy of Sciences, Magadan, Russia
Maria V. Gavrilo, Association Maritime Heritage, St. Petersburg, Russia

Keywords: Severnaya Zemlya, Zoobenthos

During multidisciplinary expedition Open Ocean: Arctic Archipelagos – 2019. Severnaya Zemlya, in late summer 2019, freshwater bodies of 7 islands were surveyed (Komsomolets, Pioneer, October Revolution, Bolshevik, Krasnoflotskie, Heiberg, Maly Taimyr). Zoobenthos was present in all studied water bodies (5 lakes, 4 rivers, 5 streams). Zoobenthos composition included Chironomidae & Simuliidae (Insecta), Enchytraeidae (Oligochaeta), Gammaridae & Harpacticoida (Crustacea), Planariidae (Plathelminthes). Benthic communities were dominated by Chironomid larvae and Oligochaets. Gammarids were tied up with marine mouths of the streams only. Single larva of Simuliidae was found in a pond on the northernmost island of Komsomolets. This is the first record of the family on the Severnaya Zemlya. Surveyed water bodies lacked such typical for the lower Arctic zone benthic taxa as Mollusca, aquatic Coleoptera, Ephemeroptera, Plecoptera, Trichoptera. By the representativeness of higher taxa, the fresh waters of Severnaya Zemlya are richer than waters of Franz-Josef Land, but less diverse than waters of Novaya Zemlya, which corresponds to its intermediate latitudinal position.

The structure and the main patterns of benthic and planktonic copepod associations formation in the arctic lakes (the Lena River Delta, Eastern Siberia)

Anna A Novichkova, Biological Faculty Moscow State University, Moscow, Russian Federation; Severtsov Institute of Ecology and Evolution, Moscow, Russian Federation
Elena S Chertoprud, Biological Faculty Moscow State University, Moscow, Russian Federation; Severtsov Institute of Ecology and Evolution, Moscow, Russian Federation

Keywords: Meiobenthos, Zooplankton, Eastern Siberia, Lena River Delta, Thermokarst

The main aim of this study is the analysis of the communities of zooplanktonic and meiobenthic Copepoda in the lakes of the Lena River Delta. An attempt to identify the common patterns of copepods associations formation in thermokarst waterbodies has been made. The research was based on the material collected in lakes of various origin on two islands Kurungnakh and Argaa-Bilir-Aryata in central part of the Lena Delta in August 2017 and July 2020. The analysis of 32 complex samples revealed 39 species of Copepoda. Of them, 6 are new to the region. Based on the original and literature data, a general list of the currently known Copepoda fauna of the Lena River Delta has been compiled. The fauna has been identified as having several sources of origin. Its basis are indigenous Arctic species, and also includes invasive taxa of temperate latitudes and ice age relics. The most important factors for the formation of Copepoda associations are the age of the water body, the mineralization and pH of the water. It is shown that the composition of benthic Copepoda of waterbodies of the Lena River Delta is characterized by high abundances and species richness of Harpacticoida. The biogeographical status of the Copepoda fauna of the Lena Delta has been assessed, and its similarity with other Arctic regions has been determined. The study was supported by the Russian Foundation for Basic Research [Project ? 20-04-00145a].

Rare plant species in alkaline fens in the eastern Fennoscandian Arctic: bottlenecks of survival and protection

Ilona Blinova, Polar-Alpine Botanical Garden-Institute, Murmansk Region, Russia

Floristically rich alkaline fens occur sporadically all over Europe in sites with calcium-rich bedrocks and have recently found in the eastern Fennoscandian Arctic. In Murmansk Region of 169 vascular plant species, 55 mosses and two fresh water macroalgae recorded in these habitats, 22 are rare species mostly from Orchidaceae and Cyperaceae. These habitats occupy extremely small isolated areas (0.04-3.8 ha) with expressed soil reaction gradient (6.7–7.4). Four aggregation patterns have been distinguished in the spatial structure of plant populations. They seem to be linked with the calcium content in soil and a degree of species specialization. Bottlenecks in species biology related to the species rarity are a combination of mostly short life cycles with 1) insect pollination, reduced seed set and complex germination, or with 2) wind seed dispersal and availability of small pits with a restricted pH and high water table, 3) intraspecific aggregation and low competition, 4) high sexual reproduction cost. Recent climatic influences (higher temperatures and higher fluctuations of snow cover and rainfall) which alter water balance may be crucial for these habitats. Further studies, control and management could protect species richness of these unique habitats in the eastern Fennoscandian Arctic.

ID: 56 - Climate change and its impact on ecosystems in subarctic Eurasia

Conveners

Gareth Marshall | British Antarctic Survey

Olga Tutubalina | MV Lomonosov Moscow State University

Polina Mikhaylyukova | MV Lomonosov Moscow State University

Climate-driven phenological changes in the Russian Arctic derived from MODIS LAI time series 2000-2019

Nikolay Shabanov, Center for Forest Ecology and Productivity of the Russian Academy of Sciences (CEPF RAS)

Keywords: MODIS, LAI, Phenology, Climate Change, Arctic

Arctic surface temperature has increased at approximately twice the global rate over the past few decades and is also projected to warm most in the 21st century. The mechanism of Arctic vegetation response to this warming remains largely uncertain. Here, we analyse variations in the seasonal profiles of MODIS Leaf Area Index (LAI) and ERA-interim cumulative near-surface air temperature (SAT?) over the northern Russia north of 60°N for 2000-2019. We find that seasonal LAI trends form an inverted S-shape over the course of the growing season with enhanced green-up and senescence and nearly no change during the seasonal peak. Spatial patterns of LAI trends are strongly correlated with SAT? trends during the green-up, while causes of the browning trends during senescence remain unclear. The strength, duration and timing of the changes depend on vegetation type: enhanced green-up is most pronounced in tundra, while enhanced senescence is pronounced in forests. Funding source: This study was performed within the framework of the state assignment of the Center for Forest Ecology and Productivity of the Russian Academy of Sciences (no. ????-?18-118052590019-7), and was financially supported by the Russian Science Foundation (project no. 19-77-30015).

How well do current climate reanalyses reproduce climate change across northern Russia?

Jack Tomaney, University of Cambridge, Cambridge, United Kingdom
Gareth Marshall, British Antarctic Survey, Cambridge, United Kingdom

Keywords: Russia, Reanalysis, Climate Change, Temperature, Precipitation

In this presentation we discuss the accuracy of five modern reanalyses in describing the surface climate of northern Russia where ground-based observations can be sparse. The reanalyses are compared against observed surface air temperature (SAT) and precipitation (PPN) measurements from ~65 Russian meteorological stations, from north of 65° latitude over the 40-year period from 1979–2018. The reanalyses we evaluate are the Climate Forecast System Reanalysis (CFSR), the Japanese Meteorological Agency 55-year reanalysis (JRA-55), the National Aeronautics and Space Administration's second Modern-ERA Retrospective Analysis for Research and Applications (MERRA2), and the European Centre for Medium-Range Weather Forecast's Interim reanalysis (ERA-Interim) and 5th Generation reanalysis (ERA5). Our initial results demonstrate that four of the reanalyses have an overall slight warm bias against observed SAT across northern Russia of 0.22-0.65°C, with MERRA typically 0.4-0.9 °C cooler than the others. All five reanalyses also generally have a positive PPN bias, with mean monthly values typically 10-20 mm greater than observed. We also examine the spatial and temporal variability of the accuracy of the reanalyses across northern Russia , including how well they reproduce the marked annual and seasonal trends in climate across this extensive region.

Regional biogeographic effects of climate changes in the Russian Arctic in the 21st century

Arkadiy Tishkov, Institute of Geography RAS, Moscow, Russia
Elena Belonovskaya, Institute of Geography RAS, Moscow, Russia
Svetlana Titova, Institute of Geography RAS, Moscow, Russia

Keywords: Arctic ecosystems, "greening" of Arctic, regional specifics, biota responces to climate change

With the 2nd cycle of "warming" in the Russian Arctic after 1930s - up to 0.8-0.9 C /10 years climate changes vary in the regions, and biota responds not only by different rates, but also by different directions. The "greening" of the Arctic (increasing the productivity), is revealed spatially unevenly and often due to different processes. The regions' "initial positions" of the state of the Arctic biota at the time of the "rapid" climate changes' beginning differed. All this allows us to conclude that models demonstrating the response of Arctic ecosystems to warming (Bala, et. al., 2005) – their almost complete disappearance with continuing temperature trends by the end of the 21st century are not correct. The methodology of "direct" assessments of the effects of temperature increases on biota by spatial extrapolations (shifting borders and replacing some biomes with others, the disappearance of cryophilic species and the expansion of thermophilic plant and animal species, etc.) does not take into account the regional specifics of the observed phenomena. It examines the regional biogeographic effects of climate change - changes in the composition of flora and fauna, population dynamics, presence of lemming cycles, species ranges (f. ex. dispersal of Atlantic, boreal and North American species), migrations. That is why we propose a methodology that takes into account the differences in biota responses to climate change in each region. There are 6 regions with different responses to climate change - Kola, Nenets, Yamal-Gydan, Taimyr, North Yakutia, North and South Chukotka, where the trends in the last 3 decades differed significantly in both the vector and intensity.

A multi-scale approach to studying disturbance dynamics in the tundra-forest ecotone: a decade of experience

Ole Petter Laksforsmo Vindstad/UiT-The Arctic University of Norway. Institute for Arctic and Marine Biology. Tromsø. Norway.
Jane Uhd Jepsen/Norwegian Institute for Nature Research. Tromsø. Norway.
Rolf Anker Ims/UiT-The Arctic University of Norway. Institute for Arctic and Marine Biology. Tromsø. Norway.
Nigel Gilles Yoccoz/UiT-The Arctic University of Norway. Institute for Arctic and Marine Biology. Tromsø. Norway.

Keywords: Mountain Birch, Moth Outbreak, Remote Sensing, Regional Ground Survey, COAT

The tundra-forest ecotone in northern Fennoscandia harbors extensive forests of mountain birch, where periodic outbreaks by defoliating geometrid moths are the main biotic disturbance factor. A decade ago, the massive, likely climate-change enhanced, scale and duration of ongoing outbreaks motivated a change from purely ground based monitoring to a multi-scale approach, including satellite monitoring of productivity anomalies, supported by versatile ground reference data. Here, we review what this multi-scale approach has contributed to the tundra-forest module of the Climate Ecological Observatory for Arctic Tundra (COAT), showing that its applications have gone well beyond the mapping and monitoring purposes that motivated the initial development. It has allowed extensive areas to be stratified according to the expected impact of moth outbreaks, thus permitting the design of regional-scale ground surveys of forest health and the response of plant and animal communities to forest state changes, as well as the allocation of experimental interventions. The construction of defoliation histories for ground sites based on remote sensing time series has also elucidated mechanistic aspects of ecosystem response to defoliation, including tipping points in the relationship between forest mortality and cumulative defoliation over several years. Future avenues involve the use of non-optical remote sensing data sources to monitor forest structure, and development of predictive models for forest mortality. This will require methodological advances, including techniques to interpret remote sensing signals for damaged forest and the transfer of data processing from local servers to more powerful cloud-based alternatives.

Estimation of Russian boreal forest biomass from high-resolution satellite imagery

Gareth Rees, Scott Polar Research Institute, University of Cambridge, UK
Jack Tomaney, Scott Polar Research Institute, University of Cambridge, UK
Olga Tutubalina, Moscow State University, Russian Federation
Sergey Bartalev, Institute for Space Science, Moscow, Russian Federation
Vasily Zharko, Institute for Space Science, Moscow, Russian Federation

Keywords: Remote Sensing, Boreal Forest, Biomass, Russia

A major part of subarctic Eurasian landcover is composed of boreal forest, and understanding interactions between this forest and climate is essential to the unravelling of ecosystem dynamics. Satellite remote sensing is well established as a method of assessing the strength of vegetation, and time series of satellite images are routinely analysed to monitor vegetation dynamics. However, most such approaches depend on the use of vegetation indices, which are only indirectly related to the amount of vegetation. Above-ground biomass (AGB) or Growing Stock Volume (GSV) are more difficult to estimate from satellite data, although recently some global-coverage, course-resolution data products have become available. In this presentation we describe a new approach to estimate spatial variation in GSV at a resolution of 20 m, using summer imagery from Sentinel-2 MSI and a satellite-derived land cover product, trained using field measurements of individual tree geometries from field plots in two contrasting areas of the Russian boreal forest. The study areas were located on the Kola Peninsula, where the forest is mainly composed of pine, spruce and birch, and in the Sakha Republic, where the forest is mainly composed of larch, pine and birch. Preliminary results suggest that the method is capable of estimating GSV to within 50% of its true value.

Coupling the individual based, spatially-explicit treeline model LAVESI with the permafrost land-surface model CryoGrid to assess the impact of permafrost-vegetation interaction on tundra-taiga dynamics of Fareast Siberia

Stefan Kruse, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Simone M. Stuenzi, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany and Humboldt Universität zu Berlin, Geography Department, Berlin, Germany
Moritz Langer, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany,
Julia Boike, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Ulrike Herzschuh, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany and Institute of Earth and Environmental Science, University of Potsdam, Potsdam-Golm, Germany

Keywords: Treeline, Boreal Forest, Larix, Siberia, Permafrost

Tundra-taiga ecotone dynamics are still highly uncertain under global warming, but play a relevant role, in terms of remaining a carbon sink or becoming a source. In the north of Siberian boreal forests, in addition to temperatures the growth response is strongly linked to the state of the permafrost underneath. Consequently, understanding the role of current and future active layer dynamics is crucial for an accurate prediction of treeline dynamics, aboveground forest biomass, and, thus carbon stock developments. Focusing on forests, we present a coupled model version combining CryoGrid, a one-dimensional permafrost land-surface model, with LAVESI, an individual-based and spatially explicit forest model for few present larch species at the treeline in Siberia. Subsequently, parameterizing against an extensive field data set of 100+ forest inventories conducted along the Siberian treeline (97-169° E), we run simulations covering the upcoming centuries under climatic change scenarios.
The model setup can reproduce the energy transfer and thermal regime in permafrost ground as well as the radiation budget, nitrogen and photosynthetic profiles, canopy turbulence and leaf fluxes and predict the expected establishment, die-off and treeline movements of larch forests. Our results will show vegetation and permafrost dynamics and reveal the magnitudes of different feedback processes between permafrost, vegetation, and climate in Northern Siberia.

Assessing and predicting spatially explicit larch above-ground biomass change in the treeline ecotone of central Chukotka

Iuliia Shevtsova, Alfred Wegener Institute (AWI), Helmholtz Center for Polar and Marine Research, Potsdam, Germany; Institute of Biochemistry and Biology, University of Potsdam, Potsdam, Germany;
Stefan Kruse, Alfred Wegener Institute (AWI), Helmholtz Center for Polar and Marine Research, Potsdam, Germany;
Ulrike Herzschuh, Alfred Wegener Institute (AWI), Helmholtz Center for Polar and Marine Research, Potsdam, Germany; Institute of Biochemistry and Biology, University of Potsdam, Potsdam, Germany; Institute of Environmental Sciences and Geography, University of Potsdam, Potsdam, Germany;
Birgit Heim, Alfred Wegener Institute (AWI), Helmholtz Center for Polar and Marine Research, Potsdam, Germany.

Keywords: Tundra-Taiga, Vegetation Change, Future Forest Dynamics, Above-Ground Biomass

Future climate changes most likely cause major changes in vegetation of the tundra-taiga ecotone as one of the most vulnerable ecological regions. One of expected changes is tundra loss through forest invasion. Therefore, we are investigating tree above-ground biomass (AGB) in the central Chukotka, including variety of vegetation types and environmental conditions such as differences in relief, wetness, soils etc. We parameterized the individual-based spatially explicit vegetation model LAVESI to be able to simulate forest dynamics. A simulated spatially distributed AGB of the current state was validated by the current state AGB in the study area, obtained using field investigations and Landsat satellite data. Using predicted climate data of different RCP scenarios, we will be able to simulate tree AGB dynamics up until 300 years in the future. Our results will show how tree AGB will possibly spatially change in case of RCP 2.6, RCP 4.5 and RCP 8.5 climate change scenarios. Obtained information would be, for example, particularly useful for conservation measures and modelling of future above-ground carbon stock dynamics.

Climate-induced vegetation change around Noril’sk, north-central Siberia

Oleg Zheleznyy, Lomonosov Moscow State University, Moscow, Russia;
Olga Tutubalina, Lomonosov Moscow State University, Moscow, Russia;
Nikolay Shabanov, Space Research Institute RAS, Moscow, Russia;
Gareth Marshall, British Antarctic Survey, Cambridge, the U.K.

Keywords: Norilsk, Arctic Greening, Google Earth Engine, NDVI

Norilsk, the second largest city north of the Arctic circle, is home to an extensive nickel and copper smelting industry. Since the 1960s, the industrial development there, and specifically, air pollution, have caused extreme damage to the neighbouring ecosystems of tundra-taiga ecotone. However, as contemporary climate change stimulates “greening” in the high latitudes, we expect to see positive vegetation dynamics even in the most disturbed areas. The goal of this research was to identify recent vegetation changes in a large area surrounding Norilsk and attribute them to primary drivers. Using a time series of maximum summer NDVI calculated from Landsat satellite data for 1985-2020, we performed a Mann-Kendall trend analysis, which showed that a statistically significant, and indeed, the greatest increase of the vegetation index has happened in the previously most affected areas. A more detailed analysis of very high resolution imagery and subsequent classification demonstrated that whereas increases are mostly linked to the expansion of grasses, some tree and shrub recovery can also be noted. Our comparative analysis of emissions and meteorological data indicated that the observed greening can mostly be attributed to rising temperatures. Cumulative summer temperatures show a distinct relationship with maximum NDVI values, and their extremes typically correspond. However, the longterm changes are driven by a composition of factors, which was also investigated in this work.

Decadal variability in the impact of atmospheric circulation patterns on the winter climate of northern Russia

Gareth Marshall, British Antarctic Survey, Cambridge, UK

Keywords: Arctic, Teleconnections, Variability, Temperature, Precipitation

The Arctic continues to warm at a much faster rate than the global average. One process contributing to 'Arctic amplification' involves changes in low-frequency macro-scale atmospheric circulation patterns and their consequent influence on regional climate. Here, using ERA5 reanalysis data, we examine decadal changes in the impact of seven such patterns on winter near-surface temperature (SAT) and precipitation (PPN) in northern Russia and calculate the temporal consistency of any statistically significant relationships. We demonstrate that the 40-year climatology hides considerable decadal variability in the spatial extent of such circulation pattern-climate relationships across the region, with few areas where their temporal consistency exceeds 60%. This is primarily a response to the pronounced decadal expansion/contraction and/or mobility of the circulation patterns' centers of action. The North Atlantic Oscillation (NAO) is the dominant pattern (having the highest temporal consistency) affecting SAT west of the Urals. Further east, the Scandinavian (SCA), Polar/Eurasia (POL) and West Pacific patterns are successively the dominant pattern influencing SAT across the West Siberian Plains, Central Siberian Plateau and mountains of Far East Siberia, respectively. From west to east, the SCA, POL and Pacific North American patterns exert the most consistent decadal influence on PPN.

Modeling the distribution of Betula nana as a key indicator of changes in subzonal tundra boundaries in the North of Western Siberia

Ivleva T. Y., Moscow State University, Moscow, Russia;
Terskaia A.I., Moscow State University, Moscow, Russia;
Ermokhina K. A., A.N. Severtsov Institute of Ecology and Evolution, Moscow, Russia;
Dudov S.V., Moscow State University, Moscow, Russia

Keywords: Tundra, Betula Nana, Species Distribution Modelling, Maxent, MODIS, CHELSA, West Siberia

The development of field and remote studies of Arctic vegetation and the observed climate change justify the relevance of clarifying and monitoring the position of the tundra subzone boundaries. Most authors of tundra vegetation classifications consider the northern limit of Betula nana distribution to indicate the border between Arctic and Subarctic tundras. New remote sensing data and the development of GIS technologies has provided new opportunities for mapping the distribution of Betula nana. In this work, we modelled the distribution of Betula nana using maximum entropy method implemented in MaxEnt program. This algorithm finds the relationship between the species occurrences (points) and the values of environmental factors (raster data) and calculate the species' potential to occupy other areas. We created the most complete database of Betula nana occurrences in the north of West Siberia. As environmental data we used layers from the CHELSA bioclimatic data set. This data was supplemented with the July's land surface temperatures obtained from MODIS satellite imagery for the period 2000-2019. We have considered the 4 different models of Betula nana distribution. As a result, a map of the area of Betula nana on the territory of the tundra zone of Western Siberia was created, based on the most complete existing datasets. In the future, the obtained area can be used to further study the current state of the border of the Arctic and Subarctic tundra.

Small Arctic islands and their seasonal and long-term dynamics according to optical and radar data

Elena Baldina, Lomonosov Moscow State University, Moscow, Russia
Fedor Romamenko, Lomonosov Moscow State University, Moscow, Russia
Nikolay Lugovoy, Lomonosov Moscow State University, Moscow, Russia
Ekaterina Zhdanova, Lomonosov Moscow State University, Moscow, Russia
Vera Shirshova, Lomonosov Moscow State University, Moscow, Russia

Keywords: Climate Change, Remote Sensing, Small Arctic Islands, Long-Term Changes, Seasonal Surface Dynamics

Climate change and the Arctic sea ice decline is a well-known downward trend, which has shown a marked acceleration since the beginning of the 21st century. This trend clearly reveals its impact on small Arctic islands that were once surrounded by thick ice fields. The response of small islands to these changes is still poorly understood. The research is focused on 2 small islands. One of them is ice-island Ushakova, and the second one is the Vise island which is low plain without ice and glaciers. These islands were surveyed during the expedition “Open Ocean: Archipelagos of the Arctic – 2019” with the oceanographic research vessel “Professor Molchanov "in 2019, including coastal observations from a vessel and UAV shooting of individual areas by JI Phantom. The study of the islands changes was carried out on the basis of topographic map of 1957 and Landsat 5, 7, old satellite images, Landsat-8 and Sentinel-2 for the current situation. Multiple interferometric surveys Sentinel-1 for the whole 2019 were analyzed to characterize the seasonal variability of the surface of Vise Island. Image analysis were accompanied by detailed meteorological data and relied on it. The results of the study show definite but different responses of these islands to observed climate change in 21st century. This work was supported by the Russian Foundation for Basic Research (project No. 18-05-60221).

Subarctic Eurasia in flames: A new perspective on wildfire impacts from an individual-based fire-vegetation model for eastern Siberia

Ramesh Glückler, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Ulrike Herzschuh, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany and University of Potsdam, Potsdam, Germany
Josias Gloy, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Stefan Kruse, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany

Keywords: Boreal Forest, Fire, Siberia, Climate Change, Model

Subarctic Eurasia is experiencing rapidly rising temperatures. This impacts many environmental processes, including wildfires as an important ecological disturbance. Fire regimes in Siberia are predicted to shift towards larger, more frequent, and more intense wildfires. Exacerbated by numerous complex interactions, the impact of changing fire regimes on vegetation and vice versa remain poorly understood. Common dynamic global vegetation models are not made to capture fine-scale interactions in individual trees' life stages and time lags that are involved in population dynamics caused by complex life-cycles. However, these interactions determine the state of a forest on population level and might thus be imperative for understanding the long-term fire-vegetation relationship. We will present our proceedings in implementing a fire module in the individual-based, spatially explicit Larix Vegetation Simulator (LAVESI; Kruse et al., 2016), which simulates long-term population dynamics of deciduous larch trees dominating eastern Siberia. Depending on weather, wind speed, fuel availability and moisture, fires can ignite and spread, burning the litter layer and damaging tree stands. Fire intensity determines fire severity and flame height, separating surface from crown fires. In combination with detailed tree population dynamics, the newly developed fire module enables LAVESI to evaluate fine-scale effects of changing fire regimes on the wide-spread larch forests of eastern Siberia.

Arctic Science Summit Week 2021
IASC 19-26 March | Online, Portugal

Theme F: Education and Capacity Building for The Polar Regions

ID: 25 - Experiences in sustaining collaborative Arctic research teams

Conveners

Olivia Lee | University of Alaska Fairbanks, International Arctic Research Center

Christina Goethel | Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science

Karen Pletnikoff | Aleutian Pribilof Islands Association, Inc

U.S. National Science Foundation Efforts to Develop and Sustain Collaborative Arctic Research Teams

Colleen Strawhacker, National Science Foundation, Alexandria, VA, USA
Roberto Delgado, National Science Foundation, Alexandria, VA, USA

Keywords: Federal Funding, Collaborative Research, Convergence Science

Designing and implementing research in the Arctic requires technical expertise, thoughtful coordination, careful logistical planning, and strong collaborative partnerships to be successful. The U.S. National Science Foundation (NSF) Office of Polar Programs promotes creative and innovative scientific research, engineering, and education in and about the polar regions, catalyzing fundamental discovery and understanding of polar systems and their global interactions to inform the nation and advance the welfare of all people. As a federal funding agency, the NSF supports a wide range of activities in support of basic research that includes but is not limited to advancing a field or creating new directions in research or education by supporting groups of investigators to communicate and coordinate their research, training and educational activities across disciplinary, organizational, geographic and international boundaries. For the Arctic, several programs focus on strengthening convergence approaches from transdisciplinary teams to understand fundamental processes, improving collaborations between researchers and Arctic residents, and supporting early career scientists. Presenters from the NSF Office of Polar Programs will share perspectives from past research experiences as well as information about available funding opportunities to establish and sustain collaborative Arctic research teams.

The EU Polar Cluster - a collaboration of projects funded by the European Commission

Elaina Ford, British Antarctic Survey, Cambridge, United Kingdom
Renuka Badhe, European Polar Board, The Netherlands
Nicole Biebow, Alfred Wegener Institute, Bremerhaven, Germany

Keywords: Eu, Polar, Cluster, Collaboration, Network

The EU Polar Cluster is a collaboration of currently 21 projects, funded by the European Commission - www.polarcluster.eu. It was formed from the EU Arctic Cluster as a bottom-up tool for a collection of Arctic-focused projects to pool resources and increase impact. Following the success of this, we expanded in scope to include polar and Antarctic projects, and the EU have supported the Cluster, in addition to facilitating meetings, by funding the Clustering activities and organisation through the EU-PolarNet 2 project.

The added value of clustering activities in this way includes:

-Higher impacts than single project's outputs;
-Upscale collective projects' efforts;
-Increased knowledge sharing;
-Less but better engagement with stakeholders;
-Greater visibility;
-Better use of citizen's money.

This presentation will cover some of the ways we have achieved this international and interdisciplinary collaboration, through five thematic focused task groups.

AHEAD – International Arctic Station “Snowflake”

Yury Vasiliev, Executive Director of the Institute of Arctic Technologies, Moscow Institute of Physics and Technology and head of the AHEAD project

Keywords: Renewable Energy, Hydrogen, Arctic Station, International cooperation

International Arctic Station «Snowflake» - AHEAD (Arctic Hydrogen Energy Applications and Demonstrations)

Snowflake Station is the global first of its kind fully autonomous year-round diesel free arctic facility powered by hydrogen fuel and renewable energy sources (wind and solar energy) and focuses on implementation of technologies, which directly affect the reduction of human impact on climate change. Establishing and opening during the Russian Chairmanship of the Arctic Council in 2021–2023 International Arctic Station «Snowflake» as an analogue of the International Space Station but in the Arctic. The Station will be a platform for development and testing new breakthrough technologies, for decarbonization of the Arctic regions, for ensuring energy to remote settlements, for international cooperation of engineers, researchers, scientists and students working on bold solutions that constitute a basis for life and work in the Arctic (such as environmentally friendly life support technologies, new materials, smart home and smart village systems, as well as biotech, medical, robotic and AI-driven solutions). On June 8 2020, the AHEAD was endorsed by all Arctic countries (Denmark, Iceland, Canada, Norway, Russia, USA, Finland, Sweden) at the SDWG Online Plenary Meeting, but the international cooperation will go beyond the Arctic Council member states and engage organizations representing the Arctic's indigenous peoples, as well as the observer nations that have no direct access to the Arctic but are interested in a comprehensive collaboration based on the new four-season facility in the northern latitudes. Functioning as a "living laboratory" IAS will provide a technological and economic foundation to scale up the newly developed solutions for widespread use.

Lessons Learned in Sustaining Collaborative Arctic Research Teams: Perspectives from the Arctic Research Consortium of the U.S. (ARCUS)

Helen V. Wiggins, Arctic Research Consortium of the U.S. (ARCUS), Fairbanks, Alaska

Keywords: Collaboration, Team Science

The Arctic Research Consortium of the U.S. (ARCUS) is a not-for-profit organization headquartered in Fairbanks, Alaska. ARCUS' vision is strong and productive connections among U.S. and international Arctic researchers, educators, Indigenous and traditional knowledge holders, Arctic residents and local experts, and other stakeholders to improve understanding of the changing Arctic. Our activities focus on collaboration, networking, and communication in Arctic research and education. We have developed and fostered a variety of teams, from small ad-hoc groups to longer-term committees steering large research programs. As is typical of many Arctic research efforts, these teams have increasingly crossed boundaries of discipline, geography, sector, and knowledge system. There are a many best practices, tips, and guiding principles that we have learned from direct experience as well as drawing from the fields of team science, virtual collaborations, convergence science, and psychology. This poster will present insights from ARCUS 20+year experiences as well as the relevant literatures, for successfully building and sustain collaborative Arctic research teams.

Institute for Atmospheric and Earth System Research (INAR) bridging research, society and international policy making

Hanna K. Lappalainen, Institute for Atmospheric and Earth System Research, INAR, University of Helsinki
Markku Kulmala, Institute for Atmospheric and Earth System Research, INAR, University of Helsinki

Keywords: Sceince Diplomacy, Northern High Latitudes

The Institute for Atmospheric and Earth System Research (INAR) has been active to find tools for upscaling its research approach and ways to solve global climate change and air quality in megacities and, at the same time, better bridge the research to society and international policy. In this task INAR has introduced Pan-Eurasian Experiment (PEEX) program (s an asset to better address the scientific challenge of the holistic system understanding e.g. understanding of Atmosphere – Earth Surface – Biosphere interactions and feedbacks in the Northern Eurasian context) INAR has also launched a measurement concept called the GlobalSMEAR for filling the observational gap of the atmospheric – ecosystem in situ data. INAR has also started the Sofia Earth Forum process to support a appearing of new ideas, perspectives and establishing a continuing framework of research community and society representatives to deliver a science based message being legitimated to fast tract policy making. The most recent activity of INAR is the “Arena for the gap analysis of the existing Arctic Science Co-Operations” (AASCO), for 2020-2021. AASCO can play a leading role in the research with its holistic and integrated understanding of the local and global feedback and interaction at the Arctic and outside the Arctic environments.

From basketball courts to ice camps: lessons in leadership, team work, and the human psyche

Allison A. Fong, Alfred-Wegener-Institut Helmholtz-Zentrum für Polar-und-Meeresforschung

Keywords: MOSAiC, Team, Collaboration, Human, Ice

Tapping into individual potential and leveraging that individual capacity to achieve big goals are not easy feats, but are essential for building teams who see opportunity when confronted with challenges, who share vision despite different viewpoints, and who ultimately strive to succeed together. For me, learning team concept fundamentals began at a young age playing basketball. Some of those same concepts to remain paramount today in my efforts as a scientist and coordinator. Great collaborations and long-term, sustainable cooperation among diverse groups requires understanding 1) what drives the need for engagement in a project, 2) what are the unique competencies of team members, and 3) how to align interests and strengths to grow self-sustaining relationships. The road to championships and great scientific outputs is littered with dismantled road blocks, patched cracks, bridges, and emergency roadside assistance call boxes. Knowing how and when to either disassemble, fix, cross, or call for help along that road is critical to leading and growing a team hungry for collaboration. I draw from a number of experiences spanning graduate student years in the Center for Microbial Oceanography: Research and Education (CMORE), and more recently as co-coordinator of the MOSAiC Ecosystem team. I aim to highlight practices from the perspective of a scientist not trained in human psychology, but all too aware of the role the human psyche plays in scientific collaboration and success.

Knowledge transfer towards tourists safety in polar region. Guide‘s competences and emergency preparedness in Arctic communities

Barbara Horyn, University of Iceland, Reykjavik, Iceland

Keywords: Knowledge Transfer, Safety, Tourism, Emergency Preparedness, Collaborative Research

Polar adventure tourism is growing rapidly, increasing risk of accidents and leading to stress on local emergency preparedness. The objective of the research is to examine the relationship between guides competences and ensuring safety in the field. The study pays attention to key issues: polar adventure guide’s risk perception, guide’s training, safety practices and emergency preparedness strategies in the Arctic region. The target population for the study includes adventure polar guides from Iceland, Svalbard and Greenland, tourism educators, safety professionals and policy makers. The project is divided into four work packages: 1) defining guide competences and building safety guiding theory, 2) examining guide’s risk perception, 3) exploring competence building among indigenous guides in Greenland and 4) investigating cooperation between search and rescue and guides in the region. The research is grounded on qualitative research methods. Data is gathered through field work, participant observation, semi-structured interviews and documentary analysis. The scientific contribution of the research is to contribute with novel theory in polar adventure tourism and raise involvement of scientific research on policy making in arctic tourism destinations. The long-term value of the studies on society includes practical applications of research findings, providing safety framework in polar adventure tourism and enhancing involvement of local guides in research and innovation.

Data sharing between Community-based observing systems and scientific observations

Stein Sandven, Nansen Environmental and Remote Sensing Center, Bergen, Norway
Peter Pulsifer, Carleton University, Ottawa, Canada
Finn Danielsen, NORDECO, Copenhagen, Denmark
Torill Hamre, Nansen Environmental and Remote Sensing Center, Bergen, Norway
Lisbeth Iversen, Nansen Environmental and Remote Sensing Center, Bergen, Norway

Keywords: Data, Knowledge, Planning, Communities, Sustainable Devlopment

To develop sustainability of Arctic communities, it is essential that planning and decision-making is based on the best available data. Observing and observing systems are therefore important to establish and operate over time based on scientific, local and Indigenous methods. In the Arctic, there is a growing number of CBM programs, including Indigenous and Local Knowledge (ILK), which play an important role in addition to scientific systems to provide environmental, climate and resource data. CBM programs are usually driven by needs in local communities to help in resource management, planning and decision making. A key challenge is to enable data sharing between CBM systems and other Arctic observing and data systems and build services upon them. This calls for development of standardization of observing methods and data management. To go into the future it is important to engage with the youth councils in the different communities. In CAPARDUS examples of useful data sharing are explored in areas that are essential for the livelihood of many communities and the Arctic, such as fisheries management, hunting and reindeer herding. The examples are taken from Greenland, Alaska and Yakutia. A main goal of CAPARDUS is to establish an Arctic Practice System where data and knowledge can be shared between people living and working in the Arctic.

Bering Strait Seabird Die-off: Partnering in Search of Answers

Robb Kaler, U.S. Fish & Wildlife Service, Anchorage, Alaska, USA
Gay Sheffield, University of Alaska-Alaska Sea Grant, Nome, Alaska, USA
Brandon Ahmasuk, Kawerak Inc., Nome, Alaska, USA
Stacia Backensto, National Park Service, Fairbanks, Alaska, USA
Jackie Lindsey, Coastal Observation and Seabird Survey Team, Seattle, Washington, USA
Tim Jones, Coastal Observation and Seabird Survey Team, Seattle, Washington, USA

Keywords: Alaska, Coordination, Communication, Die-off, Seabirds

Since 2017, coastal Alaskan communities in the northern Bering and southern Chukchi seas have reported dead seabirds that had washed up on beaches. These reports are concurrent with a massive marine ecological shift resulting from the loss of sea ice extent, quality, and duration. The 2020 numbers of carcasses was lower than the previous three years (2017-2019), anomalous mortality events are a priority for food security and a public health concern for coastal communities that rely on the marine ecosystem for their nutritional, cultural, and economic well-being. The U.S. Fish and Wildlife Service coordinated with federal, state, tribal governments, and community members to report observations and collect carcasses for examination by the U.S. Geological Survey (USGS) National Wildlife Health Center and USGS Alaska Science Center. Eighteen carcasses were examined and all were emaciated and tested negative for Avian Influenza. Coordination with coastal communities provides crucial information that would otherwise be unavailable. With increasing ocean temperatures and decreasing sea ice extent, the next decade will be critical in how coastal species and communities adapt to a fast-changing environment in western Alaska. With Alaska’s vast coastline, close coordination and communication with Indigenous partners is necessary to learn of anomalous mortality events in seabirds across Alaska, to determine the cause of seabird die-offs and disseminate results broadly and effectively.

The IARPC Model: Mechanisms for large-scale collaborative efforts

Meredith LaValley, Anchorage, Alaska, US
Liz Weinberg, Portland, Oregon, US
Hazel Shapiro, Boulder, Colorado, US
Ann-Christine Zinkann, Washington, DC, US
Sara Bowden, Reston, VA , US

Keywords: Cross-boundary, Collaborations, Interdisciplinary, Research Policy

The Interagency Arctic Research Policy Committee's (IARPC) key mission is to enhance collaboration in Arctic research across federal agencies in partnership with academia, NGOs, and industry, Indigenous, and international organizations. IARPC has a long history of building and sustaining collaborative science teams to advance interdisciplinary cooperation on the most pressing challenges. Two main tools used to enhance visibility and sustain IARPC's mission are: (1) the IARPC Collaborations website, which serves as a forum for more than 2600 Arctic researchers and stakeholders, and (2) the 9 collaboration teams, 3 sub-teams, and 9 self-forming teams that are supported by the IARPC secretariat to varying degrees. Several successful methods have been used to facilitate cross-boundary efforts including diverse leadership, cross-team collaboration, and inclusion of perspectives from multiple sectors. In light of the next five year Arctic Research Plan (currently under development), this talk will explore innovative ways collaboration teams are using the website and their monthly team meetings to build and sustain a collaborative community and work across disciplinary boundaries towards broad scientific goals. The work of these public collaboration teams has been especially important during the ongoing COVID-19 pandemic in supporting coordination of the research community and research cruises amidst cancellation of fieldwork and in-person conferences.

Svalbard Integrated Arctic Earth Observing System- a holistic approach

Heikki Lihavainen, SIOS, Longyearbyen, Norway
Dariusz Ignatiuk, SIOS, Longyearbyen, Norway
Christiane Hübner, SIOS, Longyearbyen, Norway
Inger Jennings, SIOS, Longyearbyen, Norway
Shridhar Jawak, SIOS, Longyearbyen, Norway

Keywords: Observations, Holistic, Earth System Science

The Svalbard Integrated Arctic Earth Observing System (SIOS) is a collaborative effort to develop and optimise a regional observing system for long-term measurements in and around the high-Arctic archipelago of Svalbard (78°N). SIOS is an international, multidomain and distributed infrastructure focusing on key processes in order to improve the understanding of how the Earth System functions. SIOS is providing representative observations in the Svalbard region to elucidate and quantify the roles of the interfaces on the state of the Arctic.

SIOS has several tools to enhance the interactions between member institutions and different domains. For example, the annual State of the Environmental Science in Svalbard report is gathering multinational contributions and encourage seeking connections between disciplines. As a response to consequences of the global COVID-19 pandemic, SIOS Knowledge Centre initiated several virtual activities. It might be said that these activities have made the SIOS community more tightly knit by bringing them together – if only virtually – to share knowledge, solve problems and ensure research continuity.

Prototyping an Arctic Practices System: a methodological knowledge base for sustainable development

Pier Luigi Buttigieg, Helmholtz Metadata Collaboration - GEOMAR, Kiel, Germany
Jay Pearlman, IEEE, Paris, France
Pauline Simpson, UNESCO – Intergovernmental Oceanographic Commission (IOC) - IOC Project Office for IODE, Oostende, Belgium

Keywords: Methods, Practices, Knowledge Exchange, Interoperability, Sustainable Development

Cultures of life, work, and observation in the Arctic have unique challenges and complexities. As a result, Arctic "know how" distributed across diverse communities is of critical value for the region's protection and sustainable development. Sharing this know-how is also complex, especially as climate change is intensifying the overlap of regional needs and interests. To address the opportunities and challenges of sharing Arctic methods, standards, policies, ethical guides and other methodological content, the CAPARDUS project is prototyping an Arctic Practices System (APS). Via consultation with local communities in Alaska, Greenland, Svalbard and Russia, we are co-developing a roadmap for an inclusive and scalable APS. Building on the IOC-UNESCO Ocean Best Practices System, the APS will adapt the FAIR Principles to multi-modality methodological content (documents, multimedia, etc) and explore how to effectively apply the CARE and OCAP principles. To this end, we have prioritised fine-grained and secure permission management functions, federation of (meta)content across interoperable (but locally controlled) systems, multilingual user interfaces tailored to community needs, and machine-to-machine interfaces with Arctic and Ocean data systems. Further work will focus on linking content to both Arctic and global societal benefit frameworks and Essential Variable systems, as well as further consultation to refine the scope, management, and technological basis of the APS.

Changing Coastlines

K. Pletnikoff, APIA/absi/WALCC
A. Poe, APIA/absi/WALCC
K. Murphy, APIA/absi/WALCC
A. Holman, APIA/absi/WALCC
L. Heffner, APIA/absi/WALCC
D. Holen, APIA/absi/WALCC
H. Stewart, APIA/absi/WALCC

Keywords: Outreach, Education, Communities, Change

Coastlines provide some of Alaska's most life-filled environments. From shallow nearshore waters, into tidelands, beaches and sandbars, bays and estuaries, deltas and uplands, this narrow slice of Alaska supports a disproportionately large percentage of our state's fish, bird and wildlife. This same area is also the location of the largest share of Alaska's communities and the qualities that make these coastlines so environmentally rich – the meeting of land and ocean – make these areas particularly vulnerable to the effects of climate change. One of the deliverables from the series of Promoting Coastal Resilience and Adaptation in Alaska workshops are a series of four outreach posters. They are meant to convey the current understanding and concerns of the local residents to decision-makers at the state and federal levels. This poster, the second in a set of four, synthesizes current information on the region's coastal environments, including estuaries, river systems and bluff and rocky coastlines, and key expected climate impacts on those systems. The poster targets non-specialist audiences, including western Alaska communities and local, regional, state, and national legislators. The posters have been developed through four workshops in coastal hub communities (Nome, Kotzebue, King Salmon, and Unalaska), Coastal Resilience and Community Adaptation in western Alaska, hosted by the Aleutian Pribilof Islands Association.

Sustaining Subsistence

K. Pletnikoff, APIA/absi/WALCC
A. Poe, APIA/absi/WALCC
K. Murphy, APIA/absi/WALCC
A. Holman, APIA/absi/WALCC
L. Heffner, APIA/absi/WALCC
D. Holen, APIA/absi/WALCC
H. Stewart, APIA/absi/WALCC

Keywords: Outreach, Education, Communities, Change

Alaska's coastlines are changing rapidly though the drivers of change differ across the state. Coastal erosion, sea level rise, storm patterns, changes in land elevation, and thawing permafrost are important factors to understand when addressing local change. What adaptation strategies are already in place to help communities and resource managers adapt to change? One of the deliverables from the series of Promoting Coastal Resilience and Adaptation in Alaska workshops are a series of four outreach posters. They are meant to convey the current understanding and concerns of the local residents to decision-makers at the state and federal levels. This poster, the third in a set of four, synthesizes current information about the drivers of coastal change, the data needs that limit adaptation planning, and identifies possible adaptation strategies. The poster targets non-specialist audiences, including western Alaska communities and local, regional, state, and national legislators. The posters were developed through four workshops in coastal hub communities (Nome, Kotzebue, King Salmon, and Unalaska), by the Coastal Resilience and Community Adaptation in western Alaska project, hosted by the Aleutian Pribilof Islands Association.

The ocean is our grocery store

K. Pletnikoff, APIA/absi/WALCC
A. Poe, APIA/absi/WALCC
K. Murphy, APIA/absi/WALCC
A. Holman, APIA/absi/WALCC
L. Heffner, APIA/absi/WALCC
D. Holen, APIA/absi/WALCC
H. Stewart, APIA/absi/WALCC

Keywords: Outreach, Education, Communities, Change

The diverse plants, animals and ecosystems are at the heart of the way of life in western Alaska. Climate change is altering the landscapes and water of western Alaska. Some changes are clearly negative; others, such as new game entering the region, may be positive. It is likely that these changes will continue and intensify and create new challenges and opportunities for the region. Alaska’s people are incredibly adaptive and will find a way forward through these changes. To do so they will need to engage scientists and policy makers. One of the deliverables from the series of Promoting Coastal Resilience and Adaptation in Alaska workshops are a series of four outreach posters. They are meant to convey the current understanding and concerns of the local residents to decision-makers at the state and federal levels. This poster, the final in a set of four, describes how climate change is affecting people of the region. The poster targets non-specialist audiences, including western Alaska communities and local, regional, state, and national legislators. The posters were developed through four workshops in coastal hub communities (Nome, Kotzebue, King Salmon, and Unalaska) by the Coastal Resilience and Community Adaptation in western Alaska project, hosted by the Aleutian Pribilof Islands Association.

ID: 80 - Cryosphere Outreach: Concepts and new Developments

Conveners

Inga Beck | UFS Schneefernerhaus GmbH

Josefine Lenz | Alfred Wegener Institute and APECS

Frédéderic Bouchard | GEOPS, Université Paris Saclay

Engaging scientists, educators and policy makers into Education and Capacity Building of the Polar Regions: Portugal as a case-study

Hugo R. Guímaro, University of Coimbra, MARE – Marine and Environmental Sciences Centre, Department of Life Sciences, Coimbra, Portugal / Association of Polar Early Career Scientists of Portugal (APECS Portugal);
Patrícia Fialho, Externato Cooperativo da Benedita, Portugal / Polar Educators International (PEI), ARCUS, 3535 College Rd., Suite 101, Fairbanks, AK, USA;
Marta E. Santo, Agrupamento de Escolas Professor Ruy Luís Gomes, Portugal / Polar Educators International (PEI), ARCUS, 3535 College Rd., Suite 101, Fairbanks, AK, USA;
José Seco, University of Coimbra, MARE – Marine and Environmental Sciences Centre, Department of Life Sciences, Coimbra, Portugal / Association of Polar Early Career Scientists of Portugal (APECS Portugal);
Sara Pedro, Université Laval, Département de Médecine Sociale et Preventive, Quebec, Canada / Association of Polar Early Career Scientists of Portugal (APECS Portugal);
Cármen Sousa, University of Algarve, CCMAR – Centre of Marine Sciences, Algarve, Portugal / Association of Polar Early Career Scientists of Portugal (APECS Portugal);
Carolina Viceto, University of Aveiro, CESAM – Centre for Environmental and Marine Studies, Department of Physics, Aveiro, Portugal / Association of Polar Early Career Scientists of Portugal (APECS Portugal);
Guilherme Jeremias, University of Aveiro, CESAM – Centre for Environmental and Marine Studies, Department of Biology, Aveiro, Portugal / Association of Polar Early Career Scientists of Portugal (APECS Portugal);
Joana Fragão, University of Coimbra, MARE – Marine and Environmental Sciences Centre, Department of Life Sciences, Coimbra, Portugal / Association of Polar Early Career Scientists of Portugal (APECS Portugal);
José Abreu, University of Coimbra, MARE – Marine and Environmental Sciences Centre, Department of Life Sciences, Coimbra, Portugal / Association of Polar Early Career Scientists of Portugal (APECS Portugal);
Ricardo S. Matias, University of Coimbra, MARE – Marine and Environmental Sciences Centre, Department of Life Sciences, Coimbra, Portugal / Association of Polar Early Career Scientists of Portugal (APECS Portugal);
Ricardo Ramos, Polytechnic Institute of Bragança, Department of Natural Sciences, Bragança, Portugal / Association of Polar Early Career Scientists of Portugal (APECS Portugal);
José C. Xavier, University of Coimbra, MARE – Marine and Environmental Sciences Centre, Department of Life Sciences, Coimbra, Portugal / British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge, CB3 0ET, United Kingdom.

Keywords: Education, Outreach, Science Communication, Polar Science, Awareness

The Polar Regions and the Cryosphere are known to influence the world, mainly through taking part on key issues, such as climate change, sea level rise and oceans circulation, all relevant to education and outreach. Countless countries are becoming more conscious about the importance of Polar Regions and Cryosphere and there are a growing interest in communicating polar science through education and outreach activities. Here, we provide evidence of how Portugal, with other countries, is highly engaged in communicating polar science on urgent global issues, through the work of the Association of Polar Early Career Scientists of Portugal (APECS Portugal) with Polar Educators International (PEI), and endorsed by the Portuguese Polar Program (PROPOLAR). In the last 8 years, polar scientists and educators have been carried out activities, such as the International Polar Weeks, Workshops APECS Portugal, talks and skype calls with polar scientists, and the activity “Science in the Clear”. These activities have involved more than 100.000 students, 300 schools, 2.000 educators and 150 polar scientists from more than 20 countries over the years, with links to polar organizations, such as the Scientific Committee on Antarctic Research (SCAR), Antarctic Treaty, APECS and PEI. We show how education and outreach activities are an effective strategy in raising awareness, as well as to communicate polar science to a range of different audiences, in Polar and non-polar countries.

Including innovative methods and new tools: PEI is collaboratively republishing the Polar Resource Book - Polar Science and Global Change IPY 2010

Sophie Weeks, Vice President, Polar Educators International
Inga Beck, Environmental Research Station Schneefernerhaus, Zugspitze, Germany

Keywords: Education, Outreach, Knowledge Transfer, Communication, Public Engagement

During the International Polar Year (IPY) polar scientists, educators and polar organisations produced a comprehensive book of teaching resources called Polar Science and Global Change - An International Resource for Education and Outreach. The book includes scientific information, research material, methods and hands-on activities to bring polar research into classrooms and it has been used internationally. Ten years on, scientific content needs updating and new educational methods, tools and opportunities have emerged. Polar Educators International (PEI), a network of educators and scientists formed as an outcome of the Education and Outreach activities of the IPY, is working with IASC, SCAR and APECS to update the Polar Resource Book. A new version will provide existing and new resources online, in multiple languages, downloadable as chapters and activities, including: Current science and future research questions; New topics - 3rd pole and microplastics; Activities/Labs for teaching polar science; Communication techniques for different audiences; Public outreach initiatives; Capacity building and careers; Indigenous knowledge. This year, text will be evaluated and updated by educators and scientists working collaboratively, analysing feedback to strengthen the existing publication. Next steps include the solicitation of funding, editors and authors, and design of the online format and sustainable platform. Content to be developed through 2021 and published 2022.

Inspiring Excitement for Science, Exploration, and the Arctic: Lessons learned from education and outreach during the yearlong MOSAiC Arctic expedition

Lynne Harden, Cooperative Institute for Research in Environmental Sciences at the University of Colorado Boulder, Boulder, Colorado, USA
Jon Griffith, Cooperative Institute for Research in Environmental Sciences at the University of Colorado Boulder, Boulder, Colorado, USA
Anne Gold, Cooperative Institute for Research in Environmental Sciences at the University of Colorado Boulder, Boulder, Colorado, USA

Keywords: MOSAiC, Arctic Climate, Expedition, Education, Curriculum

The 2019-2020 MOSAiC (Multidisciplinary Drifting Observatory for the Study of Arctic Climate) expedition offered an exciting and compelling context for engaging students and the public in learning about the cryosphere and gaining awareness of the changes happening to the polar regions. In our MOSAiC education and outreach efforts, we strived to increase public interest in, connection to, and knowledge of polar science by: 1) Connecting students and the public with MOSAiC scientists and team members through live video chats, blogs, and an #askmosaic question campaign; 2) Creating immersive virtual reality experiences using 360-degree footage from the Arctic, and; 3) Developing lessons and units about the Arctic and global climate systems that allow students to engage with authentic MOSAiC and Arctic climate data through inquiry and systems learning. Preliminary reviews of our outreach efforts show that students benefit from learning about Earth's climate system within the context of polar science and the MOSAiC expedition, and teachers who participated in MOSAiC curricular workshops significantly increased their understanding of climate change. We also learned through our #askmosaic campaign that students want to learn not just about the scientific goals of an expedition like MOSAiC, but also about the personal experiences of and challenges faced by scientists. We plan to develop more educational resources using the data collected during MOSAiC in the near future.

MOSAiC Education – Taking the Chance (Multidisciplinary drifting Observatory for the Study of Arctic Climate)

Rainer Lehmann, German Society for Polar Research (DGP)

Keywords: Polar Educators, MOSAiC Expedition, Teaching Material, Current Polar Research

The planning of the MOSAiC Expedition took about 10 years. Some two years before the start of the expedition in September 2019, considerations began on how to bring the questions, methods, planning and implementation of the expedition to schools. One idea was to provide interested educators with up-to-date articles for the entire duration of the expedition of one year. In addition, an advanced training course for educators was to be offered. An important focus was taken up from the 4th International Polar Year 2007/08 (IPY), in which educators were taken on polar expeditions and involved in the research work. As in the IPY and in the years after, the experiences of these Polar Educators were to be transferred to schools in various projects. For MOSAiC Education four places were made available for educators from Germany and the US. Polar Educators Germany as well as CIRES (Cooperative Institute for Research in Environmental Sciences) were involved in the implementation. The results that have been achieved so far are the publication of teaching materials, teaching units, the implementation of further education also online and the involvement of the public through lectures. In the coming years, further materials will be produced as the expedition data are evaluated and interpreted. Contacts to the scientific community and publishers are ensured by Polar Educators Germany.

Student field courses for studying permafrost in the Arctic

Vladimir Fedin, Lomonosov Moscow State University, Moscow, Russia
Valery Grebenets, Lomonosov Moscow State University, Moscow, Russia
Vasily Tolmanov, Lomonosov Moscow State University, Moscow, Russia
Fedor Iurov, Lomonosov Moscow State University, Moscow, Russia
Dmitry Streletsky, George Washington University, Washington, USA

Keywords: Arctic, Field Courses, Permafrost Investigation

The Arctic environment (including the permafrost) has been experiencing noticeable climatic and environmental changes over the past decades. The Department of Cryolithology and Glaciology of the Geographical Faculty of Lomonosov Moscow State University organized a specialized student courses for a comprehensive interdisciplinary study in the Russian Arctic since 1972. International student groups were formed almost every year since 2007. Educational field courses were held in the north of Western Siberia with the support of the Russian Center for Arctic Development since 2016. As part of the course, students investigate the typical natural landscapes of the tundra and forest-tundra; transformation of natural landscapes in urban and industrial areas; outcrops of frozen soils; cryogenic processes, their mechanisms and influence. Students got basic field methods understanding of studying permafrost during the practice: thermometric observations, measurements of the active layer (CALM technique), landscape-permafrost survey, etc. A significant block of field courses was devoted to the issue of construction on permafrost. Students studied the basic principles of foundations, permafrost management, protection from the effects of hazardous cryogenic processes. This work was supported by the RFBR grant 18-05-60080 "Hazardous nival-glacial and cryogenic processes and their impact on infrastructure in the Arctic".

The Quiet - A Different View on Polar Research

Thea Schneider, University of Potsdam, Potsdam, Germany

Keywords: Outreach, Photography, Book, Exhibition, Broad Public

At a time when the climate crisis is dividing the population and the credibility of climate researchers is being questioned again and again, "The Quiet" tries to give the public personal access to polar research and the people involved, in the hope of reaching a broad public on an emotional level and inspiring the next generation of polar researchers, especially young women. "The Quiet" is the first part of a three-part photo book series, accompanied by a travelling exhibition, which tries to open up the exclusive world of polar research by giving a personal insight into everyday life and work on board a Russian research vessel during the MOSAiC expedition in the central Arctic Ocean. The aim is to increasingly detach from the rightfully impressive, but sometimes overwhelming presentation of polar research and to show the diversity of the individual expedition participants. Only the interaction of many different characters with different abilities, tasks and life stories makes an expedition of this dimension possible. To show this diversity and the quiet, not so impressive moments in between of an incredible expedition like MOSAiC opens up the space for people to identify and empathize with the expedition participants on a human level and hopefully allow a new view on science in the polar regions. This project is part of my outreach work as an ambassador for the MOSAiC School 2019 organized by APECS.

Deepened connection to environment for youth after interacting with a climate change-impacted glacier landscape

Joanna Young, International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, USA
Laura Carsten Conner, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, USA
Erin Pettit, College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis, USA

Keywords: Youth, Glacier, Outreach, Climate Change

"Girls on Ice" is a backcountry science, art, and mountaineering expedition for 16 and 17 year-old high schoolers. During the 12 day program, participants live in, explore, and scientifically study a climate change-impacted glacier landscape. Participants learn 'leave no trace' camping ethics and grow awareness of human impact on the fragile glacier environment. With guidance from science instructors, participants also develop and carry out scientific experiments of their own design on the glacier. During their time on the ice, participants witness and learn about the highly visible signs of climate change in the glacier landscape, such as lateral and terminal moraines (debris piles) marking the former glacier extent prior to modern retreat. This presentation will highlight the findings of a study that examined how interacting with this glacier-dominated landscape impacted youths' sense of connection to the environment and climate change. Through interview and survey data, we found that participants experienced a deepened sense of personal connection to the environment, and desire to act on behalf of it, through directly experiencing the dramatic scale and rate of glacier loss. Based on our findings, we posit that experiencing glaciers or other climate change-impacted landscapes might more generally increase a sense of belief in the reality of climate change.

Dissemination and outreach of geotechnical aspects of permafrost science to secondary education students in Greenland

Sonia Tomaskovicova, Technical University of Denmark

Keywords: Education, Community Outreach, Science Communication

Greenland has shortage of skilled workers and engineers in comparison to country's development plans. We have been working with institutions of secondary education in Sisimiut, Greenland, on outreach events aimed at inciting youth's interest in engineering topics. We present two formats of outreach events prepared for two different audiences of students. In the outreach event for high school students (age 17 - 19), we held a classroom lecture, followed by a tour of an active construction site guided by an engineer. The lecture familiarized the students with the terms and concepts necessary to understand permafrost interaction with climate, with built structures, and the importance of understanding geotechnical ground properties. Active participation of the students was ensured by encouraging them to answer all the questions they were able to using their existing knowledge. In the outreach event for students of vocational education (machine worker and mine worker), we focused on demonstrating the applicability of field geophysical methods for assessing ground composition and presence of permafrost. The aim was to make the students informed conversation partners in discussion with colleague engineers. Both types of events have generated active participation and positive feedback from the students and their teachers. The year following the high school outreach, at least two of the participating Greenlandic students entered the engineering education in Sisimiut.

Enjoy the Melting Ice - an analysis of selected artworks that educate about climate change and earn corporate support

Paul Rosenbaum, Uppsala University, Uppsala, Sweden

Keywords: Art, Knowledge Transfer, Public Private Partnerships, Climate Change, Capacity Building

Although many coordinated efforts have been made across the scientific community to educate and influence policy makers and the public about climate change, there is slow action by many multinational corporations to align their huge resources in pursuit of the UN Social Development Goals. While such companies have expressed commitment to reduce their environmental footprint, they struggle to retrain staff to adapt to new ways of working that show significant positive impact. However, several firms have created partnerships with artists that have developed novel, large scale projects that attract considerable attention about climate issues. While it is difficult to quantify how much such artworks influence people to reduce their environmental impact, several studies suggest that artists have been effective to shortcut the learning process for employees to think and act creatively, particularly by changing habits that lead to lower environmental impact. This poster presents an ongoing qualitative case study of one leading multinational's attempts to integrate the creativity of artists to evolve its working processes around the world. The study also contrasts the work of several artists including Danish/Icelandic Olafur Eliasson, including his multiyear project called "Icewatch" where glacial ice from Greenland is transported to the doorstep of COP events across Europe, and how such projects have increased the opportunities for artists and multinationals to unite resources.

ID: 86 - Education, Equity and Inclusion: Teaching and Learning for a Sustainable North

Conveners

Diane Hirshberg | University of Alaska Anchorage

Tuija Turunen | University of Lapland

Mitdlarak Lennert | University of Greenland

Arctic Education Alliance - Vocational education capacity building for land and fisheries management, sustainable tourism, and hospitality in Greenland

Nathan Reigner; Pennsylvania State University; State College, Pennsylvania, USA
Byron Bluehorse: UAF Interior Alaska, Tribal Management
Lene Kielsen Holm: Greenland Institute of Natural Resources; Nuuk, Greenland
Mie Winding; Greenland Institute of Natural Resources; Nuuk, Greenland
Victoria Buschman; Indigenous Science and Conservation Advisor; Nuuk, Greenland
Gestur Hovgaard; Ilisimatusarfik/University of Greenland; Nuuk, Greenland
Courtney Carothers; UAF College of Fisheries and Ocean Sciences; Fairbanks, Alaska, USA
Tracy Michaud; University of Southern Maine; Portland, Maine, USA
Jessica Black; UAF DANSRD/ Interior Alaska, Tribal Management; Fairbanks, Alaska, USA
Kevin Illingworth; UAF Interior Alaska, Tribal Management; Fairbanks, Alaska, USA
Carrie Stevens; UAF Interior Alaska, Tribal Management; Fairbanks, Alaska, USA
Peter Newman; The Pennsylvania State University; State College, Pennsylvania, USA
Derrick Taff; The Pennsylvania State University; State College, Pennsylvania, USA
Kas Aruskevich; Evaluation Research Associates LLC; Fairbanks, Alaska, USA

Keywords: Education, Land management, Fisheries, Tourism, Greenland

The goal of the Arctic Education Alliance is to lay the foundation for vocational education capacity-building in Greenland for land and fisheries management, hospitality, and sustainable tourism.

• Objective 1. Build a wide network of Greenlandic, American, and Arctic individuals and institutions to provide information to and receive outcomes from the project.

• Objective 2. Through a Greenlandic-informed and -rooted needs assessment, identify local and relevant foundational components of land and fisheries management, hospitality, sustainable tourism, and vocational English educational needs.

• Objective 3. Develop and vet a capacity building plan for vocational education programs in land and fisheries management, hospitality, and sustainable tourism.

• Objective 4. Develop curriculum in land and fisheries management, hospitality, and sustainable tourism to meet the needs of Greenland's economy.

The University of Alaska Fairbanks and its partners will accomplish the project's goal and objectives by leveraging their specialized professional expertise, Arctic environmental experience, Inuit and Indigenous cultural relevance, and a thick network of linkages to support Greenland as it builds its educational capacity, grows its economy, and solidifies its position as a stable and self-sufficient member of the North Atlantic community of nations.

Reasons for dropout and long completion times of students at the Arctic Civil Engineering program at the Technical University of Denmark

Pernille Erland Jensen, Technical University of Denmark, Lyngby, Denmark

Keywords: Student performance, Drop-out rates, Completion time, COVID19

The Bachelor of Engineering in Arctic Civil Engineering program at the Technical University of Denmark rates successful in many aspects of its performance. Most importantly, the graduates find their first employment very soon after graduation or even before graduation, thus the demand for the education is high. Compared to other similar educations the education furthermore performs well in the number of students taking a semester abroad, the gender balance, and the satisfaction with the study environment. However, on three essential parameters the education underperforms compared to similar educations: recruitment of students, dropout rate and completion time. Numerous initiatives to improve these parameters have been undertaken, however, with no or low affect. In this presentation the measures taken are discussed in relation to known specific reasons for drop-out and delay. A postulate stated by an external evaluating panel in spring 2021, that the drop out relates particularly to the transfer from the campus in Sisimiut, Greenland to Ballerup in Denmark after the 3rd semester is investigated. Finally the impact of COVID19-restrictions and close downs during spring and fall 2020 on student performance are evaluated.

Innovations in instruction through "Problem Based Learning" that is local, equitable and relevant

Margie Turrin, Lamont-Doherty Earth Observatory of Columbia University, New York, USA
Marina Reimer, Greenland Institute of Natural Resources, Nuuk, Greenland
Aqqaluk Sorensen, Greenland Institute of Natural Resources, Nuuk, Greenland
David Porter, Lamont-Doherty Earth Observatory of Columbia University, New York, USA
Karl Zinglersen, Greenland Institute of Natural Resources, Nuuk, Greenland
Robin Bell, Lamont-Doherty Earth Observatory of Columbia University, New York, USA
Kirsty Tinto, Lamont-Doherty Earth Observatory of Columbia University, New York, USA

Keywords: Place-Based, Equity, Co-Production, Instrument, Careers

The "Greenland Rising" project is a collaboration between the Columbia University and Greenland Institute of Natural Resources focused on assessing and preparing for changing sea level along Greenland's coastline. The project includes a science and supporting education piece, both developed through regular meetings with Greenlandic partners and local educators. Co-production is at the center of both the science and education plan ensuring there is investment in the communities for long-term local benefits.We developed an educational initiative to fit the interests and needs of Greenland's students, schools and communities. Curriculum pieces were designed with the local teachers to be place-based, meaningful and immediately relevant and teach critical skills to the students and fit long-term education initiatives. Visits with the local schools have included in-person support from the Greenland partners, with materials design and supplementary support from the US partners. Greenland's students are involved in instrument deployment, ongoing data collection, field observations and data interpretation. This is both a project contribution and an opportunity to train and work with science data and technology. The Greenlandic partners are critical to the place-based component, sharing local observations and stories as they present new materials designed to strengthen the student's understanding of science, share education opportunities, provide local role models and career pathways.

Education for all in Iceland: Agenda for future actions

Edda Óskarsdóttir, University of Iceland, Reykjavík, Iceland
Rúnar Sigþórsson, University of Akureyri, Akureyri, Iceland
Hermína Gunnþórsdóttir, University of Akureyri, Akureyri, Iceland

Keywords: Inclusive Education, Policy Implementation, Inclusion Ecosystem,

This paper discusses proposed actions presented in a report: Education for All: Agenda for future actions published in 2019 by the Icelandic Ministry of Education and Culture. The report is based on data from 23 meetings held across Iceland. They were organised by a task force assigned by the Ministry, inviting representatives of preschools, primary and secondary schools, leisure services, parents, school services, social services and health care from all Icelandic municipalities to discuss the advancement of education for all. At the meetings a total of 126 groups of six to eight persons participated in an assignment: The Wall: Removing Barriers to Education for All. Each group agreed on the ten most important issues for promoting education for all and finally organised them as a cairn to establish an order of priority. In the report the prioritisation of the cairns is analysed to establish a call for actions on part of the school community. The report then presents proposals in seven sections, each containing sub-sections as a future agenda to promote education for all in Iceland. The proposals are based on the cairns but also underpinned by the knowledge base of inclusion, results of the European Agency's (2017) external audit of inclusive education in Iceland, and a model of the education system as an ecosystem of administrative levels to identify the responsibility of each level and establish a vision of shared responsibility across the levels.

Responding to growing numbers of students with immigrant background in Iceland. Perspectives of municipalities, students and parents

Hermína Gunnþórsdóttir
Hanna Ragnarsdóttir

Keywords: Students With Immigrant Background; Municipalities In Iceland; Education; Qualitative Research

In this paper we present findings from a qualitative study on how municipalities organise and structure the support for students with immigrant background and the perspectives of parents and students. The study is part of a larger research project, Inclusive Societies which is a three- year project (started in 2018) that aims to compare integration patterns of immigrants in Iceland in various municipalities across the country. In Spring 2019, qualitative data were collected in six municipalities by interviews on three levels: 1) with 10 individuals in four municipalities including head of school offices, head of schools, teachers and special education teachers on issues related to the education of students with immigrant background, 2) with eight students with immigrant background in grades 6, 7, 9 and 10 in one compulsory school in a small fishing village in the North, and 3) with fifteen parents with immigrant background who have children in compulsory schools in one municipality near Reykjavík. In this paper we present findings from the three data sets; regarding municipalities, we discuss educational policies of the municipalities regarding students with immigrant background, support and training offered to teachers, and the challenges and opportunities in the education of this group of students; findings from parents revealed that they had to rely on other immigrants rather than locals to get information on services in the municipality; and students are calling for a better support to communicate with other students and an opportunity to actively use the Icelandic language to be integrated and accepted among their peers.

Teaching Endangered languages: Strengthening Sámi language didactics

Erika Katjaana Sarivaara, University of Lapland, Finland

Keywords: Didactics, Sámi Language, Language Learning, Indigenous Education

Sámi languages are defined as severely endangered, which means that language shift is ongoing phenomena in language speakers' community. However, there has been efforts to revitalize the language for decades. Hence, language shift and language revitalization are coincident processes in the language community. This oral presentation is based on my research in Sámi language didactics and more preciously I am asking here what kind of language view there is in the textbook in Sámi language subject. The textbook is used with the pupils who have Sámi language as their mother tongue, in the other words native speakers of the language. In school context indigenous language speakers at school are rather heterogenic group, because children have variable linguistic skills and knowledge in indigenous language. In Finland, there is a subject called Sámi language and literature as a mother tongue in primary school. There is an urgent need to examine the textbooks, and assessment in order to find out what kind of content those have. Textbook analysis in the subject Sámi language and literature have not been studied before.

Educational program CORELIS (Cold Region Landscapes Integrated Sciences)

Irina Fedorova, Saint Petersburg State University, St. Petersburg, Russia
Eva-Maria Pfeiffer, Hamburg University, Hamburg, Germany

Keywords: Polar Regions, Education, Master Program, Collaboration, Young Scientists

The Arctic investigation is significant for educational program. The climate changes very quickly and effects on social, economic and politic systems in the northern regions. According to above-mentioned an international Master Program CORELIS (Cold Region Landscapes Integrated Sciences) had been created in 2016 by St. Petersburg and Hamburg Universities. The educational program is oriented on training of specialists who are capable to realize independently theoretical and applied researches on ecological, hydro-meteorological, paleogeographical, landscape, pedological and nature management processes of the Arctic, Antarctic, Permafrost zone and the upland territories. In 2020, the third generation of CORELIS students started their education. During last 5 years the study plan have been improved, new international partners from Norwegian, Spain and Finnish Institutions were accepted. About 40 teachers gives their knowledge to 35 Russian and 12 international students. Summer and winter field practice were organized in the Arctic and mountain areas. Repeatedly students of the program participated in the international conferences and schools for young scientists. The third term students have the academician mobility to UHH and UniLaSalle. Current situation with COVID gives the background for new digital form of education and online courses creation. The international Master program CORELIS is ready to extend international participants both teachers and students.

Educational Technologies as a Driver of Changes in Arctic Regions

Marina Belonozhko,Industrial University of Tyumen, Russia
Svetlana Siteva,Industrial University of Tyumen, Russia

Keywords: Level, Arctic Region, Innovations, Digital Technologies, Arctic-Oriented Programs

In a number of regions in the Arctic, the population will increase, while, for example, residents of the Barents region and most of the Finnish and Russian North will migrate to the southern regions of the country, to the capitals. The results of demographic forecasts show that by 2050, the population of the Arctic will not change much, will remain at the level of 10 million. But we do not have a unified system for evaluating the quality of Arctic-oriented programs and a method for determining the professions that are necessary for working in the Arctic regions. In fact, the situation is as follows: 80 percent are middle – level professionals, and only 20 percent are with higher education. In order to solve the problems in a comprehensive manner, the Ministry of regional development of the Russian Federation is developing fundamental documents that will determine the development of the Arctic zone for the next 15 years. These are the basics of the state policy of the Arctic zone until 2035 and the Strategy for the development of the Arctic zone of the Russian Federation. Higher education institutions in Russia are focused on training highly qualified personnel to work in the Arctic zone of the Russian Federation. 32 educational programs, as we call them, educational programs of the Arctic orientation, for 60 sectors of the economy. And the total number of students enrolled in such educational programs throughout the Russian Federation is about 31 thousand people. But the teaching staff is just over 400 people. It is worth evaluating these indicators and thinking about mechanisms to encourage and motivate people to come to work in universities and research organizations in the Arctic zone.

Gender in polar research

Gertrude Saxinger, Austrian Polar Research Institute APRI
Dina Abdel Fattah, University of Alaska Fairbanks
Stephan Dudeck, European University in St. Petersburg
Doris Friedrich, University of Vienna and The Arctic Institute
J. Otto Habeck, University of Hamburg
Lauren Thompson, University of Alberta
Petia Mankova, Arctic University of Norway
Morgan Seag, University of Cambridge
Carolynn Harris, Association of Polar Early Career Scientists
Gosia Smieszek, Arctic Centre, University of Lapland/Women of the Arctic
Sasha Leidmann, Rutgers University
Alexander E. Thornton, Pride in Polar Research

Keywords: Polar Research, Gender, LGBTQI+, Discrimination, Call For Action

As part of the 2020 Arctic Science Summit Week, IASC and the IASSA Working Group Gender in the Arctic hosted a cross-disciplinary workshop on “Gender in Polar Research”. Over 85 participants from around the world joined this online event to discuss and reflect on the gendered nature of polar research. This poster highlights our call for action and the three broad themes of gender in Polar research: (1) Conducting research in ways that depart from the ubiquitous image of heroic masculinity (2) Disadvantages to career prospects and field research activities for women and LGBTIQ+ (3) How research is shaped by the composition of researcher genders and gendered spaces. The workshop brought up stories and experiences that are often unspoken and dismissed in the polar research community as a whole. What emerged were both shortcomings of current practices and pathways to producing equitable and inclusive polar science. The poster contains a list of networks and organisations active in the field of gender in the Polar regions.

Integrating indigenous cultures in English language teaching: the affordances of visual and translingual mediation of a bilingual Sami-Norwegian picturebook

Nayr Ibrahim, Nord University, Bodø, Norway

Keywords: Multilingual Picturebooks, Translingualism, Sami, Culturally And Linguistically Responsive Teaching

Multilingual picturebooks offer teachers socially-just, diversity-focussed and language-conscious approaches in ELT. Intermingled images with different sounds and scripts enhances the authenticity of the intercultural experience, prompting the (un)silencing of languages.

The positioning of languages and images in picturebooks is significant for the representation of indigenous cultures and their presence, or absence in English classrooms. The Norwegian curriculum states that English texts should help students gain insight into the ways of life, thinking and traditions of indigenous peoples. This paper describes a scheme of work developed with 1st-year student-teachers in Northern Norway in response to a call for a stronger interdisciplinary focus on indigenous cultures in Grades 1-7. The Sami-Norwegian picturebook, Ábiid plástihkat – Plasten i havet (2020) by Rita Sørly and Malgorzata Piotrowska was chosen for its potential to:

- focus on the Sami language, mediated by the Norwegian translation,
- develop English language activities, mediated by translingual practice,
- call for action on a contemporary environmental issue.

This multilingual-visual perspective offers a multi-layered representation of local cultural diversity and decenters the discourse of exoticism/minority status. It creates a space in English classroom for culturally and linguistically responsive teaching, affords the Sami language the power to tackle critical issues and challenge the neutrality of ELT.

Distant learning : the teacher's new tasks

Tatiana Kuzmicheva, Murmansk Arctic State University, Murmansk, Russia

Keywords: Distance Learning, Social Interaction, Students With Special Education Needs

Distance learning is a reality for the modern world. New formats of such education are due to objective factors of a global nature, to which another one was added in 2020 - the spread of coronavirus infection. We conducted a survey among 90 teachers and 65 students with special educational needs, living in the urban and rural areas of the Murmansk region. The results of the survey showed that for a child and a teacher, distance learning is going beyond the usual situation, the "comfort zone", into a situation of uncertainty. So, the teachers noted that it is difficult to keep the attention of a particular student, to notice his difficulties in mastering the material, to induce independence, to cause responsibility for the result. Most of the students indicated increased requirements for them; a large amount of independent work; the complexity of contacts with teachers due to technical and other problems; the influence of distracting irritants of the home environment, which reduce attention; narrowing the sphere of communication with peers. Thus, distance learning revealed problems in the student's self-organization of learning, unwillingness to act effectively in the absence of direct teacher control, to rationally allocate their time. On the part of the teacher, deficiencies were identified associated with maintaining social interactions with students during distance learning and difficulties in individualizing the teaching of children with special educational needs.

Bullying intervention and teacher education. Research amongst teachers in Iceland 2003 and 2019

Vanda Sigurgeirsdóttir, University of Iceland, Reykjavík, Iceland

Keywords: Bullying, Intervention, Prevention, Teacher Education

Bullying is a wide spread problem, in the Artic north and all around the world. Regarding school aged children, majority of bullying takes part during school hours and thus it is not surprising that legally and morally teaches have a great responsibility to prevent bullying and intervene in active cases. Many northern schools face challenges due to smaller communities, remoteness and rurality, where help and support from psychologist and other specialist is more difficult to attain. This means that it is even more important that teachers in the Artic schools have the knowledge and tools on how to effectively reduce bullying. Research shows that it is not always the case. This research was first conduced in 2003 and repeated in 2019. Teachers (523 in 2003 and 131 in 2019) answered a questionnaire about bullying, bullying intervention, support from others and their teacher-education. The results are clear, according to the participants, their teacher education did not provide sufficient education when it comes to bullying prevention and intervention, and 94,2% in 2003 and 91,9% in 2019 agreed or strongly agreed that more education was needed. Furthermore 66% in 2003 and 70% in 2019 said that they got no education on bullying or did not remember. In the presentation these results will be discussed further with emphasis on solutions and how improvement in teacher education could have positive outcomes for both teachers and children.

Professional development in a rural community in Iceland: A collaborative action research

Anna Katarzyna Wozniczka, University of Reykjavík, Iceland; Edda Óskarsdóttir, University of Iceland, Reykjavík, Iceland

Keywords: Teacher education Distance teaching Equal access to professional development Rural context Collaborative action research

Continued teacher and staff development can be a challenge in the more rural and remote areas in Iceland. At the same time, there is a growing shortage of teachers in these areas, which calls for a joint action of local and national bodies to guarantee the access to quality schooling for all students. A compulsory school in the southeast of Iceland contracted the University of Iceland to provide a professional development course to develop more inclusive school practices. All school employees participated in the course; most of those with a bachelor degree worked towards credits, while others took the course as part of their professional development. In this presentation we discuss our collaborative action research performed while preparing and teaching the course. The purpose was to understand how a professional development course on inclusive education can be developed through a distance learning module for diverse participants. The research builds on data collected throughout the course, including student work, course evaluations, focus group interviews, our preparation meetings and journal notes. Data was analysed through a grounded theory approach, which is compatible with action research as it builds on a cyclical procedure. The presentation shows the research process that spans nine months. The process is divided into three stages: the prologue, involving the planning and first encounters with the school and principal; the action stage where we got to know the participants and developed the course content and approaches in response to their various technological, pedagogical and personal challenges; and the epilogue which focuses on the lessons learned and illustrates the development of professional learning communities.

The tundra doesn't grow trees or teachers: Solving the teacher supply crisis in Rural Alaska

Douglas Cost, University of Alaska Fairbanks, Fairbanks, Alaska, U.S.
Diane Hirshberg, University of Alaska Anchorage, Anchorage, Alaska U.S.
Edward Alexander, Fort Yukon, Alaska, U.S.

Keywords: Teacher Turnover, Rural Schools

Alaska is facing a teacher workforce crisis. The state has always struggled to attract and retain educators for rural schools, but this is becoming a challenge even in urban schools. Alaska's rural schools hire mostly teachers prepared outside the state; in-state teacher preparation programs have never met the demand for educators statewide. The recent loss of the largest teacher preparation program in the state means the local supply will be further diminished. Current efforts to prepare, recruit and retain teachers in Alaska have failed to stem high turnover rates in rural schools. Annual rural teacher turnover rates of 20-50% impact students' academic and emotional well-being. Far too many students are not successful in rural schools, and a big reason appears to be the instability in the workforce and the factors that drive much of that instability. Turnover forces students and communities to repeatedly rebuild rapport, connectivity, and communication with new educators. This chapter explores what isn't working with current teacher recruitment and retention efforts, what actions could improve these and teacher effectiveness within the current structure, and asks whether communities should rethink the whole enterprise of public education in rural Alaska.

POLAR STAR kits of activities to inspire students' interest in STEAM

Agata Goździk, Institute of Geophysics Polish Academy of Sciences, Warsaw, Poland

Keywords: STEAM, Polar Research, Inquiry Learning, Design Thinking, Interdisciplinarity

The POLAR STAR ERASMUS+ project aims to bring together state-of-the-art learning pedagogies and combine them with exciting activities that focus on contemporary science, thus helping teachers to introduce STEAM successfully in their class. The project combines innovative learning techniques like inquiry learning and the design thinking approach along with other cutting-edge educational tools into one seamless methodology, that will allow teachers to shift towards a student-centred type of teaching. To introduce contemporary science into the science classroom, POLAR STAR focuses on two main scientific areas, Arctic research and Space. Although both fields of research have contributed greatly to the advancement of science and are directly linked to our everyday life and the development of societies, they are usually not seen as science disciplines with real impact on our lives and are largely left out of science curricula. Arctic science, aside from being a unique field of science that intrigues students, the wide range of subjects that it covers also makes it highly interdisciplinary in terms of concepts and phenomena that can be discussed. Thus, it is ideal to be introduced to schools and demonstrate the interdisciplinarity of science concepts and the 'Science as a whole' approach. Five Polar kits of activities are being developed: Arctic amplification, Surviving the Arctic, Northern lights, Permafrost and Plastic in the Arctic.

The Capacity Building on Climate Change Adaptation and Polar Regions: Teaching and Learning

Deniz Vural, Polar Research Institute, The Scientific and Technological Research Council of Turkey, Istanbul, Turkey
Özgün Oktar, Polar Research Institute, The Scientific and Technological Research Council of Turkey, Istanbul, Turkey
Burcu Özsoy, Polar Research Institute, The Scientific and Technological Research Council of Turkey, Istanbul, Turkey

Keywords: Climate Change, Polar Regions, Awareness, Education, Outreach

Climatic changes have caused remarkable environmental cases, in recent decades observed as Antarctic ozone depletion, loss of large amounts of sea ice from the Arctic Ocean and exponential temperature increases through the Arctic and Antarctic Peninsula. In consequence of rising atmospheric greenhouse gas concentrations, polar regions are most vulnerable in terms of predictions upon twofold warmings compared to other regions on Earth. These amplified warmings and rapid changes, especially Arctic seems to pose substantial impact regards to local and remote weather which will influence not only related-environment but also across ecosystems in the Earth. In addition, anthropogenic input is another triggering point to unnatural greenhouse effect which indicates gradual warming by burning fossil fuels. In terms of diminishing human-induced factors from climate variability, awareness of its major effects to polar regions has to be increased among the public. Turkish Students' Polar Research Team (PolSTeam) has great motivation to raise awareness by applying several applications; climate seminar series, establishing polar-climate clubs as spare-time activity of schools, talks with scientists, Antarctica art contests and public surveys etc. towards fostering citizen science. The team reached over 10,000 people from only school presentations past 5 years and this study focuses on capacity building achievements of PolSTeam on education and outreach of climate change in polar regions.

The role of teacher education in preparing pre-service teachers for teaching in compulsory schools in The Faroe Islands to ensure equity and social justice in education

Kalpana Vijayavarathan, The University of The Faroe Islands, Torshavn, The Faroe Islands

Keywords: Teacher Education, Equity, Culturally Responsive Teaching

Given the increasingly diverse nature of compulsory school students in The Faroe Islands, there is a cry for help from schools. They see teaching second generation immigrant children and child immigrants as a problem, because they feel teachers are not equipped to teach them. Only very recently has the Ministry of Education and Culture ventured into formalising the teaching of Faroese as a second language and mother tongue teaching. The Education Act of 1997 grants each and every child the right to education. What the Ministry has not considered is the importance of culturally responsive teaching as an approach within inclusive education. The responsibility of teacher education must be to equip pre-service teachers for their profession. To enable pre-service teachers to understand, design and adopt culturally responsive praxis for promoting equity in education, the curriculum must include culturally responsive teaching to prepare pre-service teachers to meet the needs of schools. Importantly, this may build teacher competence in a way that affords them self-efficacy in teaching all students in an inclusive manner. Teachers with high self-efficacy enjoy intrinsic motivation and have a positive impact on student learning outcomes. If the school system is to fulfil its duty, equity in education must be taken seriously. All children in society must be guaranteed this social justice for their development and that of Faroese society. Teacher education has a key role in this venture.

Theme G: Living in The Arctic

ID: 83 - Human-environment relations - a multi-disciplinary perspective on their repercussions in a changing Arctic

Conveners

Dina Abdel-Fattah | Arctic University of Norway

Doris Friedrich | The Arctic Institute; University of Vienna

Olivia Lee | International Arctic Research Center, University of Alaska Fairbanks

Predicting the Impact of Future Sea Level Change Around the Coast of Greenland: Local Responses to Global Change

Kirsty Tinto, Lamont-Doherty Earth Observatory, Columbia University, USA
Robin Bell, Lamont-Doherty Earth Observatory, Columbia University, USA
Jacqueline Austermann, Lamont-Doherty Earth Observatory, Columbia University, USA
David Blockley, Greenland Institute of Natural Resources
Casey Brayton, Lamont-Doherty Earth Observatory, Columbia University, USA
Ninni Jeremiassen, Greenland Institute of Natural Resources
Jonathan Kingslake, Lamont-Doherty Earth Observatory, Columbia University, USA
Diana Krawczyk, Greenland Institute of Natural Resources
Frank Nitsche, Lamont-Doherty Earth Observatory, Columbia University, USA
Guy Paxman, Lamont-Doherty Earth Observatory, Columbia University, USA
Jane Plesner, Greenland Institute of Natural Resources
David F Porter, Lamont-Doherty Earth Observatory, Columbia University, USA
Marina Reimer, Greenland Institute of Natural Resources
Aqqaluk Sorensen, Greenland Institute of Natural Resources
Margie Turrin, Lamont-Doherty Earth Observatory, Columbia University, USA
Karl Brix Zinglersen, Greenland Institute of Natural Resources

Keywords: Greenland, Bathymetry, Sea-Level, Co-Production

Communities in Greenland are focused around the coast, and the expected impact of sea level change varies widely according to local factors of the physical, built and social environment. Melting of the Greenland Ice Sheet contributes to rising global sea levels, but local sea level around much of the coast of Greenland is falling due to rebound as the load of the nearby ice sheet is reduced. This project focuses on four communities and uses an interdisciplinary approach to identify the elements of the local environments that are sensitive to sea level change, and a combination of mapping and modeling to improve predictions of the impacts on each community. We present the preliminary results of multi-beam echosounding and submarine habitat surveys from Aasiaat and Nuuk and combine echosounder backscatter with towed camera images to create regional benthic habitat type maps. Survey plans were co-produced during meetings with local stakeholders, including the municipality, industry, and members of the local Hunters and Fishers organization. Targets include important fishing resources, geologic and sediment distribution, and mapping intercoastal passages that are becoming more dangerous to navigate. Co-production is threaded throughout the project through to disseminating and communicating results, which continue to be developed and shared with the community through follow-up visits, and educational materials.

Public Awareness of Anthropogenic Climate Change in Greenland

Kelton Minor, University of Copenhagen, Copenhagen, Denmark
Manumina Jensen, University of Greenland, Nuuk, Greenland
Lawrence Hamilton, University of New Hampshire, Durham, Denmark
David Dreyer Lassen, University of Copenhagen, Copenhagen, Denmark
Minik Rosing, University of Copenhagen, Copenhagen, Denmark

Keywords: Climate, Beliefs, Environment, Culture, Survey

Greenland's ice sheet is frequently visited by physical scientists who contribute substantially to the international scientific knowledge base on past and now human-caused climate change. The climate perceptions of Greenland's own primarily Indigenous population living on the ice sheet margins, have not been systematically consulted by large-scale public opinion surveys. Here we draw on data from the nationally representative Greenlandic Perspectives Survey (GPS, July 2018– January 2019), which surveyed nearly 2% of the adult population (n = 646). Compared to other Arctic nations, we find that more Greenlanders are both aware that climate change is happening and report that they have personally experienced its effects. Surprisingly, over a third of the population do not attribute climate change to human activity. Individuals' cultural identity, as indicated by the intertwined factors of first language (Greenlandic or Danish), post-elementary education, and community scale (settlement, town or city), proves to be the dominant predictor of whether people think that humans are causing climate change, eclipsing other possible factors of respondent age, gender, or political affiliation. Despite the flow of climate scientists to Greenland, our results reveal a gulf between the scientific consensus and coastal Indigenous views of climate change, with important implications for future intercultural climate communication and adaptation planning.

Waste Disposal in the Arctic Region: Challenges and Efforts of Small and Remote Communities in Alaska Based on Comparison with Japan

Kaori Ishii, Graduate school of Environmental Studies; Tohoku University, Sendai, Japan

Keywords: Waste, Waste Management, Community, Transportation, Human-Animal Conflicts

The increase in various waste produced caused by the modernization of human life has affected different aspects of the natural environment and human society. People's health, soil, and water quality in Arctic communities are facing an increased risk due to burning unsorted waste, including plastics and hazardous waste, and discarding it in simple dumpsites without a fence or leakage prevention, among others. Moreover, climate change is causing other problems, such as the melting of waste discarded in dumpsites on the permafrost. Waste management in the Arctic community is a progressively serious problem. This study investigated the current conditions and changes in waste management in small, remote communities in Alaska and approaches to solving these problems through literature searches and interviews. Furthermore, fieldwork conducted in local communities in Japan experiencing similar problems, such as waste transportation and conflicts with wild animals, are reported and compared with the Arctic communities. This comparative study aims to clarify the Arctic region's characteristics and problems and also explore how anthropologists can contribute to Arctic research under a pandemic when it is difficult to conduct field surveys in native communities with inadequate medical resources.

Inuit Food Sovereignty and Self-Governance: Understanding the connections between Inuit Food Sovereignty and adaptive and holistic Circumpolar management

Carolina Behe, Inuit Circumpolar Council

Keywords: Inuit, Food Sovereignty, Holistic Management

Inuit are at the forefront of the drastic changes taking place in the Arctic. As the world community increasingly turns its focus to the Arctic, it is important to ensure that Inuit food security and Food Sovereignty is a priority in every context. Inuit food security is founded upon a holistic understanding of the Arctic – one in which Inuit are a part of the ecosystem and their physical, cultural, mental and spiritual health are profoundly related to the environment. The Alaska Inuit Food Security project (ICC AK 2016), stressed the undeniable connection between food sovereignty and food security. Indicating that without food sovereignty, food security is not possible. Within this work, Food sovereignty is defined as the right of Inuit to define their own hunting, gathering, fishing, land and water policies; the right to define what is sustainably, socially, economically and culturally appropriate for the distribution of food and to maintain ecological health. Following up on a key recommendation from the food security report to analyze management and co-management structures within Inuit Nunaat, the Inuit Food Sovereignty and Self-Governance project was born. Through this Inuit led work, we explored decision-making pathways and what impedes or supports Inuit food sovereignty. The project has resulted in a technical report which links Inuit Food Sovereignty to holistic and adaptive management strategies that can ensure the food security, health, and well-being of Inuit throughout the Arctic for generations to come. This presentation will offer an introduction to what food security from an Inuit perspective is, an overview of key themes and concepts brought forward in the Food Sovereignty and Self-Governance report, and discuss the strong connections between Inuit food sovereignty and Circumpolar adaptive and holistic management.

Adapting to Social and Environmental Stressors during a 3-month moon Habitat Simulation in Greenland

Pedro Marques-Quinteiro, ISPA- Instituto Universitário, Lisboa, Portugal

Keywords: Teamwork, Extreme environments, Polar Regions, Space

The LUNARK Moon Analog habitat (MAh) located in the Artic region represents a unique opportunity to study how the people working in the Artic circle respond to the social and environmental stressors that emerge during missions. The harshness of the environment and the lack of sound studies addressing how humans perform in remote sites such as the North Pole during long periods of isolation and confinement leverage the importance of identifying which task, human, and environmental factors might challenge the human capacity to collaborate. This research investigates what are the challenges that teams face during long duration Artic missions, and how do people respond to those challenges. Participants in this research are two male volunteers, enrolled in the MAh simulation experiment in Greenland over 3 months. Data collection is ongoing and will be completed in two weeks. The outcomes of this research project should leverage current knowledge about the temporal dynamics of human collaboration in isolated, confined and extreme environments such as the Artic. The lessons learned from this project can also be transferred to other similar environments on Earth (e.g. Antarctica, off-shore platforms) and Space.

Healthy Ageing in the Post-Pandemic Arctic: Possible or not Realistic?

Anastasia Emelyanova, University of Oulu & University of the Arctic, Finland
Elena Golubeva, Northern Arctic Federal University, Russia

Keywords: Healthy Ageing, Arctic, Best Practices, Cooperation

Even though individuals are living longer than in the past, it does not mean that they are living with better health and having their needs met, in particular during pandemic times. According to the WHO Decade of Healthy Aging 2020–30 program, healthy aging creates the environments and opportunities that enable people to do what they value throughout their lives. The Decade is an opportunity to bring together governments, civil society, international agencies, academia, and others for ten years of concerted and collaborative action to improve the lives of elders, their families, and the communities. The Arctic population experiences challenges related to demographic aging, raising life expectancy and well-being in old age. We will present our international research cooperation in the healthy aging theme. It includes several on-going research projects with higher education institutions and UArctic Thematic Networks. There we find best solutions from Arctic communities about their population aging healthily. According to our research, the ways how the Arctic population ages are unique and differ from southern regions of Arctic countries under the conditions of climate change and northern cultural diversity. The success or failure of healthy aging and living-in-place depends on the complex and context-sensitive factors and local context including social and demographic circumstances. We will present also examples related to dealing with the COVID19 among elderly in the Arctic.

Incorporating mining as the traditional economy: indigenous visions of sustainability in Northwest Russia

Anna Varfolomeeva, University of Helsinki, Helsinki, Finland

Keywords: Indigeneity, Traditional Economy, Mining, Sustainability, Russia

This paper focuses on indigenous and local practices of incorporating industries as a part of traditional economic activities. It discusses the case study of Veps indigenous minority residing in the Republic of Karelia, Northwest Russia. Since the 18th – 19th centuries, Karelian Veps have been engaged in the extraction of rare ornamental stones – gabbro-diabase and raspberry quartzite. This engagement continued throughout the Soviet period, and currently, most of the residents of Veps villages are still employed in stone quarries. Karelian Veps largely incorporated mining as a part of their indigenous identity. However, these conceptualizations often do not align with dominant state discourses, focusing heavily on the traditional indigenous subsistence economy. State institutions largely view mining and other forms of industrial development as modern activities contradicting the notion of traditional lifestyle. Within this paradigm, indigenous communities become symbolically fixed in the past and are denied of their rights for technological advancement. The contradictions between state-promoted notions of traditionality and indigenous actual lived experiences result in growing distrust towards the government. Based on the example of Veps, the paper discusses the importance of incorporating indigenous and local visions of identity formation and sustainability in dominant state narratives.

Fishery resources as an indicator of changes in social-ecological systems affected by informal roads

Natalia Krasnoshtanova, V.B. Sochava Institute of Geography SB RAS, Irkutsk, Russia
Vera Kuklina, George Washington University and V.B. Sochava Institute of Geography SB RAS, Washington, USA
Andrey N Petrov, University of Northern Iowa, Cedar Falls, USA
Oleg Sizov, Oil and Gas Research Institute RAS, Moscow, Russia
Viktor Bogdanov, V.B. Sochava Institute of Geography SB RAS, Irkutsk, Russia

Keywords: Informal Roads, Fishery Resources, Social-Ecological Systems, Indigenous People, Remote Communities

Human-nature relations within social-ecological systems (SES) have already been in the focus of scholarly attention for a long time, however, infrastructural and technological development became such an important factor that increasing body of research call for studies of social-ecological-technological systems. In this paper, we aim to understand changes in local fishery brought by expansion of the informal roads (IR) network that, in turn accompanies the industrial development of oil, gas and forest resources, and is affected by global environmental changes, technological advances in off-road vehicle manufacturing, and growth of economic wealth in surrounding areas. We base our research on learning from two remote indigenous communities of Eastern Siberia. An interdisciplinary approach was used and based on methods: social research (interviews and participant observation); statistical analysis of hydrological regime data; remote sensing analysis. The local residents shared their concerns about the fish resources depletion in places of traditional fishing. IR cause physicochemical pollution and hydrological regime changes of water bodies, which affect fish resources. IR also open access to fishing places for non-resident fishermen. As a result, local indigenous residents face degradation of culture in which fish is a substantial part of traditional diet. Thus, the local fishery resources as a component of SES serve as an important indicator of changes under the impact of IR.

Reindeer husbandry in peril? How extractive industries exert multiple pressures on an Arctic pastoral ecosystem

Christian Fohringer, Department of Wildlife, Fish, and Environmental Studies, Swedish University of Agricultural Sciences, SE-90183 Umeå, Sweden.
Gunhild Rosqvist, Department of Physical Geography and Quaternary Geology, Stockholm University, Stockholm SE-106 91, Sweden.
Niila Inga, Laevas Sámi community, Kiruna SE-981 95, Sweden.
Navinder J. Singh, Department of Wildlife, Fish, and Environmental Studies, Swedish University of Agricultural Sciences, SE-90183 Umeå, Sweden.

Keywords: Cumulative Impacts, Herder Knowledge, Historical Time Series, Land Use, Reindeer Herding

1. Environmental changes and their consequences on biodiversity are known to have far reaching effects on the resilience of animal populations and associated livelihoods around the world. To better understand the need for favourable habitat and options for unrestricted mobility, as well as to counteract negative demographic and economic effects on pastoralism, knowledge about the historical and current status of the environment is essential.

2. In this study, we show how extractive industries, especially largescale mining, induced a cascade of land conversions which are affecting animal populations and pastoralists' adaptive responses in northern Sweden. By incorporating herders' traditional knowledge, semidomesticated reindeer (Rangifer t. tarandus) population statistics and public data on socio-economic variables combined with geospatial tools, we illustrate how the reindeer husbandry functions as a proxy for socio-ecological vulnerability in the Arctic.

3. Caused by accumulation of multiple competing land-use pressures, we determine that approximately 34 % of Laevas reindeer herding community's grazing grounds are functionally unavailable to reindeer at present. Reindeer numbers currently only remain stable due to increased management efforts. Moreover, we identified current hotspots of high cumulative impact and mineral exploration as the spatially dominating land-use factor in this area.

4. Our approach and results provide new insights for scientifically robust cumulative impact assessments of anthropogenic stressors by creating a baseline of current developments via a combination of reindeer herder's knowledge with historical data of trends and extents of human activity over the last century.

Center-Periphery Relations in Norway on the Example of Wolf-Related Conflicts

Doris Friedrich; University of Vienna, Austria; The Arctic Institute

Keywords: Wolf-Related Conflicts, Rural-Urban, Wildlife Management, Norway

Center-periphery relations play an important role in any conceptualization of the North, even more so in attempts to grasp the link between rural and urban spaces. As is often the case in wildlife management and in particular Norway's regulation of predators, management regulations and measures are prescribed by a center more or less removed from the area concerned. In wolf-related conflicts, center-periphery relations become particularly salient. It can even be argued that they are at the core of the issue: Wolves have come to symbolize urban dominance in rural areas. In Norway, one crucial underlying cause of the wolf-related conflict is power struggles to determine the way of life on the countryside. The rural population's feeling of having their way of life dictated by some external, geographically removed authority and of having no control, is what makes the conflict especially hard to dismantle and renders arguments around the practical side of living with wolves irrelevant. Local politicians' opportunistic reframing of wolf management as "outsiders telling us what to do" plays on the powerlessness and hopelessness of people living in rural areas. However, successful wildlife management relies on the public support of associated policies and regulations. In this presentation, I will examine how center-periphery relations manifest themselves in wolf-related conflicts and investigate what role they play in attempts to appease let alone solve the conflict.

Domestication of mink in the Arctic: hunting to fur farming

Yuka Oishi, Kobe University, Kobe, Japan

Keywords: Domestication, Fur Farming, Hunting, Global History, Re-Marginalization

This paper will reveal the changes in the global fur industry after the depletion of wild fur resources in the Arctic Area, and consider how indigenous peoples have affected as the result. Fur has always attracted people not only as a material for clothing, but also as a symbol of wealth and rights. Imperial Russian merchants moved into the northeast of Eurasia in search of pelts, and Western merchants settled in the Americas and established fur companies. However, by the 18th century, fur resources such as sable and sea otter began to be noticeably depleted due to over-hunting, and international treaties on fur resources were signed in many places at the beginning of the 20th century. On the other hand, in 19th century led to the raising of fox, mink, sable, and other carnivorous fur animals one after another, and the breeding of these animals spread throughout the world, especially in cold regions. Through cross-breeding, a steady supply of pelts of various colors became available. And today, the main method of producing fur for distribution as clothing is not hunting wild animals, but fur farming. The change in global fur production and distribution due to the domestication of fur animals is a turning point and should have an impact on hunter-gatherer societies as well. Because hunting has fallen out of the mainstream of fur production, hunters in Siberia, Alaska, and North America have been re-marginalized in terms of fur production and distribution systems.

"General cleaning" of the Russian Arctic: restoration of territories from accumulated environmental damage

V. Budayeva, Siberian Federal University, Krasnoyarsk, Russia

Keywords: Arctic, Ecology, Environmental Protection

According to the observations of experts, the ecology of the Arctic has deteriorated, and this has happened due to industrial human activity. The planned active use of the Northern Sea Route also raises concerns - the volume of solid and liquid waste will increase; the risk of accidents with vessels increases with the subsequent spillage of both the transported fuel and the fuel that is used by the vessels themselves for movement. Much attention is paid to the issues of accumulated anthropogenic environmental damage that occurs after the elimination of various objects of the military and economic infrastructure in the North (for example, military bases on Franz Josef Land). In the absence of proper conservation and liquidation, these facilities have become sources of increased danger and pollution of territories and waters of the Arctic region. Despite the efforts undertaken, no state alone is capable to ensure the preservation of the unique Arctic natural resources. Therefore, it is important to establish an active dialogue between countries. International cooperation in the field of ecology, especially on issues affecting the Arctic sector, is essential, otherwise, it will be almost impossible to ensure a sufficient level of environmental protection.

Balance of environmental-economic relations of business and authorities in the Arctic Regions of Russia

Anastasiia Chapargina, Institute for Economic Problems KSC RAS, Apatity, Russia
Natalia Dyadik, Institute for Economic Problems KSC RAS, Apatity, Russia

Keywords: Ecology, Business, Non-Financial Reporting, Green Partnership, The Russian Arctic

The Arctic is a macroregion that is of great economic, military, strategic, and transport and logistics importance. In the Arctic, there are huge reserves of natural resources, including energy resources, and significant reserves of various metals. It should be noted that more than half of all the resources of the Arctic region are concentrated on the territory of Russia. For the Arctic regions, the environmental component is becoming one of the priorities of the development strategy due to the high level of vulnerability of their natural environment. The increasing attention to the problems of environment preserving, reducing the negative impact of economic activity, the development of a green economy is the worldwide trend, which is followed by the Arctic regions of the Russian Federation. The activities of industrial enterprises cause great damage to the ecosystems of territories of their presence. Currently, various state regulators (mechanisms) are used to assess this negative impact. However, the measures taken by the state are insufficient to compensate for the negative impact of industrial enterprises on the environment. In this regard, it is necessary to create a theoretical approach to solving the problem of greening of the Arctic regions based on an analysis of the environmental and economic relations between state and business.

Ensuring the ecological safety of the Arctic for the sustainable development of indigenous peoples

V.S. Varnikova, Siberian Federal University, Krasnoyarsk, Russia
V.A. Gromyko, Siberian Federal University, Krasnoyarsk, Russia
Ya.E. Kiseleva, Siberian Federal University, Krasnoyarsk, Russia
S.V.Sokolova, Siberian Federal University, Krasnoyarsk, Russia

Keywords: Arctic, Pollution, Indigenous People, Nuclear Waste

Many of Russia's Arctic regions are heavily polluted as a result of intensive industrial development, what poses a threat to human health. Russian scientists have identified 27 so-called "impact areas" in which the degree of pollution is so high that it has led to environmental degradation and increased morbidity among the local population. In general, about 15% of the territory of the Russian Arctic is currently contaminated with toxic substances. Along with other Arctic states, Russia is concerned about the problem of nuclear security in the Arctic region, especially in the Arctic seas. The Arctic zone is most vulnerable to radioactive contamination. Although the dumping of nuclear waste has now ceased, the waste in the seas remains a major problem for the country. In addition to the radiation pollution of the Arctic, the growing oil and gas production on the Arctic shelf causes serious concerns. According to experts, Russia today is pursuing a less clear and responsible policy with regard to ensure the environmental safety of its northern territories, a significant part of the population of which are indigenous peoples. The solution to this problem is seen in the formation of close cooperation between business and the indigenous communities. As well as the development of legal documents to facilitate the involvement of indigenous peoples in the decision-making process.

The impact of industry on the environmental safety of the Russian Arctic

E. Nadirova, Siberian Federal University, Krasnoyarsk, Russia

Keywords: Arctic, Eco-Friendly Technologies, Industry

Ensuring the environmental safety of the Arctic should be based on systematic measurements of a set of indicators of the environmental state. These indicators include: the state of atmospheric air and water resources, the preservation of biodiversity, the development and implementation of environmental innovations. The data analysis results show that air emissions in the Russian Arctic are almost three times higher than the national average. First of all, this is due to the high level of development of heavy industries in the Arctic regions: energy, mining, oil and gas processing and timber processing. There are a significant number of enterprises that use a large amount of water in their activities (aluminum production, timber processing, etc.) in the Russian Arctic. The volume of recycled and consistently used water is of great importance for characterizing the environmental friendliness of enterprises. Nowadays the implementation of Arctic carbon projects is still more dependent on the factor of economic efficiency than on the environmental component. Obviously, an integrated approach is needed: from the use of prohibitive measures - to the use of environmentally friendly technologies, not only in industrial production, but also in other spheres of life in the Arctic territories - from traditional industries to the public sector of the economy, represented by housing and communal services, civil construction, transport and recreational activities.

ID: 20 - The Arctic Highway(s): Multidirectional effects of socio-economic changes

Conveners

Yulia Zaika | Kola Research Centre of the Russian Academy of Sciences

Tuyara Gavrilyeva | North-Eastern University, Yakutsk

Access to the Territories of Traditional Nature Use: Mobility of Local Communities in the Conditions of Industrial Development

Viktoriia Filippova, Institute for Humanities Research and Indigenous Studies of the North, SB RAS, Yakutsk, Russia

Keywords: Arctic, Territories of Traditional Nature Use, Mobility, Yakutia

The problem of access to the territories of nature use is particularly relevant in areas where indigenous people engaged in traditional nature use have to interact with industrial companies. This interaction can lead to contestation between indigenous peoples and industrial companies due to differences in the perception of transport accessibility by both groups of stakeholders. This paper focuses on the case of Yakutia and addresses the following questions: To what extent do industrial companies build and improve roads in areas where indigenous peoples live, and in cases where this takes place, what are the motivations for these companies? Are indigenous peoples able to maintain access to territories of traditional nature use, when their access passes through the roads constructed by industrial companies? What role do informal roads play in the lives of indigenous people? And finally, do differences in lifestyles affect perception of remoteness?

Cross-border cooperation as the element of regional science diplomacy and the factor for self-development in the Russian Arctic (by the example of Murmansk region)

Yulia Zaika, Luzin Institute for Economic Studies — Subdivision of the Federal Research Centre "Kola Science Centre of the Russian Academy of Sciences" (IES KSC RAS), Apatity, Murmansk region, Russia

Keywords: Socio-Economic Changes, Arctic Self-Development, Northern Communities, Cross-Border Cooperation, Science Diplomacy

We aim at showcasing the influence of cross-border cooperation at different levels from regional and municipal governance to other local communities on self-development of the territories of the Arctic zone in Russia. Murmansk region is the model region and the only subject of the Arctic zone of the RF which has direct land borders to two countries – Norway and Finland. The international cooperation in the Murmansk region has a systematic pattern within the well-established regional agreements of cooperation. Even though such cooperation is random within the spatial-territorial projection of the region, international financial programs for the development of the socio-economic potential of the border territory greatly contribute to the extension of social, economic, and scientific infrastructure of the region predetermining the investment attractiveness of the territories. The institutional components of regional science diplomacy take different forms and shapes. Together with the active involvement of municipal and regional governments acting within the state inquiry for the active cross-border activity, such an approach provides better support and facilitation for the science connections in the transborder area. The new concept of the Russian government for the foundation of the world-class research and educational centers may strengthen the coherence of national actors of science diplomacy and facilitate cooperation within regions and between countries.

Multidimensional poverty assessment of rural population in Sakha Republic (Yakutia)

Tuyara Gavrilyeva, North-Eastern Federal University, Yakutsk, Russia

Keywords: Social Exclusion, Material Deprivation, Poverty

Methods of multidimensional poverty assessment were tested for the first time in the Sakha Republic (Yakutia) based on a representative sociological survey. The methods include social exclusion index and assessment of material deprivations. The SEI methodology used by Rosstat was adapted to the conditions of the northern region. Based on an expert survey, as well as an analysis of Arctic Social Indicators, developing since 2006, 10 replacement variables were selected that reflect the specifics of the life of the studied social group. The results were compared with the data of federal sample observations of Rosstat. Among key factors of social exclusion and material deprivation of the rural population are: severely worn infrastructure, limited availability and low quality of social services, underdeveloped public amenities in residential housing, transport and digital isolation. An assessment of the respondents' total income confirmed that rural households heavily depended on employment in social services domain, public assistance and pensions, as well as on private subsidiary farms and traditional economic activities. It was proved that the use of non-monetary methods, despite some methodological imperfections, allows allocating poverty risks under various socio-economic and demographic groups. Improving of non-monetary poverty assessment methodology in Russia will require not only updating of the existing list of indicators, but also incorporation of regional aspects.

Oil and Gas industry and Sustainable development in the Arctic

Stepanova Nadezhda, Parliament of Sakha (Yakutia), Yakutsk, Russia
Aleksei Pobedonostsev, European University Institute in Florence, Syktyvkar, Russia

Keywords: Oil And Gas Strategy, Arctic Zone, Sustainable Regional Development

Large oil and gas companies are actively investing in the development of oil and gas projects on the Arctic shelf. Russian authorities abopted the package of federal laws of the state support for entrepreneurial activities in the Arctic zone, aimed at supporting large oil and gas production and mining projects in Russian Arctic. At the same time, Russia is taking steps to implement sustainable model of development and to adapt its economy to the climate changes, maintain the level and quality of life of local communities. We pose the question - how does the socio-economic development of the Arctic regions affect the implementation of new oil and gas projects in the Arctic zone? The authors consider the social license models and their applicability in the Russian Arctic regions on the basis of socio-economic statistics, current pandemic situation and show the institutional framework, formation features and failures of the conceptial umbrella of the social lisense to operate model in the Russian Arctic regions.

Spatial features of urbanization in the Arctic regions (case of Yakutia)

Antonina Savvinova, North-Eastern federal university, Yakutsk, Russia
Galina Gnatyuk, North-Eastern federal university, Yakutsk, Russia

Keywords: Spatial Features Of Urbanization, Arctic Settlements, Yakutia, Demographic, Social And Economic Development

Modern processes of urbanization that occur in Arctic regions are largely determined by the conditions and characteristics of the historically established settlement system, which was determined by state priorities for this territory. In recent years, there have been processes of transformation of functional types and specialization of Arctic settlements. One of the characteristic reasons that significantly affect the process of urbanization of Yakutia over the past thirty years is the predominant development of the mining industry and its very uneven location. Another significant feature is the dominant role of the Republic's capital, Yakutsk. This causes the concentration of population in large cities due to internal migrations. At the same time, medium-sized and small cities, as elements of the industrial and transport sectors, continue to be local centers of population concentration, despite the stable migration outflow. Due to the significant differentiation in the degree of development of the territory, the density of settlement and the transport network, the urbanization system of Arctic regions is extremely heterogeneous in terms of the spatial location of its elements, their transport accessibility, demographic, social and economic development potential. Thus, socio-economic changes at the regional level can have an impact on the national and global level within the framework of the concept of Arctic sustainability.

Arctic regions sustainable path

Stepanova Nadezhda, PhD, Sakha Parliament, Yakutsk, Russia
Gavrilyeva Tuyara, Doctor of Economy, North Eastern Federal University, Yakutsk, Russia

Keywords: Arctic Zone, Ecosystem Services, Local Communities

The Arctic regions sustainable path is a complex multidimensional and interdisciplinary scientific and practical task. Environmental economic studies (Bobylev, 2019, Costanza R. 1999, Porfiriev B., 2015) propose to introduce new economic mechanisms with the aim to preserve natural ecosystems through the allocation and assessment of the "ecosystem services" over the territory as part of its natural capital use. For example, studies (TEEB, 2016, Bukvareva, E . et al, 2019) confirm that the natural capital of the Arctic not only the mineral resource base, but vast terrestrial ecosystems providing life-supporting services for people and economies, moreover, they donate these services for other regions. This understanding of terrestrial ecosystems in the Arctic finds a response in the legislation and practice of the northern countries of Europe, including Finland, especially in a situation when the territory of Lapland is becoming a territory of industrial development; for example, in recent years, the concept of a “social license of a subsoil user” has become into use (Koivurova, T., et al, 2015). At the same time, "ecosystem services" projects can be developed, introduced and realized as pilot initiatives in the regions. We argue that local communities can be involved into the ecosystems markets discussing the institutional framework of the special nature protected territories.

Human Capacity and Its Influence on Social Well-being in a Circumpolar Region

Anatoly Silin, Industrial University of Tyumen,Tyumen,Russia
Aleksandr Gyurdzhinyan,Industrial University of Tyumen,Russia

Keywords: Arctic, Development, Social And Human Potential, Modeling, Sociological Research

The purpose of the study was to create a model-sociological polygon that allows you to get the necessary sociological information during the preparation and adoption of management decisions by government structures in the monitoring mode and, thanks to this, , the problems of socio-spatial transformation of the Yamal territory were considered more effectively. Based on the methodology of socio-spatial and socio-territorial identification, the application of social modeling in this regard, the authors analyze the current state and trends in changes in both human (quantitative and qualitative characteristics of human resources, their health and level of professional training) and social potential (social connections, trust, inclusion in the regional community). This methodological approach is fundamentally new; it is proposed and implemented on the materials of the Arctic region (Yamal), which is significant for Russia, for the first time. Neither domestic nor foreign sociologists have conducted such work before. The model-sociological polygon formed in this way contains sociological information about the subjects of the new development of the North represented by a direct target (forecast) property: characteristics of important components (components) of the human and social potential of the Arctic frontier, in particular, a set of direct and indirect indicators of the number and quality of people who have expressed a desire and really intend to live and (or) work in the Arctic; their educational and professional competencies; their physical, mental and social health, etc. In the General format of social potential, indicators of social identification and social trust are highlighted.

ID: 75 - Arctic Voices in Art and Literature

Conveners

Ingeborg Høvik | UiT The Arctic University of Norway

Marie-Theres Federhofer | Humboldt-Universität zu Berlin

Sigfrid Kjeldaas | GenØk - Centre for Biosafety

Gendering Arctic Memory: Understanding the Legacy of Josephine Diebitsch-Peary

Ilisimatusarfik, University of Greenland

Keywords: Arctic, Gender, History, Memory, Exploration literature.

The study of memory cultures often foregrounds the recovery of denied historical truths, with the recognition that social and cultural norms not only shape canonical versions of the past, but continue to be complicit in legitimised forms of forgetting and erasure. This paper investigates the intersections between personal archives and other forms of cultural expression in acts of collective memoralization and forgetting. Using the personal archives of Josephine Diebitsch-Peary, the research introduces the concept of coloniality to studying Arctic memory cultures by examining the role of gender in the context of Arctic exploration literature. The paper concludes that an understanding of the coloniality of knowledge and its connections to epistemic violence is crucial to the study of memory and historical legacy in the Arctic.

Mapping and Materiality: Inuit Cartography in Greenland

Isabelle Gapp, University of York, UK

Keywords: Inuit, Greenland, Map-Making, Art History

This paper situates examples of Inuit map-making from across Greenland in contrast with Anglo-American imperial cartography from the nineteenth century; and considers how these pressure the connection between cartography and art making, colonialism and Indigeneity. The primary focus is on the Inuit hunter Silas Sandgreen's driftwood and sealskin Map of the Crown Prince Islands, Disko Bay, Greenland (1926), identified as a mediator between Inuit tradition and colonial geographical aids. Located at the entrance to Disko Bay on the west coast of Greenland, the now-abandoned Kronprinsen Ejland, or Kitsissut and Imerissoq Islands, and previously Whalefish Islands, have operated under many different names and existed across many colonial frameworks. They mark a critical and centuries-long meeting point between the local Inuit community; the Dutch and British whalers; expeditionary Anglo-American attempts to navigate the North-West Passage; and the Danish colonial settlers. Sandgreen's map, commissioned by the U.S. Library of Congress, contrasts with other known forms of Inuit geographical representation, notably the Ammassalik wooden maps of East Greenland, through its adaptation of western styles of map-making to an indigenous perspective on materiality and spatial representation. As such, this paper addresses how these tangible and tactile aids adapt an indigenous engagement and relationship with materiality, to colonial and Inuit traditions and audiences alike.

Masters of the Arctic. Art Historical and Political Dimensions of a Touring “Inuit Art” Exhibition (1989–1994)

Linn Burchert, Humboldt University, Berlin

Keywords: Inuit Art Exhibition, Climate Summits, Agency, Imperialism

The travelling exhibition Masters of the Arctic was first inaugurated in New York City in 1989 on the occasion of World Environment Day and then travelled until 1994 to various locations in the US, Canada, Latin America and Asia. The exhibition contained mainly contemporary small soapstone sculptures by “Inuit artists” from Canada, Alaska, Greenland and Siberia, and was sponsored by the US-American multi-level marketing company Amway. How and to what extent were “arctic voices” made visible or limited through the exhibition? To what extent did this exhibition employ or legitimize neo-colonial, imperial practices? In order to address these issues, I will problematize several art historical and curatorial as well as political and economic aspects of the exhibition.

Samuel Hearne's Arctic Animals: on cultural blindness, knowledge transfers and hope

Sigfrid Kjeldaas, UiT The Arctic University of Norway and GenØk Center for Biosafety, Tromsø, Norway

Keywords: Samuel Hearne, Animals, Traditional Knowledge, Science, Knowledge Transfer

Samuel Hearne's celebrated early contact narrative, A Journey to the Northern Ocean (1792), has in recent years been challenged by scholars pointing out how Hearne's journey to the Coppermine River supported the structurally violent colonialist enterprise of the Hudson Bay Company and served the company's need to show off its strategic geopolitical worth (Cameron 2015; Milligan and McCreary 2011). This paper attempts to do justice to the Indigenous people with whom Hearne traveled by getting beyond analyses that reduce his representations of the natural environment to mere tools in a colonialist inscription of the Canadian Arctic as empty space. I argue that our (Western) cultural blindness towards animals should not block our acknowledgement of the fact that Hearne's text is rich in both human and animal life. With this comes a recognition not only of other cultures' more intimate relationships with animals, but also of the transfer of knowledge from Denésquliné culture – via Hearne's Journal – into the scientific discourses of his time. Hearne's engaged and ecologically informed portrayal of Arctic animals was ahead of its time. It might today inspire a more sustainable development of the region, but only if we recognize how it is at present – partly due to the activities of the Hudson Bay Company – ecologically as well as culturally emptier than in the past.

Un-highlighting icons from museum collections

Charis Gullickson, UiT The Arctic University of Norway & The Nordnorsk Kunstmuseum, Romsa/Tromsø, Norway

Keywords: Art, Art History, Decolonization, Sápmi, Museums Are Not Neutral

This presentation sets out to decolonize the Nordnorsk Kunstmuseum in Sápmi, Northern Norway, through an analysis of French painter François-Auguste Biard's Le Pasteur Læstadius instruisant des Lapons (The Pastor Læstadius Teaching Laplanders), a nineteenth-century (1840) painting and an iconic work from the museum's collections. Based on Biard's travels with a French scientific expedition (the La Recherche) to the Arctic in 1839, the imaginative aspects of the painting underscore his outsider view of Sámi people. Taking this painting as my reference point, I start by discussing the object within the colonial context it was painted. From there, I examine the 2002 acquisition and subsequent display of the painting by the museum. Contextualizing the painting against these two backdrops, the colonization of Sápmi and the institutional history of the museum, is crucial to acknowledging the histories from which, I argue, the artwork is inseparably connected. The problem is rooted in the need to evaluate the painting contextually, paying close attention to the historical contexts and being aware of my own situatedness. Positioned in this realm exposes institutionalized colonial legacy and thereby inherent need to disrupt the painting. My investigation uses decolonial theory as a framework to acknowledge institutional blind spots, counter museum neutrality, and recognize the interwoven complexities of the past, present, and future of Sámi and Norwegian co-existence.

Messy episodes. Indigenous countersigns in Ludwig Choris‘s ethnographic portraits of Kamchadal, Aleut and Chukchi (1822)

Marie-Theres Federhofer, Humboldt-Universität zu Berlin, Nordeuropa-Institut

Keywords: Aleut, Kamchadal, Chukchi, Indigenous Portraits, 19th Century

Examining representations of Aleut, Kamchadal, and Chukchi people in Ludwig York Choris’s Voyage pittoresque autour du monde (Paris 1822), my presentation discusses methods of aesthetic and scientific visualisation in an early nineteenth-century research expedition. The album was the outcome of Choris’s participation in the second Russian circumnavigation (1815-1818) and is an invaluable ethnographic record of indigenous cultures in the North Pacific. I use the concept of “indigenous countersigns” (Douglas 2014) to investigate whether Aleut, Kamchadal, and Chukchi agency is inscribed in this little studied European work on indigenous peoples. Going beyond the common binary between “us” and “the others”, I discuss how indigenous presence is still traceable in these images. Further questions addressed concern the illustrations’ intended purpose and the influence of the contact zone wherein Choris and the indigenous actors had to meet for the drawings to be made in the first place. Besides the album Voyage pittoresque my presentation relies on Choris’s private journal (published for the first time in 1999), unpublished letters of Choris to Adelbert von Chamisso, another member of the Russian circumnavigation (to be found in the Staatsbibliothek zu Berlin – Preussischer Kulturbesitz) and around thirty, hitherto unknown watercolours by Choris (part of the Beinecke Collection, Yale).

Social Encounters: Portraits of the Yup'ik Women of Taciq, Alaska, 1850-51

Eavan O'Dochartaigh, Umeå University, Sweden

Keywords: Indigenous, Portraits, Arctic, Nineteenth Century, Women

During the mid-nineteenth century, over thirty maritime expeditions searched for the infamous Franklin expedition sent by the British Admiralty in 1845 that had vanished into the Northwest Passage. Several of these expeditions and individuals had extensive and sustained contact with Indigenous peoples who lived in the region. The officers of these expeditions, particularly surgeons and assistant surgeons, were expected to keep accurate visual and written records and in the case of the latter, were encouraged to keep details on natural history, including ethnographic information. The overt racism of many of these documents speaks to the attitudes of the era, yet despite this they are replete with valuable, if flawed, information. Through examining a selection of portraits that depict the women of Taciq (Saint Michael) in Norton Sound, Alaska, complexities of visual encounters can be revealed as inherently social encounters, often leaving traces of Indigenous agency. This paper is organised in two main sections. The first deals with the complexities surrounding visual interactions between outsider and insider in the Arctic during the early to mid-nineteenth century; the second looks in more detail at specific portraits, or visual encounters, drawing out the possible circumstances surrounding their creation.

The portrayal of Inuit and Sami in the Nordic polar exploration literature of the late 19th century

Paula Zeman, Humboldt University of Berlin

Keywords: Inuit, Sami, Nansen, Astrup, Sverdrup,

I would like to contribute to the ‘Arctic Science Summit Week’ by discussing my Master’s Thesis on the portrayal of Inuit and Sami in the Nordic polar exploration literature of the late 19th and early 20th century. The subject of the study are three expedition reports: Fridtjof Nansen’s Paa ski over Grønland (1890), Eivind Astrup’s Blandt Nordpolens Naboer (1895) and Otto Sverdrup’s Nyt Land Bd. 1 and 2 (1903). The analysis is based on the premise, that all three texts – even if they do not contain openly chauvinistic or pejorative statements about the indigenous peoples of the Arctic – are permeated by the colonial discourses of their time. To unveil these text-inherent discourses, I concentrate on the narrations of nature and culture and the role that space plays as a discursive framework. In conclusion, the study finds that Sami and Inuit are functionalised as ‘Other’ for the negotiation of the authors’ own cultural identities in all three texts. Their portrayal of the indigenous people is inseparable intertwined with their imaginations of the Arctic space and the ambitions they have towards it.

Traces of an Arctic Voice: the Case of Qalaseq

Ingeborg Høvik / UiT The Arctic University of Norway

Keywords: Qaanaaq, Qalaseq, Exploration, Contact Zone, Concurrences

This paper analyses the portrait (artist unknown, National Maritime Museum, London) of a young Inughuit, Qalaseq, who involuntarily was brought back to England from Qaanaaq (Northwest Greenland) with H.T. Austin's expedition in 1851. Although never displayed as an ethnographic image, it seems easy to denounce this portrait as a clear-cut expression of European colonial dominance. Representing the sitter in two views, en face and in profile, and as wearing a black suit and white shirt, the portrait betrays an interest in nineteenth-century racial and civilizing ideologies. Alongside the problematic content of this painting is the simple fact that the portrait testifies to his presence and participation in British society and an as of yet untold story in the history of Arctic exploration. Bringing in the trail of Indigenous and European sources that this portrait connects to, I trace the nature and terms of Qalaseq's stay in British society. As a decolonizing strategy, I use the concept and methodology of concurrences (Fur 2017). Examining moments of entanglement and competing truth claims in the European and Arctic sources about or relating to Qalaseq, my intention is to voice the concurrent (Arctic) perspectives on the Arctic, exploration and British imperialism contained in this material.

ID: 08 - Arctic Engineering – Research Supporting a Better Life in the Cold

Conveners

Alevtina Evgrafova | Leibniz Centre for Agricultural Landscape Research, Germany

Hajime Yamaguchi | University of Tokyo, Japan

Anne Barker | National Research Council Canada, Canada

Investigating Longyearbyen's local granular material as a low impact solution for the construction industry

Jean-Gabriel Dorval, NTNU, Trondheim, Norway

Keywords: Arctic Engineering, Road Material Testing, Marginal Material Valorization, Sustainable Development, Svalbard

Longyearbyen is the largest town on the Svalbard archipelago, and it uses rock masses for several applications in transportation and civil infrastructures. The geology of Svalbard is diversified but unfortunately the bedrock surrounding Longyearbyen is composed of sedimentary rocks. Due to gaps in the engineering knowledge and based on past construction experiences, these rocks are considered unsuitable as a construction material. The current practice is to import good quality granular material from mainland Norway by cargo ship which creates negative environmental and economic impacts. In a sustainable development perspective, an investigation on the local rock resource was completed in order to determine various engineering parameters and compare them to standards. The resistance to fragmentation and to wear of the local gravel was evaluated with abrasion tests. The particle shape, the freeze-thaw resistance, the thermal conductivity and the grain specific density were also determined. Additionally, a repeated load triaxial test was undertaken on four samples to evaluate the material behavior in a road structure. This study found that the aggregates from Longyearbyen differ in their resistance and mechanical behavior from those originating from the mainland. However, the results show that the crushed local granular material can be used for specific purposes. Standard parameters were established to take those differences into account for future infrastructure design.

Operation of the temperature regime of soils in the urbanized territories of the Arctic

Valery Grebenets, Lomonosov Moscow State University, Moscow, Russia

Keywords: Arctic, Building Deformations, Permafrost, Regulation Of The Temperature Regime

Recent research shows massive deformations of buildings and structures in the recent decades in the Russian Arctic. The results of observations of the temperature of permafrost in built-up areas indicate a trend towards an increase, the instability of the upper icy horizons is increasing, as well as activation of dangerous cryogenic processes. Most of the facilities are in a critical state in many Arctic settlements. The degree of infrastructure deformation varies in the range from 20-25 to 70-80%. The main reason is a decrease in the bearing capacity of frozen foundations caused by degradation tendencies in the permafrost. The main task is the need to control temperature conditions to ensure the stability of the engineering infrastructure in “New Reality” modern conditions. We can divide engineering-geocryological methods of temperature control by two directions: a) changing the conditions of heat and mass transfer between the atmosphere and permafrost foundations (arrangement of cold ventilated subfields, snow removal, drainage systems from the surface, etc.); b) active impact on soils (soil freezing). Our research in the north of Siberia has shown the high efficiency of an integrated approach (a combination of different techniques) for managing the permafrost situation for engineering purposes. The research was supported by the RFBR grant No. 18-05-60080 "Hazardous nival-glacial and cryogenic processes and their impact on infrastructure in the Arctic".

Drinking water quality in northern villages in Nunavik

Stephanie Guilherme, University of Ottawa

Keywords: Drinking Water, Nunavik, Water Quality, Water Storage

Drinking water systems supplying northern communities are facing several challenges, from the source water to the storage of drinking water in houses, making them particularly vulnerable to chemical or microbiological contamination. Many communities are subject to boil water advisories. Northern communities are facing water supply challenges in terms of quantity due to freezing and drying of source waters. Also, according to projections, global warming at high latitudes would lead to an increase in precipitation, which can significantly affect water quality if treatment is not adapted. In most villages in Nunavik, water is distributed within the villages by water trucks in reservoirs located in houses. This method may present a risk of contamination especially during the storage of water in tanks. In order to study water quality throughout this process, a sampling campaign was carried out in three Nunavik villages in the summer of 2019. Water was sampled at the source, at the water treatment plant, in the water truck and in several water tank reservoirs in public buildings and houses. Water quality, both chemical and microbiological, were tested. This conference presents the results of this portrait. This portrait was enable to identify critical points in the supply system, where the risks of water contamination are higher.

Evaluation of access to safe drinking water in Greenlandic settlements

Judith Maréchal, Department of Civil Engineering, Technical University of Denmark-Arctic DTU-Ilinniarfeqarfik Sisimiut
Pernille Erland Jensen, Department of Civil Engineering, Technical University of Denmark-Arctic DTU-Ilinniarfeqarfik Sisimiut
Kåre Hendriksen, Department of Civil Engineering, Technical University of Denmark-Arctic DTU-Ilinniarfeqarfik Sisimiut

Keywords: Safe Water, Arctic, Remote Communities, Health, Greenland

According to UN, everyone has the right to sufficient, continuous, safe, acceptable, physically accessible, and affordable water for personal and domestic use. Sustainable Development Goal target 6.1 calls for universal and equitable access to safe and affordable drinking water, and is tracked with the indicator of "safely managed drinking water services" – i.e. drinking water from an improved water source that is located on premises, available when needed, and free from fecal and priority chemical contamination. While running water is available in most households of the largest cities of Greenland, there are large variations in household supply systems throughout the country (Hendriksen, Hoffmann 2018), with the rural areas reportedly still having low in house access to piped water – estimated to an average of 75% overall (Bressler, Hennessy 2018), and as low as 56% in parts of Northern Greenland (Hennessy, Bressler 2016). This may severely affect water consumption and quality, and thus the health of the population (Mosites et al. 2020). As results of the first step of a larger research project, we present detailed data on the extent of piping to homes in specific Greenlandic settlements, water consumption per capita in each settlement, and settlement specific water related issues such as water quantity and quality. In conclusion, the deficiencies of water infrastructure vary significantly from one local community to another, due to the Island-operated infrastructure.

Affordability of Arctic electricity – An analysis of the dynamic cost behavior

Magnus de Witt, Reykjavik University, Reykjavik, Iceland

Keywords: Energy, Energy Transition, Energy Costs, Systems Dynamics

The high electricity cost in remote Arctic communities contributes to high living costs. A migration away from remote communities can be observed in some cases, which links to the high living cost and low-income opportunities. The presentation will elaborate on how the penetration of renewables will interact with the local market. Therefore it is crucial to consider the unique mixed-economy resulting from traditional subsistence activities and monetary economy. The electricity market in the remote Arctic differs from temperate areas. Remote Arctic communities have an islanded electricity system, which has no grid connection to other communities. The demanded electricity has to be produced in the community. There is no possibility of selling surplus electricity or buying if shortages occur. In 80% of the communities, diesel is the primary electricity source. Some diesel use problems depend on the community's location, the different means of transportation, such as trucks on ice-roads, barges, or planes. The various means of transportation depend on environmental conditions such as frozen rivers or sea ice. Due to this complication, the fuel delivery to the communities is limited to a few times per year. The mixed economy led to a unique situation in remote Arctic villages. This presentation shows the dynamic behavior in such a market, focusing on how these dynamics influence such communities' energy market. Among the communities, different degrees of subsistence can be found.

Hull Form Optimization of an Icebreaker for Minimizing Resistance in Ice

Keisuke Anzai, Japan Marine United Corporation, Mie, Japan
Takanori Hino, Yokohama National University, Kanagawa, Japan
Yutaka Yamauchi, Japan Marine United Corporation, Mie, Japan
Shigeya Mizuno, Japan Marine United Corporation, Mie, Japan

Keywords: Hull Optimization, Icebreaker, Resistance In Ice, Hull Design, Level Ice

In the development of an icebreaker, we design a hull form which meets the performance requirements at its navigating sea area in both ice-covered and open water conditions. For evaluation of icebreaker's performance in ice, ice tank tests are needed. These tests take long time because they need to make model ice for each test. Therefore, to develop a hull form with better performance within a limited development period, it is important to pre-design a hull form close to required performance before ice tank tests. For the first step to the development of hull form optimization system for icebreakers, an optimization method for minimizing resistance in level ice is devised. In the present method, resistance in level ice is estimated by numerical calculation and the hull form with the lowest resistance is obtained using a genetic algorithm. Resistance in level ice is estimated by using the calculation method 'Ice-Covered Hull Method' (ICHM) we developed. In this method, ice resistance is decomposed into ice breaking resistance, resistance due to ice buoyancy and clearing ice pieces. ICHM accounts for the whole underwater hull geometry not only around a water line. For an optimization procedure, a genetic algorithm from the open source optimization toolkit 'Dakota' is used. Application of the present method for the hull form optimization under the same principal particulars and constraints as the existing hull successfully generated a hull form with smaller ice resistance.

2D Calculation of Ship Maneuvering Control in Ice-covered Water

Junji Sawamura, Graduate School of Engineering, Osaka University, Osaka, Japan

Keywords: Icebreaking, Simulation, PI Controller, Marginal Ice Zone

Ship transportation in the Northern Sea Route (NSR) demands safe and efficient operation of a vessel from the both economical and environmental point of views. Ship maneuvering control is one method to decrease risks and increase efficiency of the operation of ice-going vessels. Ice-classed ship operating in the NSR transits MIZ (marginal ice zone). The ship operating in MIZ not only collides with the small ice floes but also breaks the level ice. Therefore, the ship-ice interactions for the ship going though NSR needs to include the ship-ice collision and ice breaking. Several numerical models to predict ship going through level ice and small ice floes have been developed. However, ship control in both of level ice and small ice floes has not been developed yet. This study demonstrates 2D simulations of a ship advancing into ice-covered water. The ice floes and ship were numerically modeled by a physically based modeling with 3DOF equation of motion. The icebreaking is estimated by the bending behavior of a floating ice plate which is obtainable from the fluid-structure interaction. The interactions between ship and broken ice floes and the fluid force induced by ship advancing are neglected for simplification of numerical modeling. Proportional-Integral (PI) controller is applied in the numerical model to control the vessel's thrust power and to steer the vessel to the desired speed. The simulation results in different ice conditions are presented and analyzed.

Trends and Perspectives on Arctic Shipping Potential from Scientific Research

Chathumi Ayanthi Kavirathna, The University of Tokyo, Tokyo, Japan
Ryuichi Shibasaki, The University of Tokyo, Tokyo, Japan

Keywords: Arctic Shipping, Perspectives, Systematic Review, Economic Feasibility, Engineering Aspects

The retreat of the Arctic sea ice explores diverse opportunities as highlighted by a growing number of related academic publications. Focusing on trends and perspectives on Arctic shipping, this study summarizes 43 selected research articles published after 2009 that focused on cost comparison of Arctic and conventional routes, environment concerns, operational aspects of Arctic shipping, criteria for choosing Arctic routes, navigation speeds, and effects of Arctic shipping on other economics. Further, focused geographical markets of previous studies, commodities, methodological aspects, factors for model developments, navigable periods, vessel types and speeds, and routing geometry were discussed. Accordingly, Arctic routes were feasible mainly at high fuel prices, with a long navigable period, with certain vessel sizes, and with low transit fees. Studies mainly focused on container cargo, including Japan or China as focused markets, and considered summer navigation. This review highlights the gap between the economic feasibility of Arctic shipping mainly derived by transport cost models of previous studies and the crucial engineering aspects essential in modeling Arctic shipping including ice-condition, sea-ice resistance, risk, navigability conditions, among others. Hence, this review has a significant contribution by providing directions on exploring Arctic shipping potential with engineering research efforts to derive better implications on the Arctic shipping community.

Development and use of visualization tools for Arctic products

Hironori Yabuki, National Institute of Polar Research(NIPR), Tokyo, Japan
Takeshi Sugimurai, National Institute of Polar Research(NIPR), Tokyo, Japan

Keywords: Visualization, ADS, Sea Ice Thickness, AMSR2

We are constructing Arctic Date archive System (ADS) which is the online database system of the data about Arctic research collected from many researchers and institutes. ADS is constructed to aims to share the data and utilized by the many researchers specializing in the various fields of Arctic. Wide-area data sets in the Arctic include satellite products and model simulation data. The use of these data required specialized knowledge, such as the complexity of Formatting and the skill of using visualization software. For engaging among arctic research products, we developed a GUI-based online data visualization application named “VISION”. The VISION can be easily operated using only a Web Browser. It can be expected that VISION facilitates a sharing and understanding the data of the various fields in the Arctic, and the user become also use the data out of their own fields. In VISION, without understanding the format of various data products, visualization od data. It is also possible to create simple operations, 2D plot graphs, and time series graphs. The data implemented in VISION are AMSR2 products such as sea ice concentration and sea ice thickness, and simulation data of climate models such as temperature and atmospheric pressure. These users are used by university students and graduate students to create reports. It is also used in industry to analyze Arctic sea ice thickness. ADS will continue to increase the number of products that can be used with VISION.

Geography of cryogenic processes hazardous to infrastructure in the Russian Arctic

Alexander Kizyakov, Lomonosov Moscow State University, Moscow, Russia
Valery Grebenets, Lomonosov Moscow State University, Moscow, Russia
Irina Streletskaya, Lomonosov Moscow State University, Moscow, Russia
Vasily Tolmanov, Lomonosov Moscow State University, Moscow, Russia
Fedor Iurov, Lomonosov Moscow State University, Moscow, Russia

Keywords: Hazardous Cryogenic Processes, Infrastructure, Arctic

Cryogenic processes present significant problem for the infrastructure of the Arctic regions. They are activated as a result of climate change and increase in technogenic load. These processes enhance the danger for buildings and structures due to combined integral impact. The instability of the upper icy horizons is increasing under the conditions of fixed tendencies to an increase in temperature in the upper horizons of frozen soils. This significantly accelerates the development of "warm" cryogenic processes: thermokarst, thermal erosion and thermal abrasion. Temperature changes lead to decrease in stability of slopes in the mountainous regions of the cryolithozone. Special attention was paid to the study of the cryogenic destruction of the material of underground structures. A database was created on the development of various groups of cryogenic processes in the Russian Arctic and their hazard to infrastructure facilities. The geography of distribution and activity of various groups of processes was determined. The results of the analysis were presented in the form of a map of the development of dangerous cryogenic processes in cities and large settlements of the Russian Arctic on a scale of 1: 15000000. This work was supported by the RFBR grant No. 18-05-60080 "Hazardous nival-glacial and cryogenic processes and their impact on infrastructure in the Arctic".

Engineering research for resilient arctic infrastructure

Anne Barker, National Research Council of Canada, Ottawa, Canada

Keywords: Engineering, Shipping, Infrastructure, Research

Resilient northern infrastructure must not only weather changing environmental conditions, but also reflect the needs of the communities who use it. It should be appropriate for the operating conditions under which it will perform, the long term operational requirements of maintaining it, and the capacity development needs to successfully build and operate it. Further, it should be led from communities, be culturally appropriate, be at least partially de-risked prior to installation, have the potential to inform development in other regions and have the capacity to support local economic development. This type of development requires holistic approaches, encompassing more than engineering and construction, by incorporating traditional knowledge, local expectations, risks and social and economic benefits. In order to get to this development stage, research into tools and technologies that may have performance advantages is required. Past procurement decisions by communities based on certification ratings alone have shown that this is not sufficient for many commercially-available products once they move into sustained, often harsh weather environments. Coupled with changing environmental conditions and limited shipping windows in remote regions, new technologies must reflect these realities. This presentation will highlight research that addresses these challenges, focusing upon community-partnered engineering research into housing infrastructure, safety and shipping risk assessment for community resupply operations. Engineering research structured with this holistic approach in mind will lead to outcomes and impacts from which communities, first and foremost, derive benefit.

ID: 19 - Northern Roads and Railways: Social and Environmental Effects of Transport Infrastructure

Conveners

Olga Povoroznyuk | Department for Social and Cultural Anthropology, University of Vienna, Vienna, Austria olga.povoroznyuk@univie.ac.at Yes Warwick F. Vincent Centre for Northern Studies (CEN) & Dépt de Biologie, Laval University, Quebec City, Canada

Warwick F. Vincent | Centre for Northern Studies (CEN) & Dépt de Biologie, Laval University, Quebec City, Canada

Fabrice Calmels | YukonU Research Centre, Yukon University Whitehorse, Canada

Cumulative impacts of a road and climate change to the vegetation and terrain of an ice-wedge polygon landscape, Prudhoe Bay Oilfield, Alaska, 1949–2019

Donald A. Walker, Corresponding author, University of Alaska Fairbanks, Institute of Arctic Biology, and Department of Biology and Wildlife, Fairbanks, Alaska, USA
Martha K. Raynolds, Corresponding author, University of Alaska Fairbanks, Institute of Arctic Biology, and Department of Biology and Wildlife, Fairbanks, Alaska, USA
Mikhail Z. Kanevskiy, University of Alaska Fairbanks, Institute of Northern Engineering, Fairbanks, Alaska, USA
Yuri Shur, University of Alaska Fairbanks, Institute of Northern Engineering, Fairbanks, Alaska, USA
Vladimir E. Romanovsky, University of Alaska Fairbanks, Geophysical Institute and Department of Geology and Geophysics, Fairbanks, Alaska, USA
Benjamin M. Jones, University of Alaska Fairbanks, Institute of Northern Engineering, Fairbanks, Alaska, USA
Marcel Buchhorn, VITO, Boeretang 200, BE-2400 MOL, Belgium
M. Torre Jorgenson, Alaska Ecoscience, Fairbanks, Alaska, USA
Jozef Šibík, Institute of Botany, Plant Science and Biodiversity Center of Slovak Academy of Sciences, Bratislava, Slovak Republic
Amy L. Breen, Corresponding author, University of Alaska Fairbanks, Institute of Arctic Biology, and Department of Biology and Wildlife, Fairbanks, Alaska, USA; International Arctic Research Center, University of Alaska Fairbanks, USA
Emily Watson-Cook, Corresponding author, University of Alaska Fairbanks, Institute of Arctic Biology, and Department of Biology and Wildlife, Fairbanks, Alaska, USA
Jana L. Peirce, Corresponding author, University of Alaska Fairbanks, Institute of Arctic Biology, and Department of Biology and Wildlife, Fairbanks, Alaska, USA

Keywords: Arctic Change Detection, Road Dust, Flooding, Permafrost, Thermokarst, Oilfield Infrastructure, Microtopography, Snow Drifts, Species Richness, Shrubs, Mosses, Leaf-Area Index

Environmental impact assessments generally consider only the direct impacts (footprint) of roads. Here we use historical aerial photographs, climate data, transects, and permanent plots to examine the long-term indirect impact of climate change and infrastructure to vegetation structure, species diversity, polygon microtopography, water, snow, soil thaw depths, and road dust on opposite sides of the heavily traveled Spine Road, built in 1969 in the Prudhoe Bay Oilfield. We compared vegetation data from this site to data from nearby comparable undisturbed sites in the 1970s and with a current site more distant from roads. The morphology of the original low-centered ice-wedge polygon landscape changed little between 1949 and 1989, but by 2014, the landscape had transitioned to a mix of high- and low-centered polygons with extensive thaw ponds in polygon troughs. Differences in vegetation were observed in ice-wedge polygon centers and troughs and on flooded vs. non-flooded sides of the road. Heavy road dust was most apparent on the non-flooded side, where much reduced plant diversity, especially of mosses and lichens was observed. The flooded side was characterized by deeper subsidence in ice-wedge troughs, greater center-trough relief, development of interconnected thermokarst ponds, taller vegetation, and higher leaf-area indices compared to the non-flooded side. Indirect impacts of road dust extended more than 200 m from the road even on the upwind side of the road.

Roads and Railroads in the North: What Do They Do for Local Communities?

Peter Schweitzer, University of Vienna, Vienna, Austria

Keywords: Roads, Railroads, Transport Infrastructure, Community Impacts, Community Sustainability

While the paucity of modern transport infrastructures in the Arctic may be inconvenient for residents and visitors alike, it enables the continuation of subsistence and cultural practices in relatively undisturbed natural environments. In other words, arctic roads and railroads can have positive or negative social and cultural consequences for residents of the North, but they are certainly not neutral elements of the built environment. Recent years have seen increased economic and geopolitical arctic interests by outside players. The realization of these interests typically involves the construction of new or the upgrading of existing transport infrastructures in the Arctic. One of the resulting questions is whether they will benefit local residents or whether they will be used more or exclusively for transporting arctic resources south. This presentation is based on a literature review of the known impacts of roads and railroads in the North, as well as on data collected in the course of the recently completed FWF project “Configurations of Remoteness”, the ongoing H2020 project “Nunataryuk”, and the newly launched ERC project “Building Arctic Futures: Transport Infrastructures and Sustainable Northern Communities” (INFRANORTH). The goal is to explore the relationship between arctic communities and transport infrastructures, as well as to lay the ground work for comparative research on the social impacts of roads and railroads in other remote regions of the globe.

Roads and Railroads of the Russian North: Social Dimensions of Infrastructure Projects

Olga Povoroznyuk, Institute for Cultural and Social Anthropology, University of Vienna

Keywords: Roads, Railroads, Social Dimensions, Russia

Recent social science research on roads and railroads has been focused on the issues of modernization and development, mobility and immobility, connectivity, disconnection and remoteness, as well as on social and cultural transformations triggered by these infrastructures. Roads and railroads in the Circumpolar North have been drawing increasing attention of researchers due to their tremendous social effects on remote sparsely populated local communities. Russian (formerly, Soviet) North has been characterized by relatively high degrees of industrialization and urbanization that boosted the construction of roads and railroads. While the Soviet state used a mixture of ideological propaganda and forced labour for the implementation of its large-scale projects, more recent construction plans are fueled primarily by multinational resource extraction interests. This paper, drawing on some case studies from the Russian North, calls for more attention to the entanglements between humans and transport infrastructure in a long-term historical perspective. The literature-based examples of the roads and railroads' projects will be followed by an empirically based long-term study of the Baikal-Amur Mainline, a railroad that became a population magnet and an agent of major social and cultural transformations. This presentation is based on research conducted within the project "Configurations of Remoteness" (CoRe), supported by the Austrian Science Fund FWF.

Geohazards caused by massive ice below the Dempster Highway, YT: an overview and some possible adaptation approaches

Fabrice Calmels, Yukon University, Whitehorse, Canada
Louis-Philippe Roy, Yukon University, Whitehorse, Canada
Pamela Godin, Yukon University, Whitehorse, Canada
Cyrielle Laurent, Yukon University, Whitehorse, Canada
Muhammad Idrees, Yukon Highways and Public Works, Whitehorse, Canada

Keywords: Permafrost, Highways, Geohazards, Massive Ice, Yukon

The melt of massive ice (i.e. large masses of ground ice, including ice wedges, pingo ice, buried ice and large ice lenses) can result in major damage to transport infrastructure and potentially serious geohazards. Such ground ice is present under the Dempster Highway, the first all-weather year-round road route connecting the Canadian road network with the Arctic Ocean, in Canada. Permafrost conditions were investigated underneath a 135 km section (from km 65 to km 200) of the Dempster Highway, where ongoing maintenance issues have been linked to permafrost thaw. Geophysical data, aerial imagery and borehole information were combined with field investigation to identify geohazards and thaw-sensitive permafrost underlying the highway. While some sites are currently impacted by the melt of massive ice such as ice wedges, other sites underlain by buried glacial ice may not become critical for several years or decades. The study results will be used to develop recommendations for Yukon Highways & Public Works regarding strategies to adapt to climate change for the highway, allowing H&PW to prioritize maintenance areas, develop remediation methods for high-risk highway sections, and implement monitoring approaches in order to have advance warning of the need for more aggressive responses.

Tracing footprints of human-nature relations: case-study of informal roads in changing Siberian taiga

Vera Kuklina, George Washington University and V.B. Sochava Institute of Geography SB RAS, Washington, USA
Natalia Krasnoshtanova, V.B. Sochava Institute of Geography SB RAS, Irkutsk, Russia
Andrey N Petrov, University of Northern Iowa, Cedar Falls, USA
Oleg Sizov, Oil and Gas Research Institute RAS, Moscow, Russia

Keywords: Informal Roads, Remote Region, Human-Nature Relations, Siberia, Footprints

While human-nature relations are the major focus of numerous disciplines, there are still only a few studies on how these relations are manifested. Transportation infrastructure is the most evident way to connect people with resources. In remote regions, local transportation pathways quite often have an informal character. Studies of these roads are especially important for understanding human-nature relations since, unlike conventional roads connecting human settlements, they provide access for people to natural resources. In this paper, we study informal roads in an extractive remote region of Siberia, encompassing the territories of traditional land use of the Indigenous Evenki Peoples. Based on field research (interviews and in-situ observations conducted in 2019) and remote sensing analysis (very high resolution WorldView-3 and Corona images) we created maps of short- (seasonal) and mid- (decadal) term changes in informal road networks. These maps demonstrate links between dwellings and subsistence resources of local communities that have been affected by extractive industrial development. Morphology and structure of these footprints indicate changes in demand and availability of natural resources, environmental conditions, vehicle capacities, personal wealth, and driver's skills and abilities. Such detailed maps contribute to understanding sustainability and resilience issues in human-nature relations.

Small vessels in social and economic development of the Russian Arctic

Marina Nenasheva, Associate Professor, Northern Arctic Federal University

Keywords: Small Vessels, Social And Economic Development, Russian Arctic, Russian European North, Arkhangelsk Region

The study aimed at research of the role of small vessels in social and economic development of the Russian European North. The materials of field work conducted on islands of Arkhangelsk region in June 2019 and in August 2020 show that small vessels are still used by local communities for satisfaction of vital needs. In the recent years the demand of small vessels has become particularly noticeable due to the reduction of passenger's transportation by river transport as well as growing interest in use of recreational potential of the Russian Arctic. It is hypothesized that the integration of small vessels shipping into the river business can contribute to economic and social development of the territories of the Russian European North.

Changes of river ice characteristics in the North-East of Russia

Anastasia Zemlianskova, North-Eastern Permafrost Station of Melnikov Permafrost Institute, Magadan, Russia
Olga Makarieva, North-Eastern Permafrost Station of Melnikov Permafrost Institute, Magadan, Russia
Natalia Nesterova, North-Eastern Permafrost Station of Melnikov Permafrost Institute, Magadan, Russia

Keywords: Winter Road, Climate Changes, River Ice Thickness, The North-East Of Russia, Ice Cover Period

In the economic development of the Arctic regions, the main role is played by road communication between them. In winter, the river network is used as road arteries. In the North-East of Russia, winter roads are laid along the river network. Since there is no regular road connection, they make it possible to deliver cargo to remote regions. To equip a winter road, it is necessary to know the design loads for different types of vehicles. The building codes establish that for wheeled vehicles to travel on a 15-ton winter road, ice 60 cm thick and 195 cm thick is required for a 100-ton truck to pass. In connection with climate warming, the timing of ice formation changes, as well as its maximum values. The purpose of this study is to analyze these changes. A number of data for the period 1951-2017 were used to assess the changes on the thickness of the ice cover at 80 hydrological stations located in the basins of the Yana, Indigirka, Kolyma rivers, the rivers of the Chukchi Peninsula and the Sea of Okhotsk basin. The catchment areas range from 18.3 to 635,000 sq. km, and the length of the continuous series ranges from 4 to 60 years. There is a noticeable time shift in the formation of the required ice thickness for the operation of winter roads. Later, on 7-41 days, a passage for passenger cars opens (ice thickness 60 cm), and in order for heavy trucks (100 tons) to pass, conditions are not formed every year. This should have a strong impact on the regional economies.

Transport accessibility problems of the isolated settlements in Russian European Arctic Zone

Alexey A. Pankratov, Lomonosov Moscow State University, Moscow, Russia
Svetlana V. Badina, Plekhanov Russian University of Economics and Lomonosov Moscow State University, Moscow, Russia
Kirill V. Yankov, Institute of Economic Forecasting Russian Academy of Sciences, Moscow, Russia

Keywords: The Arctic Zone Of Russia, Settlements, Year-Round Ground Transport Accessibility, Roads, Railways

Authors have identified and analyzed the list of settlements in the Russian European Arctic regions that are not provided with year-round ground transport accessibility with another territory, that is, are not included in regional and federal land transport networks. The year-round ground transport accessibility concept is introduced as the availability of a year-round transport connection with the core federal highways network on hard-surface roads providing year-round operation along the entire length, or by rail, with possible transfers (congestion) between roads and by rail. A database and GIS of this settlements category are compiled; a quantitative assessment of the resident population living number in them is given. Quantitative estimates indicate an extreme unevenness between the settlements number in the existing Russian European Arctic settlement network and the distribution of their population. The features of the internal Arctic regions transport systems are identified and analyzed from their optimization point of view taking into account the isolated settlements presence. Based on the study, recommendations on specific problems of the island and other isolated territories development, including the use of “local” transport modes, transport and pedestrian infrastructure are formulated.

ID: 18 - Adapting to Climate: People and Buildings in Extremely Cold Regions

Conveners

Susan Roaf | Architectural Engineering, Heriot Watt University

Wouter van Market Lichtenbelt | Thermophysiology & Metabolism, Maastricht University

Weather, climate and human health in the Arctic

Elena Grigorieva, Institute for Complex Analysis of Regional Problems Far Eastern Branch Russian Academy of Sciences, Birobidzhan, Russian Federation

Keywords: Bioclimatic Indices, Climatic Discomfort, Human Health Indicators, Russian Arctic

The thermal load of the environment on the human body is an important indicator of climate discomfort, especially the extraordinary conditions of the Arctic with extreme cold temperatures combined with strong wind, and the most vulnerable groups of the population children and the elderly, as well as people with cardiovascular and respiratory disease. The purpose of this study is to identify and evaluate the bioclimatic conditions in the Arctic as natural drivers of the quality of life of the population. In order to show the interaction of climate and humans, objective bioclimatic conditions are relate to the health status of the population based on statistical data on morbidity and mortality. To analyze the thermal stress on human body at the circumpolar regions, a combination of bioclimatic thermal indices was calculated based on climate data. Bioclimatic discomfort metrics for the vast circumpolar area are described, mapping the results for better visualization. High correlation coefficients of health indicators with thermal discomfort expressed by bioclimatic indices confirmed the assumption about the climatic determination of the population health in the Russian Arctic. The high value of diseases of circulatory and respiratory systems, as well as low values of mortality from all causes of death and diseases of the circulatory system in Chukotka Autonomous Okrug in the far north of the Russian Far East need to be discussed.

The Sami hut – from life saver to symbol of assimilation

Peter Sköld, Arctic Research Center at Umeå University, Sweden

Keywords: Indigenous, Sami, Hut, Assimilation, Coldness

The indigenous Sami of northern Scandinavia and Russia have lived on the land in a cold region for thousands of years. Traditionally they have demonstrated a sustainable use of land and water that is based on a circular time perspective. Their traditional buildings, the Sami huts, have developed based on experiences and knowledge. The huts represent the importance of reindeer in Sami life, and as a precondition to survive in the cold climate. However, they also represent a substantially changed way of life for Sami families, thereby being part of an extensive assimilation process. It is well known that Sami languages have a plentiful of words describing snow, ice and weather conditions that are part of a terminology and a knowledge system. The Sami have had a constant struggle with coldness, and have developed techniques and strategies to live in the cold, but they have also suffered from the risks that are involved. During the past hundred years the Sami society has been influenced by an assimilation process that has changed their way of living. There are both pros and cons with this; living-conditions and health conditions have improved, but languages and knowledge systems are currently under threat and the hut has lost its function of life saver.

Thermal adaptation of buildings and people in Himalayan region of Nepal

Hom B. Rijal, Department of Restoration Ecology and Built Environment, Tokyo City University, Yokohama, Japan

Keywords: Nepal, Himalaya, Extreme cold climate, Passive building design, Comfort temperature

The thermal adaptation of buildings and their residents is important in extreme cold climates for sustainable building design. The Lo Manthang (3705m altitude), which is located in Himalayan region of Nepal, has a low outdoor air temperature (minimum: –22.5°C) and high wind velocity (above 10 m/s). A thermal measurement and a thermal comfort survey were conducted in traditional houses during the winter. Measurements were taken in 9 houses over 7 days to assess the thermal environment. Thermal comfort surveys were conducted over 4 days, and a total of 1,584 thermal responses were gathered from 36 residents. Passive heating effects were found in houses with thick brick walls and mud roofs. Residents of these houses were satisfied with the thermal environment, with 10.7°C being the mean comfort temperature, which was related to the indoor temperature of the investigated houses. People are accustomed to adjusting their comfort level at low temperatures by wearing heavy clothing, which might be a reference to determine the lower limit of acceptable temperature standards. It can be concluded from these findings that people are well adapted to the thermal environment of traditional vernacular houses, as a result of which the comfort temperature is lower than the thermal comfort standards. It would be beneficial to sustain the traditional vernacular buildings for both the local climate and culture, and their passive building design methods can be implemented in similar climates.

Performance of traditional nomadic yurts for living in extremes

Dolaana Khovalyg, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland
Arnab Chatterjee, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland
Wouter van Marken Lichtenbelt, Maastricht University, Maastricht, The Netherlands

Keywords: Traditional Living, Nomads, Cold Climate, Dynamic Performance, Thermal Environment

A round felt yurt is a traditional dwelling of Central Asian nomads that have survived over 2000 years. The structure and the use of the yurt have not changed over the centuries, making it a nomadic civilization's masterpiece. It has not lost its relevance even nowadays since many nomadic nations such as Mongolians, Tuvans, Kazakhs are still using it in everyday life. Interestingly, a significant population of nomads lives in Asia's regions with a strongly continental climate with cold winters and hot summers. Winters can be severe, with temperatures dropping below -40oC. Therefore, studying the performance of traditional nomadic yurts can provide insight into designing dwellings for extreme living. A typical yurt has a flexible lattice wall, long ceiling poles, and the crown forming the roof of the structure. The yurt's skeleton is covered with multiple layers of thin materials, including a traditional felt crafted using sheep wool. Felt, having relatively low thermal conductivity, acts as the main insulating material, although it can only be 10 mm thick. Certainly, the insulation layer of the yurt is not sufficient to withstand heat losses in cold weather; therefore, a cast-iron stove in the center of the yurt is the primary heat source that keeps the yurt warm and livable. To detail the yurt's dynamic performance as a function of nomads' lifestyle, a multidisciplinary study by the team of authors was performed in Tuva, a region in the South of Siberia, in January'2020. Monitoring of the temporal variation of indoor microclimate, outdoor conditions, and thermo-physical characteristics of multiple yurts revealed a strong relationship between indoor environmental parameters such as temperatures, relative humidity, and air speed with daily activities of nomadic occupants.

Traditional living in extremes: Thermoregulation, energy expenditure and physical activity of nomadic pastoralists

Wouter van Marken Lichtenbelt, NUTRIM, Maastricht University, Maastricht, The Netherlands
Adam Sellers, NUTRIM, Maastricht University, Maastricht, The Netherlands
Dolaana Khovalyg, TEBEL, École Polytechnique Fédérale de Lausanne (EPFL), Fribourg, Switzerland

Keywords: Cold, Nomadic Pastoralist, Energy Metabolism, Physical Activity, Thermoregulation

Tuvan nomadic pastoralists living in yurts were studied in January 2020. These nomads are living in a region with extreme seasonal differences in temperatures. In winter, they are exposed to indoor-outdoor variations of more than 50°C! This multi-disciplinary study encompasses physiological, health, and sociological aspects combined with physics of climate and yurts. Here we examine the effect of the extreme conditions on body temperatures, energy metabolism, and physical activity and compare these to earlier studies in Yakut (Siberia). Males (9) and females (3), living in Tuva (Siberia) were intensely studied during 12 consecutive days in winter. Field measurements encompassed monitoring of in- and out-door temperatures, body temperatures, average daily metabolic rate (ADMR by doubly labeled water), and physical activity (ActiGraph). Besides, under laboratory conditions resting metabolic rate (RMR) was measured. Preliminary analyses show frequent exposure to extreme temperatures (outdoor: -32 to -5 °C; indoor: -10 to +52 °C). Skin temperature variations are mild, ranging from 31-38 °C for chest and shoulder. RMR and ADMR are relatively high compared to those reported to Yakut. The physical activity level in Tuvans is also high compared to the Yakut, using the physical activity index (ADMR/RMR) or the ActiGraph recordings. In conclusion, the preliminary results indicate that the body temperatures correspond to western population. The influence of the clothing insulation will be further investigated. Interesting are the relatively high levels of energy expenditure and physical activity in these nomadic people, most likely caused by a combination of the regular cold exposure and daily living activities.

Historical advances in cold weather clothing: case study on clothing of early 20th century explorers, Robert F. Scott, Roald Amundsen, & George Mallory

George Havenith, Loughborough University, School of Design and Creative Arts

Keywords: Everest, Antarctic, Clothing, Survival, Explorer

Replica clothing as worn by Robert F. Scott and Roald Amundsen in their race to be the first on the South Pole (1911) and by George Mallory (1924) in his fatal ascent attempt of Everest was tested for thermal insulative properties. These were benchmarked against modern day explorer clothing. Results are discussed in terms of insulation, insulation per weight, and wind protection. Further the effects of the clothing on energy consumption were considered as well as the effect of altitude on insulation and on energy consumption. The biggest advantage of modern clothing seems to be its lower weight. Scott's clothing resulted in extra energy usage for the wearers and provided less insulation than Amundsen's, though sufficient while active. The Mallory clothing had a low energy requirement due to the incorporation of 'slippery' silk layers. Its insulation would have been sufficient during activity down to -30ºC in low wind. If wind were to increase, the clothing would however not have provided the required insulation for survival.

Humanization of the Built Environment: City in the Arctic versus City for the Arctic (The Case of Western Siberia, Russia)

Sofia Prokopova, Ural State University of Architecture and Arts, Russia

Keywords: Arctic Architecture, Human Adaptation, Built Environment, Urbanisation, Behaviour, Urban Design

During the long history of human presence in the Arctic, the region experienced three waves of urbanization varying from the “colonial” (16th-20th century) to “Soviet” (1920s-1980s), and, eventually, to “globalized” (1960s-70s until present) (Laruelle 2019). From the Soviet era with its staggering pace of Arctic urbanization (Agranat, 1992; Hill & Gaddy, 2003), the basic principles of built environment were rapidity and cost effectiveness. As a result, today, the Russian Arctic – with its 89 percent of the population living in cities – is the most urbanized area in the country (Zamyatina and Goncharov 2019). One of the downsides of this approach - not-so-obvious in a short run - is that a complex of psycho-emotional issues of human adaptation to extreme conditions remains unattended. The development and maintenance of conditions for human physical and psychological wellbeing is one of the main professional tasks for architects. However, the history of Arctic urban planning/architecture demonstrates the priority of physical comfort: numerous concepts of an "ideal Northern settlement" developed during the 20th century were aimed at nothing but guarding inhabitants from harsh climate by covering, roofing and walling. Through investigating the materiality of Arctic urban environment, this study aims to analyse its impact on the process of psychological adaptation to extreme living conditions and derive the architectural/design principles of facilitating and supporting the adaptation process. In further perspective, the study aims at creating a new imagery of Arctic/Northern cities with ‘friendly’ and ‘warm’ atmosphere for their residents.

Societal changes reflected in the Greenlandic building style

Eva B. Møller, Department of Civil Engineering, Technical University of Denmark, Kgs. Lyngby, Denmark
Tove Lading, Department of Civil Engineering, Technical University of Denmark, Kgs. Lyngby, Denmark

Keywords: Arctic Building Design, Building Materials, Indoor Climate, Societal Change, Building Style

The building style in an area is mainly the result of the climate, however, access to building materials and societal aspects are also important. In Greenland, society has changed dramatically several times, which is reflected in several shifts of the building style.

- Norse settlements (1000 - 1400): Stone buildings with mortar of shells
- Inuit (1200-1920) winter housing of stone and peat with roof of skin and whalebone, roof was removed every summer, walls repaired and roof reinstalled before the winter. Summer housing in tents near hunting grounds
- Europeans (1721-1940). Mostly buildings of imported timber
- Inuit (1920-1940) Permanent buildings of imported wood with exterior of stone and peat. Many people in small houses combined with high particle pollution in indoor air made the houses unhealthy. 1/3 of the population died of tuberculosis.

After World War II the unhealthy Inuit buildings were replaced by small colourful wooden single family standard houses, shipped from Denmark as assembly kits. In the 1960´s the Danish government wanted to concentrate the Greenlandic population in the larger cities, consequently, concrete blocks of up to 5 storeys - also common in Europe at that time – were erected. Greenland got home rule in 1979, multi storey houses were now a little lower, more colourful and in different shapes. Since 1989 Greenland has been self-governed, and again the building style changes; in the 2010's detached 4-7 storey houses are built in several cities.

New Antarctic Architecture

Hugh Broughton, Hugh Broughton Architects, London, UK

Keywords: Antarctica, Research, Extreme, Architecture

Hugh Broughton Architects (HBA) was set up in 1996 in London, and is now considered the world's leading designer of research facilities in the Polar Regions. HBA has worked on a range of Polar research stations including Halley VI Antarctic Research Station, the redevelopment of New Zealand's Scott Base, the Juan Carlos 1 Spanish Antarctic Base, the Atmospheric Watch Observatory in Greenland for the US National Science Foundation and others. The 21st century has seen a surge in innovative and striking architecture in these extremely cold regions designed to meets the rising needs of the scientists living and working there. Most recently the Australian Antarctic Division (AAD) appointed HBA to join a team led by multi-disciplinary consultants WSP to masterplan the modernisation of the infrastructure at Davis station in East Antarctica. Initial master-planning is now complete, and masterplan concept development is ongoing. The new Antarctic bases may look very different to buildings in the Arctic but they are subject to similar climatic forces and physical challenges faced by traditional buildings in the north. This paper outlines the key design drivers that informed the master-planning of the various bases HBA have worked on, and ends with a discussion on lessons learnt designing for the extreme cold about building form, orientation, treatment of openings in structures and materials that can make or break the success of a project.

Adapting Buildings for Cold Climate Extremes

Susan Roaf, Heriot Watt University, Edinburgh, Scotland
Manuel Correia Guedes, Instituto Superior Técnico, Lisboa, Portugal
João Pinelo, University of Bahrain, Bahrain
Gonçalo Araújo, INESC-ID, Lisbon, Portugal

Keywords: Buildings, Thermal Performance, Comfort

Two dwelling types are common in the Arctic regions: Permanent and Temporary. Both must withstand extremes of cold, wind and precipitation. A profound understanding exists between traditional peoples and the climate regarding the building of safe, comfortable and structurally stable dwellings in the extreme cold. The rapidly changing climate means that emerging weather trends are throwing new problems at those builders. This paper aims to look at growing trends from a detached and useful angles. It aims to take an arms-length look at the generic challenges of designing and constructing both temporary and permanent dwellings in the extreme cold. Based on two field trips to King George Island, Antarctica, in 2019 and 2020, and experiments in two buildings: a) The Polar Lodge, a prototype temporary shelter, designed to resist the extreme weather of Antarctica and b) Professor Julio Escudero Base is a permanent Chilean Antarctic research base. A range of equipment was involved in measuring the temperatures, humidity and wind speeds in and around the two buildings. A Comfort survey of Escudero base occupants showed how people experienced temperatures in the building. The distilled findings of these studies provide an overview of the challenges of designing for extreme cold of Antarctica, as a starting point to open further discussions on lessons for other regions, in a world of more turbulent, less predictable climate trends and events.

Forecasting of permafrost thawing consequences for buildings and structures in the Russian Arctic

Svetlana Badina, Plekhanov Russian University of Economics and Lomonosov Moscow State University, Moscow, Russia

Keywords: Russian Arctic, Permafrost Thawing Risk, Economic Damage, Fixed Assets, Municipal Economy

According to the modern scientific forecasts, global climate changes will lead to permafrost degradation in a significant part of the Russian Arctic to the second half of the 21st century. Permafrost thawing will cause massive deformations and destruction of fixed assets. The purpose of this research is to predict potential direct damage for buildings and structures located in the Russian Arctic permafrost zone. Currently, there is no reliable and comprehensive information about the cost of buildings and structures at risk area. In this case, not only data on modern buildings and structures cost are important, but also it is necessary to predict the situation by the second half of the 21st century. For these purposes, the author's method for quantitative assessing the cost of buildings and structures by Russian Arctic municipalities were created (it takes into account the cost of housing stock, modern and future buildings and structures by economy sectors). According to the results of calculations, the total cost of buildings and structures in the Russian Arctic permafrost zone by the second half of the 21st century will be about $ 133.5 billion. About $ 94.5 billion of them will be in the areas of maximum predicted permafrost thawing.

Decision-making within spray icing on small coastal fishing vessels

Marte Raknerud Hoel, University of Tromsø, Norway
Dina Abdel-Fattah, University of Tromsø, Norway
Masoud Naseri, University of Tromsø, Norway
Truls Bakkejord Ræder, SINTEF, Norway
Eirik Mikal Samuelsen, Norwegian Meteorological Institute, Norway

Keywords: Spray Icing, Decision-Making, Decision, Team, Hazard

The rapid loss of sea ice due to climate change has resulted in increases in maritime activity in the Arctic Ocean. This increased activity increases the risk of accidents in the environment or for humans. We are also seeing vessels operating further and further north. This research will address risk factors small fishing boats meet while operating in the north. We will address to what extent icing pose a problem today. In addition, we will look at today's ice alert and how it works in relation to the user's information needs. The purpose of the project itself is to develop better and more accurate methods to warn of the danger of icing on the coast and coastal waters. This research will be extended into a master's thesis within search and rescue at Svalbard. The project is also part of a larger research project 'Vessel Ice' supported by the Fram Centre in Tromsø, and is a collaboration between the University of Tromsø, SINTEF and the Norwegian Meteorological Institute.

ID: 32 - Responsible development of the Arctic – opportunities, challenges, and pathways to action

Conveners

Birigtta Evengard | Umeå University, dept Clinical microbiology

Zahra Kalantari | Stockholm university, dept natural geography

Anders Koch | University of Greenland

Grete Hovelsrud | dept social science, Norduniversity, Bodoe, Norway

Dag Avango | Luleå technical University, Luleå, Sweden

Anna Omazic | National Veterinary Institute, Uppsala, Sweden

First records of adult Hyalomma marginatum and H. rufipes ticks in Sweden – demands monitoring of new pathogens into previously free areas and communities

Giulio Grandi, Swedish University of Agricultural Sciences, Uppsala, Sweden
Ann Albihn, National Veterinary Institute, Uppsala, Sweden
Karin Ullman, National Veterinary Institute, Uppsala, Sweden
Anna Omazic, National Veterinary Institute, Uppsala, Sweden

Keywords: Hyalomma Spp., Tick-Borne Diseases, Geographical Distribution, Crimean-Congo Haemorrhagic Fever Virus, Piroplasms, Northern Europe

The impact of the ongoing climate change is most prominent at northern latitudes. These ecosystem changes are directly affecting the circulation of pathogens, together with their animal reservoirs and vectors. Climate change both facilitate the expansion of ticks to higher latitudes/altitudes and cause an increase in their abundance. Since ixodid ticks must feed on three different hosts to reproduce, they are efficient vectors of tick-borne pathogens (TBP) between humans, wild and domesticated animals. Travel, trade of animals and migrating birds are also contributing to the global spread of ticks. Such movements can introduce new tick vectors i.e. Hyalomma spp., and thus new TBPs into new areas and communities. In 2018, adult ticks of two alien species (n=41) were found on horses, cattle or humans in Sweden for the first time: Hyalomma marginatum and H. rufipes. Even if none of them was positive at PCR for Crimean-Congo haemorrhagic fever virus or piroplasms (Babesia spp. and Theileria spp.), more than half of them contained rickettsial DNA. Our findings suggest a faster rate of expansion of Hyalomma populations than recently studies have hypothesized, and most likely now permits these two Hyalomma species to develop from nymph to the adult, reproductive stage in northern Europe. These new findings require a risk assessment for the potential introduction and spread of TBPs carried by Hyalomma spp. in Sweden and in the nearby countries.

On incidence patterns of two tick-borne human diseases in the Nordic area and vegetation changes

Helena Bylund, Swedish University of Agricultural Sciences, Uppsala, Sweden
Didier G. Leibovici, University of Sheffield, Sheffield, UK
Christer Björkman, Swedish University of Agricultural Sciences, Uppsala, Sweden
Tomas Thierfelder, Swedish University of Agricultural Sciences, Uppsala, Sweden
Birgitta Evengård, Umeå University, Umeå, Sweden
Shaun Quegan, University of Sheffield, Sheffield, UK

Keywords: Climate Sensitive Infections; Tick-Borne Diseases; Land Cover; Plant Functional Type; Fennoscandia

A range of climate sensitive infections (CSIs) affecting humans are zoonotic vector-borne diseases, such as borreliosis (BOR) and tick-borne encephalitis (TBE) mostly linked to various species of ticks as vectors. Due to climate change, the geographical distributions of the tick species, their hosts and prevalence of the pathogens, are likely to change. Recent increase of human incidences of these CSIs in some regions might indicate a range expansion of the ticks and hosts, thus inclining to look into vegetation changes as potential predictors linked to habitat suitability. In this study, we focus on districts in Fennoscandia and Russia, where incidences of BOR and TBE have steadily increased over the 1995-2015 period (WI- districts). This is used as a proxy for the increasing prevalence of the tick-borne pathogens, due to increased habitat suitability for the ticks and hosts, simplifying the multiple factors explaining incidence variations. The approach allowed differentiating vegetation types and strengths of correlation specific to the WI- districts in comparison to associations found for all districts. Land cover types and their changes found in association with increasing human disease incidences are described, indicating zones with potential higher risks of these diseases in the future using forecasts up to 2070 under different scenarios. Projections combining vegetation cover and climate variables selected using a similar approach are refining these higher risks zones.

The Geography of Northern Infectious Diseases, with particular emphasis on climate-change effects

Tomas Thierfelder, Dept. of Energy & Technology, Swedish University of Agricultural Sciences SLU, Uppsala, Sweden
Anna Omazic, Dept. of Chemistry, Environment, & Feed Hygiene, National Veterinary Institute SVA, Uppsala, Sweden
Camilla Berggren, Dept. of Energy & Technology, Swedish University of Agricultural Sciences SLU, Uppsala, Sweden
Ann Albihn, Dept. of Chemistry, Environment, & Feed Hygiene, National Veterinary Institute SVA, Uppsala, Sweden
Sepp Böhme, Dept. of Energy & Technology, Swedish University of Agricultural Sciences SLU, Uppsala, Sweden
Helena Bylund, Dept. of Ecology, Swedish University of Agricultural Sciences SLU, Uppsala, Sweden
Nikolay Tokarevich, Laboratory of Zoonoses, St Petersburg Pasteur Institute, St Petersburg, Russia
Dmitry Orlov, Faculty of Geography, Lomonosov Moscow State University, Moscow, Russia
Birgitta Evengård, Dept. of Clinical Microbiology, Umeå University, Umeå, Sweden

Keywords: Climate-Sensitive Infections, Arctic Onehealth Effects

As the terrestrial realms of the Arctic thaw with climate change, relative southern infectious diseases carried by vector organisms such as ticks and mosquitoes may migrate with landscape transitions and transmit onto humans and domestic animals of the far North. The OneHealth effects of such potentially expanding climate sensitive infections (CSI's) constitute a serious global threat. In order to identify CSI's, data concerning human and animal infections were procured from national health reporting systems to cover the current thirty-year climate reference period from western Greenland to the pacific coast of Russia, from approximately 55 to 80 degrees north. The diseases chosen for their relevance to northern communities were anaplasmosis, babesiosis, borreliosis, brucellosis, cryptosporidiosis, erysopelothrix, leptospirosis, listeriosis, Puumala haemorrhagic fever, Q-fever, rabies, tick-borne encephalitis, trichinellosis, and tularaemia. Preliminary results indicate that several of these infections are due to significant regional geographic translation and/or expansion trends, and that the associated northern societies hence are due to changing CSI exposure. In addition, for each of the selected infections, their respective thirty-year average incidences were used to define "diseases climates" for future reference. Incompatibles across national health reporting systems were constraining the possibilities to infer international infectious characteristics.

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Virome in Eurasian tundra reindeer (Rangifer t. tarandus) in Norway, Sweden, Finland and Russia – Evidence from Next-Generation-Sequencing (NGS)

Ann Albihn, National Veterinary Institute, Uppsala, Sweden
Anna Omazic, National Veterinary Institute, Uppsala, Sweden
Åsa Hagström, National Veterinary Institute, Uppsala, Sweden
Morten Tryland, The Arctic University of Norway, Tromsö, Norway
Juha Kantanen, Natural Resources Institute, Jokioinen, Finland
Javier Sánchez Romano, The Arctic University of Norway, Tromsö, Norway
Tiina Reilas, Natural Resources Institute, Jokioinen, Finland
Ulrika Rockström, Farm and Animal Health, Uppsala, Sweden
Valery Fedorov, Yakutian Research Institute of Agriculture, Yakutsk, Russia
Mikael Leijon, National Veterinary Institute, Uppsala, Sweden

Keywords: Semi-Domesticated Reindeer, NGS, Known And Unknown Viruses

Reindeer husbandry is essential for the livelihood and culture of indigenous people in the Arctic. Parts of the herding areas are also used as pastures for farm animals, facilitating potential transmission of viruses between species. Further, following the COVID-19 pandemic, viruses circulating in the wild have received increased attention since they might be a potential threat for human health. Climate change influence the prevalence of infectious diseases for both humans and animals. Better knowledge is needed about the present situation of these diseases, to recognize future changes. This study aimed to detect known and previously unknown viruses in Eurasian tundra reindeer. In total, nasal swabs (575 animals) and rectal swabs (430 animals) were collected from healthy reindeer at slaughter in three herds in Norway, Sweden and Finland, respectively, and from two herds in Russia, twice from each herd during 2016-2019. Samples were pooled 5 by 5. NGS was performed on MiSeq (Illumina) with MiSeq Reagent kit v3 (600 cycle) after tagmentation with Nextera XT Index Kit (Illumina). Preliminary results from BLAST-homology search indicate the presence of viruses, associated with different wild and domesticated animal species, similar to e.g Betaherpesvirinae, Papillonaviridae, Adenoviridae, Parvoviridae, Paramyxoviridae, Flaviviridae (Pegivirus and Pestivirus), Gammaherpesvirinae (Macavirus) and Smacoviridae. Several viral species previously found in reindeer were detected, as well as novel ones. The clinical relevance of these viruses in reindeer is largely unknown. Although, results indicate that it should be possible to find emerging viruses of relevance for both human and animal health, using reindeer as a sentinel species.

Arctic Wetlands Threatened by Permafrost Thaw in a Warming Climate

Elisie Kåresdotter, Department of Physical Geography and Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden
Georgia Destouni, Department of Physical Geography and Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden
Navid Ghajarnia, Department of Physical Geography and Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden
Gustaf Hugelius, Department of Physical Geography and Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden
Zahra Kalantari, Department of Physical Geography and Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden, Department of Sustainable Development, Environmental Science and Engineering (SEED), KTH Royal Institute of Technology, SE-100 44, Stockholm, Sweden

Keywords: Arctic Wetlands, Permafrost Thaw, Regime Shift Vulnerability, Climate Projection, Climate-Driven Regime Shifts

Arctic wetlands provide multiple ecosystem services of local and global importance, but so far, there has been no comprehensive, high-quality wetland map available for the Arctic region due to challenges in mapping this terrain. To bridge this lack of knowledge essential for climate mitigation-adaptation and especially for indigenous peoples depending on wetland services, we synthesize various databases to create a comprehensive wetland map over the Arctic. We further assess wetland vulnerability to ongoing and future warming, using data on permafrost extent, soil types, and projected climate from the HadGEM2-ES climate model for different climate scenarios. We find that wetlands cover 25% of the Arctic landmass, mostly (99%) in permafrost areas, where thawing can shift local hydrological and ecological regimes, with feedbacks on regional and global climate. Up to half of the Arctic wetlands are vulnerable to such regime shifts under most future climate scenarios. To limit negative impacts and maintain a resilient Arctic, strategic adaptation and mitigation efforts focusing on permafrost wetlands are needed. Preservation of permafrost wetlands has many co-benefits, while wetland loss may increase greenhouse gas emissions and threaten local ecosystems, infrastructure, livelihoods, and human health. With the mapping provided from this study, specific wetland areas can be targeted with management efforts directed to where they are most needed and effective.

Quantifying hydroclimatic change effects on infectious disease spreading

Yan Ma, Stockholm University, Stockholm, Sweden
Guillaume Vigouroux, Stockholm University, Stockholm, Sweden
Zahra Kalantari, Stockholm University, Stockholm, Sweden
Romain Goldenberg, Stockholm University, Stockholm, Sweden
Arvid Bring, Stockholm University, Stockholm, Sweden
Georgia Destouni, Stockholm University, Stockholm, Sweden

Keywords: Hydroclimatic Change, Infectious Disease, Tularemia

Hydroclimatic changes, which may be particularly large in the Northern, sub-Arctic and Arctic region, can affect outbreaks of infectious diseases. Our study considers the zoonotic disease tularemia, observed at relatively high occurrence in the northern region recently, as a model disease for quantitative investigation and understanding of possible outbreak changes that may occur under hydroclimatic change in this region. We used site-specifically established statistical disease models for different parts of Sweden to link and reveal the combined climate and disease model implications for possible future outbreak conditions. For this, the disease models were linked with the hydroclimatic outputs from multiple global climate models and scenarios in phase six of the Coupled Model Intercomparison Project. Results show high sensitivity in tularemia outbreaks for certain combinations of hydroclimatic variable values, meaning that even relatively small variations and changes in these, within their past observation range, can greatly shift tularemia outbreaks. Increase in water flow and temperature conditions related to relative mosquito abundance, as well as in summer precipitation conditions particularly drive increases in tularemia incidence. Projections of low-medium-high radiative forcing (emissions) scenarios until year 2100 are further found to drive divergent changes in future disease outbreaks for different parts of Sweden. Scenarios of steeper future climate warming do not necessarily lead to steeper increase of future disease outbreaks, and uncertainty across models is high. The highest uncertainty in climate-driven disease projections applies to results for specific future years, while main directions of long-term change trends are more robust. Such robust overall trend projections are needed and can be used as basis for policy and management decisions for measures to evade negative future disease evolution.

Climate change will increase the risk for infectious diseases in the mouth and eyes of reindeer in the Nordic countries

Ulrika Rockström, Farm and Animal Health, Uppsala, Sweden
Ann Albihn, National Veterinary Institute, Uppsala, Sweden
Morten Tryland, UiT The Arctic University of Norway, Tromsø, Norway
Javier Sanchez Romano, UiT The Arctic University of Norway, Tromsø, Norway
Anna- Marja Kaddik, Sámiid Riikkasearvi (Sami Reindeer Association), Umeå, Sweden
Erik Ågren, National Veterinary Institute, Uppsala, Sweden
Camilla Risvoll, Nordland research Institute, Bodø, Norway
Grete K. Hovelsrud, Nord University, Bodø, Norway
Anna Omazic, National Veterinary Institute, Uppsala, Sweden

Keywords: Reindeer Husbandry, Animal Health, Supplementary Feeding, Opportunistic Infections

Climate change and extreme weather events may increase the risk for infectious diseases and change their epidemiology. Reindeer herding in the Nordic countries will be heavily affected. Warmer winters and increased precipitation will cause more frequent freeze-thaw events and form an ice cover on the ground. This hinders the reindeers' ability to both smell the forage under the ice and to reach it through digging. To avoid starvation, reindeer are fed with supplementary fodder in the field or in enclosures. This mitigation strategy is saving reindeer lives, but also leads to stress, increased animal density, and challenging hygienic conditions which increases the risks for infectious disease transmission. Infectious diseases of the mucosa of the eyes and mouth are increasingly observed. Examinations in the field and at slaughter have confirmed that herpesvirus and Chlamydia are important agents causing eye infections in reindeer. Serious oral infections, e.g. Orf and necrobacillosis are common causes to lesions in the mouth. These infections are highly contagious and require immediate action by the herder and measures to reduce animal suffering and economic loss for the herder include separating affected animals from healthy, medical treatment if possible, but also slaughter or euthanasia. Further studies on reindeer herder knowledge and perception regarding eye and mouth infections; how these affects the reindeer and herders' strategies to handle this problem is ongoing.

Climate sensitive infections in Greenland and Northern Sweden: a serological study

Anders Koch, Statens Serum Institut, Copenhagen, Denmark & Ilisimatusarfik, University of Greenland, Nuuk, Greenland
Bolette Søborg, Statens Serum Institut, Copenhagen, Denmark
Mikael Andersson, Statens Serum Institut, Copenhagen, Denmark
Birgitta Evengard, Umeå University, Umeå, Sweden
Karen Angeliki Krogfelt, Statens Serum Institut, Copenhagen, Denmark & Roskilde University, Roskilde, Denmark
Lukas Frans Ocias, Karlstad Hospital, Karlstad, Sweden
Charlotte Sværke Jørgensen, Statens Serum Institut, Copenhagen, Denmark

Keywords: Climate sensitive infections, Arctic, Zoonoses, Serology, Biobank

The Arctic is severely affected by climate changes. This affects the pattern of infectious diseases in humans, particularly those dependent on animals (zoonoses). However, little is known about the occurrence of many zoonoses in the Arctic. Seven zoonoses, representing different routes of transmission, were chosen as part of the CLINF collaboration. Stored human sera from 260 adults from representative locations in Greenland from 2013 and from 200 adults from Umeå municipality in Northern Sweden were tested for antibodies against tularemia, brucellosis, Q fever, rickettsioses, leptospirosis, tick-borne encephalitis (TBE) and borreliosis, the latter two only for Sweden. In Greenland, less than 1% had antibodies against tularemia, brucellosis and Q fever, while 7% had antibodies against rickettsioses and 21% against leptospirosis. There were substantial regional differences with lower seropositivity for rickettsioses and leptospirosis in the most Northern region. In Sweden, all samples were negative for Q fever, 1-5% were positive for brucellosis (1%), borreliosis (2%), tularemia (3%), leptospirosis (4%) and TBE (5%), while 12% were positive for rickettsioses. An additional analysis of 200 sera from West Greenland from 1998 showed 12.5% seropositivity for rickettsioses and only 2.5% for leptospirosis. This study shows that rickettsioses and leptospirosis are common zoonoses in Arctic areas and that the prevalence of leptospirosis in Greenland may have increased over time.

Climate sensitive infections will exacerbate current challenges in reindeer herding: A case from northern Norway

Grete K. Hovelsrud, Nord University, Bodø, Norway
Camilla Risvoll, Nordland Research Institute, Bodø, Norway

Keywords: Pastoralists, Multiple Stressors, Emerging Risk, Coproduction Of Knowledge, Proxies For Change

Rising temperatures are causing species to spread into the new geographic areas. Warmer and wetter conditions, and hot, dry and cold spells both, may enable vector-borne infections to move further north and find new host species. The introduction of new CSIs, especially zoonotic infections, may pose a new risk to both animal and human health. In this study we investigated how climate sensitive infections CSIs, such as Lyme borreliosis, caused by the bacteria Borrelia burgdorferi and spreading through ticks would affect reindeer and herding activities. Through a knowledge coproduction process, we considered the herders' responses to these risks. We quickly learned that CSIs were not yet considered to be a major problem and was overshadowed by adaptation to other pressing challenges such as locked pastures, encroachment and predators. This caused a methodological conundrum: how do you study an emerging risk that is not yet a major concern for the herders? We solved this by assessing the broad range of current multiple stressors in reindeer herding (e.g. predators, land encroachment, other diseases) as proxies for understanding the different factors of change that interact with significant cumulative effects. We conclude that while CSIs will require adaptation, exposure to CSIs can also increase as a result of adaptation to other stressors. Hence, increased acknowledgement of both direct and indirect aspects of the risks surrounding CSIs is important across levels and scale.

Linkage between temperature anomalies and outbreaks of climate-sensitive infectious diseases in Arctic reindeer herds

Hans Tømmervik, Norwegian Institute for Nature Research, Tromsø, Norway
Patrik Ryden, Umeå University, Umeå, Sweden
Morten Tryland, University of Tromsø, Tromsø, Norway
Romain Goldenberg, Stockholm University, Stockholm, Sweden
Jan Åge Riseth, NORCE, Tromsø, Norway
Zahra Kalantari, Stockholm University, Stockholm, Sweden
Ann Albihn, National Veterinary Institute, Uppsala, Sweden
Georgia Destouni, Stockholm University, Stockholm, Sweden
Anna Omazic, National Veterinary Institute, Uppsala, Sweden
Zoia Vylka Ravna, NIKU and Samoedna Film, Tromsø, Norway
Grete Hovelsrud, Nord University, Bodø, Norway
Camilla Risvoll, Nordland Research Institute, Bodø, Norway
Birgitta Evengård, Umeå University, Umeå, Sweden
Tomas Thierfelder, Swedish Unversity of Agricultural Sciences (SLU)

Keywords: Climate-Sensitive Infectious Diseases (Csis), Reindeer Herding, Climate, Mitigation Measures

Eurasian tundra reindeer (Rangifer tarandus tarandus) have been exploited for food and other subsistence for the northern folks since the last glaciation. Intensive hunting resulted in decimation of wild reindeer and indigenous groups (Nenets, Komi and Sámi) changed their strategies towards reindeer herding. An intensive reindeer husbandry arose in the period 1600-1700, and as result of this, outbreaks of climate-sensitive infectious diseases (CSIs) as anthrax, reindeer pest (Clostridium septicum), foot rot disease (digital necrobacillosis), eye-disease (keratitis) and pasteurellosis occurred. Since such diseases may be triggered by abnormal climatic conditions, we explored possible links between temperature anomalies and severity of CSI outbreaks. Analysis using proxy climate data (tree core data) and CRU TS Monthly High-Resolution Gridded Multivariate Climate Dataset (NCAS) was performed. Preliminary results show that there is a significant relation between positive temperature anomalies in summer (sunny and warm weather) and the outbreaks of anthrax causing high mortalities amongst reindeer (July; $R = 0{,}67$, $p< 0.001$). Outbreaks of eye-disease and pasteurellosis showed similar trends (July; $R = 0{,}97$, $p< 0.005$) as anthrax, while reindeer pest and foot rot disease were triggered by warmer springs and sunny summers. Mitigation measures like stratified herding (i.e. rotation of pastures to avoid disease) and vaccination has reduced the mortalities the last century.

Supplementary feeding and animal wellbeing

Majken Paulsen, Nord university
Camilla Risvoll, Nordlandsforskning
Grete Hovelsrud, Nord unviersity

In Sámi reindeer husbandry the connection between flexibility and adaptive capacity is strong. In the harsh arctic climate, flexible herding and husbandry practices acts as a buffer. However, centuries of colonial practices and legislative frameworks has diminished this traditional flexibility. Today Sámi reindeer husbandry is under pressure from multiple stressors. Their common trait is that they directly or indirectly cause loss of pasture - a prerequisite for animal and human wellbeing in Sámi reindeer husbandry. In this presentation we investigate the complexities of supplementary feeding, an increasingly common response to multiple stressors. As an adaptive measure, supplementary feeding can increase the survival of a heard in crisis. It can also provide a straightforward solution for developers, seeking to exploit reindeer grazing land. We draw a link between the consequences of lost pastures and altered husbandry practices and the herders and animals' ability to adapt to increased risk of disease transmission. We investigate loss, what herders, and reindeer loose in the transition towards supplementary feeding. In Sámi culture the reindeer is a free and autonomous animal. A strong reindeer can survive without human interference. We ask: what are the consequences of making the reindeer dependent on store bought feed? And how does this reflect on the increased risk from Climate sensitive infectious disease and Chronic wasting disease.

Supplementary winter feeding of domestic reindeer affects their vital rates and the herds' production output

Øystein Holand, Norwegian University of Life Sciences, Ås, Norway
Amélie Paoli, Concordia University, Montreal, Canada
Robert B. Weladji, Concordia University, Montreal, Canada
Mauri Nieminen, Kaamanen, Finland

Keywords: Reindeer Pastoralism, Winter Feeding, Production, Sustainability

In recent years, winter supplementary feeding of domestic reindeer has gained momentum in Finland and is spreading rapidly in Sweden and Norway. However, its effect on vital rates influencing the production output is not well documented. Here, we report a long-term study (1969 -2018) from an experimental herd in Finland where winter feeding started in 1986. Animal are given about half of their daily winter energy requirement, mainly by feeding concentrate and grass silage from mid-December to late April. All individuals' life histories are monitored. To test the effects on selected vital rate parameters before and after supplementary feeding started, LM and GL Models were used. We found, on average, an earlier calving date (18 May vs 22 May), a heavier calf birth mass (5.8 vs 5.2 kg), a higher calving percentage (83 vs 59%) and a higher calf first summer survival rate (0.87 vs 0.67) and a tendency towards heavier autumn body mass of calves (46.2 vs 43.4 kg) after the supplementary winter feeding started. These effects seem primarily driven by an improved winter body mass of fed females (79.8 vs 71.0 kg). Indeed, these changes in vital rates will increase herds' meat production output. However, the profitability is dubious as the extra output must balance the extra feed, labor and infrastructure costs. The transformation seems to be driven by loss of winter land to human activities, increased predation pressure and climate change. The practice may result in a negative feedback loop, keeping up the production while degrading the winter ranges. Cynically, supplementary winter feeding is resource consuming and may disrupt reindeer pastoralism sustainability. Indeed, the herders seem ensnared in a feeding trap and the expanding practice may be a game changer in reindeer pastoralism.

A Sami–Inuit youth exchange. A Youth Participatory Action Research Programm as a way to reflect on how they see their future as members of the community

Sylvie Blangy, CNRS- Centre d'écologie fonctionnelle et évolutive (CEFE): UMR5175, Université Montpellier II - France

Keywords: Participatory Action Research, Cross Cutting Views, School Children, Arctic, Global Change, Traditional Activities

The Sami–Inuit youth exchange was developed in the framework of the BOAZU and TUKTU research projects. The ongoing BOAZU project involves the Sami people from Sweden in Sapmi with the purpose of exploring the future of reindeer herding for this culture. It started in 2017. The completed TUKTU project involved the Inuit people from Baker Lake in Nunavut, northern Canada, and focused on changing relationships to the land and mining impacts. It was conducted from 2013 to 2017. Both projects were co-designed with the communities involved using participatory research methods. The aim of the Sami–Inuit exchange is for Sami and Inuit youth to share their perceptions about the future of their cultures. From 2013, school-based and community workshops have been held with Sami schools in Gällivare, Karesuando and Jokkmokk in Sweden and Inuit schools in Baker Lake in Nunavut. Children from both communities participated in workshops organized in their schools with researchers and teachers. They created radar charts, a Caribou and a Sami wheel, drawings and videos to share their daily lives with the community living on the other side of the Arctic. By exchanging these, Sami and Inuit youth were able to learn about each other’s cultures and co produce a book. The process of representing their daily lives to share this information with another community gives young Sami and Inuit the possibility to reflect on their own culture. It allows them to think about what they value about their lifestyle. They are also able to reflect on how they see their future as members of the community. Another important goal of the project was to promote dialogue between the youth and the elders in the community, so that knowledge can be appropriated by the new generation.

Accelerating climate and land use pressure on environment and people in Arctic Sweden; challenges for sustainable land use planning

Carl Österlin, Department of Physical Geography, Stockholm University, Stockholm, Sweden
Gunhild Rosqvist, Department of Physical Geography, Stockholm University, Stockholm, Sweden
Christian Fohringer, Department of Wildlife, Fish, and Environmental Studies, Swedish University of Agricultural Sciences, Umeå, Sweden
Pia Eriksson, Department of Physical Geography, Stockholm University, Stockholm, Sweden
Sandra Fischer, Department of Physical Geography, Stockholm University, Stockholm, Sweden
Dag Avango, Department of Social Science, Luleå University of Technology, Luleå, Sweden

Keywords: Multiple Pressures, Cumulative Effects, Natural Resource Extraction, Reindeer Herding, Arctic

The interest in natural resource extraction like mining, energy production and forestry continues to increase in the Arctic. Meanwhile, adaptation to the effects of climate change challenge many local livelihoods. Reindeer play an important role for ecosystem structure and function and reindeer herding has been an important livelihood of the indigenous Sámi people in northern Fennoscandia since reindeer were semi-domesticated more than 1000 years ago. Here we have tracked land use change that contributed to reduction and fragmentation of ecosystems traditionally used for reindeer herding during the past 130 years (1890-2020) in Norrbotten county, Arctic Sweden. In a warmer climate more winter precipitation will occur as rain, with an increased frequency of ice layers forming on the ground and in the snow inhibiting grazing of lichens. We find that these conditions now occur more frequently on reindeer winter grazing areas. A flexible use of the landscape has traditionally been the main strategy for reindeer herders to cope with difficult weather and snow conditions. Adaptation to more frequent weather stress will become more difficult in a landscape under increasing pressure from natural resource extraction and other societal activities. Current land use management processes in Sweden are ill equipped to identify and assess cumulative effects and need improvement to manage effects on ecosystems and livelihoods from multiple pressures and to allow for sustainable development.

Ecological justice in North – West Russia: experiences of communication between authorities and locals in the Arkhangelsk Region, Russia

Natalia Kukarenko, Northern Arctic Federal University, Arkhangelsk, Russia

Keywords: Ecological Justice, Recognition, Communication, Locals, Authorities

One of the dilemmas raised in ecological justice discussions is an issue of unjust distribution of ecological benefits and risks between different population groups. A typical example is a situation with a construction of industry which on the one hand might pollute the environment but on the other hand can provide local population with workplaces. A choice between economical benefits versus ecological sustainability creates an ecological justice dilemma. In the context of the Arkhangelsk Region two events happened recently. One is the process of digitalization of administration and the use of social media - to make the processes of decision-making transparent and to get quick response from the population on different local development initiatives. At the same time authorities made an attempt to construct garbage landfills for the garbage brought from the rest of the country in the region without any public discussions which raise an opposition of local residents to the project. In this situation the authorities turned down all the discussions in social media and switched to the use of administrative resources (including the use of police) to shut down protests and criticism. In my presentation I would like to focus on forms of communication (participation) employed by different actors (local people and authorities) concerning recognition and redistribution of risks and benefits.

Societal Infrastructure and Climate Sensitive Infections: The Complexity of Climate Change Adaptation in Arctic Pastoralism

Barbara Baczynska, Nord University, Bodø, Norway
Grete K. Hovelsrud, Nord University, Bodø, Norway
Camilla Risvoll, Nordland Research Institute, Bodø, Norway

Keywords: Climate Change Adaptation, Adaptive Capacity, Livelihoods, Health, Societal Infrastructure, Management

One aspect of climate change is the potential spread of climate sensitive infections (CSIs) to the Arctic. This may affect reindeer herding and sheep farming in northern Norway in various ways. It is not only the environmental changes that will potentially be more conducive to new infections, but the way our society is rigged will also have a bearing on whether and how such infections spread and to what extent the local communities are prepared to respond to them. We discuss how societal infrastructures, such as EU policies, Norwegian Food Safety Authority, Farmers Agricultural Cooperation, the cross-border grazing agreement between Norway and Sweden, and management, interact with each other and with local and societal processes such as mobility, fodder, slaughter, family organization and kinship, and networks, affecting the exposure to CSIs. We will also address how these interactions may enable or hinder adaptation, and the consequences for adaptive capacity. Our findings are illustrated in a multi-dimensional matrix that encompasses both subtle, indirect dependences as well as unequivocal, direct impacts between and within the identified categories or units. We show that some aspects of climate change adaptation and pastoralists' adaptive capacity are either ignored or overlooked in the policy-making process. Further, pastoralist communities are thereby subject to fragmented and diversified management with dire cultural and economic consequences for their practices.

Spreading or Gathering? Can Traditional Knowledge be a Resource to Tackle Reindeer Diseases Associated with Climate Change?

Jan Åge Riseth, NORCE, Narvik, Norway
Hans Tømmervik, NINA, Tromsø, Norway
Morten Tryland, UiT, Tromsø, Norway

Keywords: Herders' Traditional Knowledge; Disease Precaution; Historical Milking Grounds; Necrobacillosis; Climate Change Challenges

We inquire if reindeer herders' traditional knowledge provides a reservoir of precaution and adaptation possibilities relevant to counteract climate change. As our core example, we used the milking of reindeer and the risk of getting foot rot disease (digital necrobacillosis; slubbo in North Sámi), caused by the bacterium F. necrophorum. An infection makes the infected limb swell and, eventually, necrotize. The disease is often mortal. Historically, female reindeer were gathered on unfenced milking meadows near herder tents or in small corrals, from early summer onward. When the soil was wet and muddy, the risk of getting the disease was considerable. Our sources: classical Sámi narratives, ethnographic and veterinary literature, and herder interviews. Our findings seem consistent: A documented prevention strategy was, in early summer, to move the reindeer to unused grazing land and to avoid staying too long in trampled and dirty grazing land. Contemporary climate change and winter uncertainty due to freeze–thaw cycles and ice-locked pastures challenge this type of strategies. Due to lack of pasture resources, typical actions today include the increased use of supplementary feeding, which involves more gathering and handling of reindeer, higher animal density, challenging hygienic conditions, and stress, which all contribute to increased risks of contracting and transmitting diseases

The historical dimension of mining impacts in the Arctic: lessons from multidisciplinary research

Dag Avango, Luleå University of Technology, Sweden
Sandra Fischer, Stockholm University, Sweden
Jerker Jarsjö, Stockholm University, Sweden
Élise Lépy, University of Oulu, Finland
Albina Pashkevich, Dalarna University, Sweden
Ninis Rosqvist, Stockholm University, Sweden
Camilla Winqvist, Royal Institute of Technology, Sweden
Carl Österlin, Stockholm University, Sweden

Keywords: Mining, Legacies, Cumulative impacts, Environmental remediation, Heritagization

A major challenge for attaining sustainability in the Arctic in the context of climate change and growing resource interests is to understand cumulative impacts from land exploitation associated with mining - an industry that has grown because of high demand and prices for metals on global markets in the last two decades. Mineral rich areas in the Arctic are already marked by the environmental footprints of past resource booms however, in the form of abandoned mining sites and their associated socio-technical-ecological systems. These footprints make up an important, yet poorly understood and therefore underestimated component of the cumulative impacts from mining. In the Nordic Centre of Excellence REXSAC, we have mapped the legacies of such former systems for mining and explored their impacts by combining approaches from the natural-, social and human sciences. This article draws on this interdisciplinary research on abandoned mining systems in the Nordic Arctic. The objective is to explain the impacts of past mining systems on ecosystems and people. We are interested in how different societal actors have dealt with such impacts and why. Our results and insights form a basis for discussing the importance of long-term perspectives in assessments of environmental and societal consequences of mining.

Brucella spp. infection - a neglected zoonotic disease and a threat for reindeer herders in northern Russia

Irina Egorova, Federal Research Center for Virology and Microbiology, Pokrov, Russia
Anna Omazic, National Veterinary Institute, Uppsala, Sweden
Elisabeth Rajala, Swedish University of Agricultural Sciences, Uppsala, Sweden
Valery Fedorov, Yakutian Research Institute of Agriculture, Yakutsk, Russia
Juha Kantanen, Natural Resources Institute Finland (Luke), Jokioinen, Finland
Gunnar Andersson, National Veterinary Institute, Uppsala, Sweden
Denis Kolbasov, Federal Research Center for Virology and Microbiology, Pokrov, Russia
Ann Albihn, National Veterinary Institute, Uppsala, Sweden

Keywords: Brucellosis, Zoonoses, Seroprevalence, Reindeer, Marginalized People

Brucellosis is one of the most common and economically important zoonoses globally – a neglected disease mainly affecting poor people. The genus Brucella can infect a wide range of host species. Humans consuming unpasteurized milk from or being in contact with infected animals, can become chronically infected if not treated adequately. Brucellosis is considered enzootic among livestock and reindeer in the subarctic and Arctic regions of Russia. Climate change drives the spread of infectious diseases and a better knowledge of the epidemiology for Brucella infection in Eurasian tundra reindeer in Russia is needed. We aimed to 1) examine the seroprevalence of Brucella spp. infection in reindeer in the Yakutia and Yamalo-Nenets regions, 2) visualize collected retrospective disease data regarding Brucella infection in reindeer in Northern Russia. From these results identify trends and patterns on how the infection can affect animal and people. In total, 2089 samples from six herds were analyzed with the Rose Bengal test and positive samples were confirmed with I-ELISA. Two of the herds in the Yamalo-Nenets region were positive for Brucella spp. antibodies with a prevalence of 11% and 15%, respectively. Although the brucellosis status tends to stabilize all over Russia, these results show that the risk for re-emergence of the infection among semi-domesticated reindeer remains high as the nature and clinical relevance of Brucella infection circulating in wildlife is not well-known.

Climate change impacting health in Sitka, Alaska: Is justice achieved through local solutions to collective action problems?

Luke Matthews, RAND Corporation; USA
Aaron Clark-Ginsberg, RAND Corporation; USA
Max Izenberg, RAND Corporation; USA
Ilan Kelman, Institute for Risk and Disaster Reduction, and Institute for Global Health University College London; United Kingdom; and University of Agder, Norway
Laura E. R. Peters, Institute for Risk and Disaster Reduction, and Institute for Global Health, University College London; United Kingdom
Eija Meriläinen, Institute for Risk and Disaster Reduction, and Institute for Global Health University College London; United Kingdom
Geordan Shannon, Institute for Global Health, University College London; United Kingdom
Michelle Scobie, The University of the West Indies - St. Augustine; Trinidad and Tobago
Unni Gopinathan, Norwegian Institute of Public Health; Norway
Sonja Lynn Myhre, Norwegian Institute of Public Health; Norway

Keywords: Climate Change, Equity, Health Systems, Local Action

The social determinants of health are a justice issue and are affected by human-caused climate change. Around the Arctic, people and communities have been trying to respond to health effects of climate change in tandem with other climatic influences such as variabilities, seasonalities, and oscillations, indicating challenges in linking more immediate local health impacts to multiple changes in the climate at wider scales. This contribution examines climate change affecting the social determinants of health in Sitka, Alaska, especially considering heat, food, and infectious disease, while focusing on community collective action for solving locally identified problems. The method was semi-structured interviews with local environmental groups yielding insights into the operations, activities, successes, and areas of improvement for each group. Local interests and disinterests regarding climate change and health are identified, suggesting varying viewpoints for the meaning and operationalization of different aspects of justice. Lessons are also learned for so-called “participatory” processes which have the potential for perpetuating the inequities they purport to resolve.

Fresh locally grown produce in Arviat, Nunavut: The social and economic impact of a greenhouse

Julie Robertson, Ryerson University, Toronto, Ontario Canada
Brian Ceh, Ryerson University, Toronto, Ontario Canada

Keywords: Arctic Greenhouse, Food Insecurity, Food Security, Fresh Produce

In 2019 food insecurity impacted 8% of Canada's overall population. However, in the Canadian Arctic food insecurity ranges from 38 % to 82% depending on the region and community. This research will measure the social and economic impact of two 42-foot geodesic dome greenhouses on the most vulnerable community members in Arviat, Nunavut. The preliminary research survey completed in June 2019 prior to the first harvest provides the baseline data to measure the influence that fresh locally grown produce has on the community's members who receive it from June through September each year. The greenhouse is unique business model in the Arctic as the only Hamlet owned and operated greenhouse in which all food grown and harvested is provided gratis to the recipients. This research will measure the food secure status of the participants after they have benefitted from two growing seasons of fresh local produce.

Learning to co-create Intersectional and Gender-Responsible sustainable knowledge in the Arctic – mapping the terrain

Mervi Heikkinen, Faculty of Education, University of Oulu, Finland
Suvi Pihkala, Faculty of Education, University of Oulu, Finland
Leena Pääsky, Faculty of Education, University of Oulu, Finland
Sari Harmoinen, Faculty of Education, University of Oulu, Finland

Keywords: Co-Creation, Gender-Responsible, Intersectional, Knowledge, Sustainability

Recent emphasis on citizen science and the access allowed by digital technologies highlights that the Arctic region and related decisions, strategies and futures should also be accessible to the people of the region. Also, the Right for Science, as part of the United Nations Declaration for Universal Human Rights, has become a significant global debate. Therefore, we need to pay attention to how gender, Arctic localities, including Indigenous knowledges, access and science could afford to co-creating sustainable Arctic knowledge. What is at stake is learning to understand interrelated and interdependent human and other than human complexities and make connections collectively and co-creatively—being with and in relation to the planet. Thus, we frame the main challenge as to advance multidisciplinary research affordances, co-creating the understanding and cultivation of our imagination in an aim to relate with care to sustainability and responsibility in and about the Arctic through various knowledge production process that we aim to illustrate in our presentation.

Seasonality in Tourism in Arctic Regions of Russia

Oleg Barbakov, Industrial University of Tyumen, Tyumen, Russia
Lidia Belonozhko, Industrial University of Tyumen, Tyumen, Russia

Keywords: Northern Tourism, Arctic Tourism, Seasonality, Destination, Tourism Industry

To date there is no generally accepted definition of the term "Arctic tourism", although the notion is widespread and used in official state documents (e.g. in the "strategy of development of the Arctic zone of the Russian Federation and national security for the period till 2020" approved by the President of the Russian Federation). To analyze the problems and prospects of this tourist destination, impact of sesonality,it is necessary to identify the territorial framework of the phenomenon and its characteristic features. The definition of Arctic tourism as visiting the Arctic for recreational, educational, sports, religious and other similar purposes that are not related to making a profit and performing labor activities looks obvious and logical, but has a number of drawbacks. In this regard, it is appropriate to determine the territorial scope of the region, which can be implemented in practices of Arctic tourism, as follows: Arctic ocean, Northern Atlantic and Pacific oceans, Islands and archipelagos in their waters and mainland areas in the North of Eurasia and North America located in the Arctic and subarctic climatic zones related to natural areas of the Arctic desert, tundra and forest-tundra.At the same time, it seems logical to distinguish between the concepts of "Arctic tourism" and "Northern tourism". These areas, while similar in a number of parameters (the severity of climatic conditions, the residence of indigenous peoples and groups of old-timers), nevertheless have their own uniqueness. The distinctive features of Northern tourism include: more pronounced seasonality compared to the Arctic; primary localization in the natural and climatic zone of boreal (Northern) forests, with corresponding flora.

Seroprevalence of pestivirus – a potential viral health threat to semi-domesticated and wild reindeer in the Nordic countries and Russia

Javier Sánchez Romano, UiT The Arctic University of Norway, Tromsø, Norway
Caroline Aurosell, Swedish Food Agency, Uppsala, Sweden
Valery Fedorov, Yakutian Scientific Research Institute of Agriculture, Yakutsk, Russia
Åsa Hagström, National Veterinary Institute, Uppsala, Sweden
Juha Kantanen, Natural Resources Institute Finland (Luke), Helsinki, Finland
Mikael Leijon, National Veterinary Institute, Uppsala, Sweden
Torill Mørk, Norwegian Veterinary Institute, Tromsø, Norway
Christine S. Nordtun, UiT The Arctic University of Norway, Tromsø, Norway
Ingebjørg Helena Nymo, Norwegian Veterinary Institute, Tromsø, Norway
Anna Omazic, National Veterinary Institute, Uppsala, Sweden
Skarphéðinn G. Þórisson, East Iceland Nature Research Centre, Egilsstaðir, Iceland
Tiina Reilas, Natural Resources Institute Finland (Luke), Helsinki, Finland
Ulrika Rockström, Farm and Animal Health, Uppsala, Sweden
Rán Thorarinsdottir, East Iceland Nature Research Centre, Egilsstaðir, Iceland
Morten Tryland, UiT The Arctic University of Norway, Tromsø, Norway
Jonas Johansson Wensman, Swedish University of Agricultural Sciences, Uppsala, Sweden
Ann Albihn, National Veterinary Institute, Uppsala, Sweden

Keywords: Rangifer T. Tarandus, Reindeer, Pestivirus, Serology, PCR

Eurasian tundra reindeer is a keystone species in the Arctic and sub-Arctic areas of the Nordic countries and Russia. While a few wild populations exist, semi-domesticated reindeer comprise most of the herds in these countries. Reindeer herding has been of great importance for the indigenous people in the Arctic for at least 500 years. Today, climate change and other anthropogenic changes are threatening the traditional ranges of reindeer herding, among other things, by increasing the prevalence of microbial pathogens. Pestiviruses are known to cause serious health problems in ungulates worldwide. The present study aimed to determine the current seroprevalence for pestiviruses in semi-domesticated (n=392) and wild reindeer (n=128). In addition, direct screening by a pan-pestivirus real-time RT-PCR in seronegative animals was performed. Seroprevalence was higher in Sweden (48.5%, n=133) and Norway (41.2%, n=119) as compared with Finland (2.5%, n=122) and Iceland (1.6%, n=128). No seropositive animals were detected in Russia (n=19). Real time RT-PCR of seronegative animals (n=156) from seropositive herds confirmed their negative status. These results confirm the circulation of pestivirus in semi-domesticated reindeer in Fennoscandia, and for the first time, detected pestivirus seropositive reindeer in Iceland. Further studies are needed to better understand epidemiology of the pestivirus infection and the effect of the virus on reindeer health and population dynamics.

Team Dynamics and Decision-making in High Performance Environment at Svalbard within Search and Rescue Operations

Marte Raknerud Hoel, University of Tromsø, Norway
Dina Abdel-Fattah, University of Tromsø, Norway

Keywords: Search And Rescue, Decision-Making, Increased Maritime Activity, Team Dynamics

The rapid loss of sea ice due to climate change has resulted in increases in maritime activity in the Arctic Ocean. If an accident should occur on any of these vessels, the search and rescue (SAR) team in Svalbard would be one of the first, if not only, responders for a search and rescue operation in the area around Svalbard. Such limitations in response capacity makes the consequences more severe, especially in large-scale accidents. The aim of the research is therefore to understand which factors that are critical for a successful mission for SAR, focusing on important elements in SAR decision-making, specifically team dynamics working in a high-performance environment. This research will thus research the role of team dynamics in SAR in Svalbard, to understand what factors related to teamwork contribute to SAR success. With the potential growing demand for SAR capacity in the area around Svalbard, this research can help support a better understanding of a critical resource for not only the Svalbard community, but the greater international maritime community operating in Arctic waters.

Ticks on the move – increased risk for zoonotic infections in the North

Anna Omazic, National Veterinary Institute, Uppsala, Sweden
Giulio Grandi, Swedish University of Agricultural Sciences, Uppsala, Sweden
Camilla Risvoll, Nordland Research Institute, Bodø Norway
Grete K. Hovelsrud, Nord University, Bodø, Norway
Ann Albihn, National Veterinary Institute, Uppsala, Sweden

Keywords: Tick-Borne Diseases, Geographical Distribution, Species Identification, Sweden, Norway

Climate change expands the geographical distribution of ticks to higher latitudes and altitudes. However, the risk for tick-borne diseases (TBD) affecting humans and animals in the North is insufficiently studied. The unawareness of clinical symptoms of tick-borne zoonoses in new areas may lead to misdiagnosis, delayed therapies, and poor protection of the population. Reindeer is one species that can be threatened by TBDs since they are immunologically naïve towards them. Reindeer are also exposed to a multitude of other pressures e.g. area encroachments, predators, expansion of shrubs and forests, and fragmented and ill-fitted governing tools and legislations. TBDs will exacerbate these stresses. Through a citizen science study in 2018, 4500 ticks collected from animals or humans in northern Sweden were sent to SVA. Ixodes ricinus was the dominant tick species, but we could observe a spread of I. persulcatus compared to previous reports. A subset of ticks (n=1420) was analysed with a high-throughput microfluidic real-time PCR and following tick-borne pathogens were found: 25% Rickettsia spp, 20% Borrelia spp., 9% Anaplasma, 6% Neoehrlichia, 5% Babesia spp, and 2% Uukuniemi-virus. With this new knowledge, we can contribute to adaptation strategies and measures for minimizing the impacts of TBP in animal husbandry and human communities.

ID: 21 - The spectrum of intersectionality in the Arctic - from discrimination to diversity and inclusion

Conveners

Birgitta Evengard | Umea University, Sweden

Douglas Nord | Scientific Advisory Board, Arctic Programme, NordForsk

Niila Inga | Leavas cearru, Nordic Center of Excellence REXSAC

Moving From Diversity to Inclusion: Meaning, Model, and Practice

Kaja Brix, NOAA Fisheries, Fairbanks Alaska USA
Olivia Lee, International Arctic Research Center, University of Alaska Fairbanks, Fairbanks AK USA
Sorina Stalla, Interagency Arctic Research Policy Committee, University of Alaska Fairbanks, Juneau AK, USA

Keywords: Inclusion, Meaning, Model, Practice, Diversity And Inclusion, Framework Of Inclusion

The diversity and inclusion discussion permeates many sectors of society. Within this dialogue, science and scientists are acutely aware of the value of diversity and the need for inclusion. While demographic diversity in science has received considerable recent attention, very little research and understanding exists on inclusion. Our study presents empirical data on the meaning of inclusion using a crowdsourcing approach that sought responses to the question “What does inclusion mean to you?”. The most prominent concepts were those of empathy, warmth, support, love, acceptance and curiosity; diverse perspectives; and participation. We clustered conceptual elements of inclusion into four themes: access and participation, embracing diverse perspectives, a welcome environment, and team belonging. On the basis of these data, we theorize a conceptual framework model from which inclusion may be put into practice. Our model suggests a dynamic process of inclusion operating from principal structural elements of 1) a foundation that involves place, access and participation, and space; 2) reciprocal engagement as an engine for inclusion; and 3) expression of inclusion as culture. The framework model demonstrates a means by which the practice of diversity can be more than shifts in demographic statistics, and instead promote the full expression of benefits derived when the many dimensions of diversity are truly included.

Babushkas and Rural Indigenous Activisms

Sardana Nikolaeva, University of Manitoba, Winnipeg MB, Canada

Keywords: Indigenous Politics, Gendered Activism, Intersectionality, Russian Federation

There is a growing literature on the intersection of gender and activism that urges recognizing the importance of direct involvement and strategic contributions of women into variety of activist projects worldwide. This presentation will focus on the alternative Indigenous activisms, arguing that the local diverse initiatives can reveal more subtle, yet, still effective forms of local agency, and, most importantly, highlight the plurality of Indigenous mobilizations. I will discuss the grassroots women-led initiatives in the rural Indigenous village of the North-Eastern region of Russian Federation. The women involved were predominantly rural older women who developed particular radically ingenious and productive projects, which, I argue, have a potential to change our understanding of Indigenous politics as well as gendered aspects of Indigenous activism in the Russian North. Most importantly, I will emphasize the agency of rural older women and how the narratives of their experiences can open up a space for further critical interrogation of Indigenous politics within the specific context of the rural and somewhat isolated community.

Implementation of Inuit Self-Government in Nunavut

Zarina Shagieva, Volgograd State University, Volgograd, Russia

Keywords: Nunavut, Inuit, Self-Government, Indigenous Peoples

Awareness of self-government initiatives as a fundamental mechanism for preserving the inherent characteristics of indigenous peoples play an increasingly important role in the debate on the rights of indigenous peoples, and therefore a comparison of regimes of self-government is becoming more relevant. Self-government can ensure that indigenous peoples live in accordance with their own norms and values. In Canadian law, it is designated as a tool through which, through agreements with federal and provincial governments, indigenous communities have the opportunity to control the governance of their own people, their land, resources, and politics. Nunavut in this context is characterized as a subject where indigenous self-government exists and is implemented, since the Inuit make up the majority of the population of this region (85%), and the territory arose from an agreement on land claims. It should be noted that most of the powers and rights provided by the designated regulatory acts are advisory and do not affect the final decision of the federal government. In addition, the government in this territory is public in nature, which implies the participation in it not only of the indigenous people but of all citizens living in the region, regardless of their ethnicity. This fact does not allow us to say that Nunavut is a self-government unit of the Inuit. The rights of indigenous peoples presented in regulatory legal acts are in many respects declarations rather than being implemented in reality. This fact makes Nunavut a preferred territory for indigenous peoples and proclaims their paramount importance over other residents - the territory was created in accordance with the requirements of the Inuit, however, almost all components of self-government in this territory are partially implemented - the use of these rights is difficult either indirectly or directly from the state.

Inspiring Girls Expeditions Alaska: Removing barriers to accessing science and the outdoors for high school youth and early career professionals

Joanna Young, International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, USA
Sarah Clement, International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, USA

Keywords: Science, Outdoors, Outreach, Diversity, Youth

Inspiring Girls Expeditions empowers 16 and 17 year-old high school girls through 12-day backcountry science and art programs. At Inspiring Girls Expeditions Alaska, we offer expeditions in glaciology/mountaineering, marine biology/sea kayaking, and boreal ecology/packrafting. Because science and outdoor fields are traditionally male-dominated, Inspiring Girls was created to welcome young women to these arenas. Though our name is not perfect, Inspiring Girls welcomes girl-identified, non-binary and gender non-conforming youth. Teams are chosen to represent a diversity of socio-economic, racial, ethnic, and family backgrounds, and our tuition-free format removes a financial barrier. In addition to participants, Inspiring Girls serves as professional development for early career scientists, artists, and outdoor guides as instructors. We strive to ensure a supportive environment for participants and staff of all identities, through e.g. LGBTQ+ safety and land acknowledgement training. However, as a predominantly white-led organization, we acknowledge the urgent need to welcome more diverse staff, such that participants feel represented by their mentors. This presentation will discuss the ways in which Inspiring Girls Expeditions of Alaska is creating opportunities for both underserved high schoolers and young professionals. From intentional hiring practices to scholarships and training, we are committed to reimagining the diversity and inclusivity of science and outdoor fields.

Lifting barriers together for more inclusive Arctic research

Pascale Ropars, ArcticNet, Université Laval, Quebec city, Canada

Keywords: EDI, Inclusive Research, North By North, Sharing Knowledge

The community of Northern research is diverse: it includes people from the North and the South, involves workers and scientists from indigenous communities, government and academia as well as stakeholders and knowledge-holders from across the Arctic Circle. Many researchers have overcome barriers to become involved in Northern research. ArcticNet is addressing these barriers and finding ways to collectively lift them with diverse partners, to make our community inclusive to all. There is an indisputable body of evidence proving that diversity in teams produce better science. As a large research network, ArcticNet is hoping to inform and inspire the research community on best practices in Equity, Diversity and Inclusion. ArcticNet's work in renewing its committees and network members and in co-developing the North by North initiative with northerners is helping to build a foundation for novel approaches to valuing Indigenous knowledge and developing research that serves and benefits the communities in the North and the globe, in partnership with academia. We know there is still work to do, but together we aim at doing better.

From Omission to Commission and now Equity: Indigenous Representation in Arctic Research

Margaret Anamaq Rudolf, University of Alaska Fairbanks, Fairbanks, AK, USA

Keywords: Indigenous, Governance, Equity, Alaska Native, Inclusion

Historically Indigenous People have been omitted from Arctic Research, today there have been attempts at inclusion but we are not at equity. Omission and commission is a framework presented by Fryberg and Easton (2017), where ‘commission’ is rooted in tokenization upholds stereotypes that do not fully represent how Indigenous People see themselves. There is also a conflict in Indigenous representation that differs from the dominant culture. An aspect of the Indigenous worldview is relationships and being accountable to those relationships. For example, even though I am Iñupiaq I grew up in Dene territory in Fairbanks and Anchorage, Alaska. I do not have relationships nor accountability to Iñupiat living in northern Alaska to speak on certain issues. I am a researcher who is Indigenous and doing research on how to collaborate better with Indigenous People and can speak on those topics. Alaska Natives traditionally govern by consensus, not hierarchy, so the concept of who gets to speak for and represent Alaska Natives is complicated. The Tribes within Alaska are pushing for self-determination with policy, as well as research that is happening on their lands and in their waters. Arctic research still is researcher-centered with decisions on Indigenous engagement and representation being decided by researchers. To move to equity, there needs to be Indigenous-led research through self-determination and in a manner that fits their cultural ways of doing research, govern, and live.

Work-life conflicts in the Portuguese Polar community

Maria Teresa Cabrita, Centro de Estudos Geográficos (CEG), Instituto de Geografia e Ordenamento do Território (IGOT), Lisbon, Portugal
Pedro Freitas, Centro de Estudos Geográficos (CEG), Instituto de Geografia e Ordenamento do Território (IGOT), Lisbon, Portugal
Ana David, Centro de Estudos Geográficos (CEG), Instituto de Geografia e Ordenamento do Território (IGOT), Lisbon, Portugal
Margarida Queirós, Centro de Estudos Geográficos (CEG), Instituto de Geografia e Ordenamento do Território (IGOT), Lisbon, Portugal

Keywords: Polar Research, Portuguese Polar Community, Gender Inequalities, Professional Work And Family Conciliation

Research missions in Polar regions usually entail exposure of scientists to long periods of isolation and confinement away from home and family, occasionally with limited communication resources. These are major constraints to be taken into account when pursuing a research career in the Polar regions, particularly for women. Although women are entering polar research in greater numbers than ever before, gender inequalities concerning scientific empowerment and participation in field missions remains wide in Polar science. In line with this international scenario, the Portuguese Polar community also shows gender imbalances. Only 40% of Portuguese Polar community is female, being under-represented in research teams and missions, decision-making and international representation positions. This points out to less opportunity or time availability for access to leadership and prolonged field work away from other professional responsibilities or family environment. This scenario highlights the need for deeper insight into the constraints triggering work-life balance in the Portuguese Polar research community. Here, we investigate whether gender patterns are present in several aspects concerning conciliation of professional work with personal life and family. Using data from a survey conducted within the Portuguese Polar community, we will show drivers of this gender imbalance, assess and discuss possible mechanisms behind it, and consider how researchers approach these issues.

Theme H: Observing the Arctic

ID: 46 - Observing for Action: Outcomes of the 5th Arctic Observing Summit and Advances in Coordinated Observations

Conveners

Maribeth S. Murray | Arctic Institute of North America, University of Calgary

Ravi D. Sankar | Arctic Institute of North America, University of Calgary

Peter Schlosser | Arizona State University

Arctic Acoustic Environments – Federating observations and analyses with the International Quiet Ocean Experiment

Philippe Blondel, University of Bath, Bath, UK
Hanne Sagen, Nansen Environmental and Remote Sensing Center, Bergen, Norway
Ed Urban, Scientific Committee on Oceanic Research (SCOR), U. Delaware, USA
IQOE Arctic Acoustic Environments Working Group

Keywords: Ocean Sound, International Quiet Ocean Experiment, Ambient Noise, Acoustics, Underwater

Arctic waters are experiencing rapid changes due to global warming, affecting ecosystems and leading to increasing economic activities. Many of these changes can be measured directly or indirectly with underwater acoustics. The Working Group on the Arctic Acoustic Environment (AAE) of the International Quiet Ocean Experiment (IQOE) aims to stimulate observations of sound (levels and distribution) in the Arctic Ocean and its impacts. We organised a virtual conference in November 2020 to share recent results from the international community and discuss common issues and possible solutions. The COVID-19 pandemic amplified the challenges of Arctic deployments and recoveries, curtailing access to ships at very short notice, but also opening the way for more direct collaboration. The post-COVID task will be to establish more resilient international back-up mechanisms for Arctic operations to support acoustic (and other) observations. The increasing length of the measurements, spanning several decades now, with sampling rates often close to 100,000 samples/second, results in “big data” challenges of storage, sharing, data retrieval and long-term archiving. Discussions also addressed the emerging trends in acoustic propagation models across complex terrains and machine learning (with the need for accessibility and traceability). Finally, the embedding of local and traditional knowledge must be accomplished through dialogue and co-ownership of the science and results.

Harnessing the power of community science to address data gaps for Arctic observing: invasive species as case examples

Tobias Schwoerer, International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, USA
Katie V. Spellman, International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, USA
Tammy J. Davis, Alaska Department of Fish and Game, USA
Olivia Lee, International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, USA
Aaron Martin, U.S. Fish and Wildlife Service, USA
Christa P.H. Mulder, Institute of Arctic Biology and Department of Biology and Wildlife, University of Alaska Fairbanks, USA
Nicole Y. Swenson, Tyonek Tribal Conservation District, Anchorage
Audrey Taylor, Department of Geography and Environmental Studies, University of Alaska Anchorage, USA
Genelle Winter, Metlakatla Indian Community, USA

Keywords: Citizen Science, Community Science, Arctic Observing, Alien Species, Monitoring, Early Detection, Evidence-Based Policy

The Arctic is undergoing large-scale changes that are likely to accelerate in future decades such as introductions of invasive species. The Arctic region is in a unique position to prevent new introductions and spread of existing invasive species by adopting policies and actions aimed at early detection. Responding to threats from invasive species in order to minimize impacts to communities, food security, and northern economies will necessitate extensive observations and monitoring, but resource managers often face decisions without adequate data and resources at hand. Local observing programs present attractive methods for increasing observing capacity that span contributory and co-created approaches while raising awareness of an issue among stakeholders. While the co-created model has been widely applied and encouraged in the Arctic context, contributory citizen science programs offer an additional tool for addressing observing needs in the Arctic. We showcase three contributory citizen science programs that have supported the objectives of the Alaska Invasive Species Partnership. We address trade-offs between co-created and contributory approaches and illustrate additional value that the contributory citizen science approach could provide for observing Arctic change across temporal and spatial scales. We frame the three case examples within the context of the Arctic Council's Arctic Invasive Alien Species Strategy and Action Plan (ARIAS Plan). We discuss criteria for achieving ARIAS priority actions through an inclusive citizen science approach aimed at successful integration of citizen science into Arctic policy making. Finally, we discuss challenges and future directions for contributory citizen science within Arctic observing networks.

Marine mammal observing - analytical review of advanced technologies in monitoring and research of marine mammals and their feasibility for operations in the Arctic

Dmitry Udovik, Lomonosov Moscow State University Marine Research Center, Russia
Dmitry Glazov, A.N. Severtsov Institute of Ecology and Evolution, Moscow, Russia
Nikolay Shabalin, Lomonosov Moscow State University Marine Research Center, Russia,
Olga Konovalova, Lomonosov Moscow State University Marine Research Center, Russia
Anna Gebruk, University of Edinburgh, School of GeoSciences, Edinburgh, UK / Lomonosov Moscow State University Marine Research Center, Russia

Keywords: Arctic, Marine mammals, Monitoring methods, Underwater noise, Seismic survey

In this review we focus on modern techniques of marine mammal observing, monitoring and research and their applications in the Arctic region. Efficiency of methods with regards to scientific research on distribution of marine mammals and minimizing anthropogenic disturbance during offshore operations. Analysed data sources included peer-reviewed articles, cruise reports and archive data with a focus on the Eurasian Arctic shelf. Historically marine mammal observing was performed visually by trained research staff. However, visual observations are severely restricted by visibility and weather conditions, i.e. at night. In addition, visual registration of animals is a subject to human error and species identification is often difficult or impossible to carry out based on a single observation. Modern marine mammal observing approaches discussed in this paper can be categorized based on methods of detection and registration into the following categories: (1) acoustic monitoring (active / passive); (2) Radio Detection and Ranging; (3) Light Detection and Ranging; (4) thermal imaging. In addition, observation platforms were discussed, including underwater equipment (ROVs, UMVs); vessels and aerial units (AUVs and planes). All reviewed systems and platforms are discussed in the context of feasibility for implementation in the Arctic and Artic observing system.

Optimizing Arctic Observing Through Interoperable Information Sharing Across Networks

William Manley, University of Colorado
Roberta Pirazzini, Finnish Meteorological Institute
Jonathan Blythe, Bureau of Ocean Energy Management
Allison Gaylord, Nuna Technologies
Etienne Godin, Université Laval Centre d'Études Nordiques
Øystein Godøy, Norwegian Meteorological Institute, Svalbard Integrated Arctic Earth Observing System
Torill Hamre, Nansen Environmental and Remote Sensing Center
Jan René Larsen, SAON Secretariat
Peter Pulsifer, University of Colorado, Carleton University

Keywords: Observing Systems, Coordination, Implementation, Metadata, SAON ROADS

A fundamental challenge exists for assessment, planning, and synthesis of Arctic observing. Assets such as sites, transects, observatories, projects, and programs are deployed in a diverse and distributed fashion across numerous observing systems. At this time, it is difficult to strategically assess status, overlap, and gaps because most inventories and portals are limited in scope. Furthermore, only a fraction of observing systems share information about observing assets in a way that can be accessed, harmonized, and aggregated for a comprehensive perspective. To help address this challenge, a new “Polar Observing Assets Working Group” has been formed under the SAON Committee on Observations and Networks (CON). This group builds upon steps taken by the Polar data community for the interoperability of “dataset-level” metadata, but in this case for high-order, discovery-level details in “asset-level” metadata. The group will identify and promote best practices for the use of relevant metadata standards, controlled vocabularies, crosswalks, federated search, and linkages to scientific datasets. Outcomes will make it easier for networks and planners to avoid duplicated effort while optimizing resources. Participation is open and encouraged, and will help to showcase and integrate the summed contributions of multiple systems.

Support of the SAON Roadmap for Arctic Observing and Data Systems as a key outcome of the Arctic Observing Summit 2020

Hajo Eicken, International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, United States
Peter Schlosser, Arizona State University, Tempe, AZ, United States
Thorsteinn Gunnarsson, Icelandic Centre for Research, Reykjavík, Iceland
Alice Bradley, Williams College, Williamstown, MA, United States
Raychelle Daniel, Pew Charitable Trusts, Washington, DC, United States
Jan René Larsen, Sustaining Arctic Observing Networks, Oslo, Norway
Maribeth S Murray, University of Calgary, Calgary, AB, Canada
Peter L Pulsifer, Carleton University, Ottawa, Canada
Ravi Darwin Sankar, Stillwater, OK, United States
Sandra Starkweather, Cooperative Institute for Research in Environmental Sciences, Boulder, CO, United States

Keywords: Arctic Observing Summit, SAON, Sustained Observations, Shared Arctic Variables, Observing Systems

Rapid Arctic change impacts a range of communities and institutions. Sustained observations of Arctic change inform response action, support prediction and decision-making, and provide insights into the evolution of Arctic systems in a global context. We lack an integrated Arctic observing system that links the existing patchwork of observing projects, networks and programs across disciplines and scales. Sustaining Arctic Observing Networks (SAON) Roadmap for Arctic Observing and Data Systems (ROADS) serves as a framework to facilitate convergence of different observing efforts toward a broader goal, while preserving their identity and specific objectives. The Arctic Observing Summit (AOS) has been providing community-driven, science-based guidance for the design, implementation, coordination and long-term operation of such an international network of Arctic observing systems. AOS 2020 was planned in close alignment with SAON ROADS. A major outcome from the summit is the emergence of action plans at the level of AOS Working Groups that comprise observing program scientists, Indigenous peoples' organizations and community members, agency personnel, and representatives of global and regional observing initiatives. In the presentation, we will review the overall AOS approach and explore in more detail key activities at the working group level that support ROADS, and the broader goal of shared benefits emerging from coordinated Arctic observations.

The long-term monitoring of bird population on Kolguev Island in the Barents Sea

Petr Glazov, Institute of Geography Russian Academy of Sciences, Moscow, Russia
Julia Loshchagina, Institute of Geography Russian Academy of Sciences, Moscow, Russia
Alexander Kondratyev, Institute of Biological Problems of the North, Far Eastern Branch of the Russian Academy of Sciences, Magadan, Russia
Elmira Zaynagutdinova, St.-Petersburg State University, St.-Petersburg, Russia
Helmut Kruckenberg, Institute for Wetlands and Waterfowl Research, Verden (Aller), Germany
Ivan Pokrovsky, Department of Migration, Max Planck Institute of Animal Behavior, Radolfzell, Germany

Keywords: Kolguev Island, Arctic, Long-Term Monitoring, Birds

Kolguev Island is located in the Pechora Sea, the south-eastern part of the Barents Sea. The ecosystem of the island is unique due to the total absence of rodents. The avifauna of Kolguev currently numbers 111 bird species, of which 57 are nesting. The absence of rodents and the relatively stable predation pressure caused high abundance of many bird species: Willow Grouse, geese (White-fronted Goose, Bean Goose and Barnacle Goose), some waders (Dunlin) and passerines (Lapland Bunting, Meadow Pipit). Over 125-years history of ornithological studies on Kolguev, the island avifauna has changed significantly. The trend towards an increase in the proportion of widespread and Siberian species while a decrease in the proportion of Arctic species was observed. Thorough monitoring of Kolguev avifauna has been carried out since 2006. During this period, the dynamics of the population density of 36 bird species was traced. The abundance of some waders (Grey Plover, Ruff, Dunlin) decreased as well as Lapland Bunting, while the numbers of Barnacle Goose increased sharply since 1980s. The breeding density of Rough-legged Buzzard also increased in recent years. The long-term monitoring of Kolguev ecosystems has indicated the high international conservation value of the island due to the high breeding density of many bird species. Our study presents a unique case of monitoring of lemming-free ecosystem, examples of which are quite rare in the Arctic. Study was supported by RFBR 18-05-60057.

Arctic Risks and Resilience: Environment and human indicators as derived from DOPA and GHSL global products

Brigitte Koffi, European Commission, Joint Research Centre, Ispra, Italy
Julian Wilson, European Commission, Joint Research Centre, Ispra, Italy
Grégoire Dubois, European Commission, Joint Research Centre, Ispra, Italy
Andrea Mandrici, European Commission, Joint Research Centre, Ispra, Italy
Giacomo Delli, European Commission, Joint Research Centre, Ispra, Italy
Daniele Ehrlich, European Commission, Joint Research Centre, Ispra, Italy

Keywords: DOPA, GHSL, Conservation, Resilience, Indicators

The 2016 Arctic Resilience Assessment identified a total of 19 Arctic regime shifts, defined as “hard-to-predict, persistent reorganizations of Arctic ecosystems that can and have occurred in Arctic marine, freshwater and terrestrial ecosystems”. Species depending on sea ice for survival and reproduction may be disrupted by changes in sea ice thickness and extent or in the timing of ice formation and melt. Conversely, phytoplankton and non-native species may increase due to the warmer waters and sea ice reduction. The increasing frequency of wildfires and abrupt thawing of permafrost could accelerate ecological shifts, such as the spread of tall shrubs and trees into tundra. Protecting and conserving biodiversity and ecosystems is critical in order to maintain and increase the resilience of ecosystems and people in the face of the adverse effects of climate change. In this ongoing study, we investigate the use of Digital Observatory for Protected Areas (DOPA) indicators of conservation, biodiversity, human pressure, land cover and land fragmentation, together with Global Human Settlement Layer (GHSL) derived data on population dynamics, to monitor risks and resilience of Arctic ecosystems, services and human communities at ecoregion and protected area levels. The study is intended to help identify priorities and/or indicators/tools for conservation and resilience building, using a socio-ecological approach.

The Arctic Observing Summit - Emerging Challenges of co-ordinating pan-Arctic global observing activities

Maribeth S. Murray, University of Calgary, Calgary, Canada
Peter Schlosser, Arizona State University, USA
Hajo Eicken, University of Alaska Fairbanks, USA
Ravi Darwin Sankar, University of Calgary, Calgary, Canada

Keywords: Arctic Observing, Networks, Coordination,

The biennial AOS is convened to guide development and long-term operation of a Pan-Arctic Observing System. Sustained observations, including from Indigenous Peoples, regional governments and management bodies enable tracking, understanding, and projections of change leading to informed decision making. Among the outcomes of the 2020 AOS were recommendations that the observing system be reflective of societal and scientific needs with design drawing on Essential and Shared Arctic Variables. Emphasis on an observing system relevant to decision making and supported by a networked, collaborative, interoperable digital system based on co-production and ethical data principles was also a major recommendation from Summit participants. In this presentation, we review the outcomes of the five Summits to date and focus on the emerging challenges ahead including maintaining research-based observing while increasing operational observing, establishing the cost-benefit of observing activities, co-design, co- production, and co-management, and mobilizing observing outcomes for action in this period of environmental, economic, and political uncertainty.

ID: 88 - Emerging technologies and their applications in the Arctic

Conveners

Pavel Talalay | Polar Research Center, Jilin University, China

Elizabeth Bagshaw | School of Earth and Ocean Sciences, Cardiff University, UK

Claus Melvad | School of Engineering, Aarhus University, Denmark

Shridhar Jawak | Svalbard Integrated Arctic Earth Observing System (SIOS), Longyearbyen, Svalbard, Norway

Adapting the helicopter borne probe HELiPOD to the MOSAiC expedition – Technical challenges and system overview

Magnus Ole Asmussen, TU Braunschweig, Institute of Flight Guidance, Germany
Falk Pätzold, TU Braunschweig, Institute of Flight Guidance, Germany
Lutz Bretschneider , TU Braunschweig, Institute of Flight Guidance, Germany
Konrad Bärfuss, TU Braunschweig, Institute of Flight Guidance, Germany
Sven Bollmann, TU Braunschweig, Institute of Flight Guidance, Germany
Andreas Schlerf, TU Braunschweig, Institute of Flight Guidance, Germany
Stefan Nowak, Leichtwerk Research GmbH, Germany
Björn Brandt, Messwerk GmbH, Germany
Thomas Rausch, TU Braunschweig, Institute of Flight Guidance, Germany
Barbara Harm-Altstädter, TU Braunschweig, Institute of Flight Guidance, Germany
Tom Schwarting, TU Braunschweig, Institute of Flight Guidance, Germany
Astrid Lampert, TU Braunschweig, Institute of Flight Guidance, Germany

Keywords: HELiPOD, Meteorology, Surface-Atmosphere Interactions, MOSAiC

The helicopter borne probe HELiPOD was technically advanced to be deployed from Polarstern during the MOSAiC expedition for investigating the ocean-sea-ice-atmosphere interactions in the Arctic. HELiPOD measures temperature, humidity and 3D wind at high temporal resolution. Additional sensors were implemented to observe concentrations of carbon dioxide, methane, ozone, aerosols, surface roughness and short/long wave radiation. Additional mapping cameras (VIS & IR) enable to directly connect measurements to the surface. As position and attitude of the system is crucial for most of the measurements and critical at Arctic latitudes, the INS-GNSS system was expanded with two separate GNSS receivers and an additional inertial measurement unit. Insulation and a heating system were implemented to the HELiPOD to operate sensors and batteries at favourable constant room temperature. The ground handling equipment has been expanded to include skis for transporting the HELiPOD on the floe. The data acquisition is based on a flexible system with a central unit for time synchronisation, distributed data conversion and processing electronics. For inflight monitoring a WLAN data connection to the operator in the helicopter was established. Preliminary results of the measurement flights obtained between 10.05.2020 and 22.07.2020 are presented here, to show the potential and sensitivity of the HELiPOD as measurement platform for complementary environmental monitoring.

Autonomous measurements of an undisturbed epipelagic sound scattering layer at high latitudes

Muriel Dunn, Fisheries and Marine Institute at Memorial University of Newfoundland and Akvaplan-niva, Tromsø, Norway (Lead/correspondance)
Sünnje Basedow, UiT - The Arctic University of Norway, Tromsø, Norway
Stig Falk-Petersen, Akvaplan-niva, Tromsø, Norway
Lionel Camus, Akvaplan-niva, Oslo, Norway
Geir Pedersen, Institute of Marine Research, Bergen, Norway
Maxime Geoffroy, Fisheries and Marine Institute at Memorial University of Newfoundland, St. John's, NL

Keywords: Broadband Echosounder, Fisheries Acoustics, Autonomous Observations, Remote Sensing, Sound Scattering Layers

Sound scattering layers (SSL) form horizontal layers with high abundance of zooplankton and small fish throughout all oceans. Yet, describing the composition and migrations within these layers is challenging, especially near the surface. To document the Norwegian Sea's epipelagic SSLs, we conducted hydroacoustic-trawl surveys at Tromsøflaket (70°N) in June 2018. The research vessel's narrowband echosounders (18 and 38 kHz) detected a strong epipelagic SSL dominated by Calanus species between 12.5 and 40 m. However, the hull-mounted echosounder's 12.5 m blind zone prevents from confirming if the SSL extended up to the surface. Also, the avoidance from vessel noise and sampling gear might have biased the distribution and abundance estimates. An autonomous surface vehicle (ASV, Sailbuoy) equipped with a broadband echosounder (283-383 kHz) was deployed in the same region. We utilized the advantages from the ASV, such as reduced blind zone (2.5 m) and reduced disturbance, and broadband echosounders. Based on these data with high range resolution and frequency response of targets across a broad spectrum, we predict density estimates of functional groups in the epipelagic SSL. These predictions are calculated using sound scattering models and machine learning optimization routines. Here, we discuss the advantages, limitations and challenges we face with this approach and its applicability to increase the temporal and spatial coverage of acoustic surveys conducted at high latitudes.

Topology and pressure distribution reconstruction of an englacial channel

Andreas Alexander, Department of Geosciences, University of Oslo, Oslo, Norway
Laura Piho, Centre for Biorobotics, Tallinn University of Technology, Tallinn, Estonia
Maarja Kruusmaa, Centre for Biorobotics, Tallinn University of Technology, Tallinn, Estonia

Keywords: Glacial Hydrology, Drifter, Inertia, Death Reckoning

Glacial hydrology describes the way water moves over, through and under glaciers. We present a measurement method that allows to reconstruct planar subsurface water flow paths and spatially reference water pressures therein. The approach uses inertial measurements from submersible sensing drifters and reconstructs the flow path from given start and end coordinates. Validation cases show an average error of 3.90 m compared to GNSS reference. We showcase this method by reconstructing the flow path and the spatial water pressure distribution of an englacial channel on Austre Brøggerbreen (Svalbard). The average error of the reconstruction is thereby 12.1 m and the average pressure error 3.4 mbar (0.3%). Our method will allow to study en- and subglacial flow paths and the pressure distribution therein, thereby allowing for model validation and activation. Further on, our method also allows to reconstruct other subsurface fluid flow paths, when a global spatial reference (e.g. GNSS) is not available.

High spatial variability of aerosol particles observed with unmanned aerial systems at the coastal Arctic site Ny-Ålesund

Magnus Ole Asmussen, TU Braunschweig, Institute of Flight Guidance, Germany
Barbara Harm-Altstädter, TU Braunschweig, Institute of Flight Guidance, Germany
Martin Schön, Center for Applied Geosciences, Eberhard Karls University Tübingen, Tübingen, Germany
Birgit Wehner, Department of Experimental Aerosol and Cloud Microphysics, Leibniz Institute for Tropospheric Research, Leipzig, Germany
Lutz Bretschneider, TU Braunschweig, Institute of Flight Guidance, Germany
Falk Pätzold, TU Braunschweig, Institute of Flight Guidance, Germany
Konrad Bärfuss, TU Braunschweig, Institute of Flight Guidance, Germany
Jens Bange, Center for Applied Geosciences, Eberhard Karls University Tübingen, Tübingen, Germany
Astrid Lampert, TU Braunschweig, Institute of Flight Guidance, Germany

Keywords: Unmanned Aerial System, Arctic Atmospheric Boundary Layer, Aerosol Particles, Ny-Ålesund

A more profound knowledge of freshly formed aerosol particles is of vital importance in the Arctic atmospheric boundary layer (ABL). By subsequent growth, aerosol particles may act as cloud condensation nuclei and subsequently contribute to the Arctic amplification. However, due to a limited number of suitable measurement methods, a detailed 4-D picture of aerosol particles sources, their transport and mixing in the ABL is still lacking. The two unmanned aerial systems (UAS) ALADINA and MASC were used simultaneously in order to investigate the horizontal and vertical distribution of ultrafine aerosol particles (UFP), equivalent black carbon and accumulation mode particles in correlation with meteorological conditions. Around 50 measurement flights were performed at the coastal Arctic site in Ny-Ålesund between 24 April and 25 May 2018. The observed UFP showed a high variability in the vertical and horizontal distribution, mainly affected by local wind fields and ABL conditions. The observations of these local differences in UFP are of vital importance for complementing continuous ground-based monitoring stations that are deployed for long-term observations. Furthermore, UAS may be used to link observations at different ground-based sites. In addition to first results, the authors present the adaptions of the UAS which had to be performed for a safe and reliable Arctic field application.

Development and Deployment of an Internet of Things (IoT) Network for Snow and Glacier Research in Svalbard

Simon Filhol, University of Oslo, Norway
John Hulth, University of Oslo, Norway
J. David Ibáñez, Spain
Jean-Charles Gallet, Norwegian Polar Institute, Norway
Pierre-Marie Lefeuvre, Norwegian Polar Institute, Norway
Thomas Vikhamar Schuler, University of Oslo, Norway
John F. Burkhart, University of Oslo, Norway

Keywords: IoT, Sensor, Glacier, Snow, Technology

The recent multiplication of open source software and hardware for Internet of Things (IoT) technology opens new opportunities to design, build and deploy light weight, low power and connected monitoring devices for environmental sciences. We have developed and built a wireless network of sensors that measures a variety of variables for snow and glacier research. Polar nights, cold temperatures, high logistical cost for deployment and maintenance are inherent challenges of the Arctic, thus forcing design trade offs between efficiency in and optimization of power management versus simple and robust design. The first deployment season, April 2019-April 2020 on glaciers nearby Ny-Ålesund proved the potential of our approach. In April 2021, we will deploy an updated version including a radio network to push data in near-real time to a cloud infrastructure with quality assessment and quality control of the data. While still at the stage of development, we see a promising future for these technologies for scientific purpose in the Arctic as 1) the cost per device is greatly lowered in comparison to traditional systems, 2) the size of device is miniaturized, 3) the whole stack of technology is open source allowing full control and transparency of the data pipeline, 4) modern communication protocols provides live data updates from remote areas, and 5) combining scientific and engineering knowledge and skills allows for new creative approach to instrument design.

ACUASI, the FAA Alaska Test site, and Arctic Operations

Peter William Webley, Alaska Center for Unmanned Aircraft Systems Integration, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska, USA.
Catherine Cahill, Alaska Center for Unmanned Aircraft Systems Integration, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska, USA.
Nicholas Adkins, Alaska Center for Unmanned Aircraft Systems Integration, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska, USA.
Jessica Garron, Alaska Center for Unmanned Aircraft Systems Integration, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska, USA.
James Parish, Alaska Center for Unmanned Aircraft Systems Integration, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska, USA.
Michael Hatfield, Alaska Center for Unmanned Aircraft Systems Integration, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska, USA.

Keywords: Unmanned Aircraft Systems, Arctic Operations, Autonomy, Beyond Line Of Sight, Academia

As Unmanned Aircraft Systems (UAS) continue to be integrated into the U.S. National Airspace System (NAS), researchers, operators, and manufacturers are pushing the boundaries of possibilities. UAS have enormous potential for use in geoscience research and supporting operational needs. We will present the capabilities, lessons learned, and research in building and operating the Alaska Center for Unmanned Aircraft Systems Integration (ACUASI). ACUASI, the US Federal Aviation Administration designated Alaska Test site, works closely with multiple partners on integrating UAS into the NAS. We have developed a comprehensive program that incorporates pilots, mission planners, geoscientists, undergraduate and graduate students, and engineers together as one. We have extensive experience in Arctic and sub-Arctic environments and will present on how we have used our aircraft and payloads in numerous missions that include Beyond Visual Line of Sight flights, mapping river ice-hazards during spring break-up, testing safe operations of UAS in the NAS, and providing UAS-based observations for local Alaskans. This presentation demonstrates how UAS can be integrated into operational support systems for the Arctic and at the same time be used in geoscience research projects to provide high precision, accurate, and reliable observations. A discussion of current challenges and potential opportunities for safe, effective, and efficient UAS operations in the Arctic concludes this presentation.

Deployment of UAS for Arctic Atmospheric Science

Gijs de Boer, University of Colorado, Boulder, CO, USA
Dale Lawrence, University of Colorado, Boulder, CO USA
John Cassano, University of Colorado, Boulder, CO USA
Brian Argrow, University of Colorado, Boulder, CO USA
Radiance Calmer, University of Colorado, Boulder, CO USA
Jonathan Hamilton, University of Colorado, Boulder, CO USA
Gina Jozef, University of Colorado, Boulder, CO USA
Janet Intrieri, NOAA, Boulder, CO USA

Keywords: UAS, Atmosphere, Surface, Drones, MOSAiC

The Arctic system is changing at a rapid pace. Understanding this change requires a high spatial and temporal density of observations to develop process understanding, evaluate weather and climate prediction tools, and monitor the rapid change occurring in this region. To support collection of such observations, recent years have seen increased deployment of robotic observing capabilities to the Arctic environment. Such deployments have resulted in revolutionary perspectives on this delicate environment, despite myriad challenges associated with deployment of these systems in the harsh Arctic environment. In this presentation, we will provide an overview of Arctic observational efforts conducted leveraging Uncrewed Aircraft Systems (UAS) over the past five years. Our team has deployed systems to northern Alaska at a heavily-instrumented atmospheric observatory (Oliktok Point, Alaska) and to the central Arctic Ocean as part of the recently-completed MOSAiC project. Along the way, we have collected hundreds of flight hours of data on atmospheric conditions, aerosol properties, surface albedo, and the interactions between the atmosphere and underlying surface. These observations were collected at latitudes up to 86N, in temperatures reaching down to -35 C. We will highlight the most successful aspects of these deployments, provide some insight into the science that we moving forward with, and offer insight into the toughest challenges faced with operating fixed- and rotary-wing systems in the Arctic environment.

Observing Cm-Scale Changes In Sea Ice Topography with Terrestrial Lidar

David Clemens-Sewall, Dartmouth College, Hanover, USA
Chris Polashenski, USACE-CRREL, Hanover, USA
Don Perovich, Dartmouth College, Hanover, USA
Ian Raphael, Dartmouth College, Hanover, USA

Keywords: Snow, Sea Ice, Lidar, MOSAiC, VTK

Accurately observing changes in sea ice and the snow on sea ice is important for enhancing our understanding of snow on sea ice processes, sea ice dynamics, and remote sensing observations of sea ice. Terrestrial laser imaging, detection, and ranging (Lidar) offers the potential to map the snow and ice surface topography at sub-cm precision. However, the drift, deformation, and roughness of the sea ice cover present challenges for realizing this potential. Most commercially available tools are not designed to address these challenges. Here we demonstrate that open-source tools, especially the Visualization Toolkit (commonly referred to as VTK), can be used to solve these challenges. We show examples of filtering, object detection, deformation tracking, and uncertainty quantification applied to Terrestrial Lidar data collected from October 2019 to May 2020 on the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) Expedition. Collectively, these processing and analytical techniques enable us to observe cm-scale changes in sea ice topography.

The use of innovative pop-up floats to explore Arctic marine ecosystems

Sarah Donohoe, NOAA Corps, Seattle, USA
Phyllis Stabeno, NOAA/PMEL, Seattle, USA
Calvin Mordy, University of Washington, Seattle, USA
Albert Hermann, University of Washington, Seattle, USA
Heather Tabisola, University of Washington, Seattle, USA
Thomas Van Pelt, University of Washington, Seattle, USA
Scott Stalin, NOAA/PMEL, Seattle, USA

Keywords: Pop-Up Float, Ocean Instrumentation, Autonomous Float, Arctic Observing

The pop-up float is a small, low-cost, moored, autonomous float designed for easy deployment and data collection in the challenging seasonal sea ice zones of the Bering and Chukchi Seas. It was developed to fill a gap in available technology between year-round moorings and surface-based sampling in summers with a unique engineering approach. Since 2017, 14 floats have been field tested in the Bering (11) and Chukchi (3) Seas with 11 of those floats (79%) successfully returning temperature, location, photosynthetically-active radiation (PAR), fluorescence data and under-ice camera images via Iridium satellite short-burst data messages. Pop-up floats can provide insight into the winter extent of the Bering Sea cold pool and levels of algal biomass under seasonal Arctic sea ice. The small and easy-to-deploy pop-up floats are uniquely situated to be deployed by ships of opportunity. In 2020, due to COVID-19, deployments were transitioned to various partners with 1 float deployed by the Aleut Community of St. Paul Island, Alaska, 4 floats deployed by commercial fishing vessels F/V Westward1 and C/P Starbound, and 2 floats deployed by the United States Coast Guard Cutter Fir. In this presentation we will share the pop-up float design, function, and preliminary data as well as discuss their potential as a partnership building platform for autonomous, in-situ data collection in the Arctic.

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In situ exploration of ice microhabitats in deep glacial ice using Deep-UV fluorescence mapping

Michael Malaska, JPL/Caltech, Pasadena, CA, USA
Rohit Bhartia, Photon Systems Inc, Covina, CA, USA
John Priscu, Montana State University, Bozeman, MT, USA
Ken Manatt, JPL/Caltech, Pasadena, CA, USA
Bill Abbey, JPL/Caltech, Pasadena, CA, USA
Bolek Mellerowicz, Honeybee Robotics, Altadena, CA, USA
Joe Palmowski, Honeybee Robotics, Altadena, CA, USA
Gale Paulsen, Honeybee Robotics, Altadena, CA, USA
Kris Zacny, Honeybee Robotics, Altadena, CA, USA
Evan Eshelman, Impossible Sensing, St. Louis, MO, USA
Juliana D'Andrilli, Louisiana Universities Marine Consortium, Chauvin, LA, USA

Keywords: Fluorescence, In Situ, Greenland, Microhabitats, Astrobiology

We developed a down-borehole Deep UV fluorescence mapping spectrometer (the WATSON instrument) with a wireline-coring robotic drill, for in situ exploration of ice microhabitats. We successfully tested this technology to 105 m depth in the Greenland ice sheet at Summit Station, Greenland in the Summer of 2019. Glacial ice is an important environment for life on Earth and possibly elsewhere in the Solar System, including the warm deep ice of the Ocean Worlds (Europa, Enceladus, Titan, etc.). By developing techniques to explore these environments on Earth, we can understand how organic and microbial materials are distributed inside ancient and modern terrestrial ice and then translate those processes to future astrobiology missions to the Ocean Worlds. Our instrument uses in situ Deep UV fluorescence spectroscopic mapping to reveal embedded microbes and organics in the borehole ice. Our field work demonstrated borehole mapping by creating a borehole point cloud as well as detailed wall maps. Using our instrument, we were able to detect and localize materials at low concentrations and discriminate molecular classes at a pixel scale of 100 microns. We found that fluorescent materials existed as punctate isolated hotspots on the order of 1 mm in both firn and glacial ice. Our technology could be used for the targeting and classification of ice microhabitats in the shallow and deep ice sheets of Earth and perhaps the deep icy crusts of the Ocean Worlds of the Solar System.

Optical Cryobots and Other Novel Methods for Deep Ice Penetration

William Stone
Bartholomew Hogan
John Harman
Victoria Siegel
Kristof Richmond
Neal Tanner
Alberto Lopez

Keywords: Drilling Technology

We present the results of laboratory and field tests of several new innovations in ice drilling robots namely cryobot technologies developed at Stone Aerospace during the past five years. In Project VALKYRIE (2010-2016) a 5 kW industrial laser was used to beam power through a fiber optic thread to a remote cryobot. The system was tested on the Matanuska Glacier in Alaska and achieved descent rates of 1 m/hour at 5 kW input power for a 25 cm diameter vehicle. In Projects SPINDLE and ARCHIMEDES (2015-2019), focusing optics were used at the nose of the vehicle. The optics were designed to focus the beam approximately 4 vehicle diameters ahead of the nose of the vehicle. This approach led to a spectacular descent rate of 22 m/hour at 5 kW input power for a 5 cm diameter vehicle operating in temperate ice in laboratory tests. The design works because nearly 100% of the power is absorbed by the ice ahead of the vehicle, thus minimizing sidewall losses. Lastly, we present results from Projects SPINDLE, THOR and PROMETHEUS (2015-PRESENT) that are developing means for radically improving the classical Philberth probe. We will describe novel high voltage AC power transmission means and methods for liquid resistive electrical-to-thermal power conversion used to drive a closed-cycle hot water drill. We also discuss terrestrial applications for these drilling technologies and the logistics required for deployment of these drill systems to remote field sites.

BigRAID, a large diameter version of the BAS Rapid Access Isotope Drill

Chris Kerr, BAS
Julius Rix, BAS
Keith Makinson, BAS
Robert Mulvaney, BAS
Andy Smith, BAS
Ian McNulty, Extreme Instrumentation, UK Albrecht Karle, University of Wisconsin - Madison
Abigail Vieregg, University of Chicago

Keywords: Drilling, Rapid, Dry Hole, RNO-G, Auger

The British Antarctic Survey (BAS) has developed a larger diameter (~285mm) version of the record-breaking Rapid Access Isotope Drill (RAID) known as BigRAID. This recent variant of wireline auger is designed to rapidly drill dry holes of depths up to 350m. The drill will initially be used to enable multiple detector placements in the Radio Neutrino Observatory – Greenland (RNO-G) at Summit, starting in May 2021. Other planned uses include rapid and efficient pilot hole drilling of the firn layer and ice to 300m, as part of a project to access and sample Subglacial Lake CECs in West Antarctica. The vast array of holes required by RNO-G requires extensive automation of the drilling system and the new automation features and developments are outlined here. The significant increase in diameter brings new design challenges but also new opportunities. We describe the drill and the necessary modifications to the RAID design. Performance data are presented from large diameter drilling and other pre-field deployment tests.

Recoverable autonomous sonde for subglacial lakes exploration: design and tests

Youhong Sun, China University of Geosciences, Beijing, China

Keywords: Subglacial Lakes, Water Sampling, Ice Thermal Drilling

Certainly, it is suggested by remote sensing and modelling that subglacial lakes exist in Greenland and under several Arctic ice caps. In recent years, different approaches were taken to access and directly sample subglacial water environments. RECoverable Autonomous Sonde (RECAS) allows to access subglacial lake when water remains isolated from the modern ice sheet surface during sampling. The thermal drill can melt a hole to ice sheet bottom and is able to move upwards. It includes two electrically powered thermal drill bits located at the upper and lower ends of the sonde, heated body, control system, sampling chamber and coiling system. All downhole RECAS components will be sterilized prior to deployment. The melted water is not recovered from the hole and it refreezes behind the sonde. The power and signal line is released from the coil inside the sonde. When sampling and monitoring are complete, the coil motor is activated and the top drill bit is powered. It is proposed that the research personnel leave the site after RECAS deployment and the sonde operates as a fully autonomous system. The power is provided by no-live-operator diesel engine generators. Laboratory tests of the sonde were carried out during 2018-2020. Field tests are planned for 2021; however, implementation plan will depend on the global Coronavirus situation.

Subglacial bedrock drilling: recent experience and prospects in Arctic

Nan Zhang, Polar Research Center, Institute for Polar Science and Engineering, Jilin University, Changchun, China
Pavel Talalay, Polar Research Center, Institute for Polar Science and Engineering, Jilin University, Changchun, China
Xiaopeng Fan, Polar Research Center, Institute for Polar Science and Engineering, Jilin University, Changchun, China
Youhong Sun, Polar Research Center, Institute for Polar Science and Engineering, Jilin University, Changchun, China
Wei Wu, Polar Research Center, Institute for Polar Science and Engineering, Jilin University, Changchun, China
Jialin Hong, Polar Research Center, Institute for Polar Science and Engineering, Jilin University, Changchun, China
Yunchen Liu, Polar Research Center, Institute for Polar Science and Engineering, Jilin University, Changchun, China
Xingchen Li, Polar Research Center, Institute for Polar Science and Engineering, Jilin University, Changchun, China
Siyu Lu, Polar Research Center, Institute for Polar Science and Engineering, Jilin University, Changchun, China

Keywords: Subglacial Bedrock, Drilling, Arctic

A subglacial bedrock drilling system has been designed for drilling in firn, ice, and bedrock in Jilin University, China. The designed drilling system includes two movable shelters with drilling and auxiliary equipment and power supply. In the 2018–2019 summer season, the drilling system was tested in the field site ~12 km south of Zhongshan Station, East Antarctica. The ice sheet was penetrated, and 196m of ice core and a 6-cm bedrock core were recovered from the borehole. During the drilling processing, a number of mechanical, electronic, and drilling issues were met. All these problems were figured out during operating processing, and gain experience has been summarized for further application in Antarctica and Arctic. We expect that drilling system can be applied for deep drilling in Greenland Ice Sheet and Canadian or Russian Arctic ice caps for glacier dynamic observation and subglacial environment investigation. In addition, the retrieved samples of basal ice and bedrock provided valuable information regarding the Earth's paleo-environment.

TRIPLE-IceCraft - A Retrievable Melting Probe for Transporting Scientific Payloads

Dirk Heinen, RWTH Aachen University, III. Physikalisches Institut, Aachen, Germany
Simon Zierke, RWTH Aachen University, III. Physikalisches Institut, Aachen, Germany
Lutz Deriks, RWTH Aachen University, III. Physikalisches Institut, Aachen, Germany
Jan Audehm, RWTH Aachen University, III. Physikalisches Institut, Aachen, Germany
Christopher Wiebusch, RWTH Aachen University, III. Physikalisches Institut, Aachen, Germany
Marco Feldmann, GSI GmbH, Aachen, Germany
Gero Francke, GSI GmbH, Aachen, Germany
Lars Schickendanz, GSI GmbH, Aachen, Germany
Clemens Espe, GSI GmbH, Aachen, Germany

Keywords: Melting Probe, Electrothermal Drill, Exploration, Subglacial Access, Payload

Within TRIPLE, initiated by the DLR Space Administration, Technologies for Rapid Ice Penetration and subglacial Lake Exploration are being researched. The TRIPLE scenario includes three components and aims to explore the subglacial ocean of the Jovian moon Europa. The first component is a melting probe which penetrates the icy shield and navigates to the ocean below. It anchors itself at the ice water boundary and releases a small autonomous submarine, the second component, into the water. This submarine explores the reservoir and takes samples, which are analysed by the third component, a miniaturized astrobiological laboratory. We present the design and first results on subsystem tests of the TRIPLE-IceCraft, a melting probe which is currently in development. It is a modular bus system for transporting standardized payloads through ice. The design will be suitable for the transport of a scientific payload through several hundred meters of ice penetrating into a subglacial ocean or lake and returning later to the surface. The TRIPLE-IceCraft will be demonstrated in an analog scenario at the Ekström Ice Shelf in Antarctica in 2022.

Subglacial Sediment Sampling: Recent Experience and Ideas for the Future

Da Gong, Polar Research Center, Jilin University, Changchun city, China

Keywords: Subglacial Aquatic Environments, Hot-Water Access Borehole, Sediment Sampling

Subglacial sediments contain abundant paleoclimate and paleoenvironment information, which are important to study on overlying ice and history before ice covering. Moreover, unique ecosystem in extreme environments and subglacial thermal flow distribution can also obtained from such sediment samples. Before sediment sampling, an access borehole must be drilled through the ice sheet or ice shelf, then the sampling devices can pass through the ice (hundreds to thousands of meters), subglacial water column (up to hundreds of meters) and finally touch to the sediment layer. Most current hot-water drilling technologies can only build borehole with diameter range from 20 to 40 cm; thus, most ocean and lake sediment sampling devices can not be directly used. Hence, since 1975s, a series of customized coring devices and respective methods were developed for such working conditions, including grab sampling, gravity coring, hammer coring, piston coring, vibrocoring, etc. There are two main sampling objectives: (1) to obtain undisturbed water-sediment interface, and (2) to obtain undeformed sedimentary bedding structure as long as possible. However, almost all coring technologies can only get sediment core shorter than 3 m (if coring) with disturbance. In this report, we present current subglacial sediment sampling methods, based on previous experience and several recently field applied subglacial sediment coring techniques. In addition, feasible future coring methods are suggested.

Snow as construction material

Jialin Hong, Polar Research Center, Jilin University, Changchun 130026, China
Pavel Talalay, Polar Research Center, Jilin University, Changchun 130026, China

Keywords: Snow, Sintering, High Pressure, Power-Law Creep

Snow as a material is used in winter to construct sculptures, temporary shelters, igloos, snow pavements, and is an agent in forming the pore structure of powder shaping technology. The density evolution of sintered snow is crucial to apply snow as a material, however, very few studies have emphasized the effects of high pressure on snow sintering at high loading rates, although this is important in construction engineering and snow removal in cold regions. This study deals with the densification process of compacting snow under high pressures of up to 100 MPa at a temperature range from -3.5 to -17.3 ?. It highlights the importance and impact of processing variables such as sintering pressure, temperature, and time. The results show that the rate-controlling mechanism of snow sintering at a high loading rate and pressure is dominated by plastic deformation associated with dislocation creep mechanism and, to some extent, the inherent properties of natural snow.

Applications of Unmanned Vehicles in Svalbard

Richard Hann, Norwegian University of Science and Technology, Trondheim, Norway

Keywords: Svalbard, Unmanned Vehicles, UAV, UAS, Drone

This presentation is based on the 3rd issue of the State of Environmental Science in Svalbard (SESS) report: "Scientific Applications of Unmanned Vehicles in Svalbard" by Hann R, Altstädter B, Betlem P, Deja K, Draganska-Deja K, Ewertowski M, Hartvich F, Jonassen M, Lampert A, Laska M, Sobota I, Storvold R, Tomczyk A, Wojtysiak K, and Zagórski P.

The polar regions are among the most sensitive areas of the Earth. Unmanned vehicles are an important tool in this research field. This report provides a review of research conducted with unmanned vehicles in Svalbard. The main focus is on unmanned aerial vehicles (UAVs). UAVs are well-suited for Arctic research for several reasons. The Arctic regions lack high vegetation and big settlements, making them ideal for aerial observations. UAVs can access glaciers, mountains, and other difficult areas. They are cheaper and have a lower environmental impact than manned flights. Svalbard has an international research infrastructure and frequent flight connections, making it a hotspot for Arctic research. This review shows that the researchers using unmanned vehicles in Svalbard can be divided into two groups: basic and advanced users. The majority of researchers today are basic users. They use off-the-shelf UAVs to enhance their fieldwork. The most common application is mapping. A minority of the researchers are advanced users. This group includes users of unmanned marine vehicles and fixed-wing UAVs.

Arctic Vegetation Monitoring using Hyperspectral Remote Sensing under Glacier Environment and Global Climate Change

Keshav D Singh, Independent Researcher, North America

Keywords: Hyperspectral Imaging, Vegetation Monitoring, Glacier Environment, Global Climate Change, Arctic Community

The Arctic climate is generally conducive for shrubs, mosses, tundra and boreal trees. From the past few years, the main focus of global community is to cultivate and monitor potential cash crops (e.g. Rhodiola rosea) under glacier environment and global climate change. Hyperspectral imaging technology provides a significant advantage in understanding the subtle changes in the biochemical properties of the plants under different physiological processes. This has an importance for the far northern community that will develop new field tactics, new sensors to track crops, unique plant varieties via new scouting methods with environmental socio-economical sustainability. The full understanding of environmental impacts on vegetation is necessary for improving sustainability in agriculture. In recent years, the crop imaging and digital agriculture advancements have maximized the farm profitability while reducing environmental damages and enhance agro-ecosystem resiliency. I promote the uses of satellite and UAV-based hyperspectral imaging in sustainable monitoring and assessment of agro-ecosystem in glacier environment. Here, a key emphasis is the acquisition and processing of remote sensing imagery to map vegetation spectro-spatial variations. Through this, far northern communities are able to preciously monitor and enhance their crop yield via mitigating field-based risks. Further, this technology will help remote communities to understand what management practices yield the best results for their crop specific operations. Hence, this technology creates an exceptional potential for crop breeders and agronomists seeking to develop new plant varieties via determining crops health and yield improvement strategies. It will provide a unique solution for arctic communities' food security.

Hot water drill with near-bottom circulation: General concept and tests

Gaoli Zhao, Polar Research Center, Changchun, China
Babin Marcel, Takuvik University of Laval, Canada.

Keywords: Hot Water Drill,Near-Bottom Circulation,Thermal Tip

The hot water drill with near-bottom circulation was designed to drill through ice layers quickly, with light components being operable by small crew. In contrast to traditional hot water drills, the hot water is heated directly at the bottom of the hole, eliminating the need for heavy long hoses and surface pumps. The drill system consists mainly of a built-in instant electric heater and water pump. Due to the limitation of space inside the drill constraints the dill system design was focused on selecting the optimal drilling parameters and the structure of each part of the drill in order to optimize the rate of penetration (ROP). Totally six melting tips of two groups were tested: three tips of conical shape with different heights/angles and three parabolic tips with different focal parameters. In general, conical tips ensure more stable drilling process. Results from this series of preliminary tests showed that the ROP is the highest when the specific load on thermal tip is ~0.5 N/cm2 or 30 % of the total drill prototype weight. The highest ROP of 2.5-3.1 m/h was achieved with the nozzle diameter of 3.0 mm (at flow rate of 3.0 L/min). At the same time, the higher the flow rate, the faster the drilling speed.

On-edge real-time classification of hazardous Arctic environments using small unmanned aircraft system and on-board deep learning systems

Peter William Webley, Alaska Center for Unmanned Aircraft Systems Integration, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska, USA
Aashish Chaudhary, New York, USA
Matthew Brown, New York, USA
Daniel Davila, New York, USA

Keywords: Unmanned Aircraft Systems, On-Edge Classification, Autonomous Observations, Informed Decision Making

Integrating small-scale sensors along with rapid data processing algorithms onto small autonomously operated unmanned aircraft systems (sUAS) provides significant benefits for timely and widespread monitoring of the environment, including rapidly changing hazards. As sUAS operations impose strict payload restrictions then sensor and processing components need to be in a tightly integrated lightweight, low-power payload. We present on the development of our Autonomous Data Acquisition and Processing Technologies (ADAPT) system that can be hosted on a variety of sUAS to support autonomous missions. ADAPT will produce curated, geo-registered data archives as key inputs to existing deep learning systems and applications. ADAPT produces pixel-wise labeled image maps that are distilled down to vectorized, geolocated boundaries for low-bandwidth transfer over a wireless downlink. This optimizes the observations of a hazardous environment that reaches the operations center to assist in more informed decision making. For our Phase I research, river-ice sUAS data from Circle, Alaska provided a development dataset, with a browser-based annotation tool, to build the database for ADAPT. We present on how ADAPT has shown improvements in river-ice classification at the pixel-level while providing actionable intelligence through enabling on-edge in-flight, real-time deep neural network image processing on-board a sUAS. This work has been supported by the NOAA grant: NA20OAR0210083.

Redevelopment of flexodrilling in Polar Regions

Bing Li, School of Engineering and Technology, China University of Geosciences, Beijing, China
Pavel Talalay, Polar Research Center, Jilin University, Changchun, China

Keywords: Flexodrilling, Subglacial sediment, Umbilical, Downhole assembly

In order to recover subglacial sediment cores, which may contain the best geological archives of paleo-environmental changes, the flexodrilling technology was proposed. Flexodrilling has been adopted for drilling in ice: US-made system known as Rapid Air Movement Drill (RAM), which could drill an access hole in firn and ice to 100 m in 40 min or less and ice deep drilling systems with fluid circulation as SUBGLACIOR probe and RADIX system. However, all of them are not suitable for subglacial sediment drilling. So, we propose redevelop the flexodrilling in the view of subglacial drilling. Umbilical contains thermoplastic hose, electric lines to provide power to the downhole electric motor and signal lines for control and communications. Drilling fluid is pumped down-hole through umbilical using a high-pressure pump located on the surface. The drill bit is driven by brushless electric motor with a large hollow section in its center. The downhole tractor is used to compensate counter torque and to provide the required weight-on-the-bit. Standard drill bit and core barrel is attached to the motor section. The chips and fluid return to the surface outside the umbilical, using the space between the umbilical and the casing or borehole as the conduit. The downhole assembly also include control/measurement pressure chamber with electronics to control driven electric motor and measure drilling parameters (inclination, temperature, pressure, etc.).

Robotized inclinometer system for monitoring borehole deformation in ice and permafrost

Jialin Hong, Polar Research Center, Jilin University, Changchun, China
Pavel Talalay, Polar Research Center, Jilin University, Changchun, China

Keywords: Borehole Deformation, Robotized Inclinometer, Ice And Permafrost

Under viscoplastic deformation of ice, the borehole will close or expanded depending on differential pressure on borehole wall. Repeated logging of the borehole inclination and azimuth delivers an estimation of the in-situ deformation within the ice sheet. Borehole parameter was periodically measured in many deep holes in Antarctica and Greenland. Study of sharing and moving zones has special significance for the design, construction, and maintenance of all types of structures built up on permafrost. Lack of knowledge about permafrost has resulted in tremendous maintenance costs and even in relocation or abandonment of highways, railroads, and other structures. We propose to design robotized inclinometer composed of the surface winch, electronic control system, downhole probe, power supply system and data transmission system for long term borehole field observations at ice stream shear margin. The survey is carried out once-a-day in fully automatic mode. The probe is lowered into the borehole and take borehole tilt measurements with 3D accelerometer/magnetometer sensor and temperature measurements with platinum thin-film sensor installed into the nose of the probe. The measurements are stored in an intelligent electronic system in the probe. At the end of the measuring phase, using a wireless connection the data are transmitted to a central unit at the top of the borehole, and further to a remote computer using Iridium communication for real-time monitoring and analysis.

Unconventional ice drilling systems

Pavel Talalay, Polar Research Center, Jilin University, Changchun, China

Keywords: Ice Drills, Glaciers, Glaciological Technique

To address the various limitations and problems with drilling in ice, such as relatively low rates of penetration, limited depths, meltwater refreezing, the need for casing installation and safety improvements, new drilling concepts are continuously being developed and tested. Generally, these systems are referred to as 'unconventional' or 'novel' drilling systems. It is expected that new drilling concepts could allow much higher rate of penetrations, thereby reducing overall drilling time. At the same time, advanced ice drilling systems would be lighter, cheaper and more environment-friendly. Specific challenges related to developing new emerging technologies include following research trends: (1) thermal drilling with recoverable sondes for environmental exploration of subglacial lakes; (2) unmanned ice drilling systems; (3) laser drilling. The report presents also possible ways and recent state of developing these advanced ice drilling systems.

Vertical distribution and phenology of under-ice pelagic communities assessed with an ice-tethered observatory in Qikiqtarjuaq, Nunavut

Julek Chawarski, Centre for Fisheries Ecosystem Research, Fisheries and Marine Institute at Memorial University of Newfoundland, St. John's, NL
Muriel Dunn, Centre for Fisheries Ecosystem Research, Fisheries and Marine Institute at Memorial University of Newfoundland, St. John's, NL
Jennifer Herbig, Centre for Fisheries Ecosystem Research, Fisheries and Marine Institute at Memorial University of Newfoundland, St. John's, NL
Pierre Priou, Centre for Fisheries Ecosystem Research, Fisheries and Marine Institute at Memorial University of Newfoundland, St. John's, NL
Tiffany Small, Centre for Fisheries Ecosystem Research, Fisheries and Marine Institute at Memorial University of Newfoundland, St. John's, NL
Pedro De La Torre, Department of Marine Technology, Norwegian University of Science and Technology, Trondheim, Norway
Philip Anderson, The Scottish Association for Marine Science, Oban, Scotland
Jorgen Berge, Department of Arctic and Marine Biology, UiT The Arctic University of Norway, Tromsø, Norway
Maxime Geoffroy, Centre for Fisheries Ecosystem Research, Fisheries and Marine Institute at Memorial University of Newfoundland, St. John's, NL

Keywords: Ice-Tethererd Observatory, Acoustics, Arctic, Fish, Zooplankton

In the Arctic, seasonal changes in sea-ice and light attenuation modify the distribution and behavior of zooplankton and fish. Yet, most of these biological studies are conducted during the open water season and miss integral parts of these animals' life cycles. While thick ice pack complicates studying fish and zooplankton, autonomous platforms can provide new insights. From February to June 2020, in collaboration with the community of Qikiqtarjuaq, we deployed an ice-tethered observatory (ITO) composed of an Acoustic Zooplankton and Fish Profiler, a Sea Ice Mass Balance Array, and a light chain from the landfast ice pack near Qikiqtarjuaq, Baffin Island. The ITO facilitates the collection of large amounts of data without instrument retrieval. We document seasonal changes in vertical distribution and migration patterns, backscatter, and predator-prey interactions of functional groups of zooplankton and fish in relation to the physical environment. We observed diel vertical migrations of animals starting from the start of deployment in February which diminished toward the onset of the midnight sun in June. Preliminary results also suggest that migration amplitude responded quickly to short-term weather events (e.g., melt event, cloud cover). This study demonstrates the advantage of ITOs for under-ice pelagic ecology and highlights the feasibility of deploying them near remote Arctic communities.

ID: 13 - Advancing SAON's Roadmap etc. through Regional and Global capabilities

Conveners

Sandy Starkweather | SAON Chair, NOAA, USA

Jan Rene Larsen | SAON Secretariat

Sustaining Arctic Observing Networks' (SAON) Roadmap for Arctic Observing and Data Systems (ROADS)

Sandy Starkweather; Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, USA; National Oceanic and Atmospheric Administration, Boulder, USA
Jan Rene Larsen, SAON Secretariat, Tromsø, Norway

Keywords: Framework, Roadmap, Observing, Data, Indigenous Knowledge, Societal Benefit, Value Tree

Sustaining Arctic Observing Networks (SAON) set forth a bold vision in its 2018-2028 strategic plan to develop a Roadmap for Arctic Observing and Data Systems (ROADS). The lack of consistent and holistic planning mechanisms to assess observing system priorities and link independently funded efforts across the Arctic can be viewed as a persistent short-coming that has hindered adaptation strategies and hampered funding responses for an improved observing system. ROADS seeks to address this short-coming through generating a systems-level view of observing requirements and implementation strategies, across SAON's many partners, through its Roadmap. A critical success factor for ROADS is the equitable inclusion of Arctic Indigenous Peoples in the design and development process, using the design of process to build needed equity. ROADS is both a holistic concept, building from the societal benefit-based approach of the International Arctic Observing Assessment Framework, and one that can proceed step-wise so that the most imperative Arctic observations – Shared Arctic Variables (SAVs) – can be rapidly improved. SAVs will be identified through rigorous assessment at the beginning of the ROADS process, with an emphasis in that assessment on increasing shared benefit of proposed system improvements across a range of partnerships from local to global scales.

Framework for key Arctic sustainability monitoring and key variables identification

Tatiana Vlasova, Institute of Geography RAS, Moscow, Russia
Andrey Petrov, ARCTICenter and Department of Geography, University of Northern Iowa, USA

Keywords: Sustainability, Monitoring, Challenges, Solutions, Key variables

Sustainability achievement can not be a fixed goal in a rapidly changing Arctic. Challenges as well as their solutions are changing gradually over time as people's values orientations also changes. That is why it is so important to monitor these changes involving knowledge and assessments from different groups of arctic stakeholder (such as Indigenous peoples, scientists, educators, business, decision-makers, etc.) at diverse and cross-cutting territorial and administrative scales- from global, national to local Arctic community. Achieving sustainability means implementation of Sustainable development goals as well as building resilient Socio-Ecological systems in the Arctic. Sustainability is becoming a top priority for many Arctic institutions, programs and forums. Based on the deep content analysis of available information from Arctic institutions, programs and meetings as well as local media, first of all we identify priority themes concerning Arctic Sustainability. Within them we delineate main challenges, their best solutions and key variables to be monitored within the Sustainability monitoring network which construction is envisioned to be tightly connected with the SAON Roadmap for Arctic Observing and Data Systems. Acknowledgements.The research was supported by State Assignment IGRAS (? 0148-2019-0008) and within the framework of the Belmont Forum project "Arctic Sustainability: Synthesis of Knowledge" (NSF # 1532655).

Greenland Integrated Observing System (GIOS)

Lise Lotte Sørensen, Aarhus University
Signe Bech Andersen, Geological Survey of Denmark and Greenland
Torben Røjle Christensen, Aarhus University
Dorthe Dahl-Jensen, Copenhagen University
Karen Edelvang, Technical University of Denmark
Anne Merrild Hansen, Aalborg University
Uffe Jakobsen, University of Greenland
Eva Mätzler, Greenland Survey
Peter Schmidt Mikkelsen, Aarhus University
Gert Mulvad, University of Greenland
Søren Rysgaard, Aarhus University
Marit-Solveig Seidenkrantz, Aarhus University
Colin A. Stedmon, Technical University of Denmark
Mie S. Winding, Greenland Climate Research Centre

Keywords: Multidisciplinary Observations, Arctic Climate Gradient, Autonomous Monitoring

Greenland plays a unique and central role in the global climate system. The purpose of the GIOS) is to resolve and understand the mechanisms behind climate and environmental change in Greenland and beyond. GIOS is a new coordinated network of sustainable long-term research infrastructures in and around Greenland observing the changing air, ice, land, and ocean conditions. GIOS is an important and timely national research infrastructure linking all institutions and universities currently carrying out Arctic research in the Danish Realm. The added value of GIOS is an increased national collaboration through a coordinated and visible research infrastructure combining key sites around Greenland representing the climate gradient in the Arctic as a whole. New and improved observations, also ensuring vital long-term observation, combined with a more efficient logistic collaboration will expand opportunities for national and international collaborations. GIOS will reduce its carbon footprint by implementing renewable energy sources and reduce fossil fuel emissions by optimizing shared logistics between institutions hereby sending a strong signal for a sustainable development in the Arctic.

A decade of contribution to the Greenland Ice Sheet Monitoring Network (GLISN)

Masaki Kanao, National Institute of Polar Research, Tokyo, Japan
Genti Toyokuni, Tohoku University, Sendai, Japan
Seiji Tsuboi, Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan

Keywords: Greenland, Ice Sheet, Seismic Network, Glacial Earthquakes, GLISN

Greenland ice sheet and its response to climate change have potentially a great impact upon both on the Earth system and human society, through sea-level rise and modulation of fresh water input to the oceans. Monitoring of the dynamic response for Greenland ice sheet to climate change has been a fundamental component of long-term observations in global science as viewed from the Arctic. “Glacial earthquakes” have been observed along the edges of Greenland and increased the frequency in 21st century by the regional data from Global Seismographic Network (GSN). Greenland glacial earthquakes are considered to be closely associated with major outlet glaciers at the margins of the continental ice sheet. Temporal patterns of these earthquakes indicate a clear seasonal change; the pattern is positively correlated with seasonal hydrologic variations, significantly increased flow speeds, calving-front retreat, and thinning at many outlet glaciers. The detection, enumeration, and characterization of smaller glacial earthquakes were limited by the propagation distance to globally distributed stations of the GSN. In order to define the fine structure and detailed mechanisms of glacial earthquakes in Greenland, a broadband, real-time observing network needs to be established throughout the ice sheet and perimeter. After the International Polar Year (IPY2007-2008), an international program named as the “Greenland Ice Sheet Monitoring Network (GLISN)” was initiated for the purpose of identifying the dynamic response of Greenland ice sheet to climate change by developing regional seismic network around the Greenland. This presentation summarise a dacade of seismologial contribution from Japan to the GLISN project; such as including statistic analysis of glacial earthquake acitivity, waveform propagation charcteristics within the ice sheet, detecion of the basal melting process benearth the ice sheet derived from seismic noise correlaiton method, etc. Long-term monitoring of Greenland ice sheet dynamics by GLISN could surely contribute for building a new strategy among the Sustainable Arctic Observing Network (SAON).

Apps for the Who, What, Where, and When of U.S. Arctic Science and Observing: ARMAP & AOV

Craig E. Tweedie, Biological Sciences, University of Texas at El Paso, Texas, USA
William Manley, INSTAAR, University of Colorado, USA
Allison Gaylord, Nuna Technologies, Homer, Alaska, USA
Mauricio Barba, Biological Sciences, University of Texas at El Paso, Texas, USA
Ryan Cody, Biological Sciences, University of Texas at El Paso, Texas, USA
Dilan Ramirez, Biological Sciences, University of Texas at El Paso, Texas, USA
Ari Kassin, Biological Sciences, University of Texas at El Paso, Texas, USA

Keywords: Arctic Observing, Web Mapping, Interoperability, Informatics, Information And Data Management

The Arctic Research Mapping Application (ARMAP; http://armap.org) and the Arctic Observing Viewer (AOV; https://www.arcticobservingviewer.org) are applications and services that support US Arctic science. ARMAP tracks over 3100 field-based research projects funded by the US National Science Foundation, as well as 17 other US agencies and organizations. AOV encompasses over 35,000 observing sites across 39 observing networks – with details and precise locations for individual monitoring assets such as: Boreholes, ship tracks, buoys, towers, sampling stations, sensor networks, instrumentation trams, vegetation plots, stream gauges, ice cores, observatories, and more. Together they convey the "who", "what", "where", and "when" of US-partnered Arctic research and Arctic observing, respectively, with links to data and more information. Both Viewers provide custom 3D navigation, multiple high-resolution basemaps, near real-time ship positions, medical facilities, observatories, and more. A new "Who's in the Field" Dashboard provides data on active field campaigns at a glance. In sum, these apps have the capacity to aid the SAON ROADS Process to: Assess status, identify observational/research overlap and complementarity, fill gaps, facilitate collaboration, access data, and clarify directions to better meet scientific objectives.

KEPLER: Improving the capacity of Copernicus for the Polar Regions

Nick Hughes, Norwegian Meteorological Institute

Keywords: Copernicus, Earth Observation, Sustainable Seas

The Horizon 2020 project Key Environmental monitoring for Polar Latitudes and European Readiness (KEPLER) is a EU H2020 project is developing a roadmap for the evolution of the EU Copernicus programme to cover the information needs of polar regions end-users and stakeholders in the 2020's. As part of this it is investigating how new and enhanced Earth Observation technologies, in particular the plans for High Priority Candidate Missions (HPCMs), can play a role in the development of European information and knowledge needed to drive innovations resulting in more resilient societies through improved infrastructures and connectivity, both on land and in the maritime domain. Enhancing information provision will result in more sustainable seas so that communities throughout the Arctic can benefit.

ID: 73 - Pollution of the Arctic Environment

Conveners

Sergey Gromov | Yu.A.Izrael Institute of Global Climate and Ecology (IGCE)

Alisa Trifonova-Yakovleva | Institute of Geography, Russian Academy of Sciences

Black carbon and methane emissions from maritime transport in Russian Arctic zone in 2018

Vladislav Lytov, Institute of Global Climate and Ecology (IGCE), Moscow, Russia
Veronika Ginzburg, Institute of Global Climate and Ecology (IGCE), Moscow, Russia

Keywords: Black Carbon, Methane, Maritime Transport, Emission Forecast

The development strategy of the Arctic zone of the Russian Federation includes the development of the industrial and transport complex as a priority area. Accordingly, it will contribute to the development of transport infrastructure. Maritime transportation may become more intensive owing to growing demand for cargo transportation along the Northern sea route (NSR), reconstruction of existing seaports and building of new ones. Maritime transport is important source of short climate active pollutants such as black carbon and methane which could significantly influence regional climate. The main problem for determining the effectiveness of future measures to protect the Arctic zone of the Russian Federation from short-lived pollutants from marine transport activities is the lack of baseline emissions inventory in this region. Therefore, the aim of this study was to assess emissions from Russian marine fleet in the Arctic zone in 2018. We estimated emissions from 20 Russian ports in the Arctic basin. About 85% of cargo turnover is exported, mainly oil products, natural gas and coal. Based on the reporting data of various port services, water transport activities of various entities, information on the use of fuel and energy resources, as well as other literature sources, it was estimated that in 2018, emissions from marine transport activities amounted to 101 tons of black carbon and 55 tons of methane.

Distribution, sources and risk assessment of PCBs and PAHs in the seawater of Arctic fjords (Hornsund, Kongsfjorden and Adventfjorden)

Anna Pouch, Institute of Oceanology Polish Academy of Sciences, Sopot, Poland
Agata Zaborska, Institute of Oceanology Polish Academy of Sciences, Sopot, Poland
Mikołaj Mazurkiewicz, Institute of Oceanology Polish Academy of Sciences, Sopot, Poland
Aleksandra Winogradow, Institute of Oceanology Polish Academy of Sciences, Sopot, Poland
Ksenia Pazdro, Institute of Oceanology Polish Academy of Sciences, Sopot, Poland

Keywords: Polychlorinated Biphenyls, Polycyclic Aromatic Hydrocarbons, Seawater, Fjords

Arctic is undergoing unprecedented change due to global warming, and therefore prospective climate change effects - such as thinning of sea ice, increased glacier melts, higher influx of Atlantic water masses - have the potential to alter contaminant dynamics in Arctic ecosystems. The aim of this study is to present results of the concentration of selected polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) in the seawater of Arctic fjords - Hornsund, Kongsfjorden and Adventfjorden. GC-ECD and GC –FID were used for qualitative and quantitative analysis of PCBs and PAHs respectively. The ?7 PCB and ?12 PAH concentrations in seawater ranged from, respectively: 0.002 to 41.2 ng/L; and from 0.2 to 311.7 ng/L. In general, concentrations of contaminants in suspended particulate matter (SPM) were higher than those measured in dissolved form, which may be caused by the physicochemical properties of these compounds. The highest concentration of PCBs and PAHs were detected in seawater collected from Adventfjorden, suggesting that local human activity can be recognized as a significant source of pollution in the Arctic region. Higher concentrations of most contaminants were detected near melting glaciers in Hornsund, confirming that glacier meltwaters can play a significant role in contaminant delivery. PCB and PAH concentrations in most of the seawater samples were at levels classified as good, only in a few SPM samples contaminants were at toxic levels.

Monitoring mercury distribution at the Arctic and sub-Arctic Atlantic scale with the use of Arctic seabirds as bioindicators

Céline Albert, LIENSs, La Rochelle Université, La Rochelle, France

Keywords: Spatial Ecotoxicology, Feathers, Pollutants, Bioindicators

Mercury (Hg) is a natural element that has increased in the environment because of human activities. Being of high concern for both Human and wildlife, Hg is mostly emitted in northern mid-latitudes, but then transported over large distances to the Arctic. Once deposited in the marine environment, Hg enters the food chains where it bioamplifies, making top predators such as seabirds, some of the most contaminated and vulnerable Arctic species. Seabirds are one the largest group of animals breeding in the Arctic, covering a large part of the Arctic and sub-Arctic through their life cycle, and different habitat and diet. Therefore, they are important bioindicators of their environment. In addition, understanding the Hg contamination of Arctic seabirds and its spatio-temporal origin is essential to fully apprehend the risk associated with still increasing Hg emissions globally. Nonetheless, most of the studies investigating seabird Hg contamination focused on their breeding period. Yet, recent studies showed that the non-breeding period could also be a critical part of their life cycle. In that context, it is crucial to identify the yearly spatial sources of contamination and what areas are at most risk. In that context, we combined tracking data with Hg analyses in seven seabird species breeding at 30 sites along the Atlantic Arctic. Our objectives were 1) to map Hg concentrations in the Atlantic Arctic by using Arctic seabirds as bioindicators, 2) to identify hotspot of Hg.

Atmospheric aerosol carbon isotope composition of 2018-2020 arctic expeditions

Daria Kalashnikova, Institute of Monitoring of Climatic and Ecological Systems of SB RAS, Tomsk, Russia
Galina Simonova, Institute of Monitoring of Climatic and Ecological Systems of SB RAS, Tomsk, Russia

Keywords: Carbon Isotope Composition, Aerosol, Svalbard, Ice Base Cape Baranov

Results of the carbon isotope composition (d13?) analysis of atmospheric aerosols sampled at the Research Station Ice Base Cape Baranov (the Severnaya Zemlya archipelago), at Barentsburg (the Svalbard archipelago) and during sea expeditions: in the 71st cruise of RV Akademik Mstislav Keldysh and in the 1st stages of the Trans?rctic-2019 expedition ?f RV Akademik Treshnikov are being discussed. The analysis of aerosol d13? value and the air masses backward trajectories made it possible to determine the carbon soot source input into the Arctic zone. The largest difference in d13? values was recorded in winter period: at Barentsburg the d13? value was –26.9 ± 0.7‰, at the Cape Baranov station the d13? value was –28.1 ± 0.8‰. The low d13? values at the Ice Base indicate the predominance of carbon soot sources formed during the combustion of oil products in winter. The isotope analysis was performed at the Shared Research Facilities of the Tomsk Scientific Center SB RAS employing DELTA V Advantage isotope ratio mass spectrometer (Thermo Fisher Scientific, Germany). The authors are grateful to the staff of the V.E. Zuev Institute of Atmospheric Optics of SB RAS (Tomsk) and the Arctic and Antarctic Research Institute (St. Petersburg) for carrying out the expedition work. This work was partially supported by the IMCES SB RAS Basic Project and the Complex Program of Basic Research of SB RAS “Interdisciplinary Integration Studies” for 2018-2020 (project ?RTD AAAA-A18-118012490017-8).

Input of terrestrial organic matter linked to deglaciation increased mercury transport to the Svalbard fjords

Haryun Kim, Korea Institute of Ocean Science and Technology, Uljin, South Korea
Seung-Il Nam, Korea Polar Research Institute, Incheon, South Korea

Keywords: Mercury, Deglaciaion, Fjords, Organic Matter

Deglaciation has accelerated the transport of minerals as well as modern and ancient organic matter from land to ford sediments in Spitsbergen, Svalbard, in the European Arctic Ocean. Consequently, such sediments may contain signifcant levels of total mercury (THg) bound to terrestrial organic matter. The present study compared THg contents in surface sediments from three ford settings in Spitsbergen: Hornsund in the southern Spitsbergen, which has high annual volume of loss glacier and receives sediment from multiple tidewater glaciers, Dicksonforden in the central Spitsbergen, which receives sediment from glacifuvial rivers, and Wijdeforden in the northern Spitsbergen, which receive sediments from a mixture of tidewater glaciers and glacifuvial rivers. Our results showed that the THg (52±15ngg-1) bound to organic matter (OM) was the highest in the Hornsund surface sediments, where the glacier loss (0.44 km3 yr-1) and organic carbon accumulation rates (9.3 ~ 49.4gm-2 yr-1) were elevated compared to other fords. Furthermore, the d13C (–27 ~ –24‰) and d34S values (–10 ~ 15‰) of OM indicated that most of OM were originated from terrestrial sources. Thus, the temperature-driven glacial melting could release more OM originating from the meltwater or terrestrial materials, which are available for THg binding in the European Arctic ford ecosystems.

Local and regional variability in snow concentrations of chosen POPs in Svalbard: lessons learned on field sampling protocols

Filip Pawlak , Department of Analytical Chemistry, Chemical Faculty, Gdańsk University of Technology, Gdańsk, Poland
Krystyna Koziol, Department of Analytical Chemistry, Chemical Faculty, Gdańsk University of Technology, Gdańsk, Poland
Zaneta Polkowska, Department of Analytical Chemistry, Chemical Faculty, Gdańsk University of Technology, Gdańsk, Poland.

Keywords: Pops, Snow, Svalbard, Variability

The presence of compounds belonging to persistent organic pollutants in Arctic snow has been confirmed in many cases (1-3). However, in publications describing the content of POPs in snow, the description of the sampling for testing itself is usually limited to the place where the sample was collected and what tools were used for this. Based on the descriptions provided and the field practice, it can be assumed that snow samples are taken from one place. Taking this into account, we decided to conduct an experiment comparing snow samples collected at a short distance from each other - to represent the local scale variability. Then, we contrasted them with samples of snow collected at greater distances - to represent the landform (regional) scale. We analyzed fresh snow samples collected around the Polish Polar Station Hornsund in spring 2019. The probable error in the content of persistent organic pollutants in snow, due to local variability, may be 100%. We conclude that there is a need for a more precise methodology for snow sampling in a representative manner, defining the area from which several snow samples would be collected, which would then be averaged.

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Microplastic Pollution in Arctic Water: Evidence from Kongsfjord, Ny-Ǻlesund

E.V. Ramasamy, School of Environmental Sciences, Mahatma Gandhi University, Kottayam, Kerala, India
Ajay Kumar Harit, School of Environmental Sciences, Mahatma Gandhi University, Kottayam, Kerala, India
Naveen Babu, School of Environmental Sciences, Mahatma Gandhi University, Kottayam, Kerala, India
V. G. Gopikrishna, School of Environmental Sciences, Mahatma Gandhi University, Kottayam, Kerala, India

Keywords: Marine Debris, Arctic Ecosystem, Arctic Fjords, Raman Spectroscopy, Plastic Pollution

Microplastic pollution of global Oceans has been well documented while the reports on Microplastics (MPs) in Arctic environment are limited. Till date, to the best of our knowledge there exists no report on the MPs contamination in Kongfjord of Arctic. In this study, water samples were collected from ten locations in Kongsfjord as a part of the Indian Arctic Expedition-2019 (summer batch 2). Sampling was done by trawling the Microplastic net (Hydrobios) for 20 minutes at 2 - 3 knot speed. Samples were processed for the extraction of MPs adopting NOAA procedure starting with wet peroxide oxidation (WPO) followed by density separation and vacuum filtration of the supernatant. The glass-fibre filter paper (GF/A) used in filtration was observed under the stereomicroscope (Zeiss Stemi 508) for visual observation of the MPs. Micro Raman spectroscopy (WITee Alpha 300RA, Germany) was used to identify the polymer profile. MPs were recorded from all locations; most of them were of fibre shape followed by fragments, sphere and film. Polyamide, Polyethylene, Nylon-6, High density polyethylene, Polystyrene, and Polypropylene were the predominant polymers identified. This study, being the first evidence of occurrence of MPs in the surface water of Kongfjord , provide impetus for further research on the distribution and impact of this emerging pollutant in various matrices of Arctic fjords.

Polymer Type Identification of Marine Plastic Litter in Arctic seas Using a Miniature Near-Infrared Spectrometer (MicroNIR)

Igor Zhdanov, Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia
Svetlana Pakhomova, Shirshov Norwegian Institute for Water Research, Oslo, Norway & Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia
Bert van Bavel, Norwegian Institute for Water Research, Oslo, Norway

Keywords: Plastic Identification; Marine Plastic Litter; Plastic Pollution; Near-Infrared (NIR) Spectroscopy

Plastic pollution in the marine environment has turned into an important research topic in recent decades. Until recently, studies were often based on visual assessment only, which is not enough to draw any conclusion about the chemical nature of found plastic items and could lead to incorrect results. Standardized, fast, and efficient low-cost methods for marine plastic litter identification are urgently needed to monitor the occurrence and distribution worldwide especially in the Arctic, as data on plastic pollution are scarce in this region. In this research, we demonstrate that a miniaturized handheld near-infrared spectrometer—MicroNIR—can be used for on-site identification of different plastic polymers. A database containing polymer spectra of the most produced and reported polymer types in the marine environment was created. Using spectral match value (SMV, included in the instrument software) for spectra analysis resulted in an accurate classification of all nine polymer types. The method was used for the identification of marine macro-, meso-, and microplastic litter collected on beaches in sediments and seawater in Arctic and enabled the correct identification of marine plastic litter for macro-, meso- (96%), and microplastics (73%) with exception of totally black items and items less than 1 mm in size. Method and the equipment presented here is very well suited for monitoring of plastic pollution in the Arctic and other regions in all matrices.

ID: 35 - Learning from Indigenous methodologies in collaborative Arctic science

Conveners

Megan Sheremata | University of Toronto

Victoria Qutuuq Buschman | University of Washington

Stanislav Ksenofontov | Ammosov North-Eastern Federal University

Forwarding Meaningful Indigenous Partnerships in Arctic Conservation

Victoria Qutuuq Buschman, University of Washington/Greenland Institute of Natural Resources, Nuuk, Greenland
Enooyaq Sudlovenick, University of Manitoba, Winnipeg, Canada
Margaret Rudolf, University of Alaska Fairbanks, Fairbanks, Alaska
Katarina Inga, Stockholm Environment Institute, Jokkmokk, Sweden
Robert Way, Queen's University, Kingston, Canada
Tayana Arakchaa, KTH Royal Institute of Technology, Stockholm, Sweden
Sascha Schiøtt, Greenland Institute of Natural Resources, Nuuk, Greenland
Robert Comeau, Nunavut Arctic College, Iqaluit, Canada

Keywords: Indigenous Communities, Conservation, Partnerships, Indigenous Knowledge, T-Mosaic

Under threat of climate change and shifting environmental realities, Indigenous communities in the Arctic are increasingly responsible for contributing time, labour, and knowledge to the conservation of lands, waters, and species across our homelands. This team of Indigenous scholars recognizes these contributions and the importance of ethical, equitable, and meaningful partnerships in pursuing conservation efforts that meet our collective conservation targets and goals. This project explores various conservation efforts, including the establishment and management of Arctic protected areas, wildlife management programs, restoration and adaptation initiatives, and others through the lenses of our represented expertise in conservation biology, wildlife science, marine biology, environmental science, co-production of knowledge, anthropology, Indigenous arts, and law. We aim to provide perspective on the question – how do partnerships in conservation efforts better reflect Indigenous worldviews, perspectives, needs, concerns, and knowledge and what conditions must be met for success? This presentation will focus on the foundations of the project, justification for Indigenous partnerships and co-production, and preliminary results. This project will culminate in a manuscript submission to the T-MOSAiC special issue of Arctic Science.

Practicing from Indigeneity: Blending Indigenous and Science Methodologies

Margaret Anamaq Rudolf, University of Alaska Fairbanks, Fairbanks, AK, USA

Keywords: Indigenous Research Methods, Co-Production of Knowledge, Boundary Spanners, Social Science, Interdisciplinary

To be Indigenous means to live and work by your Indigenous values. Indigenous research methodologies advocates for doing research with your community in a traditional way of building knowledge. My dissertation research is with other Iñupiat as well as with other Indigenous and non-Indigenous individuals, so in developing my methods I pulled from Indigenous, critical, and science research methodologies with the goal of allowing everyone to be their full selves in my research. I reflected on concepts presented by Harris and Wasilewski (2004) with the 4 R's (Relationship, Responsibility, Reciprocity, and Redistribution) and the two P's (Power and Profit). I also reflected on the principles presented in the Behe, Daniel, and Raymond-Yakoubian (2020) co-production of knowledge conceptual model with equity, communication, intentional and deliberate, empowerment, sovereignty, and decolonization. From there I adapted grounded theory and phenomenology in developing cultural-responsive facilitation to convene a two-day meeting on understanding the role of boundary spanners in Arctic co-production of knowledge research.

Collaborative Research: Indigenous Methodologies in Arctic Sciences

Stanislav Ksenofontov, ARCTICenter, University of Northern Iowa, USA

Keywords: Indigenous Methodologies, Indigenous Peoples, Arctic Sciences, Collaborative Research, Indigenous Knowledge System

Indigenous methodologies are alternative reflections on a research. They aim at assuring research performance in a way that it is favourable, respectful and ethically accurate from an Indigenous perspective (Louis, 2007). According to one of the definitions "Indigenous methodology is a body of Indigenous and theoretical approaches and methods, rules and postulates employed by Indigenous research in the study of Indigenous peoples. The main aim of Indigenous methodologies is to ensure that research on Indigenous issues can be carried out in a more respectful, ethical, correct, sympathetic, useful and beneficial fashion, seen from the point of view of Indigenous peoples" (Porsanger, 2004). Thus, an Indigenous approach to a research significantly varies from the one of non-Indigenous. Louis (2007) distinguished four differences between Indigenous and non-Indigenous methodologies: 1) acceptance of Indigenous knowledge system (IKS). IKS sometimes enormously differs from scientific knowledge in many ways with respect to context, roots, rhetoric, metaphysics, narratives and spirituality. 2) Acknowledgement of Indigenous peoples as collaborators rather than "subjects" or informants, which is quite common in non-Indigenous research. 3) Designation of a research agenda based on a real (and honest) interest rather than funding possibilities. 4) Sharing knowledge of the (past) research with involved Indigenous peoples.

Towards a holistic evaluation of food security challenges: The work of the Indigenous Food Security Working Group

Food Security Working Group members

Keywords: Food Security, Indigenous Knowledge, Indigenous Peoples, Indigenous frameworks, Indigenous-ledresearch

The Indigenous Food Security Working Group (FSWG) was formed to provide guidance on observing for Pan-Arctic food security as part of the activities of the Sustaining Arctic Observing Networks (SAON). Our work is shaped by Indigenous Peoples' worldview that recognizes that food security is part of an interconnected system and must be addressed holistically. Recent analyses by the Inuit Circumpolar Council Alaska and affiliated communities of the Tanana Chiefs Conference and the Council of Athabascan Tribal Governments have documented the ways that food security is impacted by multiple systems including social, biological, ecological, chemical, physical, cultural, spiritual, health and well-being. They identified six interconnected determinants of food security that include 1) Availability, 2) Inuit culture, 3) Decision-making power and management, 4) Health and wellness, 5) Stability and 6) Accessibility. A clear understanding of the ways that multiple factors impact food security is especially needed now, as Indigenous communities deal with the legacy of colonialism and the multiple stressors of rapid environmental change, social and economic uncertainly and a global pandemic, among others. In this presentation, the FSWG draws on the framework of interconnected dimensions and drivers outlined above and the real-life stories of our members to demonstrate the high stakes that necessitate an Indigenous-centered approach toward addressing food security issues.

Building lasting research relationships

Megan Sheremata, University of Toronto, Toronto, Canada
Lucassie Arragutainaq, Sanikiluaq Hunters and Trapper Association, Sanikiluaq, Nunavut, Canada
Joel Health, Arctic Eider Society, St John's, Canada
William Gough, University of Toronto, Toronto, Canada
Gita Ljubicic, McMaster University, Hamilton, Canada

Keywords: Relational Accountability; Collaborative Research; Inuit Knowledge; Cumulative Impacts Of Environmental Change

Relational accountability as a methodological principle emphasizes the responsibility of researchers to address the priorities of community partners. Drawing on the collaborative approach of a non-Indigenous researcher working in partnership with the Arctic Eider Society and the eastern Hudson Bay Community-Driven Research Network, this presentation discusses the role of relational accountability in research involving Inuit knowledge. First proposed by hunters from the communities of Kuujjuaraapik, Umiujaq, and Inukjuak in Nunavik (northern Québec) and the community of Sanikiluaq, Nunavut, this research characterizes Inuit knowledge of the cumulative impacts of environmental change on sea ice and salinity in eastern Hudson Bay. We outline the critical role of enacting relational accountability in research throughout all stages of the project, which creates space for the motives, concerns, and values of community research partners to inform research practices and the interpretation of research results. In this way, relational accountability plays an important role in building a shared understanding of Inuit community contexts and values, and of what meaningful and equitable knowledge co-production means to community members. We share these reflections to contribute to the emerging discourse on collaborative methodologies in environmental research involving Indigenous Peoples and non-Indigenous research partners across the circumpolar north.

Qikiqtait: Progress on a Protected Area for the Belcher Islands Archipelago

Mick Appaqaq, Arctic Eider Society, Sanikiluaq Hunters and Trappers Association, Municipality of Sanikiluaq
Johnny Kudluarok, Arctic Eider Society, Sanikiluaq Hunters and Trappers Association, Municipality of Sanikiluaq
Emily Kattuk, Arctic Eider Society, Sanikiluaq Hunters and Trappers Association, Municipality of Sanikiluaq
Johnnie Kuki, Arctic Eider Society, Sanikiluaq Hunters and Trappers Association, Municipality of Sanikiluaq
Joel Heath, Arctic Eider Society, Sanikiluaq Hunters and Trappers Association, Municipality of Sanikiluaq
Lucassie Arragutainaq, Arctic Eider Society, Sanikiluaq Hunters and Trappers Association, Municipality of Sanikiluaq

Keywords: Collaborative Methodologies, Environmental Change, Inuit Knowledge

Sanikiluaq is taking a whole-of-community approach and working with the Qikiqtani Inuit Association to create Qikiqtait: an Inuit-led Protected Area for the Belcher Islands Archipelago. Qikiqtait will protect the unique habitats and wildlife that rely on the islands, support a local conservation economy and will manage terrestrial and marine habitats through Inuit-led research and stewardship programs, governance models, and a holistic management plan for the region. Substantial progress has been made over the last year, in particular, over 100 community members have been crowd sourcing a resource inventory and baseline data for the protected area using the SIKU app, including fish, mammals, birds, invertebrates and plants. The project contributed substantially to food security during the pandemic with over 1500 hunting trips and 2000+ posts, directly involving women, men, elders and youth from across the community, with over 20% of the community now on SIKU and tracking the project's progress on an ongoing basis. This will provide key data for the feasibility study and as a reference point for ongoing monitoring and management. Qikiqtait is setting a new precedent for community-driven stewardship. Governance activities have been advancing through ongoing meetings with the Qikiqtani Inuit Association, and progress has been made in completing the design of a multi-purpose community research centre to support project objectives, with construction planned for summer 2021. This presentation will share the outcomes of project activities to-date and next steps towards the creation of Qikiqtait.

SIKU: The Indigenous Knowledge Social Network, a summary of progress a year since public launch

Candice Pedersen, The Arctic Eider Society
Mick Appaqaq, The Arctic Eider Society
Johnny Kudluarok, The Arctic Eider Society

SIKU: The Indigenous Knowledge Social Network, is an online platform and mobile app designed by, for Inuit. SIKU provides a wide variety of tools supporting Inuit self-determination in research, education and environmental stewardship while providing full ownership, access and control over their data. Across Inuit Nunangat, community members, Indigenous organizations, and researchers are increasingly using SIKU to implement their own community-driven research and stewardship programs, leveraging the wide variety of tools and services for weather, dangerous ice and environmental monitoring. This presentation will report growth in usership and content creation since SIKU's launch in December 2019, and future development towards empowering conservation economies across northern communities. The Arctic Eider Society has maintained engagement with SIKU's growing user base through remote engagement during the pandemic through initiatives like the 2020 Goose Watch Competition (27+ Inuit communities) and community-driven stewardship efforts, including Qikiqtait project. The latter involved over 100 community members documenting 1500 hunting trips and 2000+ posts crowd sourced baseline data for a resource inventory while contributing substantially to food security and local incomes during the pandemic in an accountable, equitable and actionable way with long-term benefits for the community. Efforts are ongoing to develop similar programs with regional Inuit organizations in communities across Inuit Nunangat. New features will be showcased including a new GPS interface with offline maps, charts and ice imagery, as well as upcoming concepts for sharing Inuit arts and craft stories that can be linked to their respective harvesting stories (e.g., seal products to seal hunting stories), supporting local entrepreneurs and helping document conservation economies. As we build usership across Inuit Nunangat, we have an eye on SIKU in the broader international audience and will showcase our national programs to demonstrate the transferability of SKU among users across the Circumpolar arctic, and beyond.

Reflections from Inuit and non-Indigenous researchers in practising decolonizing Arctic science

Katherine Wilson, Memorial University of Newfoundland, Ottawa, Canada
Andrew Arreak, SmartICE Nunavut Operations Lead for Qikiqtaaluk North, Mittimatalik, Canada
Shelly Elverum, Ikaarvik Northern Coordinator, Mittimatalik, Canada
Trevor Bell, Memorial University of Newfoundland, St. John's, Canada
Gita Ljubicic, McMaster University, Hamilton, Canada

Keywords: Decolonizing, Inuit Knowledge, Sea-Ice Travel Safety, Climate Change Adaptation, Inuit Self-Determination In Research.

For the past five years Inuit and non-Indigenous researchers in Mittimatalik, Nunavut, Canada have been working together to reconceptualise research to support Inuit self-determination in research. The collaborative and decolonizing methodological approach, called the Sikumiut Model (Wilson, 2020), was put into practice in a community-based project to document and mobilize Inuit knowledge to improve sea-ice travel safety for younger generations. This presentation provides a practical example that changed the status quo by establishing an Inuit management committee (Sikumiut) to be in charge of the research project, and having Inuit youth conduct and facilitate the research. The role of the non-Indigenous scientists was changed from doing the research to providing training and mentorship for Inuit to do this research themselves. This presentation describes the reflections from the non-Indigenous partners in their journey to understand, adapt and practise relational accountability, and the specific Inuit values of the Sikumiut model. The presentation will also share the feedback received from Sikumiut, which describes the research values that were important to them, what they felt we did well together, and what we could do differently next time to further support Inuit self-determination in research.

What does Food Sovereignty Have to do with understanding the Arctic?

Carolina Behe, Inuit Circumpolar Council

Keywords: Food Security Lens, Indigenous Knowledge

Rapid changes occurring within the Arctic heighten the need to understand the multiple drivers pushing change and their cumulative impacts. Most importantly to better understand Arctic change a holistic view is needed that can only be achieved through bringing together multiple knowledge systems and scientific disciplines. Inuit have called the Arctic home from time immemorial acquiring a unique knowledge system. The Inuit knowledge system continues to grow and holds methodologies and assessment processes that provide a pathway for holistically understanding the Arctic. This holistic view is largely attributed to a focus on relationships between system components, close attention to food webs, and a unique understanding of interconnecting systems. Applying an Inuit food security lens represents an Indigenous way of viewing the world – where food security encompasses complex and interlinked cultural and environmental systems. These systems are comprised of connections among the health of people, animals, and plants; the different states of land, sea, and air; and the cultural fabric held together by language, cultural expression, and social integrity. Within the Inuit knowledge, it is impossible to disentangle some of these relationships; when we discuss an Inuit food security perspective, it is this interconnectivity and these relationships that we refer to. Food Sovereignty is a fundamental part of these relationships. This presentation will offer an introduction to what it means to adopt a food security lens approach and discuss the connection between Food Sovereignty and a holistic understanding of the Arctic – a view needed to build our knowledge and further our understanding of cumulative impacts while illuminating the nexus between all pieces that make up Arctic ecosystems.

ID: 91 - Arctic in Transition: Monitoring ecosystem change from the ground, air, and space

Conveners

Annett Bartsch | b.geos & Austrian Polar Research Institute

Sue Natali | Woods Hole Research Center

Ingmar Nitze | Alfred-Wegener-Institute for Polar and Marine Research

Jennifer Watts | Woods Hole Research Center

Examining Tundra Greening from Ground-based to Satellite Observations

Karl F. Huemmrich, University of Maryland Baltimore County, Baltimore, MD, USA
Sergio A. Vargas Z., University of Texas El Paso, El Paso, TX, USA
Craig Tweedie, University of Texas El Paso, El Paso, TX, USA
Petya P.K. Campbell, University of Maryland Baltimore County, Baltimore, MD, USA
Robert Hollister, Grand Valley State University, Allendale, MI, USA

Keywords: Tundra, Greening, NDVI

Multiple studies have shown multiyear trends in satellite measured Normalized Difference Vegetation Index (NDVI) in tundra. Increasing trends, referred to as “greening,” are considered indicators of ecological change, yet the nature of that change is unclear. Ongoing ground data collections of tundra spectral reflectance and plant type cover begun in 2010 near Utqiag?vik (Barrow) and Atqasuk, AK, USA provide a unique opportunity to link ground measurements to satellite observations from MODIS. Visible-near infrared spectral reflectance and plant coverage data were collected at plots in the Circumpolar Active Layer Monitoring (CALM) grids, consisting of 30 plots arranged in a 5 by 6 matrix separated by 100 m, providing a framework for repeatable measurements sampling areas about the size of a MODIS pixel. For the combined CALM plot data, multiyear trends in summertime NDVI track change in total green vegetation cover, mainly related to increased graminoid cover. Within these MODIS pixels with greening trends there were plots that were either browning, not changing, or greening at greater rates. Browning plots tended to have low shrub and high graminoid cover, while strongly greening plots tended to have relatively high shrub and low graminoid cover. This measurement strategy provides critical links between satellite observations and tundra ecological change and these types of measurements should be continued and expanded to other regions across the Arctic.

Historic AVHRR-derived Burned Area for Siberia (1979 – 2000): Data and patterns of change

Amber Soja

Keywords: Biomass Burning, Satellie, Fire Scar, Climate, Weather

Siberia is a distinct and critical region that has the size necessary to effect regional and global climate. The lack of accurate historic fire data in the Russian arctic-boreal hampers research. These data are necessary to forecast climate change impacts and feedbacks in this carbon-rich region. Fire is the dominant natural disturbance in the boreal, which acts to cycle carbon and maintain ecosystem diversity in sync with the climate. The Northern Hemisphere upper latitudes are currently warming, and under current climate scenarios, this region is expected to experience temperature increases that far exceed the global mean, which effects ecosystems and fire. We present a long-term burned area (BA) database that has been developed using Advanced Very High Resolution Radiometer (AVHRR) Global Area Coverage (GAC) data from 1979-2000. BA has been validated using available Landsat imagery (160 scenes, 5.6 Mha BA, 219 fires, 11% of the total BA in AVHRR data). Analyses show a 42% intersection, with commission and omission errors of 31% and 25%, respectively. Of the fire events missed by AVHRR (omissions), 86% are fires <10,000 ha (6 GAC pixels). Total BA compares well, and the AVHRR database under-represents BA by 10% compared to Landsat data (correlation 0.98 for all fires and 0.68 for fires < 0.1 Mha). We use these data to show long-term seasonal patterns of fire with fire weather. This long-term BA database will enable novel analyses on multi-decadal time scales.

Detecting and Mapping Gas Emission Craters on the Yamal and Gydan Peninsulas, Western Siberia

Greg Fiske, Woodwell Climate Research Center, Falmouth, MA, USA
Scott Zolkos, Woodwell Climate Research Center, Falmouth, MA, USA
Sue Natali, Woodwell Climate Research Center, Falmouth, MA, USA
Tiffany Windholz, Oklahoma State University, Stillwater, OK, USA
Gabe Duran, Woodwell Climate Research Center, Falmouth, MA, USA
Zhiqiang Yang, Oregon State University, Corvallis, OR, USA
Vladimir Olenchenko, Trofimuk Institute of Petroleum Geology and Geophysics, Novosibirsk, Russia
Alexey Faguet, Trofimuk Institute of Petroleum Geology and Geophysics, Novosibirsk, Russia

Keywords: Permafrost, Thermokarst, Landscape Change, Remote Sensing

Rapid climate warming at northern high latitudes is reflected by diverse geomorphic activity. In the Yamal and Gydan peninsulas, subterranean accumulation of biogenic methane beneath lenses of ice- and sediment-rich permafrost can form pressurized mounds at the land surface. Mound explosion ejects cryolithic blocks and forms a gas emission crater (GEC), posing a hazard to human populations and infrastructure. Automated detection of GECs could help to understand and mitigate potential effects, yet such capabilities are limited by scarce knowledge on the distribution of GECs and the context of land surface change in which they occur. To understand land surface change and the distribution of GECs within 327,000 km2 of the Yamal-Gydan region, we developed a semi-automated multivariate landscape change detection algorithm using satellite data products for surface reflectance, elevation, and water extent in the Google Earth Engine cloud computing platform. We found that 5% of the landscape changed from 1984–2018. The algorithm detected all seven GECs reported in the scientific literature and three new GEC-like features, and further revealed that retrogressive thaw slumps were more abundant than GECs. Our methodology can be refined to detect and better understand diverse types of land surface change, and potentially mitigate hazards across the northern permafrost zone.

Ocean stratification and sea-ice cover in Arctic seas modulate sea-air methane flux: satellite evidence

Leonid Yurganov, University of Maryland Baltimore County, Baltimore, USA
Dustin Carroll, Moss Landing Marine Laboratories, San José State University, Moss Landing, USA
Hong Zhang, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, USA

Keywords: Arctic, Greenhouse Gases, Methane, Climate Change, Remote Sensing

The diverse range of mechanisms driving Arctic amplification is not completely understood and furthermore, the role of the greenhouse gas methane in Arctic warming remains unclear. Strong sources of methane at the ocean seabed are well documented. Nevertheless, these sources have been interpreted as having a negligible impact on ocean-atmosphere methane exchange, with roughly 90% of the methane consumed by bacteria in the water column. However, these observations are primarily taken during summer, which is favorable for collecting data but also characterized by a strongly-stratified water column. In winter, stratification weakens and after a breakdown of the pycnocline, convection, storms, and turbulent diffusion can mix the full-depth water column in high latitudes. As the Mixed Layer Depth (MLD) deepens, the ocean-atmosphere methane exchange increases. An additional barrier for the air-sea flux is seasonally and interannually variable sea-ice cover in partially ice-covered seas. To better understand these processes, we present Thermal IR space-based spectrometer data from 2002–2020 that show increased methane concentration anomalies in winter months. These observations are then combined with ECCO ocean state estimates to understand the role of MLD variability in driving regional methane flux. The methane seasonal cycle amplitude in some areas, e.g., north of the Kara Sea, has more than doubled since the beginning of the century; this may be interpreted as an effect of sea-ice decline and/or an evidence for growth of seabed emissions. A progressing degradation of pan-Arctic sea-ice cover may lead to increased methane fluxes and, through a positive feedback loop, to further warming.

Seismic detection of coastal sea ice stabilization

Alice Bradley, Williams College, Williamstown, USA
Marshall Borrus, Williams College, Williamstown, USA

Keywords: Shore-Fast, Sea Ice, Coastal, Seismic

Shore-fast ice is a critical part of the coastal Arctic, providing both a stable platform for travel and subsistence hunting and a protective buffer against coastal erosion during the winter storm season. As the sea ice growth season shrinks in response to climate change, the period in which coastal sea ice is shore-fast decreases as well. Seismic sensors, typically used for detecting earthquakes, can detect the collisions in near-shore sea ice that build the ridges that can stabilize that shore-fast ice. This study used the sea ice radar data from Utqiagvik, Alaska in the 2014-2016 ice season and the Transportable Array seismic sensor (A21K) to demonstrate how on-shore seismic sensors can detect ice ridging events in coastal ice, and how that signal changes over the course of the ice season in response to the thickening of sea ice and the grounding of ice ridges.

Performance of spectral vegetation indices to assess Arctic Browning

Murk.K.Memon, University of Sheffield
Rob.G.Bryant, University of Sheffield
Julie.M.Jones, University of Sheffield
Gareth.k.Phoenix, University of Sheffield
Gareth Marshall, British Antarctic Survey
Rachael Treharne, Woodwell Climate Research Center, USA
Holly Croft, university of Sheffield

Keywords: Arctic, Browning, Climate Change, MODIS, Vegetation Indices

Remote sensing analyses of Arctic vegetation change has been highly dependent on spectral vegetation indices. Four decades of vegetation indices extracted through different sensors have helped researchers assess the impacts of climate change across Arctic's various types of vegetation. While most satellite-based research has highlighted the greening trends, recently there has been field based evidence of vegetation browning in the Arctic. Since, majority models predict large scale Arctic greening, and hence researchers have been focused predominantly on regional scales satellite data to quantify the projected vegetation increase, this study aims to mobilize the Arctic browning research through much needed integration of ground and satellite data. However, research on linking ground and sensor data are rare and could be a highly complex process mainly due to differences in spatial resolution of both. The aim of this research is to link plot-scale and satellite data in context of mapping and quantifying Arctic browning. And for this we evaluate the effectiveness of conventional vegetation indices to detect and quantify the vegetation decrease observed on ground on a per pixel basis. Secondly this work aims to explore the potential of a lesser incorporated index, the Chlorophyll-Carotenoid Index (CCI), for assessing browning events in the context of highly heterogenous Scandinavian landscape.

Monitoring changes in vegetation phenology at two contrasting Arctic tundra sites

Elise Gallois, University of Edinburgh, United Kingdom
Maude Grenier, University of Edinburgh, United Kingdom
Joe Boyle, University of Edinburgh, United Kingdom
Geerte de Jong, Gothenburg University, Sweden

Keywords: Phenology, Arctic Greening, Phenocams, Remote Sensing, Tundra Ecology

As the Arctic continues to warm, we are observing enhanced ecosystem change in tundra environments across the Arctic - increased plant productivity, alongside a northward advance of woody shrub species. However, we lack understanding of how tundra plant phenology (the timing of plant growth and reproduction within the growing season) is influenced by climate warming, particularly across contrasting locations and across environmental gradients. There is therefore a need to monitor phenology change across contrasting tundra sites to observe differing growing season lengths and the varying effects of warming, microclimate, and snow cover on the timing of Arctic plant phenology. While phenology is an increasingly important variable in the Arctic, it is difficult to measure as it requires observations early and late in the growing season, when most field researchers are away from their field sites. Remote observations are easily accessible and cover the whole biome, but are not fine-grained and allow for significant error when interpreting phenology. Time-lapse cameras (phenocams) are a novel technique which may allow for individual-level observation of disparate sites simultaneously. We compare satellite imagery, in-situ data, and phenocams from two contrasting field sites (Qikiqtaruk-Herschel Island, YT Canada, & Latnjajaure, Sweden), focusing on three focal species, analysing the respective precision, accuracy, and viability of monitoring phenology in tundra systems.

Drones reveal sub-landscape insights about the 'greening of the Arctic'

Jeff Kerby, Aarhus University, Aarhus, Denmark
Jakob Assmann, Aarhus University, Aarhus, Denmark
Isla Myers-Smith, University of Edinburgh, Edinburgh, UK
Logan Berner, Northern Arizona University, Flagstaff, USA
& The High Latitude Drone Ecology Network

Keywords: UAV, Greening, Arctic, Drone, Remote Sensing

Drones enable a cross-scale perspective and have the potential to produce novel ecological insights when combined with long-term ecological and remote sensing datasets. Arctic tundra 'greening' is one of the clearest, broad-scale biological responses to climate warming on the planet. Yet satellite-measured circumarctic vegetation trends do not always correspond with local ecological dynamics within tundra landscapes. To address how and why these seeming contradictions may result from ecological scaling, we examine ultra-high resolution drone data from a network of 70+ mapping sites (High Latitude Drone Ecology Network – HiLDEN) spanning diverse tundra landscapes across the Arctic. We present analyses of how long-term greening trends from the Landsat satellites vary within HiLDEN landscapes (9 ha) as a function of local vegetation cover and quality, landscape context, and temperature. We then explore how upscaling trends both explains and complicates interpretations of broad-scale Arctic vegetation dynamics and their carbon cycle implications.

SiDroForest: Siberian Drone mapped Forest inventory

Femke van Geffen, Helmholtz Centre for Polar and Marine Research, Research Unit Potsdam, Alfred Wegener Institute (AWI), Germany
Birgit Heim, Helmholtz Centre for Polar and Marine Research, Research Unit Potsdam, Alfred Wegener Institute (AWI), Germany
Ulrike Herzschuh, Helmholtz Centre for Polar and Marine Research, Research Unit Potsdam, Alfred Wegener Institute (AWI), Germany
Luidmila A Pestryakova, Institute of Natural Sciences, North-Eastern Federal University of Yakutsk, Yakutsk, Russia 10
Evgenij S Zakharov, Institute for Biological Problems of the Cryolithozone, Russian Academy of Sciences, Siberian branch, Yakutsk, Russia
Ronny Hänsch, German Aerospace Center (DLR), Microwaves and Radar Institute, SAR Technology, Germany
Begüm Demir, Technische Universität Berlin, Remote Sensing Image Analysis (RSiM) Group, Germany
Stefan Kruse, Helmholtz Centre for Polar and Marine Research, Research Unit Potsdam, Alfred Wegener Institute (AWI), Germany

Keywords: Drones, Point Clouds, Forest, Data Science, Machine Learning

We present a data collection on forest structure that covers two transition zones in NE Siberia and Central Yakutia. The locations covered are where fieldwork was performed by the Alfred Wegener Institute for Polar and Marine research, AWI) upscaled through the addition of Red Green Blue(RGB) UAV (Unmanned Aerial Vehicle) camera data and Sentinel-2 satellite data cropped to a 5km radius around the fieldwork sites. The dataset is created with the aim of providing ground truth validation and training data to be used in various machine learning tasks. The dataset contains: 1. Individual identified tree information per 30x30m plot assigned in field work with additional data on species, height, crown width and biomass. 2. Structure from Motion (SfM) point clouds that provide 3D information about the forest structure, including generated Canopy Height Model (CHM), Digital Elevation Model (DEM) and a Digital Surface Model (DSM) per 50x50m. 2. Multispectral Sentinel-2 satellite data (10 to 20m res.) cropped to a 5km radius with generated NDVI, available in three seasons: Early Summer, Peak Summer and Late Summer. 3. Extracted tree crowns shapes from drone images with species information. 4. Synthetically generated large (10.000 samples) dataset from tree crowns. The dataset will be made publicly available on the data repository PANGAEA and all elements are geocoded to facilitate multimodal analyses.

Applicability of Sentinel-2 for Coloured Dissolved Organic Matter regimes in lakes of the Lena River Delta and central Yama

Birgit Heim, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Yury Dvornikov, Earth Cryosphere Institute of Tyumen, Scientific Centre Siberian Branch of RAS, Tyumen, Russian Federation
Sebastian Rößler, German Aerospace Center DLR, Oberpfaffenhofen, Germany
Anne Morgenstern, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Antje Eulenburg, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Bennet Juhls, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Stefan Kruse, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Antonina Chetverova, Arctic and Antarctic Research Institute, and Saint-Petersburg State University, Institute of Earth Sciences Saint Petersburg, Russian Federation
Irina Fedorova, Saint-Petersburg State University, Institute of Earth Sciences Saint Petersburg, Russian Federation
Marina Leibman, Earth Cryosphere Institute of Tyumen, Scientific Centre Siberian Branch of RAS, and Tyumen State University, Tyumen, Russian Federation
Ulrike Herzschuh, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany and Institute of Earth and Environmental Science, University of Potsdam, Potsdam, Germany
Annett Bartsch, B.GEOS and Austrian Polar Research Institute, Austria

Keywords: Lakes, Siberia, Lake Colour, Sentinel-2

We investigate Sentinel-2 remote sensing for ‚lake colour‘ applications related to CDOM in lakes of the Lena River Delta and central Yamal (RU). We also included SAR remote sensing to map the surface water extent to support the understanding of the seasonal lake dynamics, namely of the season of spring flood. The Alfred Wegener Institute AWI in Germany works in long-term cooperation with the St. Petersburg-State University and the Arctic and Antarctic Research Institute AARI (RU), sampling since 10 years in the Lena River Delta lakes and the river channels. The sampling covered mostly shallow thermokarst lakes on the Holocene and Pleistocene delta terraces. In contrast, the Central Yamal permafrost landscape has deeper lake basins due to tabular ground ice degradation. The Earth Cryosphere Institute established a long-term monitoring site, Vaskiny Dachi close to the Bovanenkova gas field. First water sampling started in 2011, then continued with including a large number of different lake types. In this study, we seek to understand which optical types of lakes occur in the thermokarst landscapes of central Yamal and the Lena River Delta. We show simulations of cDOM influence on lake colour using the ‘Water Colour Simulator’ WASI©. However, turbidity seems to play a more dominant role than CDOM in providing the water-leaving colour of thermokarst lake types.

Persistence of turbid Freshwater Plumes in a High Arctic Fjord Ecosystem

Daniela Marianne Regina Walch, Potsdam University, UNIS Svalbard
Rakesh Kumar Singh, Université du Québec à Rimouski (UQAR)
Janne Søreide, UNIS Svalbard
Hugues Lantuit, Alfred-Wegener-Institute (AWI), Potsdam University
Konstantin Klein, Alfred-Wegener-Institute (AWI)
Amanda Poste, Norsk Institutt for Vannforskning (NIVA)

Keywords: Suspended Particulate Matter, Fjord Ecosystem, Ocean Optics, Light Availability, Variability

In high Arctic fjords, riverine inputs of freshwater and terrestrial particles give rise to turbid plumes in the near-shore zone during melt season and thus act as a major impediment to light availability and primary productivity within the water column. However, the remoteness of Arctic fjords limits our understanding of key drivers of these plumes. Surface water colour reflects concentrations of dissolved or suspended optically active constituents, incl. suspended particulate matter (SPM). The present study aims to use remote sensing to better understand how freshwater inputs affect seasonal and spatial patterns in SPM concentrations in Adventfjorden, Svalbard. By linking spatially high resoluted Sentinel-2 imagery to contemporaneous in-situ values, a semi-analytical single-band SPM algorithm had been regionally calibrated, which significantly improved the accuracy of the analysed time-series data of two contrasting years (2019/2020). This approach facilitates predictions of SPM and monitoring of freshwater impacts on highly dynamic Arctic fjord ecosystems. The resulting data offers the possibility to identify environmental drivers as well as seasonal and interannual fluxes in extent and persistence of freshwater plumes in coastal areas. Given ongoing changes in precipitation and glacial discharge due to the warming climate in the Arctic, satellite-based monitoring of fjords holds promise for monitoring environmental change in these highly productive yet remote ecosystems.

An archive for animal-borne sensor data supports ecological monitoring and collaboration across the Arctic

Sarah C. Davidson, Ohio State University, Department of Civil, Environmental & Geodetic Engineering, Columbus, USA; Max Planck Institute of Animal Behavior, Radolfzell, Germany
Gil Bohrer, Ohio State University, Department of Civil, Environmental & Geodetic Engineering, Columbus, USA
Scott LaPoint, Max Planck Institute of Animal Behavior, Radolfzell, Germany; Columbia University, Lamont-Doherty Earth Observatory, Palisades, USA; Black Rock Forest, Cornwall, USA
Eliezer Gurarie, University of Maryland College Park, Department of Biology, College Park, USA; University of Montana, Department of Ecosystem and Conservation Sciences, Missoula, USA
Peter Mahoney, University of Washington Seattle Campus, Department of Environmental and Forest Sciences, Seattle, USA
Jyoti S. Jennewein, University of Idaho, Department of Natural Resources and Society, Moscow, USA
Emma Greier, University of Maryland College Park, Department of Biology, College Park, USA
Ophélie Couriot, University of Maryland College Park, Department of Biology, College Park, USA; National Socio-Environmental Synthesis Center, Annapolis, USA
Todd E. Katzner, U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, Boise, USA
Allicia Kelly, Government of Northwest Territories, Department of Environment and Natural Resources, Fort Smith, Canada
Tricia A. Miller, Conservation Science Global, Inc., West Cape May, USA; Division of Forestry and Natural Resources, West Virginia University, Morgantown, USA
Mark Hebblewhite, University of Montana, Department of Ecosystem and Conservation Sciences, Missoula, USA

Keywords: Wildlife Monitoring, Movement Ecology, Phenology, FAIR Data, Remote Sensing

Animal-borne sensors offer a unique and growing source of data documenting the movements and behavior of wildlife and the external conditions they experience. Such data offer a valuable resource in the Arctic, a remote region experiencing rapid ecological change. The Arctic Animal Movement Archive, a collaborative and growing collection of avian, marine and terrestrial animal tracking datasets, combines data for nearly 100 species over more than 3 decades and expertise from hundreds of organizations. Through the Archive, data are harmonized, made discoverable, and can be accessed publicly or upon request. We use data assemblages from the Archive to identify long-term, large-scale and multi-species patterns in animal behavior in relation to climate and weather conditions, and explore how animal-derived observations compare to other remote sensing and reanalysis data. First, in golden eagles, we reveal climatic influences on arrival timing at summering grounds over three decades. Second, in caribou, we show a shift toward earlier calving dates for northern caribou populations across western North America over the past decade. Third, we find differing responses in animal movement rates to seasonal weather conditions within and across trophic levels. Finally, we validate temperature estimates from ungulate collars against those from a global weather forecasting model. We welcome participation in the Archive to support research, wildlife management and environmental monitoring.

Appearing of desappeared

Anastasia Deyko, independent researcher, Peru

Keywords: Art For Climate Change, Photography Archive, Remote Monitoring, Climate Change

Idea to apply "Appeared disappearing" as abstracts for Arctic Science Summit came based on my collaborations with Barents region and archive research of glassier of Andes. The core of the "Appearing disappeared" is: to unite - to collaborate - to aware. My experience in the world of photography is adapted to the needs of monitoring global warming in the Arctic. Through national official photo archives and private visual memories of the elderly to scientific photo documentations, I intend to make the younger generations aware of how dramatic and rapid climate change, especially with snow peaks, mountain lagoons and glaciers. One Arctic-thousands cameras is the mix of modern internet technologies and traditional art of photography. Project is devoted to changes in Arctic regions from the value and aesthetic point of view, but based on the visual evidence. I believe that photo bridges (online archives in the end) are the easiest way to explain (visualize) climate change, independently of age, nationality, geographical position. On the other hand photo bridges over the generations (EG from archives of elderly through professional photos and to Instagram of recent residents) will unite synergy of propaganda in the united language. To listen "Before we had permanent snow here" from indigenous habitants means nothing for millennials, relocated to cities. Neither, scientific data or satellite maps. But photography remains unique and the most informative, dogmatic language.

Arctic change revealed by satellite - Data collections of ESA DUE GlobPermafrost and ESA CCI+ Permafrost

Annett Bartsch, b.geos, Korneuburg, Austria
& ESA DUE GlobPermafrost team
& ESA CCI+ Permafrost team

Keywords: Permafrost, Remote Sensing, Time Series, Circumpolar

A Permafrost Information System (PerSys) based on satellite data has been setup as part of the ESA DUE GlobPermafrost project (2016-2019, www.globpermafrost.info). This includes a data catalogue as well as a WebGIS, both linked to the Pangaea repository for easy data access. The thematic products available include InSAR-based land surface deformation maps, rock glacier velocity fields, spatially distributed permafrost model outputs, land surface properties and changes, and ground-fast lake ice. Extended permafrost modelling (time series) is implemented in the new ESA CCI+ Permafrost project (2018-2021, http://cci.esa.int/Permafrost), which will provide the key for our understanding of the changes of surface features over time. Additional focus is on documentation of kinematics from rock glaciers in several mountain regions across the world supporting the IPA action group 'kinematics as an essential climate variable'. We will present the Permafrost Information System including the time series of ground temperatures and active layer thickness for the entire Arctic from the ESA CCI+ Permafrost project and results from the latest update (extension to 1997-2018). Ground temperature is calculated for 0, 1m, 2m, 5m, and 10 m depth and has been assessed based on a range of borehole data. A survey regarding data repositories containing relevant borehole data has been conducted. The records have been evaluated for the project purpose and harmonized.

Organization of monitoring of hazardous cryogenic processes in the Arctic

Vasily Tolmanov, Lomonosov Moscow State University, Moscow, Russia
Valery Grebenets, Lomonosov Moscow State University, Moscow, Russia

Keywords: Permafrost, Arctic Environment, Field Monitoring, Cryogenic Processes

The issue of the detailed study of the cryogenic processes arises in the XXI century. This is especially truthful for a rapidly changing environments like tundra. Scientists of different branches usually organise monitoring process using various methods and techniques. It does not allow us to evaluate the modern mechanics of the process development or compare it on a regional scale. A continuous series of field standardized observations of these processes, is required also for a correct forecast of cryogenic processes development. We have identified 5 main processes suitable for the field monitoring, revealed its general parameters and triggers for its activation. We chose "model" territories for the field monitoring, identified it based on the analysis (GIS, statistics etc.) of geographic and geological parameters. The degree of manifestation of the process is the highest on this territories. We have analysed modern and archival literature, field data and personal experience of the field work in order to draw up a monitoring methodology for five chosen processes and to create the projects of the sites. Supported by the grant. RFBR 18-05-60080 “Dangerous nival-glacial and cryogenic processes and their impact on infrastructure in the Arctic”.

Recent impacts of climate change on the landforms and dynamics of Pingo Canadian Landmark (Northwest Territories, Canada): preliminary results

Daniel Batista, Institute of Geography and Spatial Planning, University of Lisbon, Lisbon, Portugal
Gonçalo Vieira, Centre of Geographical Studies, IGOT, University of Lisbon, Lisbon Portugal
Dustin Whalen, NRCAN, Dartmouth, Canada
Pedro Pina, Centre of Natural Resources and Environment, IST, University of Lisbon, Lisbon, Portugal

Keywords: Pingo, Coastal erosion, Permafrost, Thermokarst, UAV

Pingo Canadian Landmark (PCL) is a protected coastal area located in the SW region of Tuktoyaktuk Peninsula (NWT, Canada), close to the Mackenzie River delta, the region with the highest concentration of pingos in the world (Mackay, 1998). PCL shows high geomorphological relevance and high cultural importance to the Inuvialuit People, with the reported presence of archeological sites and a long relation to the landforms, namely the pingos. Data shows a rise in frequency and magnitude of erosion and permafrost degradation events, linked to increased marine storms and higher air and sea temperatures, which may put the unique pingo landforms into risk of degradation or complete disappearance. The main focus of this research is to assess the changes occurring on the landscape of PCL supported by remote sensing data of unprecedented quality and GIS analysis. Remote sensing imagery has been acquired in 2017 (WorldView), 2018 (Pleiades) and through an extensive UAV survey of almost the whole PCL in 2019. This allowed for the production of an ultra-high resolution orthomosaic and digital surface model. The former allowed the construction of a very high resolution geomorphological map, while the later will be compared with a LiDAR survey of 2004, allowing to identify the main morphological changes in the park. This e-poster shows the first results of this research, developed in the framework of the EC H2020 Project Nunataryuk and a collaboration with Parks Canada.

Siberian High Latitude Lake Chemistry Data Collection

Birgit Heim, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Kathleen Stoof-Leichsenring, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Luidmila A Pestryakova, Federal State Autonomous Educational Institution of Higher Education "M.K. Ammosov North-Eastern Federal University", Yakutsk, Russian Federation
Izabella Baisheva, Federal State Autonomous Educational Institution of Higher Education "M.K. Ammosov North-Eastern Federal University", Yakutsk, Russian Federation
Yury Dvornikov Earth Cryosphere Institute of Tyumen, Scientific Centre Siberian Branch of RAS, Tyumen, Russian Federation
Boris Biskaborn, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Stuart Andrew Vyse, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Mareike Wieczorek, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Anne Morgenstern, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Antje Eulenburg, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Paul Overduin, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Antonina Chetverova, Arctic and Antarctic Research Institute, and Saint-Petersburg State University, Institute of Earth Sciences Saint Petersburg, Russian Federation
Irina Fedorova, Saint-Petersburg State University, Institute of Earth Sciences Saint Petersburg, Russian Federation
Stefan Kruse, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Marina Leibman, Earth Cryosphere Institute of Tyumen, Scientific Centre Siberian Branch of RAS, and Tyumen State University, Tyumen, Russian Federation
Artem Khomutov, Earth Cryosphere Institute of Tyumen, Scientific Centre Siberian Branch of RAS, and Tyumen State University, Tyumen, Russian Federation
Evgenij S Zakharov, Federal State Autonomous Educational Institution of Higher Education "M.K. Ammosov North-Eastern Federal University", Yakutsk, Russian Federation and Institute for Biological Problems of Cryolithozone Siberian Branch of RAS, Yakutsk, Russian Federation
Ulrike Herzschuh, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany and Institute of Earth and Environmental Science, University of Potsdam, Potsdam-Golm, Germany

Keywords: Lakes, Siberia, Water Chemistry

The footprint of human activity is small in many high latitude regions. Water chemistry from high latitude lakes may provide deeper insights into land to lake fluxes in comparatively pristine regions. However, high latitude lakes are often difficult to get to. Within the framework of long-term Russian-German cooperation we measured the water chemistry of a large variety of lake types across Siberia. As an example of the utility of a lake chemistry data collection, a conceptual model of the influence of Siberian larch forest vegetation on fluxes of dissolved ions into lakes could be developed. The lake chemistry data collection is expanding, currently containing more than 500 lake chemistry data sets, mostly representing the summer state. The sampled lakes span from the permafrost lowlands of the Yamal Peninsula in the west, along taiga-tundra transects in the Khatanga and Lena lowlands, to the glacial lakes of the Chukotkan mountain region in Eastern Siberia. The water chemistry includes the concentrations of the major cations and anions, the alkalinity, pH and conductivity- Lake morphometric data include lake location, lake area, catchment area (if applicable), elevation and land cover. The data can be used to investigate how the ionic content of lake waters relates to lake type and the catchment characteristics, and in combination with ecosystem investigations, how the lake chemical compositions affects high latitude biodiversity in the lakes in the early 21st Century.

The NorthSTAR field network: challenges in Arctic NDVI interpretation revealed by comparing field and satellite NDVI measurements

John A. Gamon, University of Alberta, Edmonton, Alberta, Canada
K, Fred Huemmrich, University of Maryland, Baltimore, MD, USA
Peter Lafleur, Trent University, Peterborough, Ontario, Canada
Eugenie Euskirschen, University of Alaska Fairbanks, Alaska, USA
Scott Williamson, University of Alberta, Edmonton, Alberta, Canada
Craig Emmerton, University of Alberta, Edmonton, Alberta, Canada
Ran Wang, University of Nebraska, Lincoln, NE, USA
Rong Yu, University of Nebraska, Lincoln, NE, USA
& Members of the NorthSTAR Team.

Keywords: NDVI, GPP, Phenology, Arctic Tundra, Remote Sensing

To help understand the utility of satellite measurements for assessing Arctic tundra gross primary production (GPP), we established a network of automated optical phenology stations to record NDVI measurements at flux tower sites ranging from the Low to the High Arctic. Field sensors provided a temporally-rich NDVI within the flux tower footprint for independent validation and comparison with flux phenology. Large differences in NDVI patterns emerged across sites with contrasting vegetation and productivity. The majority of the NDVI signal was driven by snowmelt and snowfall, not by vegetation phenology per se. Maximum value compositing failed to capture the dynamics resulting from snowfall and snowmelt events, but time-integrated NDVI matched site-to-site differences in annual productivity. Overall, NDVI time series poorly captured the annual patterns of GPP phenology. Similarly, typical phenological metrics applied to satellite data were poorly related to the ground NDVI or seasonal productivity patterns, often showing large errors at the start and stop of the growing season, particularly for the High Arctic sites where snow dynamics dominated the seasonal NDVI patterns. We conclude that NDVI-based seasonal metrics are primarily driven by snow dynamics and not vegetation dynamics for many Arctic sites. New methods are needed to correct for these effects and derive more reliable metrics of GPP dynamics from satellite reflectance data.

Utilizing high resolution drone and satellite imagery to monitor changes in northern high latitude ecosystems

Hailey Webb, Woodwell Climate Research Center, Falmouth, MA USA
Nathan Barnes, Montana State University, Bozeman, MT USA
Mary Farina, Woodwell Climate Research Center, Falmouth, MA USA
Scott Powell, Montana State University, Bozeman, MT USA
Jennifer Watts, Woodwell Climate Research Center, Falmouth, MA USA
Sue Natali, Woodwell Climate Research Center, Falmouth, MA USA

Keywords: Drone, Remote Sensing, Methane, Ecosystem, Monitoring

As microbial activity and soil decomposition rates increase due to thawing permafrost, large amounts of carbon can be emitted to the atmosphere as carbon dioxide (CO2) or methane (CH4). CH4 is only produced under very wet, anoxic, conditions. The release of CH4 is of particular concern because it has a warming potential 28 times that of CO2. However, there is uncertainty regarding the magnitude and spatial variation of CH4 emissions in thawing permafrost regions. In this work, we utilize drone technology to analyze the relationship between in-situ measurements of soil and vegetation properties and the magnitude of CH4 emissions around Big Trail Lake, a boreal wetland north of Fairbanks, AK. We conducted drone flights over a 50 hectare area surrounding the lake to collect high resolution multispectral imagery and collected the following variables from 28 sites in proximity to the lake: chamber-based CH4 flux, soil temperature, soil pH, soil moisture, and ground-based vegetation cover. Results indicate that CH4 flux observations vary based on dominant vegetation type and water saturation conditions, providing a promising new method of data analysis at much finer scales than satellite imagery. High resolution drone-based vegetation mapping is a useful but under-utilized tool for analyzing a large study area's CH4 fluxes. Our results help inform bottom-up modeling approaches that estimate CH4 flux by analyzing fine-scale flux processes and their drivers.

ID: 68 - Progress Towards Realizing Data Sharing for the Arctic Region and Beyond

Conveners

Peter L. Pulsifer | Carleton University, Ottawa, Canada

Kirsten Elger | GFZ German Research Centre for Geosciences, Potsdam, Germany

Mareike Wieczorek | Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany

SIOS Data Management System for a regional observing system in and around Svalbard

Dariusz Ignatiuk, Svalbard Integrated Arctic Earth Observing System (SIOS), Longyearbyen, Norway
Øystein Godøy, Svalbard Integrated Arctic Earth Observing System (SIOS) and Norwegian Meteorological Institute, Longyearbyen and Oslo, Norway
Lara Ferrighi, Norwegian Meteorological Institute, Oslo, Norway
Inger Jennings, Svalbard Integrated Arctic Earth Observing System (SIOS), Longyearbyen, Norway
Heikki Lihavainen, Svalbard Integrated Arctic Earth Observing System (SIOS), Longyearbyen, Norway
Christiane Hübner, Svalbard Integrated Arctic Earth Observing System (SIOS), Longyearbyen, Norway
Shridhar Jawak, Svalbard Integrated Arctic Earth Observing System (SIOS), Longyearbyen, Norway

Keywords: Data Sharing, FAIR Data, SIOS, Svalbard

Svalbard Integrated Arctic Earth Observing System (SIOS) is an international consortium to develop and maintain a regional observing system in Svalbard and the associated waters. SIOS brings together the existing infrastructure and data of its members into a multidisciplinary network dedicated to answering Earth System Science (ESS) questions related to global change. The Observing System is built around “SIOS core data” – long-term data series collected by SIOS partners. SIOS facilitates access to data from Svalbard, through a free and open data portal that enables the users to search, retrieve, visualise, transform, and harvest ESS data relevant to Svalbard. SIOS portal includes the Observation Facility Catalogue (OFC) and SIOS Data Access Point. The OFC allows collecting and sharing information about research infrastructures distributed in Svalbard. The purpose of the OFC is to make better use of the existing research infrastructure by facilitating the search for given parameters and their location. In this way, duplication can be avoided, and new measurements can be co-located with existing ones. The catalogue has a map interface and advanced search function. The SIOS Data Access Point gives access to data and metadata by the SIOS Data Management System that relies on the principles of distributed data management. Datasets that are relevant for SIOS, as well as their associated metadata, are managed by several physically distributed Data Centres.

Shared Arctic Variable framework links global and Arctic observing system priorities and requirements

Polina Mikhaylyukova, Lomonosov Moscow State University Marine Research Center, Moscow, Russia
Marina Semenova, Lomonosov Moscow State University Marine Research Center, Moscow, Russia
Anna Gebruk, Lomonosov Moscow State University Marine Research Center, Moscow, Russia
German Titov, Marine Information Technologies, Moscow, Russia

Keywords: Arctic Observing, Geoportal, Remote Sensing, Russian Arctic

There are two principal approaches to environmental observations in the Russian Arctic: based on in-situ measurements; based on remote sensing. Instrumental In-Situ measurements are conducted in the Russian Arctic from the mid-XIX century preliminary based at the weather or research stations collecting hydrometeorological data. Weather stations remain scarce and dispersed over large geographical areas, hence the spatial resolution and accuracy of predictions is limited. Observing systems based on remote sensing are specifically designed to maintain long-term data series. Observing systems that are currently in operation in the Russian Arctic are mostly based on assembling and analysing remote sensing satellite data, whilst data sets from instrumental measurements are stored as archives (digital or hard copy) and are independent from monitoring systems. Russian Arctic observing systems currently lack integrity on monitored parameters and analyses which is why defining the observation variables is an essential step towards an integrated system. Geoportal of the Lomonosov Moscow State University Marine Research Center (under development; https://gis.marin.tech) is an integrated monitoring and observation system product collecting environmental data from the Russian Arctic, Far East, the Black Sea, and the Caspian Sea. Database of Geoportal combines field data from the stakeholders, and open source remote sensing data.

The EMERGE Database: An interdisciplinary data management solution for ecosystems biology and environmental research

Suzanne B. Hodgkins, Department of Microbiology, The Ohio State University, Columbus, OH, USA
Benjamin Bolduc, Department of Microbiology, The Ohio State University, Columbus, OH, USA
Ruth K. Varner, Earth Systems Research Center, Institute for the Study of Earth, Oceans and Space, University of New Hampshire, Durham, NH, USA
Patrick M. Crill, Department of Geological Sciences and Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden
Carmody K. McCalley, Thomas H. Gosnell School of Life Sciences, Rochester Institute of Technology, Rochester, NY, USA
Jeffrey P. Chanton, Department of Earth, Ocean, and Atmospheric Science, Florida State University, Tallahassee, FL, USA
Gene W. Tyson, Australian Centre for Ecogenomics, School of Chemistry and Molecular Biosciences, University of Queensland, Brisbane, QLD, Australia
William J. Riley, Climate and Ecosystem Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA, USA
Michael Palace, Earth Systems Research Center, Institute for the Study of Earth, Oceans and Space, University of New Hampshire, Durham, NH, USA
Melissa B. Duhaime, Department of Ecology and Evolutionary Biology, University of Michigan, Ann Arbor, MI, USA
Moira A. Hough, Department of Ecology and Evolutionary Biology, University of Arizona, Tucson, AZ, USA
Scott R. Saleska, Department of Ecology and Evolutionary Biology, University of Arizona, Tucson, AZ, USA
Matthew B. Sullivan, Department of Microbiology, The Ohio State University, Columbus, OH, USA
Virginia I. Rich, Department of Microbiology, The Ohio State University, Columbus, OH, USA
EMERGE Biology Integration Institute Team
IsoGenie Project Team
A2A Project Team

Keywords: Graph Database, Data Management, Ecosystem Science, Interdisciplinary, Information Analysis, Database, EMERGE Project, Isogenie Project, Stordalen Mire

Modern microbial and ecosystem sciences require diverse interdisciplinary teams that are often challenged to communicate and share data due to different languages and heterogenous data product types. Here we address this challenge by introducing a novel data management and exploration platform, the EMERGE Database (EMERGE-DB). The EMERGE-DB was developed for the NSF-funded Emergent Ecosystem Responses to ChanGE (EMERGE) Project, whose goal is to enable predictive modeling of ecosystem response to change using the model thawing permafrost peatland Stordalen Mire. The EMERGE-DB is based on the IsoGenie Database (IsoGenieDB; https://isogenie-db.asc.ohio-state.edu/), a public and private graph data infrastructure designed to integrate data generated by the DOE-funded IsoGenie Project. The IsoGenieDB provides (i) a platform for exploring the project's data through the inherent relationships among data entities, (ii) a framework to consolidate the datasets needed by the team's modelers, and (iii) a public venue to share published datasets.

The EMERGE-DB adds several enhancements to the IsoGenieDB to improve data FAIRness, including built-in integration of ENVO, EML, and other community metadata standards and formats; more streamlined integration of the web portal content with the underlying graph database; and more customized database queries available to project members. The EMERGE-DB's expandability and flexible architecture allow it to serve as an example ecosystems database.

SIOS's response to COVID-19 and the strategy for future

Shridhar Jawak, Svalbard Integrated Arctic Earth Observing System (SIOS), Svalbard, Norway.
Veijo Pohjola, Uppsala University, Sweden
Inger Jennings, Svalbard Integrated Arctic Earth Observing System (SIOS), Svalbard, Norway
Christiane Hübner, Svalbard Integrated Arctic Earth Observing System (SIOS), Svalbard, Norway
Dariusz Ignatiuk, Svalbard Integrated Arctic Earth Observing System (SIOS), Svalbard, Norway
Øystein Godøy, Norwegian Meteorological Institute (MET Norway), Oslo, Norway.
Heikki Lihavainen, Svalbard Integrated Arctic Earth Observing System (SIOS), Svalbard, Norway
Bo N. Andersen, University of Oslo, Norway
Kim Holmén, Norwegian Polar Institute, Tromsø, Norway

Keywords: COVID, SIOS, Earth System Science, Observing System, Remote Sensing, Earth Observation

Svalbard Integrated Arctic Earth Observing System (SIOS) is an international collaboration of 24 research institutions from 9 countries studying the environment and climate in and around Svalbard. Here, we focus on our practical activities to support the Svalbard science community in filling gaps in scientific observations and bringing the scientific community together in times of global pandemic COVID-19. The pandemic has affected the Svalbard research in several ways because of nationwide lockdown in many countries, strict travel restrictions in Svalbard, and quarantine regulations. Many field campaigns to Svalbard were cancelled and future campaigns are still uncertain for an unforeseen future. Many conferences have been either cancelled or postpones or converted into online mode leading to fewer opportunities for networking. In response to this situation, SIOS developed new activities suitable to counteract these challenges. Presently, SIOS is planning a dedicated workshop during our annual Polar Night Week (PNW-2021) to make sustained plans and strategy for the future. Our talk will highlight the summary of our activities conducted in response to Covid-19 and outcomes of our strategy workshop to define the strategy for the future. We hope that our practical services, experiences, and activities implemented in these difficult times will motivate other similar monitoring programs and observing systems to respond to future disruptions to research activity.

Merged Observatory Data for Arctic Air Temperature (MODAAT): Under the hood of an interoperable system to mobilize automated weather station data

Etienne Godin, Centre d'Études Nordiques, Université Laval, Québec, Canada
Warwick F. Vincent, Centre d'Études Nordiques et Département de Biologie, Université Laval, Québec, Canada

Keywords: Nordicana D, OpeNDAP, ERRDAP, CCADI, Air temperature

Merged Observatory Data for Arctic Air Temperature (MODAAT) is a test case within the Canadian Consortium for Arctic Data Interoperability (CCADI) and the IASC-project Terrestrial Multidisciplinary distributed Observatories for the Study of Arctic Connections (T-MOSAIC). This test case aims to facilitate the ethical discoverability and interoperability of Arctic data the 'FAIR' way. MODAAT is an effort to to mobilize air temperature data logged by weather station operators at the circumpolar scale between 2017 and 2020, often involving unpublished datasets or records with limited distribution. These records are of the utmost importance due to the sparsity of terrestrial stations in the Arctic - this entire region is a 'data desert', as reflected in the constraints on re-analysis models such as ERA5-Land. In this presentation we demonstrate how the data were collected from various sources and weather stations operators around the Arctic using a common metadata template, and then organized by way of a comprehensive, easily queryable, customizable system (ERDDAP). One challenge was to organize heterogeneous data sources due to the individuality of each submitted dataset, the variety of data field definitions and naming conventions. The mobilized air temperature data for the 4-year interval is set under an umbrella DOI, with each site-specific dataset assigned its own unique DOI, allowing rapid analysis of the time series at a particular site, and of differences among sites.

Streamlining disparate research data and analysis – The Ocean Acidification Use Case for the Canadian Consortium for Arctic Data Interoperability

Claire Herbert, Centre for Earth Observation Science, University of Manitoba, Winnipeg, MB
Tim Papakyriakou, Centre for Earth Observation Science, University of Manitoba, Winnipeg, MB
Peter Pulsifer, Carleton University, Ottawa, ON
Amos Hayes, Carleton University, Ottawa, ON
Rebecca Ingram, Carleton University, Ottawa, ON
Adam Stone, Carleton University, Ottawa, ON
Miyen-Ebi Victory Iyakoregha, Centre for Earth Observation Science, University of Manitoba, Winnipeg, MB
Gabrielle Alix, University of Waterloo, Waterloo, ON
Emmanuel Igbeinkutu, University of Waterloo, Waterloo, ON
Tahiana Ratsimbazafy, Université Laval, Quebec City, Quebec

Keywords: Carbonate System,Data Analysis,Ccadi,Ocean Acidification

As a member of the Canadian Consortium for Arctic Data Interoperability (CCADI), the Centre for Earth Observation Science (CEOS) through its data center, the Canadian Watershed Information Network (CanWIN), is working towards co-producing solutions for the ethical sharing of arctic research data. This takes the form of a distributed system of inter-related data nodes working together to develop, design and integrate foundational protocols, technologies and methods to share data and provide integration and analytical tools to a variety of audiences. Three use cases were developed as a component of CCADI, and CEOS leads Use Case 3 - an ocean acidification study. The inorganic carbon system that determines pH in Arctic waters is rapidly transforming under the influence of anthropogenic climate change associated with, among other things, rising carbon dioxide and temperature, changing distribution of sea ice, water mixing including increased inputs of freshwater from river run-off and melting glaciers. The current workflow from data collection to analysis requires significant time and effort to re-combine data associated with shipboard instrumentation and multiple lab analyzed samples. The resulting CO2 product is unwieldly and difficult for non-specialists and the broader community to use. This use case looked at simplifying and standardizing the processing and analysis of these datasets and developed tools to integrate additional data products (e.g. satellite data).

A new and simple protocol for data collection on permafrost thaw during the period of TMOSAiC (Terrestrial Multidisciplinary distributed Observatories for the Study of Arctic Connections)

Julia Boike, Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research (AWI), Telegrafenberg, Potsdam, Germany &Humboldt University Berlin, Geography Department, Unter den Linden 6, 10099 Berlin, Germany
Sarah Chadburn, University of Exeter, College of Engineering, Mathematics and Physical Sciences, Exeter, UK
Julia Martin, AWI & WSL Institute for Snow and Avalanche Research SLF, Flüelastrasse 11, Davos Dorf, Switzerland
Simon Zwieback, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska, USA
T-MOSAiC action group on permafrost

Keywords: Permafrost Degradation, Thaw Depth, Vegetation, Snow, Water Level, Soil

Climate change is destabilizing permafrost landscapes, leading to increased greenhouse gas emissions and changes in hydrology. Permafrost thaw is affected by surface and subsurface properties and processes, all of which are potentially linked with each other. Yet, no simple standardized protocol exists for measuring permafrost thaw and connected processes in a linked manner. Within the framework of the T-MOSAiC action group "permafrost thaw", we developed a protocol, which can be used by experts, non-specialists, and citizen scientists, to collect standardized data and metadata. Data on thaw depth are collected along transects across landscapes together with land surface and subsurface parameters of snow, vegetation, soil, and water level. A mobile, user-friendly App facilitates the data entry of field measurements and provides easy means for standardized data collection and documentation. We apply the Observation to Archives (O2A) dataflow framework which includes the comprehensive description and management of all data with metadata, central data storage and controlled data access. Through this new T-MOSAiC permafrost study protocol, we aim to standardize the documentation of climate change impacts on permafrost.

Building Globally Interoperable Data Infrastructure: contributions from the Arctic data community

Peter Pulsifer, Carleton University, Ottawa, Canada
Amos Hayes, Carleton University, Ottawa, Canada
Gabrielle Alix, University of Waterloo, Waterloo, Canada
Herman Anker, University of Waterloo, Waterloo, Canada
David Arthurs, Polar View, Ottawa, Canada
Nick Brown, Carleton University, Ottawa, Canada
Shannon Christoffersen, University of Calgary, Calgary, Canada
Byron Chu, Cybera, Calgary, Canada
Etienne Godin, Laval University, Quebec, Canada
Claire Herbert, University of Manitoba, Winnipeg, Canada
Emmanuel Igbeinkutu, University of Waterloo, Waterloo, Canada
Rebekah Ingram, Carleton University, Ottawa, Canada
Piers Kreps, Inuvialuit Regional Corporation, Inuvik, Canada
Tahiana Ratsimbazafy, Amundsen Science, Quebec, Canada
Ravi Sankar, University of Calgary, Calgary, Canada
Samir Sellars, Carleton University, Ottawa, Canada
Greg Vey, University of Waterloo, Waterloo, Canada
Graham Wilkes, Natural Resources Canada, Ottawa, Canada

Keywords: Data, Interoperability, Scientific Cooperation, Standards, Indigenous Knowledge

Polar data are required by the Arctic community to support research on a wide variety of topics and domains (physical, social, economic, etc.). Mobilizing and maximizing the value of Arctic data requires data infrastructure that can serve and mediate data for a wide range of different users and applications. Developing useful and usable infrastructure requires attention to system design and emergence at many different levels: foundational data storage, management, and preservation; methods and technologies for transforming and mediating data; representation and portrayal for different audiences; use of emerging technologies such as online platforms, machine learning, semantics, and natural language processing; ensuring respectful and ethical use of data and infrastructure. In this paper, we build on the activities and experiences of the international Arctic and polar data communities, primarily through the activities of the Arctic Data Committee, but including partnered initiatives with the Antarctic and broader global data communities. More specific examples and conclusions are drawn from the work of the Canadian Consortium on Arctic Data Interoperability. From these experiences, we share a number of lessons learned.

Communication and Knowledge Transfer in the Canadian Consortium for Arctic Data Interoperability (CCADI)

Rebekah R. Ingram, Carleton University, Ottawa, Canada

Keywords: Communication, Knowledge Translation, CCADI, Interoperability

Established in 2015, the Canadian Consortium for Arctic Data Interoperability (CCADI) is composed of Canadian Arctic scholars and data managers from several universities, non-profit partners, Canadian governmental agencies, and Indigenous organizations. The objective of the project is to make multiple types of data FAIR (Findable, Accessible, Interoperable, Reusable) through an online research platform in order to serve a large and diverse group of users. Thus, the overall goal of communication encompasses many different and inter-related facets, both human and non-human. The non-human component consists of machine interoperability of geomatic data, iconography, metadata and terminology, only some of which utilizes language. The human component includes intercommunication between team members, between users, and between people and machines. However, the human communication component must also reflect the diversity of backgrounds of team members in order to successfully complete the platform as well as anticipate the communication and data needs of potential users, including Indigenous and non-Indigenous community members, scientists, academics from different fields, technical developers and policy-makers. This paper will examine these different components of communication in the CCADI project and ultimately ask how we effectively transfer and translate knowledge between them.

Towards a collective vision for interoperable Canadian permafrost data management

Nick Brown, NSERC PermafrostNet, Ottawa, Canada
Stephan Gruber, NSERC PermafrostNet, Ottawa, Canada
Ashley Rudy, Northwest Territories Geological Survey, Yellowknife , Canada
Brendan O'Neil, Geological Survey of Canada, Ottawa, Canada
Sharon Smith, Geological Survey of Canada, Ottawa, Canada
Panya Lipovsky, Yukon Geological Survey, Whitehorse, Canada

Keywords: Permafrost, Data, Canada, Interoperability

Permafrost underlies over a third of the Canadian landmass. Much of this area will experience permafrost degradation leading to landscape changes, challenges for the design and maintenance of infrastructure, and threats to the health of northerners. However, support for the management of permafrost data has been relatively modest in Canada; most data holders identify a lack of resources as one of the biggest challenges they face in data management. The resulting reduced availability of data impedes adaptation efforts. Recently, The Geological Survey of Canada, the Northwest Territories Geological Survey and Yukon Geological Survey, have begun centralizing their permafrost data and developing web portals to facilitate access. Additionally, the creation of tools and prototype services to improve access to data is an aim of NSERC PermafrostNet, a Strategic Partnership Network for research, funded from 2019–2024. A workshop was held in May 2020 to identify challenges for those creating and accessing permafrost data and to form a vision for the future of Canadian permafrost data management. Overall, discoverability and access to standardized data remains a challenge. Good communication will be essential to ensure that data systems are not developed in isolation. An informal working group was established, bridging different levels of government and academia to coordinate the development of databases, and ensure interoperability between platforms.

Analysis of Arctic Data Center Metadata using FAIR Principles Shows Increased Quality across Multiple Metrics

Christopher W. Beltz, UC Santa Barbara, Santa Barbara, USA
S. Jeanette Clark, UC Santa Barbara, Santa Barbara, USA
Ted Habermann, Metadata Game Changers, Boulder, USA
Matthew B. Jones, UC Santa Barbara, Santa Barbara, USA
Peter Slaughter, UC Santa Barbara, Santa Barbara, USA

Keywords: FAIR, metadata, quality, metrics, repository

The Arctic Data Center, the main data and software repository for the Arctic section of the National Science Foundation Office of Polar Programs, implements automatic metadata quality analysis using the DataONE FAIR suite, originally developed by the MetaDIG Project. The suite checks 51 aspects of a dataset's metadata to evaluate the degree to which each metadata record aligns with FAIR data principles. All of the checks include an assessment of the presence, length, or resolvability of metadata content and return either PASS or FAIL. The checks are spread across each of the four FAIR categories and can be used to assess both the overall quality of the metadata, as well the quality within any single category. Analysis of the Arctic Data Center catalog indicates that the FAIR scores have continually improved since the repository's transition to management at NCEAS in March 2016. The data curation and submission processes have both played important roles in improving metadata quality throughout this time. Data curation improves the FAIR scores of metadata records from initial submission to final publication, and the ability of the data curation processes to improve metadata has increased over time. In addition, advances in the submission processes have led to more complete metadata in more recent submissions. These analyses highlight that both data curation and improvements to the submission system can increase the quality of metadata.

ESA CCI Permafrost continues ESA GlobPermafrost product visualization and publication using GIS and WebGIS technology

Antonie Haas, Alfred Wegener Institute Helmholtz Centre for Polar and Marine research, Bremerhaven, Germany
Birgit Heim, Alfred Wegener Institute Helmholtz Centre for Polar and Marine research, Potsdam, Germany
Annett Bartsch, b.geos, Korneuburg, Austria
Andreas Walter, Alfred Wegener Institute Helmholtz Centre for Polar and Marine research, Bremerhaven, Germany
Isabel Herrarte, Alfred Wegener Institute Helmholtz Centre for Polar and Marine research, Bremerhaven, Germany
Christian Schäfer-Neth, Alfred Wegener Institute Helmholtz Centre for Polar and Marine research, Bremerhaven, Germany
Frank Martin Seifert, ESA Centre for Earth Observation, Frascati, Italy

Keywords: Visualization, Webgis, ESA, Permafrost, Public

Providing permafrost monitoring products was focus of ESA DUE GlobPermafrost as well as it is of the ongoing ESA CCI+ Permafrost project. GlobPermafrost initially started to provide a broad spectrum of products as a service: Landsat trends, Arctic land cover, lake ice grounding, land surface deformation rock glacier velocities, spatially distributed permafrost model output (permafrost probability, ground temperature). With CCI+ Permafrost the continuity of the service is given and arises the opportunity to put another important variable in respect to climate change in focus: time. CCI+ Permafrost models data for mean annual ground temperatures, permafrost probability, and the active layer thickness for the Northern Hemisphere. Data products are available in a yearly resolution (1997-2018) or as average product of these years period. Providing these data products to the public is an essential part of the projects and realized by visualizing them using AWI WebGIS-technology via maps@awi. A newly Time Series WebGIS was established to visualize the new data products in an environmental context, time slider functionalities and descriptive information to the individual data product. maps@awi is a user-friendly tool for data visualization, exploration and intercomparison of data products and time slices. maps@awi is accessible via any web browser, and its user-friendliness improved by user-feedback received on several permafrost community workshops (e.g. AGU, EGU, conferences related to the International Permafrost Association IPA). Meanwhile, the GlobPermafrost and CCI+ Permafrost WebGIS became an official component of the IPA action group on “Specification of a Permafrost Reference Product in Succession of the IPA Map”.

Progress of the Russian Arctic Vegetation Archive (AVA-RU)

Vitalii Zemlianskii, University of Zurich, Department of Evolutionary Biology and Environmental Studies, Zurich, Switzerland
Ksenia Ermokhina, A.N. Severtsov Institute of Ecology and Evolution RAS, Moscow, Russia
Anna Lapina, Komarov Botanical Institute RAS, Saint Petersburg, Russia
Elena Troeva, Institute for Biological Problems of Cryolithozone RAS, Yakutsk, Russia
Natalia Koroleva, Polar-Alpine Botanical Garden RAS, Kirovsk, Russia
Maria Kurysheva, HSE Tikhonov Moscow Institute of Electronics and Mathematics, Moscow, Russia
Denis Korolev, HSE Tikhonov Moscow Institute of Electronics and Mathematics, Moscow, Russia
Gabriela Schaepman-Strub, University of Zurich, Department of Evolutionary Biology and Environmental Studies, Zurich, Switzerland

Keywords: Database, Russian Arctic, Tundra Vegetation

The Arctic Vegetation Archive (AVA) is an international effort to assemble circumpolar Arctic vegetation plot data into a publically accessible web-based archive. The goal of the AVA is to standardize vegetation data for the analysis of vegetation communities and their changes at pan-arctic scale. Data comprise vascular plant, bryophyte and lichen species, and abundance estimates following the Braun-Blanquet methodology, as well as environmental variables at the plot level. While many plot data of other parts of the Arctic are already standardized in the AVA format, the Russian section is now under rapid development. About 2500 West Siberian plots and relevés from NE European Russia were integrated in 2018. About 1200 plots with a wider geographical range were incorporated in 2019-2020, including relevés from Yakutia, Taymyr and Kola peninsula, Bolshezemelskaya tundra, and Severnaya Zemlya. An overview of integrated data is available at the AVA-RU website (http://avarus.space). 9 more datasets from Russian authors are indicated for potential integration to AVA in 2021 (incl. Svalbard, Polar Urals, Gydan and Yamal peninsula, and Wrangel island). These additions are filling important data gaps in Central and Eastern Siberia, and provide a better picture of the vegetation distribution and diversity of the Russian Arctic, which covers roughly a third of the terrestrial Arctic and is hence crucial to increase the understanding of the status and future of Arctic plant biodiversity.

QGreenland: Lessons from developing an open source Greenland GIS package

Twila Moon, University of Colorado, Boulder, USA
Trey Stafford, University of Colorado, Boulder, USA
Matt Fisher, University of Colorado, Boulder, USA
Lynne Harden, University of Colorado, Boulder, USA

Keywords: Greenland, GIS, Open Source, Data, Tool

Greenland, the world's largest island and home to ~57,000 people as well as one of Earth's major ice sheets, is undergoing rapid change. Attention on Greenland has increased in recent years. Simultaneously, many of the most vexing questions bridge multiple research disciplines and communities. For those newly arriving to Greenland-focused research or seeking to connect with other disciplines, it can be difficult to identify relevant data, understand its quality, and bring disparate data together for analysis. QGreenland, an NSF EarthCube-funded project, reduces this burden via a free Greenland GIS package for use on the open source QGIS platform. In early 2021, QGreenland v1.0.0 was released, along with supporting training materials. The package includes interdisciplinary data curated by an international Editorial Board and developed into a unified GIS environment for fully offline or optional online use. Open science is a QGreenland emphasis and we have established an open source system that other groups can leverage to create unique, independent data packages. Though we are still early in our project, we have already learned important lessons about collating wide-ranging data into a single analysis framework, and seek to share our experience, lessons learned, and continued challenges with others. By connecting with other data stewards, we hope to help inform continued evolution of the application of FAIR and CARE data principles in the context of subsequent data use.

Two decades of mooring data across the Canadian Arctic available through the ArcticNet and Amundsen Science program

Tahiana Ratsimbazafy, Amundsen Science, Quebec, Canada
Amélie Desmarais, Amundsen Science, Quebec, Canada
Thibaud Dezutter, Amundsen Science, Quebec, Canada
Anissa Merzouk, Amundsen Science, Quebec, Canada
Shawn Paul Meredyk, Amundsen Science, Quebec, Canada
Simon Morisset, Amundsen Science, Quebec, Canada
Forest Alexandre, Amundsen Science, Quebec, Canada

Keywords: Conductivity, Temperature, Depth, Moorings, Canadian Arctic

Environmental changes in the Arctic are acknowledged to be one of the most pervasive effects of Global Warming. Since 2003, the CCGS Amundsen collects oceanographic data across the Canadian Arctic to support national and international research through several major initiatives. These activities are managed by Amundsen Science, the organization responsible of the scientific mandate of the icebreaker. In addition to the data acquired with the ship itself, 177 oceanographic moorings were deployed over 12 regions to provide long-term time series of physical, chemical, and biological data over the last 17 years. Mooring deployed as part of various programs were equipped with multiple sensors and instruments such as ice profiling sonars, CTDs, ADCPs, current meters and sediment traps. The moorings are serviced annually by the Amundsen Science technical team with the support of the Canadian Coast Guard crew. Data are retrieved and sensors are redeployed to maintain measurements until the next year. These data are processed and made publicly available to the scientific community. A key role of Amundsen Science is to manage and promote the core datasets of the mooring programs. Here, we present the extent of the mooring database, covering nearly two decades of time series. In this poster, metadata and the breadth of oceanographic variables such as Water Temperature, Salinity, Current Velocity, Turbidity, Dissolved Oxygen and Fluorescence will be presented.

ID: 17 - The International Synoptic Arctic Survey (SAS) Activities

Conveners

Jacqueline M. Grebmeier | University of Maryland Center for Environmental Sciences, Chesapeake Biological Laboratory, Solomons, Maryland, USA

Oyvind Paasche | Bjerknes Centre for Climate Research and NORCE Climate, Bergen, Norway

Christina Goethel | University of Maryland Center for Environmental Sciences, Chesapeake Biological Laboratory, Solomons, Maryland, USA

Preliminary results of the R/V Mirai Arctic Ocean cruise in 2020

Shigeto Nishino, JAMSTEC, Yokosuka, Japan
Amane Fujiwara, JAMSTEC, Yokosuka, Japan
Motoyo Itoh, JAMSTEC, Yokosuka, Japan
Jonaotaro Onodera, JAMSTEC, Yokosuka, Japan
Akihiko Murata, JAMSTEC, Yokosuka, Japan
Takashi Kikuchi, JAMSTEC, Yokosuka, Japan

Keywords: Synoptic Arctic Survey, Pacific Arctic, R/V Mirai, Ocean Environmental Changes, Marine Ecosystem Changes

Since spatial and temporal variability is inherently large in the Arctic Ocean, we urgently need baseline data for the Arctic Ocean as a whole to prepare for the further changes to come. Critically needed understandings would be advanced from a coordinated multi-ship, multi-nation pan-Arctic ship-based sampling campaign, based on shared state-of-the-art protocols for data collections and sharing and carefully planned ship tracks during the same period. This could allow for a synoptic view of the totality of hydrographic and ecosystem changes taking place in the Arctic Ocean and facilitate advancing model development using integrated data sets to predict the future state of the Arctic. To obtain such baseline data, we have planned a pan-Arctic research program, the Synoptic Arctic Survey (SAS), with a goal of conducting it in 2020 and 2021. In 2020, under the SAS program, the Research Vessel (R/V) MIRAI conducted hydrographic and biogeochemical surveys, including plankton, microplastic, and bottom sediment samplings, from the Chukchi Sea shelf to marginal ice zones of the Canada Basin. We tried to recover a mooring off Pt. Barrow (but it was left there because of difficulties in dragging operations). Furthermore, a sediment trap was deployed in the Northwind Abyssal Plain, where is on the pathway of the Pacific-origin water, to monitor its transport and impact on marine ecosystem. In a marginal ice zone, we tried to use flying drones to assess the conditions of sea ice and waves (but they were cancelled due to bad weather). Various drifting buoys were launched to measure the ocean waves, currents, and temperature. In our presentation, we will show some preliminary results, for example, on the biological hotspot in the southern Chukchi Sea, aragonite super-corrosive water found near the sediment trap site in the northern Chukchi Sea, interannual variation in water masses and phytoplankton distributions over the Chukchi shelf slope, and submesoscale interdisciplinary observations in a marginal ice zone.

Understanding the behavior of water masses in the Chukchi Borderland from the observation and reanalysis data

Kyoung-Ho Cho, Korea Polar Research Institute, Incheon, Republic of Korea
Taewook Park, Korea Polar Research Institute, Incheon, Republic of Korea
Jaeill Yoo, Korea Polar Research Institute, Incheon, Republic of Korea
Jinyoung Jung, Korea Polar Research Institute, Incheon, Republic of Korea
Eun Jin Yang, Korea Polar Research Institute, Incheon, Republic of Korea
Sung-Ho Kang, Korea Polar Research Institute, Incheon, Republic of Korea

Keywords: Spatio-Temporal Variation, Water Mass Intrusion, Arctic Circulation Pattern

The water masses in the Chukchi Borderland (CB) of the Pacific Arctic region have complicated behaviors due to their variable pathways and correlated physical processes such as lateral intrusion, subduction, and isopycnal/diapycnal mixing. To understand their behaviors in CB, we have carried out hydrographic surveys since 2010. Especially during the summer of 2020, in spite of COVID-19 pandemic circumstance, we explorered 88 CTD stations from the Bering Strait to the Makarov Basin as a part of the Synoptic Arctic Survey (SAS) and the Pacific Arctic Climate Ecosystem Observatory (PACEO). The behaviors of water masses were mainly analyzed with absolute salinity (SA), conservative temperature (CT), and ocean current estimated from the observation data and model reanalysis data. We found that some water masses show interannual variations and intrusion induced by large circulation pattern. We will discuss on possible mechanisms which lead spatio-temporal variation of water mass distributions in the Chukchi Borderland and suggest the pathways of water masses in the Pacific Arcitic region.

The Swedish SAS-Oden expedition in 2021

Pauline Snoeijs-Leijonmalm, Stockholm University, Stockholm, Sweden
Maria Samuelsson, Swedish Polar Research Secretariat, Luleå, Sweden

Keywords: Synoptic Arctic Survey, Central Arctic Ocean, Ecosystem Research, Ice-Breaker Oden, Sweden

The Swedish SAS-Oden expedition, postponed by one year due to the Covid19 pandemic, is now scheduled for July-September 2021 – with Covid19 quarantines stipulated by the SPRS Medical Team. SAS-Oden will measure all SAS Core Parameters listed in the SAS Science plan. Icebreaker Oden will cover the area with the toughest Arctic ice conditions north of Greenland, and then follow the Lomonosov Ridge to the North Pole before turning south. The SAS-Oden preparatory work started by a SPRS Call for cruise participation, including three ARICE projects, and selection of the ideal set of projects that together would contribute most to SAS. Some of the projects include only SAS Core Parameters, but most projects deliver both SAS and project-specific parameters. Thus, SAS-Oden will cover a broad variety of ecosystem variables along the cruise track. Altogether, 39 scientists (7 physics, 11 chemistry, 2 geology, 19 biology) will carry out the field work in collaboration with 32 project participants on shore. While logistics, organisation and technical support are provided by the SPRS, the projects are expected to have their own funding. For laying the puzzle, the SPRS produces a living document, the "Scope of Work" (SoW), for its expeditions. This is a transparent document that in its final version constitutes a detailed science and implementation plan. Collaboration between the research projects is greatly enhanced by the SoW as synergies between projects can easily be identified.

Norwegian contributions to the Synoptic Arctic Survey on the RV Kronprins Haakon in 2021

Mats A. Granskog, Norwegian Polar Institute, Tromsø, Norway
Bodil Bluhm, UiT - The Arctic University of Norway, Tromsø, Norway
Agneta Fransson, Norwegian Polar Institute, Tromsø, Norway
Marit Reigstad, UiT - The Arctic University of Norway, Tromsø, Norway

Keywords: Synoptic Arctic Survey, Norway, RV Kronprins Haakon, Nansen Legacy, Fram Strait Arctic Outflow Observatory

Two Norwegian programs that operate in ice covered Arctic waters: the Norwegian Polar Institute's long-term climate monitoring program in the Fram Strait and the Nansen Legacy (NL) project, a 6-year holistic research project that provides integrated scientific knowledge on the marine climate and ecosystem in the northern Barents Sea, will contribute to the Synoptic Arctic Survey on the icebreaking RV Kronprins Haakon. The primary goal of the Fram Strait expedition in Aug 2021 (FS2021) is to characterize sea ice and ocean climate in the Arctic outflow with the East Greenland current, this includes for example, sea ice thickness, physical oceanography and chemical oceanography (including water mass tracers and ocean acidification). The primary aim of the NL cruise planned for late Aug-late Sept 2021 is to extend the holistic understanding of functioning of the northern Barents Sea ecosystem beyond the continental slope northward into the Nansen Basin and across the Gakkel Ridge into the Amundsen Basin. Priority will be given to measurements of physical, chemical and biological processes and conditions that allow a comparison with the northern Barents Sea, but also to understand the conditions in the deep basin itself. In the long-term, both efforts aim to integrate with other SAS cruises for true synoptic data sets. We will present an overview of the planned activities on these two expeditions on RV Kronprins Haakon that will contribute to the SAS program in 2021.

Taking the Pulse of the Arctic Ocean System, from the Shelves to the Pole – A US Contribution to the International Synoptic Arctic Survey

Carin Ashjian, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts USA
Jacqueline Grebmeier, University of Maryland Center for Environmental Science, Solomons, Maryland, USA
Nicolas Bates, Bermuda Institute of Ocean Sciences, St. George's, Bermuda
Robert Campbell, University of Rhode Island, Narragansett, Rhode Island, USA
Lee Cooper, University of Maryland Center for Environmental Science, Solomons, Maryland, USA
Seth Danielson, University of Alaska, Fairbanks, Alaska, USA
Lauren Juranek, Oregon State University, Corvallis, Oregon, USA
Cynthia Pilskaln, University of Massachusetts Dartmouth, New Bedford, Massachusetts, USA
Mary-Louise Timmermans, Yale University, New Haven, Connecticut, USA

Keywords: SAS, Ecosystem, Physics, Biogeochemistry, Linkages

The Central Arctic Ocean is expected to experience marked changes over the next decades, driven by climate warming. Yet, limited data precludes reliably predicting these changes and their Pan-Arctic linkages. The US proposed contribution to the international Synoptic Arctic Survey (SAS) seeks to quantify the present states of the physical, biological, and biogeochemical systems of the Pacific and Canadian Arctic during summer 2022. A core proposal was submitted by the US SAS Science Steering Committee to the US National Science Foundation to lead a cruise on which focused research hypotheses that fall under the broader SAS questions and that will directly and immediately advance our basic understanding of the Arctic system while also providing data that will contribute to the broader SAS objectives would be addressed. The proposed work would describe the present state of the system, quantify changes over the past several decades through comparison with historic data, and identify linkages between the adjacent shelves, slopes, and deep basins. The proposal also seeks to establish a small coordination office to facilitate coordination of US project components and of synergies with international research activities and to encourage and recruit additional US complementary proposals to join the project. The proposed hyptheses and work will be outlined so that complementary scientific efforts and opportunities for additional science teams to join the cruise can be identified.

The multidisciplinary expedition "Open Ocean: Arctic Archipelagoes – 2019. Severnaya Zemlya" (O2A2-2019)

Maria V. Gavrilo, Association Maritime Heritage, St. Petersburg, Russia
Vassily A. Spiridonov, Shirshov Institute of Oceanology of Russian Academy of Sciences, Moscow, Russia
Ksenia N. Kosobokova, Shirshov Institute of Oceanology of Russian Academy of Sciences, Moscow, Russia
Fedor A. Romanenko, Lomonosov Moscow State University, Moscow, Russia
Andrei B. Krasheninnikov, Institute of Biological Problems the North of Russian Academy of Sciences, Magadan, Russia
Alexei V. Ezhov, Murmansk Marine Biological Institute of Russian Academy of Sciences, Murmansk, Russia
Alexander B. Basin, Shirshov Institute of Oceanology of Russian Academy of Sciences, Moscow, Russia
Vitaly L. Syomin, Shirshov Institute of Oceanology of Russian Academy of Sciences, Moscow, Russia
Alisa V. Baranskaya, Lomonosov Moscow State University, Moscow, Russia
Ali R. Alayutdinov, Lomonosov Moscow State University, Moscow, Russia
Nikolai N. Lugovoi, Lomonosov Moscow State University, Moscow, Russia
Sergei V. Golubev, Association Maritime Heritage, St. Petersburg, Russia
Alexander S. Solomatov, Northern Administration of Hydrometeorological Service, Arkhangelsk, Russia

Keywords: Arctic, Expedition Study, Marine Biodiversity, Coastal Ecosystems

The multidisciplinary expedition O2A2-2019 aboard R/V Professor Molchanov (16.08–18.09.2019) carried out for the first time a comprehensive survey of the Severnaya Zemlya Archipelago (SZA) coastal zone. Hydrobiology included water column profiling, sediment sampling for granulometry and organic carbon, sampling for plankton, zoobenthos, macroalgae, microphytobenthos. Divers conducted video recording and benthos sampling. In total, 55 stations were performed (34 shipboard, 13 coastal, 7 scuba-dives, 1 from a boat). Zoology included ship-based seabird and marine mammal surveys, land bird surveys, seabird colony counts, sampling for toxicology, genetics, parasitology. Freshwater & terrestrial studies: water and sediment sampling for chemistry, plankton, benthos, microbiota. In total, 13 objects were surveyed (5 lakes, 3 rivers, 3 streams), insects, vascular plants, mosses, lichens, macrofungi collected. Geomorphology & palaeogeography included geomorphological profiling, geodesic surveys, drone-based mapping, sampling for stable isotopes, geochronology, lithology, microfauna. In total, 160 km traversed at 21 land sites, over 200 samples collected. Our expedition provided a baseline data on biological and landscape diversity of SZA. The results obtained allowed to evaluate the SZA coastal zone as holistic ecosystem which can be rated as a high-Arctic core area with habitat and biodiversity, almost unaffected by human impact, and where Arctic biota undergoes natural evolution.

Long term variability of Barrow Canyon fluxes and its impact on subsurface warming in the western Arctic Ocean

Motoyo Itoh, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokosuka, Japan
Takashi Kikuchi, JAMSTEC, Yokosuka, Japan
Shigeto Nishino, JAMSTEC, Yokosuka, Japan

Keywords: Seawater Warming, Sea Ice Reduction, Chukchi Sea, Canada Basin

Over the past few decades, sea ice retreat during summer has been particularly pronounced in the western Arctic Ocean. Pacific-origin water from the Bering Strait which is predominant heat source in the western Arctic Ocean has recently increased. Thus, temperature of subsurface water that is mainly composed by Pacific Summer Water (PSW) has increased since 1990s. However, details of distributions and properties of PSW in the whole western Arctic Ocean and their year to year variabilities are still unclear. Barrow Canyon, in the northeast Chukchi Sea, is a major conduit through which the PSW enters the Arctic Basins. We have conducted year-round mooring observations since 2000 in the Barrow Canyon to monitor interannual variabilities of PSW flux. Annual averaged heat fluxes after 2015 were much higher than the historical mean, due to high temperature of PSW. Anomalous high temperature of PSW was observed in summer 2019 in the Barrow Canyon. These warm events will be related to enhancement of summer sea ice retreat in the Chukchi Sea. R/V Mirai will conduct hydrographic observation in the Chukchi Sea and Canada Basin and moorings turn-around in the Barrow Canyon in 2021. Synoptic pan-Arctic hydrographic observations under the Synoptic Arctic Survey (SAS) project and time series of PSW at the gateway into the basin will be effective to understand distributions and properties of PSW in the whole Arctic Ocean and impacts on subsurface water in the Arctic Basins.

Long-term variability of carbonate parameters of the surface and bottom layers of the Kara sea

Julia Pronina, Shirshov Institute of Oceanology RAS, Moscow, Russia
Alexander Polukhin, Shirshov Institute of Oceanology RAS, Moscow, Russia
Svetlana Stepanova, Shirshov Institute of Oceanology RAS, Moscow, Russia

Keywords: Climate Change, Carbon Cycling, Pan-Arctic, Acidification

The aim of the study is to assess the relationship of climate changes in the Arctic (water temperature T and river runoff) with variability of carbonate parameters (pH, total alkalinity AT, aragonite saturation ?Ar) in the surface and bottom layers of the Kara sea. We used archived (1930 – 1979) and modern (1993 – 2016) data received in the Shirshov Institute expeditions to the Kara Sea. One of the main factors determining the structure of the Kara sea waters is the incoming continental runoff, which volume is permanently increasing. The results of the study show an increase in the average annual values of T in the surface (by 2 – 4 oC) and bottom layers of the Kara sea (by 0.5 – 0.6 oC). An increase of AT up to 3 – 7 % were detected only in the riverine plume. A decrease of pH and ?Ar of the Kara sea is observed both in the plume and in the ambient sea water. Since 1930s, in the surface layer (0 – 20 m) the annual average values of pH have decreased by 0.20 – 0.21 and ?Ar by 0.36 - 0.38 (23 – 28 %). In the bottom layer pH decreased by 0.08 – 0.10 and OAr by 0.12 – 0.13 (11 – 12%). The acidification of the bottom layer of the Kara sea is higher than in the surface layer. However, pH decreases in the surface layer in 2 – 2.5 times faster than in the bottom layer and ?Ar almost 3 times faster. This work was supported by the State Agreement of Shirshov Institute (theme ?0128-2019-0008) and by the President grant MK-860.2020.5.

Observation Plan of the R/V MiraiArctic Ocean Cruise in 2021

Amane Fujiwara, JAMSTEC, Japan
Shigeto Nishino, JAMSTEC, Japan
Motoyo Itoh, JAMSTEC, Japan
Jonaotaro Onodera, JAMSTEC, Japan
Akihiko Murata, JAMSTEC, Japan
Eiji Watanabe, JAMSTEC, Japan
KikuchiTakashi, JAMSTEC, Japan

Keywords: Pacific Arctic Region, Synoptic Arctic Survey, Hydrography, Biogeochemical Cycles

The Arctic Ocean is the area with the fastest rate of global oceanic warming in the world. The detailed research of the Research Vessel (R/V) MIRAI has been held to document the impact of inflow of the Pacific origin water on Arctic sea ice decrease and the marine ecosystem, which is known as important sources of heat, nutrients, fresh water for the Arctic Ocean. In 2021, the R/V MIRAI will conduct hydrographic and biogeochemical surveys, including plankton, microplastic, and bottom sediment samplings, from the Chukchi Sea shelf to marginal ice zones of the Canada Basin. Moorings and a sediment trap will be deployed on the pathway of the Pacific-origin water to monitor its transport and impact on marine ecosystem. In marginal ice zones, we will approach to sea-ice floes using a small working boat to measure marine environments by various sensors and to collect water, sea ice, plankton, and microplastic samples. An underwater drone will be launched from an ice-edge to ice-covered areas. A Remotely Operated Vehicle (ROV) will be deployed to film gelatinous zooplankton in the water. Some flying drones will be used to assess the conditions of sea ice and waves. Various drifting buoys will be launched to measure the ocean waves, currents, and temperature.

ID: 101 - Sea, lake and river ice monitoring and modelling

Conveners

Hyun-Cheol Kim | Korea Polar Research Institute

Seung Hee Kim | Korea Polar Research Institute

Shawn Marshall | University of Calgary and Environment and Climate Change Canada

Homa Kheyrollah Pour | Department of Geography & Environmental Studies, Cold Regions Research Centre, Wilfrid Laurier University, Ontario, Canada

First results of the L-band ARIEL radiometer measurement during the MOSAIC expedition

Carolina Gabarró, BEC, ICM-CSIC, Spain
Joaquin Salvador, ICM-CSIC, Spain
Roger Jove-Casulleras, Balamis, Spain
Pau Fabregat, UPC, Spain
Gunnar Spreen, U. Bremen, Germany
Luisa von Albedyll, AWI, Germany
Amy Macfarlane,WSL Institute for Snow and Avalanche Research SLF, Switzerland
Lina Thielke , U. Bremen, Germany

Keywords: MOSAIC, L-band Radiometry, Emissivity, Sea Ice, SMOS

The MOSAiC expedition (September 2019 – October 2020) offered a great opportunity to review the performance of different emissivity models for Arctic sea ice and snow. Thanks to the funded ICE-MOD project (PCI-AEI) we deployed a portable dual polarization L-band (1.4GHz) radiometer (ARIEL from the BALAMIS company)on the sea ice. Data was acquired by performing long transits which enabled us to measure different ice types and snow conditions at different times throughout of the year. In addition, ARIEL was measuring in close vicinity to other radiometers and scatterometers, all observing the same area of snow and ice. In addition, ARIEL radiometric data was acquired simultaneously to other in-situ measurements to characterize the ice and snow, e.g. ice thickness from GEM surveys, snow depth and snow characteristics from magnaprobe and snow pits, and infrared properties from infrared cameras. These measurements enable us to study the dependence of the radiometric measurements to different types of ice and snow surfaces, as well as to derive new improved emissivity models at 1.4GHz. That will be important to improve the quality of the ESA SMOS Sea ice thickness estimatesof thin sea ice, which is complementary to the Altimeter sea ice thickness measurements which can only measure thick ice with acceptable quality. The sensitivity analysis of the emissivity to different snow and ice conditions is presented.

Fresh Eyes on Ice: Connecting Arctic Communities through a Revitalized and Modernized Freshwater Ice Observation Network

Chris Arp, University of Alaska Fairbanks, Fairbanks, USA
Dana Brown, University of Alaska Fairbanks, Fairbanks, USA
Laura Oxtoby, University of Alaska Fairbanks, Fairbanks, USA
Katie Spellman, University of Alaska Fairbanks, Fairbanks, USA
Karin Bodony, U.S. Fish and Wildlife Service, Galena, USA
Allen Bondurant, University of Alaska Fairbanks, Fairbanks, USA
Sarah Clement, University of Alaska Fairbanks, Fairbanks, USA
Melanie Engram, University of Alaska Fairbanks, Fairbanks, USA
Peter Webley, University of Alaska Fairbanks, Fairbanks, USA

Keywords: Rivers, Lakes, Ice, Observation Networks, Community-Based Monitoring, Ob

Snow and ice are essential parts of life in cold places, and northern peoples observe, understand, and appreciate how these change every year. Wide-scale observations of freshwater ice, and how its presence and extent are changing, are a fundamental need for a broad range of people, from rural communities that depend on ice for transportation and subsistence, to industries that rely on winter ice roads, to scientists studying climate change and ecosystem services. The Fresh Eyes on Ice observation network collects data across Alaska using satellite and aerial observations, monitoring stations, and field campaigns—all integrated with a partnership of community-based scientists and K-12 students and teachers. We are currently partnering with 12 communities in western, interior, and northern Alaska to make ice observations, while at the same time providing STEM education opportunities. Citizen photographic observations of river and lake freeze-up and break-up and hazardous open-water or overflow zones are regularly shared through social media and a new Ice Observer Portal, and these observations help to inform recreationalists, subsistence users, forecasters, and scientists of ice conditions. In addition to collecting freshly observed river and lake data, Fresh Eyes on Ice is also working to revitalize, archive, and analyze historic datasets of interest to understand changing conditions in Alaska and other northern regions where freshwater ice still dominates winters.

Remote Sensing of Sea Ice on the MOSAiC Ice Floe

Gunnar Spreen, University of Bremen, Institute of Environmental Physics, Germany
Estell Cardellach, Instituto de Ciencias del Espacio (ICE-CSIC/IEEC), Spain
Tânia Casal, European Space Agency (ESA), ESTEC, Netherlands
Oguz Demir, The Ohio State University, ElectroScience Laboratory, USA
Claude R. Duguay, University of Waterloo, Canada
Carolina Gabarró, Institut de Ciències del Mar (CSIC), Spain
Stefan Hendricks, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Germany
Marcus Huntemann, University of Bremen, Institute of Environmental Physics, Germany
Joel T. Johnson, The Ohio State University, ElectroScience Laboratory, USA
Roger Jove-Casulleras, BALAM Ingenieria de Sistemas, Spain
Lars Kaleschke, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Germany
Felix Linhardt, Kiel University (CAU), Germany
Malik S. Mahmud, University of Calgary, Canada
Reza Naderpour, Swiss Federal Institute WSL, Switzerland
Vishnu Nandan, University of Manitoba, Canada
Robert Ricker, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Germany
Steen Savstrup Kristensen, Technical University of Denmark (DTU), Denmark
Randy Scharien, University of Victoria, Canada
Mike Schwank, Swiss Federal Institute WSL, Switzerland
Maximilian Semmling, German Aerospace Center DLR, Institute for Solar-Terrestrial Physics, Germany
Julienne Stroeve, University College London (UCL), UK
Aikaterini Tavri, University of Victoria, Canada
Linda Thielke, University of Bremen, Institute of Environmental Physics, Germany
Rasmus T. Tonboe, Danish Meteorological Institute, Denmark
Luisa von Albedyll, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Germany
Wei Wan, Peking University, China
John Yackel, University of Calgary, Canada

Keywords: Sea Ice, Remote Sensing, MOSAiC, Satellites, Arctic

During the one-year long MOSAiC drift expedition several remote sensing instruments designed for observing the sea ice and its snow cover were installed on the ice floe next to Polarstern and on the vessel itself. This allowed the monitoring of the freeze-up to melt onset cycle and different ice types with the suite of instruments. Satellite measurements constitute a few of the most important climate data records for polar regions. The MOSAiC experiments will help to improve their quality and better assess their uncertainties. In particular the following measurements were performed during MOSAiC: (i) 0.5-89 GHz microwave radiometers, (ii) L to Ka-band microwave radar scatterometers, (iii) reflected GNSS measurements, and (iv) infrared, visual, and hyperspectral cameras. The instruments on the ice floe were oriented to observe similar snow and ice conditions. The remote sensing measurements were accompanied by extensive measurements of snow and ice properties. By having these coincident multi-frequency remote sensing and in-situ observations and as well the environmental conditions measured by other MOSAiC teams, factors influencing the emission, reflection, and scattering of microwaves in sea ice and snow can be better understood so that new remote sensing methods can be developed and contribute to new and upcoming satellite missions. Here we will present an overview of the measurement program and first results from simultaneously measuring instruments.

Sea ice type separability during melt conditions using C-band frequency compact-polarimetric synthetic aperture radar data

Aikaterini Tavri, University of Victoria, Victoria, Canada
Randall Scharien, University of Victoria, Victoria, Canada

Keywords: Sea Ice, SAR, RCM, Melt

The Arctic region sea ice extent has been rapidly decreasing in recent years, though the regional scale response to warming is more uncertain in terms of ice conditions experienced during the spring-summer period. Satellite synthetic aperture radar (SAR) at C-band frequency plays a key role in observing ice conditions, however image interpretation is complicated by variable melt conditions and radar signal masking by surface melt water. This work aims to enhance sea ice melt stage detection and ice type discrimination during melting conditions using compact polarimetric (CP) SAR data. CP parameters are simulated from polarimetric RADARSAT-2 data collected from the Canadian Arctic Archipelago (CAA) region. An optimal set of simulated CP parameters is determined for sea ice melt stage and ice type discrimination. This is done by ranking parameters according to a measure of statistical separability, while parameter correlation and mutual information analysis will eliminate parameter redundancy. Subsequently, this study is extended to include a preliminary assessment of CP parameters from the RADARSAT Constellation Mission (RCM) data collected during melt conditions as part of the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition. RCM is a constellation of three identical satellites operating on the same orbital plane. It provides wide area and rapid revisit data of sea ice conditions at a nominal 50m spatial resolution.

High Arctic lakes through the seasons: Under-ice limnology and instrument deployment to study the effect of ice phenology on freshwater biogeochemical dynamics

Yohanna Klanten, Université Laval, Québec, Canada
Katherine Triglav, Université Laval, Québec, Canada
Derek Muir, Centre canadien des eaux intérieures, Burlington, Canada
Xiowa Wang, Centre canadien des eaux intérieures, Burlington, Canada
Warwick F. Vincent, Université Laval, Québec, Canada
Dermot Antoniades, Université Laval, Québec, Canada

Keywords: Lake Ice, Oxygen Depletion, Climate Change, Ice Phenology, Water Column Gradients

The northern coast of Ellesmere Island is a fast-changing region where the Canadian Arctic Archipelago meets the Arctic Ocean ice pack. Regional lake ice cover dynamics have already changed in response to warming. However, the effect of these changes on biogeochemical conditions is poorly understood since there are few data from High Arctic freshwaters, and those are mostly limited to the short, ice-free period. Before the onset of spring melting in 2017, 2018 and 2019, we sampled four coastal lakes located in Stuckberry Valley (82°54' N, 66°56' W), which is among the northernmost terrestrial ecosystems on the planet, and adjacent to the 'Last Ice Area' of thickest ice in the Arctic Ocean. Our studies, including physicochemical profiles, water chemistry and photosynthetic pigments, revealed a surprising diversity of limnological conditions. Two shallow lakes were oxygen deficient beneath the ice, while two deeper lakes had mostly oxygenated water columns. Pronounced vertical gradients in major ions, metals and nutrients in the shallower lakes also suggested substantial anaerobic microbial processes under ice. In order to better understand annual cycles in the lake water columns, we installed moorings with oxygen, temperature, and conductivity probes in each lake ecosystem type. The data recorded over two years (June 2019 to August 2021) will help understand the interplay of warming climates, ice phenology, mixing regimes and anoxia in high latitude lakes.

Observing sea ice using scatterometers onboard MetOp/ASCATs series and CFOSAT scatterometer data

Ifremer, LOPS, CNRS, IRD, Univ.Brest, Brest, France

Keywords: Sea Ice, Satellite, Arctic, INTAROS Project

Microwave sensors onboard polar orbit satellites are commonly used for sea ice monitoring at high latitude : radiometers are routinely used for this application and scatterometers have also shown they can contribute significantly to it. Since 1991, numerous scatterometers data at C and Ku-bands are available. Here, we will show how the ASCAT sensors could be used jointly to build a data time series for sea ice monitoring for both Arctic and Antarctic areas. Backscatter data enable to discriminate sea ice from open ocean areas. Results of C-band and Ku-band sensors results will be presented. Moreover, sea ice displacement maps can be built in central Arctic from backscatter data. This presentation will enhance the need of scatterometer data for sea ice application with examples of inferred parameters, the need of the continuity of scatterometers missions and benefit of the combination of sensors (scatterometers, scatterometers with radiometers) for a long-term observation of the polar areas. Moreover Ifremer is involved in the calibration/validation of CFOSAT data, scatterometer data over the poles will be presented. The qualified data are routinely processed at IFREMER/CERSAT and available for the scientific community. They provide an exceptional basis for future analysis and synthesis of long-term variations of the sea ice in the polar areas. They are available through the CERSAT, they are also part of the H2020 INTAROS iAOOS system of systems of Arctic data.

Northern Lakes Under Global Environmental Pressures

Homa Kheyrollah Pour, Department of Geography and Environmental Studies, Wilfrid Laurier University, Waterloo

Keywords: Climate Change, Lake Ice, Remote Sensing, Water Quality, Numerical Modeling

Lakes, particularly those in cold regions, are vulnerable to a range of environmental pressures that are being exacerbated by climate change. A clear understanding of the future trajectories of these lakes is of crucial importance to the communities that depend on them for their livelihood, but in many cases meaningful predictions are constrained by limited spatial and temporal coverage of field observations and monitoring programs, and by inadequate knowledge of in-lake processes and their resilience to changing external drivers. We are currently studying the physical and biogeochemical processes and dynamics of Northern Lakes. Our research goal is to 1) understand past, present, and projection of lake ice phenology and thickness, 2) investigate the interplay between ice condition variability and lake water attributes, and 3) characterization and projection of lake ice subsurface-surface-atmosphere interaction and exchange processes in a changing climate using advanced remote sensing techniques. Our ultimate goal, however, is to develop transferable approaches for predicting the sensitivity and vulnerability of cold regions' lakes to changes in climate. Using a combination of field observational and remote sensing data series, and statistical and mechanistic modeling, we capitalize on our ongoing work on northern lake ice to develop a roadmap for predictively assessing the coupled hydrodynamic-biogeochemical evolution of large cold regions' lakes worldwide.

ID: 60 - Integrating Arctic observing systems – results from the H2020 INTAROS project

Conveners

Stein Sandven | Nansen Environmental and Remote Sensing Center

Alexandra Touzeau | University of Bergen

Roberta Pirazzini | Finnish Meteorological Institute

Exploitation of existing observing systems

Roberta Pirazzini, Finnish Meteorological Institute, Helsinki, Finland
Michael Tjernström, Stockholm University, Stockholm, Sweden
Peter Thorne, National University of Ireland Maynooth, Maynooth, Ireland
Andreas Ahlstrøm, Geological Survey of Denmark and Greenland, Copenhagen, Denmark
David Gustafsson, Swedish Meteorological and Hydrological Institute, Norrköping, Sweden

Keywords: Gap Analysis, Maturity, Observing Systems, Roadmap

The main objectives of the INTAROS Working Package 2 “Exploitation of existing observing systems” were 1) to perform a gap analysis and maturity assessment of the existing Arctic observing systems and 2) to enhance the quality and accessibility of existing Arctic data. The accomplishment of these two objectives is the pre-requisite for the development and optimization of an integrated Arctic Observing system. In this presentation we will focus on the highlights from the Work Package and provide a synthesis of results. We will also provide information about and lessons learned from our work and implications for future observational strategy. For instance, we will address the relevance of multidisciplinary supersites at low spatial density versus distributed, focused networks at higher spatial density in the marine and terrestrial Arctic for different applications. Sustained observations enabling the generation of climate time series is an absolute imperative, which should be possible to achieve with a revision of the funding mechanisms and a more direct involvement of the private sector. Finally, different challenges for infrastructures over the marine and terrestrial Arctic call for different technological solutions and optimization strategies. This Work Package will provide input to the INTAROS roadmap and will contribute to the SAON’s Roadmap for Arctic Observing and Data Systems (ROADS).

Demonstrating applications of an Integrated Arctic Observing System towards selected, diverse stakeholder groups

Geir Ottersen, Institute of Marine Research, Oslo, Norway
Mikael Sejr, Aarhus University, Silkeborg, Denmark
Tim Kruschke, Swedish Meteorological and Hydrological Institute, Norrköping, Sweden
Gro van der Meeren, Institute of Marine Research, Bergen, Norway
Hanne Sagen, Nansen Environmental and Remote Sensing Center, Bergen, Norway
Anne M. Solgaard, Geological Survey of Denmark and Greenland, Copenhagen, Denmark
Mathias Göckede, Max Planck Institute for Biogeochemistry, Jena, Germany
Finn Danielsen, Nordic Agency for Development and Ecology, Copenhagen, Denmark
Marie Maar, Aarhus University, Roskilde, Denmark

Keywords: Observations, Model, Pilot Study, Arctic Roadmap, Stakeholders

The overall objective of INTAROS is to build an efficient and sustainable integrated Arctic Observation System (iAOS) by extending, improving and unifying existing systems. An important part of this is the work done in INTAROS' WP6 to demonstrate application of the iAOS by delivering a suite of products targeted at issues of societal importance. These pilot applications will demonstrate services towards end-users. WP6 will show the iAOS' capability for advancing the economic role of the Arctic by providing support for better-documented processes and better-informed decisions within key sectors such as shipping, petroleum, fishing, and tourism. Further, WP6 aims to demonstrate how the iAOS may be applied to develop the accuracy of climate models, improve the understanding of biogeochemical cycles and ecosystem functioning, enhance fisheries and environmental management, increase the level of preparedness towards natural hazards, and develop better management and decision making concepts for selected local communities. Concrete demonstrations include for heavy snow precipitation on Svalbard, hydrographic data in the Barents Sea, trawl data on fish off Greenland, and modelling of large-scale fresh-water flow. In this presentation we will focus on the Highlights from WP6 and provide a Synthesis of results. We will also provide information about and lessons learned from our work and implication for future work. WP6 will provide input to the INTAROS roadmap.

Enhancement of in situ observing systems in the Arctic

Agnieszka Beszczynska-Möller, Institute of Oceanology PAS, Sopot, Poland
Andreas Ahlstrøm, Geological Survey of Denmark and Greenland, Copenhagen, Denmark
Peter Voss, Geological Survey of Denmark and Greenland, Copenhagen, Denmark
Truls Johannessen, University of Bergen, Geophysical Institute, Bergen, Norway
Hanne Sagen, Nansen Environmental and Remote Sensing Center, Bergen, Norway
Thomas Soltwedel, Alfred Wegener Institute Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
Mathias Göckede, Max Planck Institute for Biogeochemistry, Jena, Germany

Keywords: Arctic, In Situ Observations, Key Arctic Variables, Observing Technologies

The main goal of the INTAROS WP3 “Enhancement of in situ observing systems in the Arctic“ was to increase the temporal and geographic coverage of sustained observations and add new key geophysical and biogeochemical variables in selected regions of the Arctic. By using a combination of mature and new technologies integrated with existing observing infrastructure, INTAROS aimed to fill selected gaps in the present-day system. New observations were implemented in three reference sites: Costal Greenland, paramount for freshwater output from the Greenland ice sheet; North of Svalbard - the hot-spot for ocean-air-ice interactions and heat input to the European Arctic; and Fram Strait - the critical gateway for exchanges between the Arctic and the World oceans. Two distributed observing systems: for ocean and sea ice and for terrestrial and atmospheric measurements were augmented with new multidisciplinary measurements. In this presentation we will focus on the highlights from WP3 and provide a synthesis of technical development, system integration and design, and implementation of new observing assets, carried out during two INTAROS field seasons (2018-2019 and 2019-2020) at the reference sites and distributed systems. We will also address the lessons learned from the design and implementation of new observations and implications for future work. WP3 will provide input to the INTAROS roadmap and contribute to the SAON’s Roadmap for Arctic Observing and Data Systems (ROADS).

Acoustic networks - in an Integrated Arctic Ocean Observing System

Hanne Sagen, Environmental and Remote Sensing Center, Bergen, Norway
Matthew A. Dzieciuch, Scripps Institution of Oceanography, University of California, San Diego, USA
Peter F. Worcester, Scripps Institution of Oceanography, University of California, San Diego, USA
Espen Storheim, Environmental and Remote Sensing Center, Bergen, Norway
Florian Geyer, Environmental and Remote Sensing Center, Bergen, Norway
Stein Sandven, Environmental and Remote Sensing Center, Bergen, Norway

Keywords: Arctic Ocean Observing System, UN Ocean, OceanObs2019, Acoustic Networks

The United Nations have dedicated the next decade to achieve sustainable development goal number 14 (SDG14): 'Conserve and sustainably use the ocean, seas and marine resources for sustainable development'. Existing ocean research and observing systems must be sustained and improved significantly to achieve this. To improve the Arctic Ocean Observing capability OceanObs19 recommended 'to pilot a sustained multipurpose acoustic network for positioning, tomography, passive acoustics, and communication in an integrated Arctic Observing System, with eventual transition to global coverage'. The overarching aim of an Arctic Multipurpose Acoustic Network is to improve the Arctic Ocean Observation System, and sustain long-term observations of ocean and sea ice variables in the central Arctic. The Coordinated Arctic Acoustic Thermometry Experiment CAATEX deployed and recovered six moorings spaced across the Arctic Ocean equipped for multi-disciplinary ice-ocean observations (https://caatex.nersc.no/). CAATEX is a first step towards a basin wide multipurpose acoustic system for thermometry, underwater geo-positioning system (UW-GPS), and monitoring of ocean sound. CAATEX is a one-year experiment but is seen as a forerunner for a sustained Pan Arctic Acoustic Observation Network. This presentation will focus on our experiences in CAATEX and the role of acoustic networks in the future integrated Arctic Ocean Observing System.

Monitoring of an Arctic underwater soundscape (Kongsfjorden, Svalbard) and impact of shipping noise (INTAROS Project)

Gaëtan Richard, Institut Universitaire Européen de la Mer, CNRS (UMS3113), Technopôle Brest Iroise rue Dumont d'Urville, Plouzane
Delphine Mathias, SOMME, Brest
Julien Bonnel, Woods Hole Oceanographic Institution, Applied Ocean Physics and Engineering department, MA, USA
Erwan Amice, Institut Universitaire Européen de la Mer, CNRS (UMS3113), Technopôle Brest Iroise rue Dumont d'Urville, Plouzane
Laurent Chauvaud, Institut Universitaire Européen de la Mer, CNRS (UMS3113), Technopôle Brest Iroise rue Dumont d'Urville, Plouzane

Keywords: Soundscape, Anthropogenic Impact, Shipping Noise, Long Term Monitoring

Anthropogenic underwater noise has been a growing issue in Arctic waters with the decrease of sea ice covering attributed to global warming. Indeed, Arctic waters are opening to human activities such as resource exploration and exploitation, military exercises activity, pile driving for construction and all maritime shipping. Underwater noise from these activities constitutes an acoustic pollution that can affect marine wildlife. In this study, we focus on human activity in a fjord of Svalbard (Kongsfjorden), where tourist-shipping activity has tripled this last decade. Within this purpose we assessed the soundscape of Kongsfjorden using autonomous recorders deployed three months in 2013 and then between 2018 and 2020. We aimed characterizing anthropophony from biophony and geophony. We thus measured sound levels through different sampling periods and compared them to the shipping trajectories (obtained from AIS data) paired with sound propagation modelling in order to assess potential impacts on marine fauna in the fjord.

Communities and environmental monitoring

Finn Danielsen, NORDECO, Copenhagen, Denmark
Lisbeth Iversen, NERSC, Bergen, Norway
Martin Enghoff, NORDECO, Copenhagen, Denmark
Michael K. Poulsen, NORDECO, Copenhagen, Denmark
Peter Voss, GEUS, Copenhagen, Denmark
Mathilde B. Sørensen, UiB, Bergen, Norway

Keywords: Community-Based Monitoring, Citizen Science, Adaptation, Local Knowledge

Work Package 4 of INTAROS aims at enhancing community-based observing programs for participatory research and capacity-building. This work package has involved field activities in Disko Bay, Greenland and in Svalbard - and close collaboration with many partners across the Arctic since 2017. Key deliverables have been: 1) a survey of capabilities, good practices, challenges and opportunities in existing community-based observing programs, 2) a library with tools for cross-fertilizing indigenous and local knowledge with scientific knowledge, 3) pilot-testing of a range of community-based and citizen science observing approaches in Disko Bay, Greenland and in Svalbard, and 4) the establishment of metadata on existing data collections from community-based observing in the INTAROS data discovery catalogue. In this presentation, we will focus on recent highlights from this work (2019-2020). We will provide a synthesis of the results, share key lessons learned, and discuss the potential implications for future work. The work package will provide important input on community-based observing and citizen science to the development of the INTAROS "roadmap for a future sustainable Arctic observing system".

Actions towards maximizing dissemination and communication for an Integrated Arctic Observing System (INTAROS).

Ruth Higgins, EurOcean, Lisbon, Portugal;
Finn Danielsen, NORDECO, Copenhagen, Denmark;
Lisbeth Iversen, NERSC, Bergen, Norway;
Donatella Zona, U.Sheffield, Sheffield, UK;
Agata Gozdzik, IGPAN, Warsaw, Poland;
Thomas Juul Pedersen, GINR, Nuuk, Greenland;
Kjetil Lygre, NERSC, Bergen, Norway;
Stein Sandven, NERSC, Bergen, Norway;.

Keywords: Arctic, Dissemination, Communication, Communities, Education

The INTAROS project aims to establish an integrated observing system for the entire Arctic region, which implies bringing together a broad range of interested parties, stakeholders, local communities, decision makers, industry and more. Here, we describe the approaches, tools and materials used to maximize the dissemination of INTAROS results and to communicate to the broader and ever-growing Arctic community the activities and achievements of the project. We also describe the work done towards empowering commmunities through Community-Based Managment, towards building capacity among young researchers, and showcase the new educational tools developed for high school students and the general public. We will also focus on the highlights from the Dissemination and Communication work (WP7), provide a synthesis of results, insights, lessons learned, and implications for future work. This will provide input to the INTAROS roadmap.

Building integrated Arctic observing systems from in situ platforms

Stein Sandven, NERSC, Bergen, Norway
Hanne Sagen, NERSC, Bergen, Norway
Roberta Pirazzini, FMI, Helsinki, Finland
Agnieszka Beszczynska-Möller, IOPAN, Sopot, Poland
Peter Voss, GEUS, Copenhagen, Denmark
Finn Danielsen, NORDECO, Copenhagen, Denmark
Lisbeth Iversen, NERSC, Bergen, Norway
Pedro Goncalves, Terradue, Rome, Italy
Torill Hamre, NERSC, Bergen, Norway
Geir Ottersen, IMR, Bergen, Norway
Mikael Sejr, Aarhus University, Aarhus, Denmark
David Gustavson, SMHI, Norrkøbing, Sweden
Donatell Zona, University of Sheffield, Sheffield, UK
Ruth Higgins, EurOcean, Lisbon, Portugal
Erik Buch, EuroGOOS AISBL, Brussels, Belgium

Keywords: Data Access, Monitoring, Climate, Environment

A major objective of the H2020 INTAROS project is to strengthen and extend the Arctic in situ observing systems for atmosphere, ocean and terrestrial disciplines (www.intaros.eu). The in situ observing systems are only used in very limited areas, due technological and infrastructures limitations. Extensive research efforts are undertaken in order to develop, test and operate new observing platforms under Arctic conditions. In addition to scientific observing systems, there are Community-Based Monitoring programmes where data are collected by local communities to support their requirements for information about climate change, natural resources, and other topics. A major challenge in Arctic data management and data sharing is the heterogeneity and complexity in data collected in the difference scientific disciplines. INTAROS has focus on improving the data accessibility from a large number of distributed observing systems and to develop adequate data management systems. To enable data sharing it is necessary to develop interoperability between observing systems and data systems. The observing systems are developed in agreement with the overarching principles FAIR (Findable Accessible, Interoperable, Reusable) and CARE (Collective benefit; Authority to control; Responsibility; Ethics). Data provided by the project partners are available from a number of different data repositories via the INTAROS data catalogue (https://catalog-intaros.nersc.no/).

Data management in an integrated Arctic Observing System

Torill Hamre, Nansen Environmental and Remote Sensing Center, Norway
Herve Caumont, Terradue Srl, Italy
Ingo Schewe, Alfred Wegener Institute for Polar and Marine Research, Germany
Arnfinn Morvik, Institute of Marine Research, Norway
Fabien Ors, Association pour la Recherche et le Développement des Méthodes et Processus industriels, France

Keywords: Integrated Arctic Observation System, iAOS, Data Catalog, Data Portal, Cloud Platform

The overall integrated Arctic Observation System (iAOS) consists of observing infrastructures, data systems storing and providing access to data, and computer platforms for integration, service development and deployment. Data management activities of WP5 in INTAROS include integration of distributed Arctic data repositories holding ocean, atmosphere, cryosphere, terrestrial, and community based data. Focus is on promoting use of established repositories that support standard formats and protocols for metadata and data exchange, and that offer persistent identifiers enabling unique citation of data. A data catalog and portal provide a common entry point to both external data and new data generated within the project. State of the art cloud computing technologies are used to facilitate seamless access to multidisciplinary data, and scalable resources for storage and computing for processing, integration and analysis including geo-statistical methods. This cloud platform is used to develop services within the project to showcase applications in different domains (science, public and private sector). In this presentation we will focus on the highlights from the WP and provide a synthesis of results. We will also provide information about and lessons learned from our work and implications for future work. This WP will provide input to the INTAROS roadmap.

INTAROS Educational packages on terrestial and marine monitoring to enhance literacy of Arctic Observations and interest in scientific careers among secondary schools' students

Agata Goździk, Institute of Geophysics Polish Academy of Sciences, Warsaw, Poland

Keywords: Educational Material, Arctic Observation Literacy, Secondary Schools, Terrestial Monitoring, Marine Monitoring

The INTAROS project offers educational materials, which were produced specifically for teachers and students of secondary schools in order to enhance literacy of Arctic Observations among teachers and students. Although, there are many polar materials available, they are usually not specifically targeting schools in the context of monitoring and field works. This material includes real life examples of field campaigns and observations conducted in the Arctic, which goes beyond the more general picture of scientific work presented in the previously available resources. It is also oriented towards demonstration of various monitoring tasks in order to inspire interest of youngsters in undertaking similar careers in the future. The educational material includes texts, graphics, videos and online games and quizzes and is foreseen as a tool for promoting natural science to students and early recruitment of future potential polar researchers. In the first package dedicated to terrestial monitoring students get the general information about the Arctic, its borders and living conditions and find out why integrated Arctic observation system is crucial for understanding our Planet. Moreover, they become familiar with researcher's work at polar stations. The second package is dedicated to the Arctic Ocean and its monitoring. Students learn about the importance and uniqueness of the Arctic Ocean and how its observations help us understand the changing climate.

ID: 78 - The Distributed Biological Observatory: A Change Detection Array in the Arctic

Conveners

Jacqueine M. Grebmeier | University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory, Solomons, Maryland, USA

Sue E. Moore | University of Washington, Seattle, Washington, USA

Chelsea Wegner Koch | University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory, Solomons, Maryland, USA

Ecosystem Changes in the Pacific Arctic: Multi-Year Studies within the Distributed Biological Observatory

Jacqueline M. Grebmeier, University of Maryland Center for Environmental Science, Solomons, Maryland, USA
Lee W. Cooper, University of Maryland Center for Environmental Science, Solomons, Maryland, USA
Christina L. Goethel, University of Maryland Center for Environmental Science, Solomons, Maryland, USA
Chelsea E. Wegner Koch, University of Maryland Center for Environmental Science, Solomons, Maryland, USA
Karen E. Frey, Clark University, Worcester, Massachusetts, USA
Sue E. Moore, University of Washington, Seattle, Washington, USA

Keywords: Arctic, Observing, Ecosystem, Carbon, Benthos

Warming seawater and reduced seasonal sea ice have influenced ecosystem status in the northern Bering and Chukchi Seas. Variations in upper-ocean hydrography, light penetration, lower and upper trophic level species responses, pelagic-benthic coupling and carbon cycling are being evaluated through the Distributed Biological Observatory (DBO), which was initiated in 2010. The DBO sampling approach emphasizes annual standardized sampling by an international suite of ships occupying standard transect lines and stations to measure ecosystem status and developing trends for the ecosystem. Continuous data are also obtained through mooring and satellite observations, along with autonomous glider data collections. DBO data indicate seasonal and interannual hydrographic changes are driving shifts in biological species composition across trophic levels, abundance and expanded northward range expansions for some temperate species, with negative impacts for some ice dependent species. The seasonal timing of plant growth influences food export to the underlying sediments that are then used by secondary benthic organisms that are important prey for benthic-feeding marine birds and mammals in the region. The sediments are also indicators of changing organic carbon components that provide seasonal and interannual records of water column biological events. We will present results that document recent biological change and use of sediment chemistry to understand ecosystem shifts in the region.

Riverine and marine dissolved organic carbon in the Chukchi Sea

Jinyoung Jung, Korea Polar Research Institute, Incheon, Republic of Korea
MiHae Jeon, Korea Polar Research Institute, Incheon, Republic of Korea
Kyoung-Ho Cho, Korea Polar Research Institute, Incheon, Republic of Korea
Youngju Lee, Korea Polar Research Institute, Incheon, Republic of Korea
Eun Jin Yang, Korea Polar Research Institute, Incheon, Republic of Korea
Sung-Ho Kang, Korea Polar Research Institute, Incheon, Republic of Korea

Keywords: Dissolved Organic Carbon, River, Chukchi Sea, Western Arctic

The Arctic Ocean is currently experiencing rapid environmental changes, including accelerated warming, a decline of sea ice coverage, and increases in riverine discharge. Especially, massive inputs of river water make influences of terrigenous dissolved organic carbon (DOC) stronger in the Arctic Ocean than in other ocean basins because the Arctic Ocean receives about 10% of the global river discharge while accounting for only ~1% of the global ocean volume. In addition, primary production in the Arctic Ocean has increased because of the increased open water area and longer sea ice-free days. These recent environmental changes in the Arctic Ocean affect the biogeochemical carbon cycle. In this study, we investigate the spatial distributions of riverine and marine DOC in the Chukchi Sea. We also use the oxygen isotope ratios (d18O) to assess the relative fractions of river water (friver) and sea ice meltwater (fsea ice melt). The results for riverine and marine DOC from this study provide insight on their spatial distributions and could be valuable for filling the data gap, especially for the northwestern Chukchi Sea.

Seasonal and Interannual Variability of Nitrate in the Eastern Chukchi Sea: Transport and Winter Replenishment

Calvin W. Mordy, University of Washington, Seattle, USA
Shaun Bell, University of Washington, Seattle, USA
Edward D. Cokelet, NOAA/PMEL, Seattle, USA
Carol Ladd, NOAA/PMEL, Seattle, USA
Geoff Lebon, University of Washington, Seattle, USA
Peter Proctor, University of Washington, Seattle, USA
Phyllis Stabeno, NOAA/PMEL, Seattle, USA
David Strausz, University of Washington, Seattle, USA
Eric Wisegarver, NOAA/PMEL, Seattle, USA
Kevin Wood, University of Washington, Seattle, USA

Keywords: Chukchi Sea, Bering Sea, Nitrate Flux, Transport, Replenishment

Rapid changes in sea ice and ocean properties are occurring in the Chukchi Sea, and there are reports of large changes in phytoplankton production which forms the basis of the food chain. The level of phytoplankton production is controlled by the availability of nitrate, a limiting nutrient. In this study, hourly measurements of nitrate were made over six years between 2010 and 2018 and provide a first look on how nitrate concentrations vary by season and year-to-year. Nitrate concentrations were depleted in spring during phytoplankton growth and replenished in winter primarily through transport of nutrient-rich water from the Bering Sea. Transport of Bering Sea nutrients into the Chukchi Sea varied depending on winds. For example, nutrient transport was negligible in the winter of 2011-2012 when sustained winds were from the north. In the winters of 2010–2011 and 2017–2018, sustained winds from the south enhanced nutrient transport such that nitrate concentrations in the Chukchi Sea closely resembled nitrate concentrations in the Bering Sea from the previous fall. This study demonstrates that, in years when winds blow from the south, nutrient measurements from the Bering Sea in the fall can be used to predict nitrate concentrations available for primary production in the Chukchi Sea the following spring. Since 2005, inorganic nitrogen concentrations in the northern Bering Sea have varied between 11 and 22 µM; an indication that phytoplankton production over the eastern Chukchi Sea may have varied by 50% (30 to 70 g C m-2) during this time.

Late Season Observations of Productivity in the Northern Bering and Chukchi Seas: Initial Results from an October 2020 Research Cruise

Lee Cooper, University of Maryland Center for Environmental Science, Solomons USA
Jacqueline Grebmeier, University of Maryland Center for Environmental Science, Solomons, USA
Ruth Cooper, The National Academies of Sciences, Engineering and Medicine, Washington DC, USA
Clare Gaffey, Clark University, Worcester, USA
Christina Goethel, University of Maryland Center for Environmental Science, Solomons, USA
Jordan Maisch, University of Alaska Fairbanks, USA
Savannah Sandy, University of Alaska Fairbanks, USA
Peter Shipton, University of Alaska Fairbanks, USA
Seth Danielson, University of Alaska Fairbanks, USA
Katrin Iken, University of Alaska Fairbanks, USA

Keywords: Distributed Biological Observatory, Bering Sea, Chukchi Sea, Arctic benthos, Marine Biodiversity Observing Network

Benthic communities and the water column were sampled at all five Distributed Biological Observatory (DBO) regions in the productive Bering and Chukchi seas during a late season cruise in October 2020. In addition to recovering and re-deploying the Chukchi Ecosystem Observatory mooring on the southern flank of Hanna Shoal, a new ecosystem mooring with chlorophyll, CDOM, and turbidity sensors, and a sediment/organic carbon collection sediment trap was deployed southwest of St. Lawrence Island. Biodiversity sampling was also completed in support of the Arctic Marine Biodiversity Observing Network, including water samples for environmental genomic markers (eDNA) and collection of phytoplankton and zooplankton for taxonomy and community composition. Early DBO results indicate warm surface seawater temperatures of up to 5 °C in the southern Chukchi and up to 3°C in the northern Chukchi. Chlorophyll a concentrations were also unexpectedly high for the late season, surpassing 1 µg L-1 throughout the US portion of the Bering Strait at most depths, suggestive of late-season production. Concentrations were also high in coastal waters. In addition, the deep (25-35 m) chlorophyll maximum usually observed in the summer had dissipated, presumably by mixing from recent storms that brought inorganic nutrients into surface waters. These observations suggest that shoulder season production can be significant and can occur in coastal locations not generally thought to be strongly productive.

Lingering Chukchi Sea sea ice and Chukchi Sea mean winds influence population age structure of euphausiids found in the bowhead whale feeding hotspot near Pt. Barrow, Alaska

Stephen Okkonen, University of Alaska Fairbanks, Fairbanks, AK, USA
Carin Ashjian, Woods Hole Oceanographic Institution, Woods Hole, MA, USA
Robert Campbell, University of Rhode Island, Narragansett, RI, USA
Philip Alatalo, Woods Hole Oceanographic Institution, Woods Hole, MA, USA

Keywords: Krill, Population Structure, Chukchi Sea, Winds

Interannual variability in euphausiid (krill) population structure and associations of those measures with environmental drivers were investigated in an 11-year study conducted in late August – early September 2005-2015 offshelf of Pt. Barrow, Alaska and just downstream of Distributed Biological Observatory site 5. Significant positive correlations were observed among the proportion of krill juveniles and adults (JAD), the volume of Late Season Melt Water (LMW), and preceding-fall and late-spring Chukchi Sea sea ice extents. High proportions of JAD were seen in years with larger volumes of LMW and greater spring sea ice extents (2006, 2009, 2012-2014) while high proportions of furcilia were seen in years with smaller volumes of LMW and lower spring sea ice extent (2005, 2007, 2010, 2011, 2015). These patterns represent integrated advective responses to mean fall and/or spring Chukchi Sea winds, driven by prevailing atmospheric pressure distributions. In years with high proportions of JAD, late-spring and preceding-fall winds were weak and variable while in years with high proportions of furcilia, late-spring and preceding-fall winds were strong, easterly and consistent. The interaction of krill life history with yearly differences in the northward transports of krill and water masses along with sea ice retreat determines the population structure of late-summer krill populations in the DBO5 region, with the larger krill providing greater biomass prey to bowhead whales.

Seasonal abundance, distribution, and growth of larval polar cod (Boreogadus saida) and saffron cod (Eleginus gracilis) in the US Arctic

Alison L. Deary, NOAA/NMFS/AFSC, Seattle, USA
Cathleen D. Vestfals, NOAA/NMFS/NWFSC, Newport, USA
Franz J. Mueter, UAF, Juneau, USA
Elizabeth A. Logerwell, NOAA/NMFS/AFSC, Seattle, USA
Esther D. Goldstein, NOAA/NMFS/AFSC, Seattle, USA
Phyllis J. Stabeno, NOAA/OAR/PMEL, Seattle, USA
Seth L. Danielson, UAF, Fairbanks, USA
Russell R. Hopcroft, UAF, Fairbanks, USA
Janet T. Duffy-Anderson, NOAA/NMFS/AFSC, Seattle, USA

Keywords: Gadidae, Ichthyoplankton, Forage Fishes, Chukchi Sea, Arctic Cod

Polar cod and saffron cod are dominant forage fishes in the Arctic that link plankton to upper level consumers. We characterized the distribution, abundance, and growth of larval polar cod and saffron cod in late spring and late summer of 2017 in the Chukchi Sea. Ship-based plankton tows showed that polar cod and saffron cod larvae were centered in Kotzebue Sound in the late spring. By late summer, polar cod juveniles were centered offshore in the northern Chukchi Sea whereas saffron cod were distributed nearshore and further south. Empirical fish collections were paired with an individual-based biophysical transport model to examine connectivity and relate changes in seasonal distribution to potential environmental variables. Modeled drift trajectories and growth in spring for polar cod and saffron cod coincided with empirical observations, especially along the northern coastline of Kotzebue Sound, offshore of Point Hope/Cape Lisburne. Given the coherence between modeled and observed distributions, Kotzebue Sound is likely a source of larval gadids in the nearshore areas of the Chukchi Sea and offshore of Cape Lisburne/Point Hope, although it is not the likely source of polar cod further north and offshore in the late summer. This is the first study to examine seasonal distribution, abundance, and growth of polar cod and saffron cod in the US Arctic, and provides data necessary to evaluate the impacts of climate change on forage fishes in the Arctic.

Investigating water-column and sediment N2O cycling in the Western Arctic using stable isotopes

Annie Bourbonnais, School of the Earth, Ocean and Environment, University of South Carolina, 701 Sumter street, Columbia, SC, USA
Calvin W. Mordy, Joint Institute for the Study of Atmosphere and Oceans, University of Washington, USA
Cédric Magen, Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, Solomons, Maryland, USA
Lee W. Cooper, Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, Solomons, Maryland, USA
Jacqueline M. Grebmeier, Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, Solomons, Maryland, USA
Mark Altabet, School for Marine Science and Technology, University of Massachusetts Dartmouth, New Bedford, Massachusetts, USA

Keywords: Nitrous Oxide Cycling, Greenhouse Gases, Biogeochemical Cycling, Stable Isotopes, Isotopomers

Given its large expanse of continental shelves, the Arctic Ocean may be a significant net source to the atmosphere of nitrous oxide (N2O), which is both a greenhouse and ozone destroying gas. N2O is a by-product or intermediate during aerobic nitrification and denitrification either in the water-column or the sediments. We measured water-column N2O concentrations, N and O isotopes, and isotopomers at water-column stations during the Distributed Biological Observatory (DBO) cruise USCGC Healy 1702. We also measured these parameters in 10 sediment cores on the productive Chukchi continental shelf and at offshore stations in western flank of the Beaufort Sea. In addition, we measured water-column N2O production rates using 15N-labeled incubations. At shallow shelf stations, N2O concentrations and saturation generally increased with depth up to ~190% saturation. Low d15N-N2O values were measured in bottom waters (Pacific Winter Water, PWW) indicating N2O production. Water-column N2O production rates were however too low to explain the relatively large N2O accumulation in PWW. A significant positive linear correlation between N2O concentrations and N deficit at both shelf and offshore stations as well as high sedimentary N2O fluxes suggest an important role for denitrification in the sediments as the main source of N2O. While atmospheric N2O fluxes were relatively minor at the time of sampling (less than 1% of total oceanic N2O emissions), sea ice formation and convective overturning of the water column during fall could inject substantial amount of N2O into overlying surface waters.

Multi-year ecosystem assessments of DBO 8: Physical drivers of benthic fishes, invertebrates and habitats in 2013, 2017-2019

Ashley Ehrman, Fisheries and Oceans Canada, Winnipeg, Canada
Andrew Majewski, Fisheries and Oceans Canada, Winnipeg, Canada
David Capelle, Fisheries and Oceans Canada, Winnipeg, Canada
Philippe Archambault, Université Laval, Québec, Canada
Andrea Niemi, Fisheries and Oceans Canada, Winnipeg, Canada

Keywords: Canadian Beaufort Sea, Physical-Biological Coupling, DBO 8, Fish, Benthic Invertebrates

The region offshore Cape Bathurst in the Canadian Beaufort Sea is a demonstrated biological hotspot, characterized by frequent upwelling, high benthic invertebrate densities, unique communities of ampeliscid amphipods, and relatively high copepod biomass that attracts marine mammals. In 2015, the Distributed Biological Observatory (DBO) expanded into the Canadian Beaufort Sea by establishing a transect offshore of Cape Bathurst (DBO 8). Here, initial results are presented from the first integrated fish (i.e., bottom trawling) and ecosystem sampling program conducted along an extended DBO 8 transect in August 2017-2019 by the Canadian Beaufort Sea Marine Environmental Assessment, and an adjacent transect sampled in August 2013 by the Beaufort Regional Environmental Assessment Marine Fishes Project. Analyses will investigate how temporal and spatial variation in the biodiversity and abundance of biological communities (fish, benthic invertebrates, and zooplankton) offshore Cape Bathurst are related to upwelling/downwelling intensity, the timing of sea-ice break up, and sedimentary proxies for food supply and benthic-pelagic coupling. Results will provide an enhanced understanding of physical-biological coupling across years with distinctive differences in ocean-sea ice-atmospheric dynamics, including years with unusual sea-ice dynamics and anomalous winds.

Ocean acidification in the Distributed Biological Observatory, 2017-2019

Jessica N. Cross, NOAA Pacific Marine Environmental Laboratory, Seattle, WA USA
Natalie M. Monacci, University of Alaska Fairbanks Ocean Acidification Research Center, Fairbanks, AK USA
Hongjie Wang, University of Washington Cooperative Institute for Climate, Oceans, and Ecosystem Studies, Seattle, WA USA

Keywords: Ocean Acidification, Carbonate Chemistry, Climate, DBO

Ocean acidification (OA), driven by rising anthropogenic carbon dioxide (CO2), is rapidly advancing in the Pacific Arctic Region (PAR), producing conditions newly corrosive to biologically important carbonate minerals like aragonite. Naturally short linkages across the PAR food web highlighted by the Distributed Biological Observatory (DBO) array mean that species-specific acidification stress can be rapidly transmitted across multiple trophic levels, resulting in widespread impacts. Here, we present new data from 2017 - 2019, collected with both novel autonomous systems and traditional ship-based methods. This data shows the formation of corrosive conditions in colder, denser winter-modified Pacific waters over shallow shelves, resulting from the combination of seasonal terrestrial and marine organic matter respiration with anthropogenic CO2. While biological impacts from this recent acidification remain unclear, they could have detrimental effects on ecosystems already undergoing substantial environmental pressure from other forms of global climate change. In order to support the management and sustainability of the fisheries in the PAR, it will be critical to continue to monitor global emissions and the rate of OA in the Arctic.

Seasonal variations and effects of temperature on oxygen consumption rates within sediments and by dominant macrofauna in the Pacific Arctic

Christina L. Goethel, University of Maryland Center for Environmental Science, Solomons, Maryland, USA
Jacqueline M. Grebmeier, University of Maryland Center for Environmental Science, Solomons, Maryland, USA
Lee W. Cooper, University of Maryland Center for Environmental Science, Solomons, Maryland, USA
Christopher L. Rowe, University of Maryland Center for Environmental Science, Solomons, Maryland, USA

Keywords: Arctic, Benthos, Oxygen Consumption, Carbon Cycling, Bivalves

Evidence of late season production in the Arctic indicates the potential importance of fall season chlorophyll production on benthic carbon cycling. We compared sediment community oxygen consumption (SCOC) using Distributed Biological Observatory (DBO) shipboard incubations in August 2019 in the northern Bering Sea (DBO 1) and SE Chukchi Sea (DBO 3). These incubations examined the effects of increased temperatures and food supply (chlorophyll a) on overall benthic community oxygen consumption. Our findings indicate SCOC is higher at warmer temperatures (4-5°C) than at ambient bottom water temperatures (0 to 2°C) when food availability is not limiting. Similarly, results from SCOC experiments during the fall 2020 DBO cruise had higher SCOC rates when food supply was higher and similar values to summer levels, but no temperature effect at low food supply levels, suggesting that food is the primary driver for variable SCOC rates, with temperature a secondary driver. Respiration rates were also measured for individual specimens of dominant benthic organisms, specifically bivalves and amphipods at each site. These respiration rates increased at higher temperatures in both 2019 (August) and 2020 (October). The 2020 results indicate that late season macrofaunal respiration remains significant, specifically the metabolic activities of bivalves, which form an important component of benthic oxygen utilization well into the fall season prior to sea ice formation.

ID: 85 - Use and Usability of Data and Information within Arctic Community-Driven Research

Conveners

Noor Johnson | National Snow and Ice Data Center, University of Colorado Boulder

Finn Danielsen | Nordic Foundation for Development and Ecology

Roberta Glenn | University of Alaska Fairbanks

Lisbeth Iversen | Nansen Environment and Remote Sensing Centre

A usability framework for community data management: Supporting knowledge mobilization through the Exchange for Local Observations and Knowledge of the Arctic (ELOKA)

Matthew Druckenmiller, National Snow and Ice Data Center, University of Colorado, Boulder, Colorado, USA
Noor Johnson, National Snow and Ice Data Center, University of Colorado, Boulder, Colorado, USA

Keywords: Community Data Management, Data Sovereignty, Arctic Observing, Data Usability

The Exchange for Local Observations and Knowledge of the Arctic (ELOKA) partners with Indigenous organizations and researchers to facilitate the collection, preservation, exchange, and use of Indigenous knowledge and community-based observations. Working with partners from across the Arctic, ELOKA ensures that information from community data is preserved while also made discoverable, accessible, and useful for Arctic residents, researchers, managers, and policy makers. This presentation will summarize ELOKA's collaborative efforts to develop a community data management (CDM) system and a framework to assess the use and usefulness of CDM infrastructures. We are convening two thematic working groups to meet over multiple years to co-develop use cases for how data management tools are used by communities and others. The first working group will focus on digital place name atlases as used for educational curriculum, documenting traditional land use, language and cultural preservation, and understanding landscape change within a cultural, place-based context. The second working group will focus on the use of long-term environmental observing datasets collected by community-based monitoring or local observer networks. ELOKA's collaborative effort to develop a usability framework will broadly consider how cross-cultural sharing, storytelling, data sovereignty protocols, and capacity building may strengthen the use and dissemination of community data.

Bridging Inuit knowledge and academic research to study a shifting marine ecosystem and Arctic Char fisheries in the Canadian High Arctic

Marianne C. Falardeau
Elena M. Bennett
Brent G.T. Else
Aaron T. Fisk
C.J. Mundy
Emily S. Choy
Mohamed M. M. Ahmed
Les N. Harris
Jean-Sébastien Moore

Keywords: Bridging Knowledge, Monitoring, Arctic Char, Environmental Change, Marine Ecosystem

Monitoring the biophysical changes that are reshaping the Arctic and understanding their implications for wildlife and communities require transdisciplinary approaches that bridge contrasting and complementary disciplines and ways of knowing. We studied Arctic Char (Salvelinus alpinus) in the Kitikmeot region of Nunavut over a three-decade period by combining interviews with Inuit fishers and Elders and quantitative analyses of climatic and fish proxies (i.e., stable isotopes, condition factor, lipid content). Fish proxies reflected a shifting food web with potential ramifications for fisheries. The isotopic niche position and width of Arctic Char changed through time, which was aligned with climatic changes. We detected earlier dates of ice breakup of over 12 days in some areas. Inuit fishers echoed these findings through observations of changing sea temperature, ice dynamics, and weather patterns. Fish condition was improved in years with earlier ice breakup, and lipid content increased through time. Some fishers also reported that Arctic Char appear to be in better condition in recent years and that meeting their commercial quotas is easier. They provided insights into new species in the region, including Salmon (Oncorhynchus spp.) that may interact with Arctic Char via competition. Overall, the Kitikmeot marine system is changing in dynamic ways, and close partnerships among communities, researchers, and managers, will be essential to monitor and respond to these changes.

Linking top down and bottom up initiatives and knowledge: Community-based monitoring and co-creation approaches for sustainable urban development in the Arctic

Lisbeth Iversen, NERSC, Bergen and Oslo School of Architecture and Design, Oslo, Norway

Keywords: Planning, UN SDGs, Asset Based Community Development (ABCD), Place Leadership , Arctic

I will share and discuss experiences from the EU H2020-supported INTAROS (Integrated Arctic Observing System) Project and ongoing PhD work at Oslo School of Architecture and Design on holistic and proximal approaches to sustainable urban development. I argue that knowledge-based planning and monitoring of the future is required. This will strengthen the societal and economic role of the Arctic and the wellbeing of people. It will also support the EU strategy for the Arctic and related policies. Dealing with both long term planning and knowledge-based safety and risk management are demanding tasks for local communities. There is a need for methods and tools for co-creation and for downscaling and localizing the UN Sustainable Development Goals. This will contribute to strengthen the capacity of scientists, local authorities, business actors and community members, to attain sustainable results and equity, in times of flux and uncertainty. The physical infrastructure, environmental management, relationel welfare and a "care for each other" culture must be seen in a holistic context. This can be achieved through participatory planning and research, co-creation of knowledge, sharing of best practices, as well as through a tailormade Place Leadership and Management Design. New solutions can be found through combining theory and practice from natural science and community based monitoring programs, participatory planning and urban development.

The Coproduction of Unmanned Aircraft System Solutions in Support of U.S. Arctic Sustainability and Stewardship

Jessica Garron, University of Alaska Fairbanks; Fairbanks, Alaska, USA
Jereme Altendorf, United States Coast Guard, Sector Anchorage; Anchorage, Alaska, USA
John Henry, Native Village of Unalakleet; Unalakleet, Alaska, USA
Margaret Hall, Model Forest Policy Program; Priest Lake, Idaho, USA

Keywords: UAS, Knowledge Coproduction, Emergency Response, Infrastructure Assessment

Technology-based solutions to problems associated with climate change, food security, environmental stewardship and emergency response can bolster workforce development opportunities in remote Arctic communities while also meeting the needs of regulatory and response agencies. In Alaska, the United States Coast Guard (USCG) is responsible for the inspection of 380 bulk fuel storage facilities, 347 of which are only accessible by boat or airplane; five of these facilities are located in the hub community of Unalakleet, Alaska, along the Bering Strait. The Native Village of Unalakleet recently completed a feasibility study about using unmanned aircraft systems (UAS) and on-line data tools to support community planning and emergency response activities. Using the results from the feasibility study combined with the mission needs of the USCG in western Alaska, this project was designed to develop UAS pilot teams in the Bering Strait region in support of decision-making about infrastructure status and emergency response activities. This work includes the remote training and certification of 7 UAS pilots in Unalakleet, the coproduction of bulk fuel infrastructure assessment and emergency response UAS protocols, the feasibility of expanding this training program regionally, and the broad dissemination of knowledge gained to other remote Arctic communities. This presentation will highlight the partnerships, methodologies and milestones of this multidisciplinary project.

Tracking changes in the coastal ecosystem of the Alaskan Arctic through a collaborative network of observers in coastal Indigenous communities

Roberta Glenn
Donna D.W. Hauser
Johsua Jones
Krista Heeringa
Billy Adams
Joe Leavitt
Guy Omnik
Steven Patkotak
Roberta Puya Shaeffer
Carla SimKayotuk
Hajo Eicken

Keywords: Sea Ice, Community-Based Observations, Arctic Communities

Arctic Indigenous communities are among the first people to experience and detect changes in the environment given their deep connections to place and integral reliance on traditional subsistence resources. Community-based observing efforts, such as the Alaska Arctic Observatory & Knowledge Hub (AAOKH), provide long-term observations of shifting environmental conditions in coastal Arctic Alaska. AAOKH is an ongoing observing network with the primary goal to provide northern Alaskan communities with the tools, resources, and scientific support to share their expertise and Indigenous Knowledge through observations of changing coastal conditions and associated impacts to their traditional marine resources. AAOKH focuses on tracking environmental observations, creating research partnerships, and building capacity across six coastal communities, extending from Kotzebue to Kaktovik. Observations from local observers provide a broad-scale view of changing coastal sea ice and ocean conditions, and ultimately impacts at the community scale. Here, we share recent themes in these community-based observations from the network of Iñupiat observers spanning the Alaskan Arctic coast. Observers documented abrupt changes in sea ice cover, ocean temperatures, and associated weather patterns. Environmental changes were often linked to food security and impacts to the traditional way of life.

Connecting Top-Down and Bottom-Up Approaches in Environmental Observing: Lessons for the Arctic and a review of programs across the globe

Hajo Eicken, International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, USA
Finn Danielsen, NORDECO, Copenhagen, Denmark
Josephine-Mary Sam, International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, USA
Maryann Fidel, Yukon River Inter-Tribal Watershed Council, Anchorage, USA
Noor Johnson, National Snow and Ice Data Center, University of Colorado, Boulder, USA
Michael K. Poulsen, NORDECO, Copenhagen, Denmark
Olivia A. Lee, International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, USA
Katie V. Spellman, International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, USA
Lisbeth Iversen, Nansen Environmental and Remote Sensing Center, Bergen, Norway
Peter Pulsifer, Department of Geography and Environmental Studies, Carleton University, Ottawa, Canada
Martin Enghoff, NORDECO, Copenhagen, Denmark

Keywords: Community-Driven Monitoring, Global Observing Networks, Indigenous Knowledge, Local Knowledge

Effective responses to rapid environmental change rely on observations to inform planning and decision-making. Reviewing literature from 124 programs across the globe, including the Arctic, and analyzing survey data for 30 Arctic community-based monitoring programs, we compared top-down, large-scale program driven approaches with bottom-up approaches initiated and steered at the community level. Analysis of this information yielded insights into benefits gained from combining both approaches. The study also confirms the important role of Indigenous and Local Knowledge in ensuring observing activities are relevant in decision-making and planning at the local scale. Arctic observing programs are disproportionately represented in the global literature on this topic. Our analysis points to a number of strategies that can help maximize benefits from observing efforts. These include matching observing program aims, scales, and ability to act on information; aligning observing program and community priorities; respect of Indigenous intellectual property rights and implementation of Free, Prior, and Informed Consent; creating sufficient organizational support structures that help sustain community members' commitment.

ID: 31 - Aerosol observations in the Arctic from ground-based and satellite systems during T-MOSAIC

Conveners

Mauro Mazzola | National Research Council, Institute of Polar Sciences (Italy)

Carlos Toledano | Universidad de Valladolid, Grupo de Óptica Atmosférica (Valladolid, Spain)

Liviu Ivanescu | Université de Sherbrooke (Québec, Canada)

Advances in Polar night AOD retrieval

Mauro Mazzola, CNR, Institute of Polar Sciences, Bologna, Italy
Carlos Toledano, University of Valladolid, Valladolid, Spain
Liviu Ivanescu, University of Sherbrook, Sherbrook, Canada
Robert Stone, NOAA, Boulder, Colorado, USA
Christoph Ritter, AWI, Potsdam, Germany
Vito Vitale, CNR, Institute of Polar Sciences, Bologna, Italy
Lionel Doppler, DWD, Lindenberg, Germany
Thomas Stone, USGS, Flagstaff, Arizona, USA
Georg H. Hansen, NILU, Kjeller, Norway
Natalia Kouremeti, PMOD, Davos, Switzerland
Kazutoshi Sasamoto, Prede Inc., Tokio, Japan
Allison McComiskey, BNL, Upton, New York, USA
Africa Barreto, AEMET, Tenerife, Spain
Roberto Roman, University of Valladolid, Valladolid, Spain
Ramiro Gonzales Caton, University of Valladolid, Valladolid, Spain
Victoria Cachorro, University of Valladolid, Valladolid, Spain
John E. Barnes, NOAA, Boulder, Colorado, USA
Akihiro Uchiyama, NIES, Tsukuba, Japan
Takashi Yamanouchi, NIPR, Tokio, Japan

Keywords: Aerosol, AOD, Polar Night, Svalbard

Globally, aerosols tend to cool the surface, but in the Polar regions their radiative impact may lead to warming when the surface albedo is high and through thermal effects during the polar night. Lunar photometers for measuring at night were developed in the 1990s, but only recently have they been used within the Polar-AOD network. To evaluate their performance, a nighttime inter-calibration campaign was conducted at Izaña Observatory during June 2017. Differences in derived AOD were found between photometers indicating possible errors in the measure of the dark current. The accuracy of the lunar exo-atmospheric irradiance model also came into question. However, greater variability in AOD derived from stellar measurements showed that lunar photometry is the more reliable approach for monitoring at night. A second campaign was held in Ny-Ålesund (Svalbard) during winter 2020, with the goal of improving instrument performance and adopting common processing procedures. Systematic differences in AOD were derived in response to varying atmospheric conditions and data processing. In addition, aerosol profiles from lidar and in-situ measurements were assimilated to construct an aerosol data set for the February 2020 lunar cycle enabling an assessment of biases and error sources. The presentation will provide an overview of Polar-AOD goals and how improvements to nighttime monitoring will fill gaps in our knowledge and AOD climatologies.

Long range transported aerosol events over Ny-Ålesund (Svalbard) in 2020 observed with Sun-sky-Moon photometry

Sara Herrero, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain.
David Mateos, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain.
Carlos Toledano, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain.
Roberto Román, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain.
Ramiro González, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain.
Christoph Ritter, Alfred-Wegener-Institut, Potsdam, Germany
Juan Carlos Antuña-Sánchez, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain.
Daniel González-Fernandez, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain.
Abel Calle, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain.
Victoria E. Cachorro, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain.
Ángel M. de Frutos, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain.

Keywords: Biomass Burning, Svalbard, Aerosol Properties, AERONET, Arctic Haze

The recent development of the of Sun-sky-Moon photometers allows using both Sun and Moon as light sources to retrieve columnar aerosol properties. In this framework, the Group of Atmospheric Optics, University of Valladolid and the Alfred Wegener Institute for Polar and Marine Research, installed in 2017 a CE-318T Sun-sky-Moon photometer (Cimel Electronique S.A.S) in the Arctic station Ny-Ålesund (79ºN, 12ºE). This instrument contributes to the AErosol RObotic NETwork (AERONET), and it is recording a continuous (summer + winter) database of columnar aerosol properties. This study presents an inventory of all high-turbidity aerosol episodes recorded in 2020 based on the mentioned photometer measurements. Complementary information provided by HYSPLIT air mass back trajectories, MODIS images, forecast aerosol models, CALIOP/CALIPSO satellite data, and other collocated instruments on the station are also used. Special focus is given to long-range transport of aerosols from forest fires in Canada, United States and Russia.

Aerosol properties derived by Lidar and star photometer at Ny-Ålesund during the winter 2019 / 20

Christoph Ritter, AWI
Sandra Graßl, AWI
Konstantina Nakoudi, AWI

Keywords: Aerosol, AOD, Lidar

In the research village of Ny-Ålesund, Svalbard, a Raman Lidar and a star photometer are installed in the AWIPEV station. Svalbard and the eastern part of the European Arctic face a strong warming in winter time. For this reason it is a relevant question to analyse how aerosol properties are changing in time. However, so far only few information of aerosol properties during Arctic winter exists and the annual cycle of AOD from the fall minimum to the spring maximum in the Arctic Haze season is not fully understood. In this work we will show data from Raman-Lidar and star photometer to compare both instruments and to monitor temporal evolution of aerosol quantities like the AOD, Ångström-exponent, and profiles of backscatter, color ratio, depolarization ratio and Lidar ratio. The evolution of the aerosol in the MOSAiC winter season over Svalbard will be summarized. Overall, we found clear conditions in the troposphere. However, in the stratosphere a persistent aerosol layer and polar stratospheric clouds in winter have been observed. This has implications for the annual cycle of the AOD and shows the variability and complexity of the winter-time AOD pattern. By this work we want to contribute to a broader, pan-Arctic understanding of aerosol properties during Polar Night.

Monitoring of long-range transported smoke in polar regions with remote sensing instruments

Ramiro González, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain
Carlos Toledano, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain
Roberto Román, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain
David Mateos, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain
Eija Asmi, Finnish Meteorological Institute, Helsinki, Finland
Edith Rodriguez, Finnish Meteorological Institute, Helsinki, Finland
Juan Carlos Antuña-Sánchez, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain
Sara Herrero, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain
Victoria E. Cachorro, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain
Abel Calle, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain
Ángel M. de Frutos, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain

Keywords: Biomass Burning, Transport, Aerosol Properties, Polar Regions, AERONET

Long range transported aerosol from biomass burning affects polar regions, especially the Arctic. The frequency and intensity of bushfires in the context of a warming climate has been pointed out in the last report of the Intergovernmental Panel on Climate Change. In high latitudes, these events impact large areas through long-range transport of the smoke particles in the troposphere or even the stratosphere. The lifetime and radiative impact are related with the height of the plumes and the processes that modify particle size and absorptive properties during the transport. Several recent publications have shown the impact of the Australian smoke in the southern hemisphere, including Antarctica, in January-March 2020. The tools that were used to monitor that extraordinary event can be used in the Arctic to investigate similar effects in the frequent biomass burning events that generate smoke plumes in boreal regions. In this work, we present the results derived from ground-based instrumentation as well as satellite and model data. The change of the smoke properties after several days of transport is also provided, namely an increase in the fine mode particle size and the single scattering albedo, as well as a decrease in the coarse mode particle concentration. These features are relevant for radiative forcing calculations and therefore the impact of long range transported smoke in the radiative balance over polar regions.

Preliminary results on the third lunar/stellar AOD intercomparison campaign at Lindenberg's MOL-RAO Observatory

África Barreto, Izaña Atmospheric Research Center (AEMET), Santa Cruz de Tenerife, Spain
Lionel Doppler, Deutscher Wetterdienst, Meteorological Observatory Lindenberg - Richard Assmann Observatory. Lindenberg, Germany
Carlos Toledano, University of Valladolid, Valladolid, Spain
Mauro Mazzola, National Research Council of Italy, Bologna, Italy
Natalia Kouremeti, Physikalisch-Meteorologisches Observatorium Davos, Davos, Switzerland
Akihiro Uchiyama, National Institute for Environment Studies, Tsukuba, Japan
Victor Novikov, Pulkovo Observatory, Saint Petersburg, Russia
Francisco Navas-Guzmán, MeteoSwiss, Zürich, Switzerland
Roberto Román, University of Valladolid, Valladolid, Spain
Christoph Ritter, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany.
Ramiro González, University of Valladolid, Valladolid, Spain
Vito Vitale, National Research Council of Italy, Bologna, Italy
Robert Stone, National Oceanic and Atmospheric Administration
Liviu Ivanescu, Université de Sherbrooke, Sherbrooke. Canada
Karl-Heinz Schulz, Dr. Schulz and Partner GmbH. Buckow, Germany
Akihiro Yamazahki, Japan Meteorological Agency, Tsukuba, Japan

Keywords: Aerosols, Polar, Photometry

The third lunar/stellar AOD intercomparison campaign was carried out in Lindeberg (Germany) in the summer 2020. This campaign, organized by DWD with the collaboration of UVa, AEMET, PMOD-WRC, CNR, NIPR, Pulkovo Observatory Sankt Petersburg, Dr. Schulz & Partner GmbH, Meteo Swiss, ETH Zurich, University of Sherbrooke, and others, took place at Meteorologisches Observatorium Lindenberg - Richard Aßmann-Observatorium (MOL-RAO). SCILLA (Summer Campaign for Intercomparison of Lunar measurements of Lindenberg's Aerosol) campaign involved synchronous measurements from three different types of lunar photometers and one kind of stellar photometer. Some other aerosol remote sensing observations were also included in SCILLA thanks to the wide variety of measurements provided in MOL-RAO supersite (vertical profiles from Raman lidars and ceilometers, COBALD radiosondes or an all-sky camera). This field campaign, together with the field campaign carried out in Ny-Alesund in February 2020, have been conceived within the Polar-AOD community as critical field tests to verify the capability of the current remote sensing techniques to extend the aerosol monitoring during nocturnal period, which is of special interest for polar studies. With this purpose, the Polar-AOD group started with these challenging issues in the frame of the International Polar Year 2007–08. In this work we will present the preliminary results provided from SCILLA in terms of the AOD.

Analysis of gravity wave periodicities in starphotometry AOD data

Liviu Ivanescu, Université de Sherbrooke, Sherbrooke, Canada
Norman T. O'Neill, Université de Sherbrooke, Sherbrooke, Canada
Samuel Kristoffersen, University of New Brunswick, Fredericton, Canada
Dustin Gamblin, University of New Brunswick, Fredericton, Canada
William Ward, University of New Brunswick, Fredericton, Canada

Keywords: Starphotometer, Gravity Waves, AOD Oscillations

Starphotometer optical depth oscillations were identified in the high-Arctic winter-time measurements performed at the Eureka Weather Station (NU, Canada). Similar oscillations were identified in gravity wave spectra acquired by a nighttime, green-line sky imager. In this study we investigated the source of such variations to determine the physical underlying process. The Two-Star measurement mode of the starphotometer was preferentially employed, since this mode increases the accuracy of the measurement of those oscillations. Fine and coarse mode analysis was then performed in order to ascertain if a particular size of aerosol particle was involved in this process. In addition, we performed correlation analysis with gravity wave measurements acquired by the green-line imager in the same region of the sky as the starphotometer measurements. Aside from considerations such as sky brightness variations induced by the gravity waves, we analyzed the possibility of starphotometer signal oscillations (and thus derived AOD oscillations) induced by wind speed variations (retrieved from the green-line sky imager measurements of gravity waves).

New methodology to calculate AOD from lunar photometer

R. Román, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain
R. González, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain
C. Toledano, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain
A. Barreto, Izaña Atmospheric Research Center, Spanish Meteorological Agency, Tenerife, Spain
D. Pérez-Ramírez, Andalusian Institute for Earth System Research, Granada, Spain
J.A. Benavent-Oltra, Andalusian Institute for Earth System Research, Granada, Spain
F.J. Olmo, Andalusian Institute for Earth System Research, Granada, Spain
V.E. Cachorro, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain
L. Alados-Arboledas, Andalusian Institute for Earth System Research, Granada, Spain
A.M. de Frutos, Group of Atmospheric Optics, University of Valladolid, Valladolid, Spain

Keywords: Lunar Photometry, RIMO, ROLO, Polar AOD

Recent technical advances in lunar photometers have positioned lunar photometry as a plausible technique to fill the gaps in AOD data series in Polar regions during winter. To this end, the knowledge of the extra-terrestrial lunar irradiance with high accuracy is needed. This irradiance is usually estimated by RIMO model (an implementation of the ROLO model); however some previous studies revealed a bias in this model, underestimating the real lunar irradiance. This work proposes a correction of this bias as a function of the Moon phase angle and wavelength, based on photometric measurements recorded with a Cimel 318TS radiometer under pristine and cloud-free conditions at the Izaña Atmospheric Research Center high altitude station (Canary Islands, Spain). This correction has been applied to other lunar photometers in different stations to retrieve AOD values. The obtained results are promising, observing agreement, within the estimated uncertainties, between the AOD retrieved by this method and the inferred by other techniques like Sun and star photometry.

In situ eBC vertical profiles in the Arctic troposphere: a comprehensive analysis of 9 years (2011-2019) of tethered balloons experiments

David Cappelletti, University of Perugia, Perugia, Italy
Mauro Mazzola, ISP-CNR, Bologna, Italy
Luca Ferrero, University of Milano Bicocca, Milan, Italy
Justyna Lisok, University of Warsaw, Warsav, Poland
Chiara Petroselli, University of Southtampton, UK
Jurgen Graeser, AWI, Potsdam, Germany
Marion Maturilli, AWI, Potsdam, Germany
Christoph Ritter, AWI, Potsdam, Germany
Kostas Eleftheriadis, Environmental Radioactivity Laboratory, NCSR "Demokritos", Athens, Greece
Grisa Mocnik, Jozef Stefan Institute, Ljubljana, Slovenia
Beatrice Moroni, University of Perugia, Perugia, Italy
Stefania Gilardoni, ISP-CNR, Bologna, Italy
Vito Vitale, ISP-CNR, Bologna, Italy
Angelo Viola, ISP-CNR, Bologna, Italy
Andrea Spolaor, ISP-CNR, Bologna, Italy
Kris Markowicz, University of Warsaw, Warsav, Poland
Stefano Crocchianti, University of Perugia, Perugia, Italy

Keywords: Aerosol, Long Term Measurements, Vertical Profiles

Primary objective of this long-term research activity is to build a climatology of aerosol vertical profiles in and above the Arctic Boundary Layer. To this aim since 2011 an international research team has performed yearly field campaigns at the Ny-Ålesund super-site (Svalbard isl.). Making use various aerosol payloads and tethered balloons systems (TBS) up to date more than 500 aerosol profiles have been recorded in the first km of the Arctic troposphere, providing detailed information on black carbon concentration, aerosol size distribution, aerosol scattering coefficients and chemical composition. Seasonal trends have been obtained for spring, summer, autumn and winter. Case studies has already been reported describing the impact of ship emissions, Arctic haze and new particle formation events on the vertical aerosol structure. In situ TBS activities have been often accompanied by parallel lidar profiling and a closure study of aerosol microphysical property retrieval has been recently published on a full chemical aerosol characterization both at bulk level on filter samples and on single particles by scanning electron microscopy.

List of authors