IPS-2023

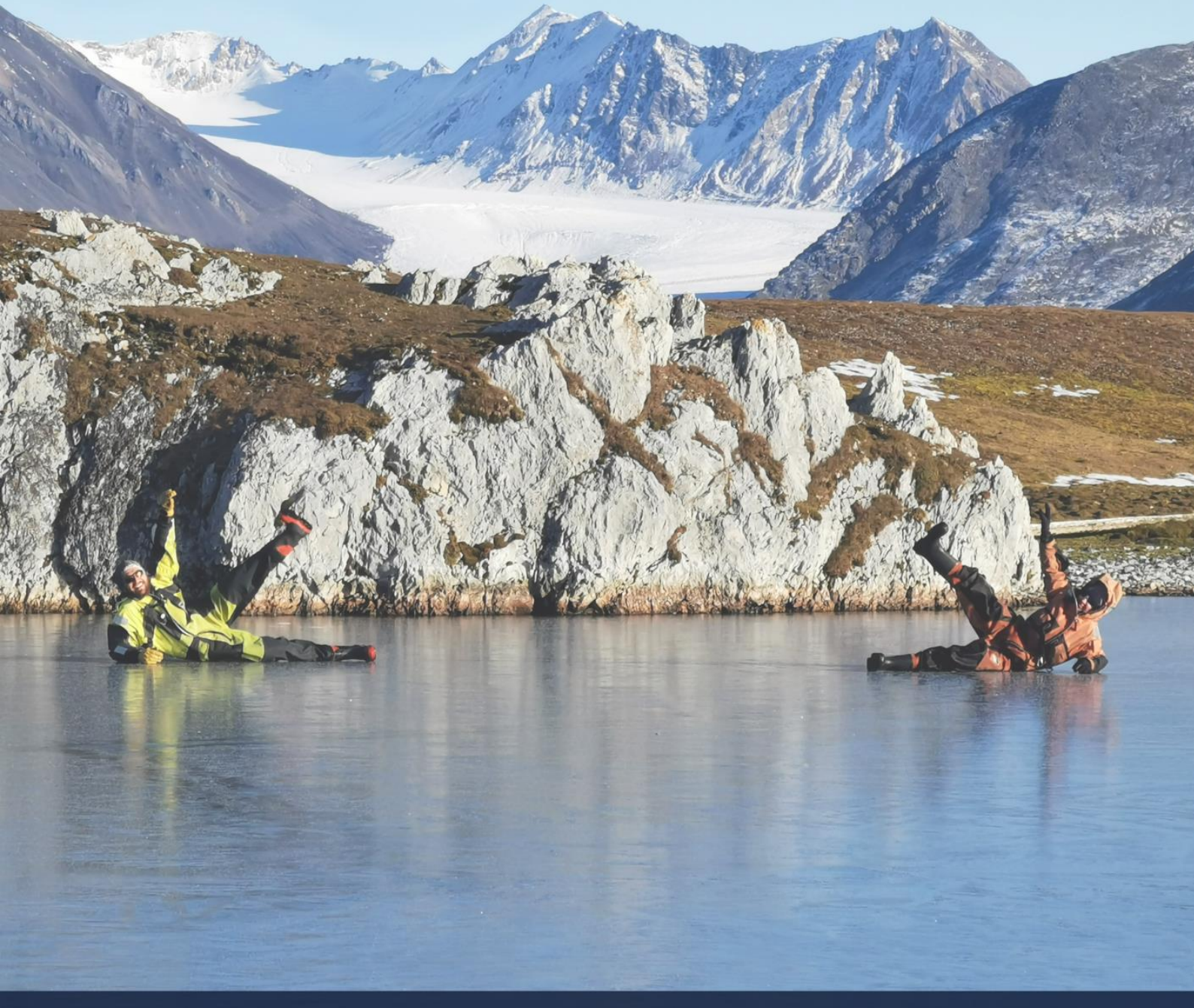
Interdisciplinary Polar Studies
Modular Meeting:
Arctic Amplification-Glaciers-Environment

LONGYEARBYEN ISFJORDEN HORNSUND

30 AUGUST - 4 SEPTEMBER 2023

INTERDISCIPLINARY POLAR STUDIES (IPS-2023) MODULAR MEETING: ARCTIC AMPLIFICATION – GLACIERS – ENVIRONMENT

BOOK OF ABSTRACTS



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Centre for Polar Studies

Interdisciplinary Polar Studies (IPS-2023) Modular Meeting: Arctic Amplification-Glaciers - Environment

BOOK OF ABSTRACTS

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Interdisciplinary Polar Studies
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Sosnowiec-Svalbard, 26 July 2023

Dear Colleagues,

Interdisciplinary Polar Studies (IPS-2023) Modular Meeting: Arctic Amplification-Glaciers - Environment consists of a conference and field workshop. The meeting will be held at UNIS in Longyearbyen, Svalbard and within Isfjorden and Hornsund Fjord areas on 30 August – 4 September 2023.

The primary motivation and goal of the IPS-2023 are (1) to strengthen a holistic approach to studies and a better understanding of environmental changes due to the accelerated warming of the Arctic and (2) to prepare the new generation of scientists for creative involvement in the 5th International Polar Year 2032/2033 by active participation in the IASC ICARP IV (2025) process and the ongoing Ocean Decade (2021-2030) programme.

An enhanced, long-term and coordinated monitoring of landscape and seascape evolution in Svalbard and other regions of the Arctic is needed for deepening studies of interactions of the cryosphere with other components of the polar environment. Identification of gaps, suggestions for coordination of international efforts and standardisation of methods will be discussed during the conference and directly in the field. We don't expect that the IPS-2023 will resolve all problems related to proper preparation for the 5th IPY research program. Nevertheless, it should be one of the meetings to spark creative thinking on interdisciplinary studies and a grasp of the warming Arctic.

The target group of the meeting are ECRs working on topics related to the Arctic in diverse disciplines, including glaciology, hydrology, oceanology, biology and climatology, as well as technology and social sciences. As a result of their contribution, we provide summaries of the IPS-2023 presentations in the book of abstracts (in alphabetical order).

The main organiser of this modular meeting is the Centre for Polar Studies (CPS), established in 2013. CSP is an active and successful cooperation platform between the University of Silesia in Katowice, the Institute of Geophysics in Warsaw and the Institute of Oceanology, both of the Polish Academy of Sciences. All three institutions are leaders in polar research activities in Poland and were among the founders of the Polish Polar Consortium in 2012. The Centre cooperates with other polar research groups in our country and internationally.

We wish to acknowledge the generous financial support of the Ministry of Education and Science, Republic of Poland (grant No. *DNK/SP/513817/2021)*, Svalbard Integrated Arctic Earth Observing System (SIOS) for co-organisational effort, The University Centre in Svalbard (UNIS) for the hosting of plenary sessions and Association of Polar Early Career Scientists (APECS), The Committee on Polar Research of the Polish Academy of Sciences, Polish Polar Consortium for patronage to this conference. The International Arctic Science Committee provided travel grants for the participation of ECRs. The Centre for Polar Studies, the University of Silesia in Katowice, provides an additional financial support for the conference.

Yours faithfully,

Prof. Dr. Jacek A. Jania

Head of the Centre for Polar Studies
Chair of the IPS-2023 Scientific Committee

Dr. Elżbieta Łepkowska

Chair of the IPS-2023 Organizing Committee

Contents

Soil moisture investigation using UAV-based Thermal and Multi-Spectral data with in situ measurements in the Hornsund area (SW Spitsbergen)

Abhishek Bamby Alphonse

Authors: Abhishek Bamby Alphonse[1] (balphonse@igf.edu.pl), Tomasz Wawrzyniak; Marzena Osuch and Nicole Hanselmann

Affiliation: [1]Institute of Geophysics, Polish Academy of Sciences

Keywords: UAV, Thermal, Multi Spectral, Hornsund, Svalbard

Abstract:

The accurate spatial determination of soil moisture content is important for a range of applications, including permafrost and hydrological monitoring and modeling. Traditional methods of measuring soil moisture, such as gravimetric and electrical conductivity, can be time-consuming and expensive and particularly gives point measurements. In recent years, remote sensing has emerged as a powerful tool for estimating soil moisture content over large areas. In this study, we investigated the use of thermal images and multi-spectral data to estimate the soil wetness index (SWI) in the High Arctic catchments of Fuglebekken and Ariebekken, located in the vicinity of the Polish Polar Station, Hornsund. Thermal images were acquired with Zenmuse H20T mounted on DJI Matrice 300RTK, while multi-spectral data were obtained from MicaSense Red Edge-MX camera. The soil moisture index was calculated with the NDVI-LST triangle method. The SWI was correlated using in-situ measurements of soil moisture content collected by Tomst TMS-4 sensors. The results showed that the soil wetness index could be estimated with a high degree of accuracy by utilizing UAV-based thermal and multi-spectral data. Overall, our study demonstrates the potential of drone-based remote sensing data to estimate soil moisture content over large areas and visualizes the spatial variability in a micro-catchment. The thermal and multi-spectral data offer a fast method for estimating soil moisture content, which can be applied to model the hydrological cycle in the warming Arctic.

Characterization of meltwater discharging channels and their influence on Hansbreen front position

Eva De Andrés

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Keywords: Glacier retreat, Subglacial hydrology, Submarine Melting

Abstract:

Mass loss of tidewater glaciers in Svalbard has increased over the last decades, with frontal ablation accounting for up to 30 % of the total loss. Hansbreen front retreated >1 km over the period 1999-2016. The limited size of this tidewater glacier makes it highly vulnerable to changing ambient conditions, with atmospheric (PDD) and seawater temperature as main controls on glacier front retreat. Coupled glacier-fjord models have also confirmed the tight dependency of intraseasonal glacier retreat with both subglacial meltwater discharges and seawater temperature. However, some aspects, such as the actual meltwater production and its subglacial distribution, remain poorly constrained.

In this study, we combine a subglacial-hydrology model along with downscaled surface melting and time-lapse-camera front observations. We compare the location of modelled vs observed discharging channels at Hansbreen front from Jan 2010 to Sept 2011. Submarine melting within each subglacial channel is estimated by using the line-plume model with their corresponding subglacial discharges and observed seawater properties.

Peaks of maximum glacier-surface melting in 2010 (2011) takes place in early August (mid July and late August) reaching 1.9 106 (1.7 106) m^3d^{-1}. Matching observations, our subglacial-hydrology model suggests the existence of three channels. The widest (~100 m) and fastest-flowing one is located at the deepest zone (~70 m depth) at the central-west side of Hansbreen front. The two other channels are narrower (~50 m), shallower (~30 m depth) and closer to the margins. Submarine melt rates peak in August, being slightly higher at the central channel, and reaching up to 60 m/month in 2010, and 40 m/month in 2011. Submarine melting alone does not explain the total observed front retreat. Nevertheless, this channel configuration might be responsible for the front destabilization and we aim to introduce it in a 3D glacier model.

Funded by MCIN/AEI (PID2020-113051RB-C31) and NextGenerationEU (RD289/2021).

Effects of an active volcano on bound water behavior in Antarctic lichen Caloplaca regalis

Aleksandra Andrzejowska

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Keywords: Lichen, Caloplaca regalis, NMR, Deception Island, King George Island, Antarctica, Volcanic Activity

Abstract:

Caloplaca regalis is a lichen strongly associated with penguin colonies. It plays a crucial role in nitrogen cycling in Antarctic ecosystems, making its survival critical for maintaining the ecological balance. Therefore, understanding of the water behavior in this Antarctic lichen can help us predict the impact of climate change on Antarctic ecosystems and develop conservation strategies to preserve these vital habitats.

Our goal was to emphasize the differences in defensive strategies against desiccation in relation to the origin site using 1H-NMR and sorption isotherm. Therefore, a comparative analysis of molecular behavior of residual water bound in C. regalis from an actively volcanic Deception Island (DI) and from volcanically inactive King George Island (KGI) was performed.

We distinguished three water fractions in gaseous phase hydration kinetics: very tightly, tightly and loosely bound. Samples from inactive volcanically island (KGI) has shown faster uptake of water from gaseous phase than ones from DI, which may suggest better adaptation to changing environmental conditions for C. regalis from KGI.

For 1H-NMR signal only one, averaged, water fraction was detected. Moreover, the dissolution effect was observed at least up to $\Delta m/m_0 = 0.5$, for lichens from both sites. Both of them contain a solid water-soluble fraction but the value of saturation concentration (cs) varies between habitats. For C. regalis from actively volcanic island (DI) cs= 0,3(1) corresponds to mannitol or galactitol, while for lichen from KGI cs= 0,6(1) corresponds to galactose or xylose. These substances are known to be accumulated by lichens to stabilize proteins or other cellular components under desiccation stress .

The results obtained suggest that C. regalis employs similar sugar-based defensive strategies against desiccation but the specific sugar composition differs between samples from different sites. This provides insights into their adaptation strategies and the ability to survive in harsh and in changing conditions.

INVITED LECTURE

Changes of ocean climate and feedbacks in the warming Arctic

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Abstract:

The Arctic is warming faster than the other regions on Earth due to amplification of anthropogenic climate change by sea ice loss and its impact on albedo feedbacks and heat uptake by the upper ocean. The physical environment of the Arctic Ocean is rapidly changing under ongoing warming. Not only air temperature is rising faster than average and sea ice is shrinking, thinning and its seasonal cover is lasting shorter but profound changes are also observed in the upper ocean climate and dynamics. The upper ocean heat content is rising to due advection of warmer waters from lower latitudes and increased solar warming. Warm and salty anomalies progressing from the North Atlantic into the Arctic Ocean through Fram Strait and Barents Sea result in Atlantification - a change toward more Atlantic conditions. Warming and salinification alter vertical fluxes and weaken vertical stratification which leads to increased heat exchange between ocean and atmosphere. At the same time more open water and less dense sea ice enable stronger wind mixing which further helps to break down stratification and increase fluxes. Ocean circulation patterns are also changing, especially in connection to altered wind and sea ice drift patterns. Atlantification has substantial impacts on Arctic ecosystems. Atlantic inflow brings nutrients and organisms into the Arctic Ocean and weaker stratification supports upward nutrient fluxes, which together with higher temperatures and more available light due to less compact ice cover may lead to increased primary production. Environmental changes linked to Atlantification also promote borealisation of the Arctic Ocean, i.e. its invasion by boreal species of plankton, fish, sea mammals, and seabirds which modifies vulnerable Arctic ecosystems. In this talk we review the current knowledge of ongoing changes in the Arctic Ocean climate and feedbacks and zoom on observational evidence from the selected key areas along the Atlantic water inflow.

INVITED LECTURE

Long-range transport or local sources of contamination potential impact and solutions

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Abstract:

The presence of persistent organic pollutants (POPs) in the Arctic has long been an area of concern with respect to human health and the impact on the ecosystem. Long range transport of pollutants through the atmosphere and by ocean currents from lower latitudes to the Arctic has been the focus of the Arctic Monitoring and Assessment program since 1991. While some traditional contaminants like polychlorinated biphenyls (PCBs) have shown a decreasing trend new contaminants of emerging arctic concern (CEAC) have been identified in the Arctic environment (AMAP, 2017). In addition to long range transport local sources as a result of human activity in the Arctic are gaining increasing attention.

Per- and Polyfluoroalkyl substances (PFAS) is one of the emerging contaminant groups of high concern. PFAS are widely used in surfactants and polymers. Its application in aqueous film forming foams (AFFF) for firefighting purposes has resulted in significant pollution around airports globally. Despite being produced since the 1950, PFAS were only detected in Arctic wildlife in the early 2000s (Muir et al. 2019). Recent studies have found that aviation activities constitute a significant local source of PFAS contamination in Svalbard. There are presently 3 airports in operation: the main Svalbard airport in Longyearbyen (LYR), the short runway airport in Ny-Ålesund, Hamnerabben (QEN) and the Barentsburg Heliport, Heerodden.

Svalbard airport has one active and one historic firefighting training site. These sites have been contaminated with PFAS due to extensive training activities. PFAS concentrations in runoff-/leachate water from the firefighting training sites at the airport (365 ng L-1 and 57 ng L-1 for the ∑ PFAS 14) have been concluded to be major local PFAS sources with significant effects on PFAS concentrations in nearby marine biota (Ali et al., 2021).

At the research station Ny-Ålesund, high PFAS concentrations have been reported in runoff water (113–119 ng L-1 ∑14 PFAS) and soil (211–800 µg kg-1 dry weight ∑14 PFAS) collected close to the local firefighting training site associated with the airport serving the research station (Skaar et al., 2018).

Risk assessment and potential remediation methods for these sites are presently studied to limit the local impact on the environment while preventing further environmental degradation as a result of invasive clean-up techniques (Breedveld et al., 2023).

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Designing sustainable and resilient communities and research stations in the Arctic

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Keywords: resilience, adaptation plans, research stations, communities, cities, urban planning, sustainability, vurnelabity

Abstract:

Designing sustainable and resilient communities and research stations in the Arctic

The Arctic region is experiencing rapid environmental changes, leading to an urgent need for designing sustainable and resilient communities and research stations. This presentation will explore how sustainable design principles can be integrated into the planning and development of Arctic communities and research stations.

Adaptation plans are strategies and measures designed to help communities and research stations in the Arctic adapt to the impacts of climate change. These plans typically involve a range of activities and interventions aimed at reducing vulnerability to climate risks and increasing resilience. Components of adaptation plans include risk assessment and mapping, infrastructure planning and design, land use and urban planning, emergency management, and community engagement.

As permafrost thaws, it can lead to unstable ground conditions, which can damage buildings and infrastructure, and increase the risk of landslides and other natural disasters. Therefore, it is crucial to develop infrastructure that is resilient to climate impacts, such as sea level rise, coastal erosion, and more extreme weather events. Additionally, land use policies that reduce exposure to climate risks and promote sustainable development can be implemented through urban planning. This approach can help adapt to the accelerated warming of the Arctic, including topics such as sustainable land use, zoning, transportation, and energy planning.

Research stations in the Arctic face similar challenges, requiring adaptation plans to support research activities in the region. These plans include infrastructure design that can withstand extreme weather events and the impacts of climate change. They also include the development of emergency response plans and community engagement to ensure that research activities do not negatively impact local communities or the environment.

Adaptation plans are typically developed through a collaborative process that involves input from a range of stakeholders, including local communities, government agencies, and other organizations. The plans are designed to be flexible and adaptable over time, as new information becomes available and as climate conditions change.

As an example, I want to talk about how the Polish Polar Station Hornsund has been designed to minimize its environmental impact, with features such as energy-efficient systems and waste

management facilities. The station's infrastructure has been designed to be resilient to climate impacts such as permafrost thaw and extreme weather events. I want to present ideas on how the station could implement an adaptation plan. In the context of settlements, I would like to discuss the example of Longyearbyen.

This presentation will emphasize the importance of designing sustainable and resilient communities and research stations in the Arctic. By implementing effective adaptation measures, Arctic communities, and research stations can reduce their vulnerability to climate risks and build a more sustainable and resilient future.

Mental health control system in isolated areas

Lidia Dyląg
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Keywords: isolation, mental health, Arctic, space technologies, stress control

Abstract:

During isolation people working in Arctic areas may face a lot of difficulties connected with mental health. We notice these problems after the behavior of the patient changes, but human's body is showing symptoms way before we can see other effects. Our aim is to react right after physical symptoms occur – before behavior of the crew member influences other people in isolation and puts these people's lives in danger. Due to rising mental health awareness there is a big increase in the amount of knowledge about physical symptoms foreshadowing mental condition deterioration. Our goal is to conduct the experiment which would be based on collecting data by examining polar explorer's temperature, heartbeat, shaking of the hands, respiratory rate and blood pressure. They would also be asked about their current mood. This would allow us to create a database containing physical parameters linked to mental state of being. The next step would be to make small sensor which would allow people in isolation to measure their physical parameters in an easy way. Sensor would be connected to mobile application which would monitor the amount of stress polar explorers are facing and alert about negative impact it has on them. It could prevent depressive episodes, aggression acts and anxiety which are common issues for people in isolation. This application with the sensor can also be used for astronauts. In space mental disorders are one of the biggest problems concerning the crew and our sensor would help mission control center to react quickly when first symptoms appear. Experiment would also allow to do a research on connection between humans exposition to external factors and mental condition deterioration.

INVITED LECTURE

Greening of the Arctic - Invasive Vaucheria aff. compacta (Xanthopyceae) in Adventfjorden tidal flat, Svalbard

Josef Elster

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Abstract:

The high Arctic Svalbard tidal flat ecosystem is impacted by global warming, which could allow invasion by additional species with changes in the environment supporting their growth. The transport of additional species to Svalbard could be aided by an increase in the numbers of people traveling there. Anthropogenic activities related with global warming create opportunities for organisms to move across previously isolated regions, thus advancing biotic homogenization and extinctions. Our study focused on essential quantitative and qualitative information about the occurrence of widespread mats of the invasive siphonaceous yellow-green alga Vaucheria aff. compacta in the Adventfjorden tidal flat. We outline the present ecological state of V. aff. compacta mats (land cover estimation) and discuss the origin and future development of this microphytobenthic community. Phylogenetic analyses based on rbcL genes confirmed that the studied alga is closely related to V. compacta, inside the section Piloboloideae. With the help of a drone mapping survey, we estimated that V. aff. compacta area cover was about ca 231.1 m² (± 10.55%, n=11) across the drone mapped tidal flat area of 2 475 m². We confirmed that invasive V. aff. compacta is a coastal cosmopolitan species widely disseminated on shores in both hemispheres. Invasive V. aff. compacta is an important component of the Adventfjorden sea-land ecotone, which affects large-scale changes within the intertidal system, stabilizes the sediment coming in with the regular tides and protect the seashore ecosystem against erosion. As a result of global warming in the Arctic, invasive V. aff. compacta facilitates the greening of the Arctic.

Salinity and Freshwater distribution in Barents Sea and Fram Strait

Carolina Gabarró
Authors: Carolina Gabarró[1] (cgabarro@icm.csic.es), M. Umbert, E. De Andrés, M. Sánchez-Urrea, E. Olmedo, V. Gonzalez-Gambau, A. Garcia-Espriu, Laurent Bertino,Roshin Raj
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Keywords: Salinity, Atlantification, Satellite, Barents, Nordic Seas, SMOS

Abstract:

The increase in air temperatures in the Arctic has led to significant melting of sea ice and glaciers in various regions, including Svalbard. This melting has resulted in an increase in the liquid freshwater content (FWC) of the ocean.

Additionally, it has been reported by many authors that the Barents Sea is undergoing an "atlantification" process, which involves the expansion of the typical Atlantic oceanic regime towards higher latitudes. This process has resulted in increased surface heat and salinity content, a weaker halocline, and enhanced sea-ice loss. It is critical to understand the future evolution of the Atlantic water masses in high latitudes and their interactions with Arctic waters, but the lack of measurements is limiting progress in this area.

The Soil Moisture and Ocean Salinity (SMOS) satellite mission, launched by the European Space Agency in 2009, measures the sea surface salinity (SSS) of the ocean when it is free of ice. In our study, we computed the SSS anomaly in the Barents, Greenland and North Norwegian seas using 10 years of SMOS data (BEC-SMOS SSS v3.1 product) and compared it with TOPAZ4b reanalysis outputs. Additionally, setting 34.8 psu as the salinity-reference value we computed the FWC by combining SMOS SSS with in-depth TOPAZ4b ocean salinity.

Our results indicate that the SMOS SSS is fresher than the surface layer of TOPAZ4b, and that the variation of the uppermost mixed layer depth (where SMOS SSS is allocated) has a non-negligible impact on the computed FWC. Furthermore, in order to monitor the potential changes in FWC distribution, we aim to investigate whether SSS variations could serve as a proxy for that FWC variability in the Barents, Greenland and North Norwegian seas.

This research is being conducted within the framework of the European Space Agency's ESA ARCTIC+SSS project and the Spanish-funded ARCTIC-MON project.

Mental health control system in isolated areas

Marta Gajewska
Authors: Marta Gajewska[1] (gajewska@student.agh.edu.pl), Lidia Dyląg
Affiliation: [1]AGH University of Science and Technology
Keywords: isolation, mental health, Arctic, space technologies, stress control

Abstract:

During isolation people working in Arctic areas may face a lot of difficulties connected with mental health. We notice these problems after the behavior of the patient changes, but human's body is showing symptoms way before we can see other effects. Our aim is to react right after physical symptoms occur – before behavior of the crew member influences other people in isolation and puts these people's lives in danger. Due to rising mental health awareness there is a big increase in the amount of knowledge about physical symptoms foreshadowing mental condition deterioration. Our goal is to conduct the experiment which would be based on collecting data by examining polar explorer's temperature, heartbeat, shaking of the hands, respiratory rate and blood pressure. They would also be asked about their current mood. This would allow us to create a database containing physical parameters linked to mental state of being. The next step would be to make small sensor which would allow people in isolation to measure their physical parameters in an easy way. Sensor would be connected to mobile application which would monitor the amount of stress polar explorers are facing and alert about negative impact it has on them. It could prevent depressive episodes, aggression acts and anxiety which are common issues for people in isolation. This application with the sensor can also be used for astronauts. In space mental disorders are one of the biggest problems concerning the crew and our sensor would help mission control center to react quickly when first symptoms appear. Experiment would also allow to do a research on connection between humans exposition to external factors and mental condition deterioration.

Automated Aquaponic System

Mikołaj Gąbka
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Affiliation: [1]AGH University of Science and Technology
Keywords: automation, modularity

Abstract:

Standing on the ground and looking at the stars, we often see two different worlds, but some of the problems we face on a daily basis concern both of them. Due to the prevailing conditions, in extreme areas on Earth, such as Arctica, Antarctica or Africa, as well as on space stations, the cultivation of plants in the soil is very difficult. An automated, modular aquaponic system will allow for the cultivation of various plant species regardless of the conditions outside, limit human intervention to a minimum and allow the cultivation area to be adjusted depending on the needs.

Our goal is to create a fully automated aquaponic system, but ultimately, we plan to create a system composed of modules, enabling the expansion of the cultivation area by adding subsequent modules. Thanks to full automation, the cultivation system will be self-sufficient, the role of the human being will be reduced only to removing the finished crops from the system. The subsystems will provide optimal conditions thanks to the connection with other subsystems and with the mobile application on the owner's phone. Our system will also enable growth of various plants with different fish species depending on the caloric needs and dietary restrictions. The system will allow highly efficient usage of resources such as continuous water recirculation. Due to the fact that in aquaponics fish and plants constitute a natural ecosystem, no artificial fertilizers are needed.

The entire system will be controlled via an application on the user's phone. Its simple interface will allow adjusting the parameters inside the system to the currently cultivated plants, and will inform the owner about the system parameters such as humidity, temperature, light, concentration of carbon dioxide, oxygen and other gases and compounds contained in water.

Spatiotemporal Changes of the Supraglacial Hydrology on Ellesmere Island, Canadian High Arctic

Pénélope Gervais

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Keywords: Glacier hydrology, Surface mass balance, Surface melt, Supraglacial streams, Remote sensing

Abstract:

In the last two decades, the Canadian Arctic Archipelago (CAA) has experienced the greatest rate of glacier mass loss outside of the Greenland and Antarctic ice sheets. Surface melt and runoff have been the primary factors behind 90% of this mass loss since 2005, contributing to the development and growth of supraglacial streams. While previous studies have mapped these stream networks and their connection to ice dynamics for single points in time, none have explored their temporal evolution or spatial variability.

In this study we assess spatiotemporal changes in supraglacial hydrology across the ~800 km latitudinal gradient of Ellesmere Island. The utility of various semi-automated methodological frameworks for present-day supraglacial stream mapping is being evaluated, using optical satellite imagery of ~5-30 m spatial resolution, including Planet, Sentinel-2 and Landsat-8. These methodologies typically use the Normalized Difference Water Index to enhance spectral contrast for linear feature enhancement and/or use a digital terrain model to identify potential flow routes. The optimal methodology is then applied to quantify changes in supraglacial hydrology across Ellesmere Island over the past ~40 years by making comparison with historical ASTER, SPOT and Landsat satellite imagery, and potentially to the 1950s by making comparison with historical air photos. Preliminary findings show significant changes in perennial streams' width, incision, and sinuosity since the late ~1950s, with an acceleration in the rate of change over the last decade. The changes, especially in the rate of incision, appear to occur along a spatial gradient with greater relative changes found in far northern areas. Overall drainage density has also increased as new streams form and as perennial streams extend up glacier into previous accumulation areas.

INVITED LECTURE

Glacier changes in Svalbard in a global context

Jon Ove Hagen
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Abstract:

Glaciers are vulnerable to climate changes. The ice mass changes are driven by snow accumulation during the winter season and summer temperature (ice melt) during the summer. The glaciers in Svalbard had their maximum extent as late as early 1900 which can represent the end of the Little Ice Age in Svalbard. Since then, the glaciers have retreated.

The most recent inventory of Svalbard glaciers shows reduced ice masses and gives an area of 33 775 km² of glaciers covering 57% of the total land area of the archipelago. At present, 68% of the glacierized area of Svalbard drains through tidewater glaciers that have a total terminus width of ~ 740 km. The glacierized area over the entire archipelago has decreased by an average of 80 km² a−1 over the past ~30 yr, representing a reduction of 7 %.

Mass balance monitoring were started by the Norwegian Polar Institute in 1967 at two small glaciers in Kongsfjorden, North-West Spitsbergen. These have been extended to larger glaciers in the same region since 1986 and since 1988 Hansbreen in South Spitsbergen has been monitored. The mass balance time series are among the longest continuous data series from the Arctic. However, they cover only a small fraction (~2%) of the total glaciated area. The larger glaciers are in general more positive, since their accumulation areas are both higher and larger than the smaller glaciers. On all glaciers, summer ablation is more variable than winter accumulation, thus summer temperatures provide most of the control on the net balance. The hypsometry (area/altitude distribution) is important for the response to climate changes. The bulk of the glacier area is close to the equilibrium line altitude and thus the Svalbard glaciers are very sensitive to small temperature changes.

Geodetic mass balance over entire Svalbard has been obtained by analysing and digitizing older maps from the 1930ies and more recent satellite data after 2000. This shows that most glacier regions in Svalbard have experienced low-elevation thinning combined with high-elevation balance or thickening. The general thinning rate has increased over the last decades. The largest ice losses have occurred in the west and south, while northeastern Spitsbergen and the Austfonna ice cap have been more stable.

Many glaciers are of surge-type and surges may alter the are/altitude distribution and for calving glaciers give a temporary increased mass loss. A recent surge in Basin 3 on Austfonna ice cap resulted in a temporary tripling of the calving loss from the entire ice cap with c. 4.4 Gt calving loss from the basin during one year.

The glacier changes in Svalbard are representative of the Arctic Glacier and Ice Cap changes and these ice masses currently contribute almost 1/3 of the glacier melt contribution to global sea-level rise.

Temporal and spatial variability of evaporation in Hornsund area (SW Spitsbergen)

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Keywords: Evaporation, Water Balance, Climate Change, Svalbard, Hornsund

Abstract:

Evaporation is an important component of the hydrological cycle but remains understudied in High Arctic Svalbard.

In this study, we investigate land evaporation at SW Spitsbergen in High Arctic catchments using in-situ pan evaporation measurements and calculated potential evaporation. The study area is located in the vicinity of the Polish Polar Station Hornsund in Svalbard, where long time series of meteorological measurements and multiple hydrological studies have been conducted.

With ongoing climate change and an increase in air temperature, evaporation rates are likely to increase. For a better understanding of evaporation in the study area, one pan evaporometer was installed at the meteorological site in the summer seasons of 2019-2022. In 2022 additional four pan evaporometers were placed in Fuglebekken and Ariebekken catchments to investigate the spatial variability.

According to literature from the early 2000s annual evaporation of ca. 80mm/year for glacier-free areas in Svalbard was estimated. Analyses of recent in-situ measurements indicate higher annual evaporation rates. The use of multiple potential evaporation formulas based on different approaches revealed that the choice of the calculation method could have a large influence on the derived estimates. Identification of the meteorological variables, that influence the amount of evaporation, helps to improve the estimates of potential evaporation applied in hydrological models.

Monitoring of the environmental impact from human habitats; a case study from Aquarius underwater base, AATC habitat and Polish Polar Station, Hornsund

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Keywords: Monitoring, Environment, Polution, Habitat, Scientific, Diving

Abstract:

Aquarius underwater base, AATC Moon/Mars habitat and Polish Polar Station, Hornsund are three examples of a permanently manned scientific research laboratories existing in a unique ecological setup. Those facilities constantly manifests an environmental impact on their niche. AATC scientist are conducting research of such effect. During the presentation authors will demonstrate methods, tool, techniques and also preliminary results of monitoring the environmental impact of human habitats.

INVITED LECTURE

The Biogeochemical consequences of glacier retreat in Svalbard: a landscape perspective

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Abstract:

Great attention is currently being given to the influence of glaciers upon fjord ecosystems in Svalbard. Quite often, the transition from marine-terminating to land-terminating glaciation is emphasised, because this can drastically alter the circulation of nutrient-rich bottom waters in fjords and potentially reduce access to productivity-limiting nutrients in the photic zone. These relatively rapid changes deserve research attention, but so too do the changes that follow long after the glaciers have retreated onto land. For example, the most important productivity-limiting nutrient in Svalbard fjords is arguably nitrate, whose delivery by runoff can be enhanced by rock-water interaction and nitrification in shallow groundwater flowpaths typical of those in recently deglaciated terrain. The first part of this talk will therefore emphasise nitrate dynamics and assess to what extent new sources of nitrate can be anticipated during sustained glacier retreat. It will consider how uncertainty in the relative impacts of nitrification and denitrification is a barrier to understanding the future nitrate economy of runoff, and show that we need to do a lot more work to better understand these processes beneath larger glaciers and within lowland permafrost.

Glacier retreat means that expanding glacier forefields require direct consideration as critical zones for regulating the Svalbard landscape's biogeochemical response to climate change. The second part of the talk will therefore focus upon this environment and switch emphasis from nutrients to greenhouse gases. A lot of attention will be given to permafrost processes in glacier forefields, and the extent to which they regulate methane emissions. It will be shown that most (84%) of methane emission sites associated with groundwater springs are located in glacier forefields, and that they might release in excess of 2M kg CH4 per year across Svalbard. It will also be shown that more of these emission sites can be expected as glacier forefields grow, especially if rates of permafrost aggradation are reduced by climate warming. However, it will also be shown that there are major uncertainties predicting how large methane emissions will occur as permafrost thaw and glacier volume reduction occur in tandem. More emphasis upon the slower, more nuanced responses of the landscape to climate warming is therefore required before we can claim to have a holistic understanding of the changes that lie ahead.

Non-invasive method of measuring vitamin D level

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Keywords: vitamin D, non-invasive, sunlight deficiency

Abstract:

Vitamin D is one of the most important substances circulating in the human blood, as it is responsible for the correct functioning of the skeletal system. Control and easy monitoring of vitamin D concentrations in the human body is needed to maintain health and prevent many diseases associated with vitamin D deficiency. In particular, people living in the Arctic regions of our planet are exposed to the unpleasant consequences associated with lack of access to the vitamin's source, the sun. The production of vitamin D3 in our skin is dependent on access to sunlight. A deficiency experienced by polar explorers is not only caused by the occurrence of polar nights but also because of the need to wear thick clothing that covers most of the body and restricts access to the sun. Currently, the measurement of vitamin D concentrations is done by taking the subject's blood and is carried out in specialised laboratories, access to which in the Arctic is severely limited, so the desire to carry out such a test would incur huge costs. If every person staying for a long period of time in the Arctic Circle were provided with a personal vitamin D measurement device in the form of a sensor integrated into a smartwatch, all the problems associated with performing the test would be solved. The test would be based on the sensor's measurement of the absorption of radiation of the appropriate wavelength absorbed by the VDBP (Vitamin D Binding Protein), which is the carrier of vitamin D3 and D2, and so the test would be completely non-invasive. Continuous access to information on vitamin D levels would enable appropriate dosage and would prevent vitamin D deficiency. Presented solution is not only much cheaper in comparison with traditional procedure but also requires no medical education or experience.

INVITED LECTURE

Rapid change at the ice-ocean interface: mass loss and retreat of marine-terminating glaciers

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Abstract:

Marine-terminating glaciers hold more than 99% of potential sea level rise from land ice and are critical in many Arctic ecosystems. Until recently, we did not have accurate maps of their locations, much less data on their terminus position changes and calving rates (i.e. frontal ablation). We mapped the ~1700 marine-terminating glaciers in the Northern Hemisphere and found that 85% of glaciers have retreated since 2000, with the loss of ice shelves being the main reason for the biggest retreats we observed. We also found that surge-type glaciers and those with unstable geometries (i.e. reverse slopes) and/or wide calving margins were also the most likely to experience large retreats. Frontal ablation includes mass lost at the calving front, mainly the calving of icebergs. We found a total frontal ablation of 559 ± 17 Gt a^{-1} for the Northern Hemisphere, 91% of which comes from the Greenland Ice Sheet and peripheral glaciers. These observations show how sensitive many marine-terminating glaciers are in the face of a changing climate and how important they will be in determining how quickly sea level rises in coming decades. These studies would not have been possible without trans-national collaborations amongst modelers, field scientists, and remote sensors. To better our understanding of these dynamic environments, we need diverse international collaborations that work across disciplines to advance our science.

Can polar be green? Biological and chemical analysis of ground samples collected around the Hornsund base to determine the optimal medium for food production in extreme environments.

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Keywords: microorganisms, symbiosis, extreme agriculture

Abstract:

Over 120 years of polar agriculture is helping scientists to grow food in extreme environments such as space. Despite this experience and application of the most advanced techniques such as hydroponics, aquaponics and aeroponics, obtained cultivation result is not sufficient to support people for a long time. The main reason is that full isolation of living organisms in sterile conditions without symbiotic species fungi and bacteria, reduces growth and terminates their existence. Here we ask wether it is advantageous to implement collected in situ microorganisms into the cultivation system, which could possibly activate symbiotic relations with plants. Such multi species consortium should be more resistant to polar conditions due to adding polar organisms already adapted. Another problem we elaborate in this work is how to determine proper ground samples needed to be collected to optimize the food production. Are there any biomarkers, which could be easily characterized?

In order to answer mentioned above questions, samples were collected in Svalbard around the Hornsund Research Station from 4 different directions and 5 different distances (0m, 1m, 10m, 100m, 1000m), and then analyzed using genetical screening, ICP, TOC and imaging. Symbiotic relations were observed on different types of ground samples by seeding cress plants Lepidium sativum. Grown plants were analyzed after 7, 14, 21 and 28 days of cultivation under the microscope. Similar screening was made for the microflora using a microbial purity sensors and imaging techniques.

Our results highlight the meaning of multiple species in polar agriculture. Especially interesting seems to be fact, that local microorganisms can be implemented in the cultivation systems and may either improve the food production or invade the crops depending on the type of microorganism. Participation in this conference and especially field workshop would be another chance to collect more information about this unique for life environment.

Modeling ice flow variability of the Kangerlussuaq Glacier, southeast Greenland, during 1900-2021

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Keywords: Kangerlussuaq Glacier, glacier modelling, ice-flow variability, little ice age, importance of ice-front retreat

Abstract:

Kangerlussuaq Glacier has been the single largest source of mass loss from the central-eastern sector of the Greenland Ice Sheet since 2000. Observations show significant ice loss associated with the speed-up of the Kangerlussuaq Glacier from 2004, followed by a moderate deceleration during 2006-2008. However, the post-2008 ice discharge rate was well above the pre-2004 rate. These short-term, episodic, dynamic perturbations significantly impact its mass balance at the decadal scale. A long-term data record that reveals the mass balance beyond episodic events is required to improve the projection of future Greenlandic glacier mass loss. Here, we use an extended observational record of surface elevation change and terminus position retreat of the Kangerlussuaq glacier over the entire 20th century, from 1900 to 2021, to improve our understanding of the processes controlling the dynamics and mass balance of Kangerlussuaq on a centennial time scale.

We model Kangerlussuaq Glacier with the Ice-sheet and Sea-level System Model (ISSM). The model is initialized by inferring the basal conditions from 2007 data and running the model forward in time from 1900 using an estimate of ice thickness derived from trimline-based observations of ice surface elevation during the Little Ice Age. We force the model using a surface mass balance model and by constraining the ice front position using 1298 terminus position observations between 1900-2021.

The final model state is in excellent agreement with today's observed velocity and ice thickness. We estimate a 476 Gt ice mass loss over the past 121 years. Experiments with various external forcings reveal that the retreat of the ice front alone explains most of the glacier's dynamic variability and mass change. We find that the glacier was relatively stable until 1958-1970 when the mass loss started accelerating, reaching the highest mass loss rate in the 2000s.

Geodetic mass balance of Hansbreen in the period 1990-2017

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Keywords: Svalbard, Hansbreen, geodetic mass balance, volume change

Abstract:

Svalbard is one of the fastest-warming regions on the Earth. Ongoing climate changes influence the mass balance of glaciers. Glaciers continue to lose their mass, which affects global sea level rise.

The primary objective of this case study was to estimate the geodetic mass balance of Hansbreen located in southern Spitsbergen in the period 1990-2017 as an example of tidewater glaciers of this region. Satellite and airborne remote sensing data, as well as digital elevation models (DEM) from 1990, 2011 and 2017 were used in this study. Also an assessment of their accuracy was done. The comparison of data from these time slices by the GIS tools permitted to quantify geometry changes of the glacier (in area, and elevations of particular altitudinal zones).

The results show significant differences between rates of changes in both periods (1990-2011 and 2011-2017). Greater intensity of the ice mass loss was noted in the second period, i.e. -2,001 ± 0,07 m w.e. a^{-1}, while in the first one equals to -0,765 ± 0,12 m w.e. a^{-1}. The values are higher than obtained by the direct measurements of climatic mass balance conducted on the Hansbreen surface due to frontal ablation. The study also tries to complete the total mass budget of Hansbreen by attempting to estimate the frontal ablation using the glacier velocity data.

The results were also interpreted in the context of changing climatic conditions based on the data from the Polish Polar Station Hornsund located near the glacier. Throughout the studied period we observed an increase in the mean annual air temperature, and lengthening of the ablation period, which affects changes in the Hansbreen's geometry.

Other research confirm that we can expect increasing losses in the mass of glaciers. Therefore, further studies of their geometry changes and dynamics are needed to confirm and quantify acceleration in deglaciation of the Svalbard archipelago.

INVITED LECTURE

Probabilities of Snowfall and Rainfall in the Atlantic Arctic under the Current Climate Warming

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Abstract:

Precipitation, an important element of the water cycle, plays a significant role in the climate system, triggering numerous environmental processes including river runoff and discharge, flooding, landslides, transport of sediments, and glacier mass balance and dynamics. The impact of precipitation on the environment depends on its phase. Liquid precipitation in the cold part of the year may lead to the build-up of ground ice on the tundra, causing icing that reduces the availability of food for herbivores. Solid precipitation plays a profound role in the Arctic and global climate systems since it is crucial for the development of snow cover to be involved in a feedback mechanism that has significantly contributed to accelerated Arctic warming.

The precipitation phase depends on the thermal structure of the troposphere between the ground and the cloud base. Temporal changes in precipitation phases are also temperature dependent. Generally, higher temperatures lead to reduced snowfall and an increased rainfall fraction, but the rate and geographical distribution of these changes are nonlinear and depend on the ambient temperature and average climate conditions.

Changes in the probabilities of liquid, mixed, and solid precipitation on annual, monthly, and sub-monthly scales were studied using data from six synoptic stations representing various climate conditions in the study area with mean annual air temperature from –0.18 to –4.8°C which may alter rainfall to snowfall proportions in response to climate change.

The following questions are raised: (1) Are precipitation types in the Atlantic sector of the Arctic sensitive to accelerated warming of the Arctic, and if so, how? (2) Is geographical and intra-annual variability present in these reactions? (3) How strong is the impact of atmospheric circulation on temporal variability in precipitation phases?

In the studied region, snowfall and rainfall were sensitive to warming and atmospheric circulation to various degrees, depending on the phase, mean climate features, month, and local conditions. The probability of days with rainfall increased, whereas the probability of days with snowfall decreased. The increasing trends in the probability of rainy days at all stations and decreasing trends in the probability of snowy days in the southern part of the region are warming-induced.

The most significant and widespread trends in snowy and rainy days were found in September. The probability of days with mixed precipitation exhibited no trends due to an inverse reaction to warming in the warmer and colder parts of the year. Temporal variability in the probability of precipitation phases was significantly linked to three teleconnection patterns that played a role in various parts of the year.

Extreme precipitation over Svalbard and its relation to the recent decline of sea-ice in the Greenland Sea

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Keywords: Arctic warming, sea-ice decline, extreme precipitation

Abstract:

In the last decade, several extreme precipitation events over Svalbard have been observed, which all had a strong impact on the environment and society. The most recently observed events in the years 2012 and 2016 were the highest events in the entire precipitation record from 1974 till today. The key question of our study is, whether those recently observed extremes are part of a climate change signal or are a random accumulation of extremes. Those precipitation extremes are connected to atmospheric rivers, which bring warm and moist air towards higher latitudes. Only very few historical observation records exist and thus it is not possible to understand recent changes in the extreme precipitation characteristics over Svalbard from observations only. We developed a novel approach to determine recent (1980 to 2018) trends in extreme weather from a large high-resolution ensemble hindcast. The hindcast is from a seasonal prediction system and constrained to atmospheric and oceanic reanalysis data. With this large 100-member ensemble the confidence intervals are greatly reduced and it allows us to study instationarity of climate extremes and to identify processes that are drivers for changes in extreme Arctic precipitation. It shows that return values over Svalbard have been changing by about 10 % within the last 35 years and the largest trends are found in the northern parts of Svalbard. The major cause of this change can be attributed to the reduction in sea-ice extent east of Greenland, because the presence of sea ice shields the west coast of Svalbard from the incoming southerly moist air. Our analysis suggests, that in the future with a further decline of the sea ice coverage east of Greenland, the recently observed precipitation extremes will become even more frequent.

On the use of a 3D glacier-fjord model to study a marine-terminating glacier front position

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Keywords: Calving, fjord, frontal ablation, glacier dynamics, ice-ocean interactions, marine-terminating glacier, modelling, plume model, submarine melting

Abstract:

To analyse the evolution of a tidewater glacier front position provides a good approximation of its ice-loss due to frontal ablation and a general overview about how this climatic-sensitive system can be affected in the current global warming scenario. The main contributors to frontal ablation are iceberg calving and submarine melting. Even if the direct effect of submarine melting is less than calving, this process can promote calving through the changes induced in the stress field at the glacier terminus. Therefore, it is important to take into account both mechanisms. Among the factors influencing submarine melting, another relevant process that has to be considered is the formation of a buoyant plume due to the emergence of fresh subglacial water at the glacier grounding line.

In this study we use a 3D glacier-ocean model including calving, subglacial hydrology coupled and a line-plume model fed both by the subglacial discharge that accounts for the submarine melting at the calving front and by the fjord ambient conditions. The model provides the calving front position at every time-step.

We apply this model to the Hansbreen-Hansbukta glacier-fjord system in Southern Spitsbergen, Svalbard, where a large set of data are available. Our results show that the evolution of the modelled front positions are in agreement in terms of advance and retreatment with those observed from time-lapse images of the glacier front, reproducing, therefore, the expected tidewater glacier cycle.

Dynamic Responses to Evolving Basal Drainage Systems in Western Greenland

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Keywords: Greenland Ice Sheet; ice dynamics; ice velocity; remote sensing; feature tracking; drainage systems; basal channels; ice/atmosphere interactions

Abstract:

The Greenland Ice Sheet constitutes a major contributor to the eustatic sea-level rise, having undergone significant acceleration in ice-mass loss over the recent decades. The magnitude of its deglaciation depends closely on ice-flow behaviour which varies at different spatiotemporal scales in response to a combination of changing atmospheric, oceanic and geometric conditions. Current evidence points to a potential link between seasonal fluctuations in ice-flow speed and development of channelised hydrologic systems due to melt-season influx of surface meltwater to the ice base. However, the paucity of the satellite data makes the task of generating continuous ice-velocity timeseries that resolve seasonal variability difficult, largely restricting previous observations to lower ablation zones. Here, the feature-tracked NASA ITS_LIVE datacubes are utilised to produce a high-resolution record of year-round changes in ice flow of 50 major outlet glaciers in western Greenland for three years of contrasting melt (2018-2020). For the first time, data collection is conducted along glacier flowlines, allowing for investigation of surface-velocity patterns and propagation of dynamic signals up to 1500 metres above sea level. Intra-annual ice-flow observations are employed to examine dynamic responses to evolving basal drainage systems and to infer the likely upglacier limits of subglacial channelised network development. By incorporating the RACMO runoff data, the amount of surface meltwater, which is routed in large channels, causing slowdown, or accommodated in distributed systems when channels are absent, causing speedup, is quantified. The study advances the understanding of the relative significance of channelisation and cavitation in terms its net overall effect on annual velocity and explains the observed differences in the dynamic effect of melt injections at different elevation bands, latitudes and between land- and marine-terminating margins in relation to hydropotential gradients, relative speeds and meltwater availability, offering insights into how a glacier interacts with various forcing mechanisms.

Fluctuations of glaciers in S Svalbard from geochronological data and numerical modelling

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Keywords: Hornsund, Spitsbergen, glacier retreat, radiocarbon dating, ice flow modelling

Abstract:

Over the last 40 years, Svalbard has been warming seven times faster than the global average. Due to their hypsometry, glaciers in Svalbard, especially in the southern part of the archipelago, are highly sensitive to temperature rise. Landforms and sediments in the marginal zones of glaciers are the legacies of their fluctuations in the past. However, the temporal and spatial resolution of geomorphological records is limited. Hence, interpreting glacier dynamics based on geological data may be challenging. Our study aims to reconstruct the fluctuations of glaciers in Hornsund (S Svalbard) in the Holocene, combining geochronological data with numerical modelling of glacier dynamics. Radiocarbon dating of molluscs shells, driftwood, whalebone and other types of organic material indicates glacier retreat in the Early Holocene and the Medieval Warm Period. In turn, glacier advances occurred c. 2 ka cal. BP and during the Little Ice Age. Ice flow modelling has proven a high sensitivity of land-terminating and tidewater glaciers in S Svalbard to even a minor increase of the equilibrium line altitude and high dependence of glacier dynamics to subglacial topography. However, each glacier response differently to climate change depending on geometry. Finally, a rapid retreat of tidewater glaciers in the warmer phases of the Holocene allowed the colonization of new fjord branches.

Geochronological records of glacier activity in S Spitsbergen in the Holocene

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Abstract:

Glaciers in Hornsund (S Spitsbergen) and their forefield environment have been the subject of numerous investigations, including glaciological, meteorological, hydrological, and oceanographic monitoring. However, the Holocene history of even the most studied glaciers, Hansbreen and Werenskioldbreen, is still not widely understood. Our study aims to reconstruct the fluctuations of marine- and land-terminating glaciers in Hornsund in the Holocene. To this aim, we compile new and published results of radiocarbon and cosmogenic exposure dating to outline the periods of glacier retreat and re-advances. Radiocarbon dating of molluscs shells, subfossil vegetation, whalebones, and other types of material collected in the glacier forefields indicates glacier recession in the Early Holocene as well as during the Medieval Warm Period in the Late Holocene. The oldest marine shells collected at the forefield of Hansbreen indicate extensive recession by 11.2 ka cal. BP, similar to Hornbreen and Vestre Torellbreen. Subsequently, glaciers retreated to the inner part of their valleys and presumably onto land throughout the Early and Middle Holocene. In turn, glacier advances occurred during the Neoglacial and the Little Ice Age. However, despite gradual climate cooling in the Late Holocene, the termini of tidewater glaciers have not reached their maximum Neoglacial positions before c. 2.0 ka cal. BP. The fluctuations of Hornsund glaciers occurred synchronously with other regions of Svalbard. However, the uniqueness of this area is connected with switching between a fjord and a strait depending on the dynamics of tidewater glaciers at the head of Hornsund. The recession of the Hornbreen-Hambergbreen system has led to the opening of the strait, whereas the glacier advances have led to building the ice isthmus at the head of the fjord.

Paraglacial lagoons of Svalbard

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Keywords: barrier-lagoon system, paraglacial coasts, glacier retreat, storms, Svalbard

Abstract:

Coastal lagoons are shallow bodies of water that have been completely or partially separated from the sea by a barrier (often a spit system), connected to the ocean by one or more restricted inlets which remain open at least periodically.

Still, only few studies have focused on the response of Svalbard's barrier-lagoon systems, which is one of the most sensitive coastal environments to climate change and sea level changes. One of the interesting examples of climate change impacts of Svalbard coastal environments is the formation of paraglacial lagoons. They are formed due to the retreat of the marine-terminating glaciers which are exposing new bays. Their barriers that separate lagoons from the open sea are usually composed of the remnants of the frontal moraines transformed into littoral landforms by waves and tides. I have detected 36 paraglacial lagoon systems that are currently developing on Svalbard. Here I present the results of a pilot study of the evolution of the largest 6 paraglacial lagoons since the end of the Little Ice Age. For this purpose, I used remote sensing data - an orthophotomap from 1936, aerial photos from the 1960s, 1970s, 1990s, 2010-12 from Norwegian Polar Institute, as well as satellite images from Sentinel and Landsat for the most recent years. I concentrate on the rates of lagoon formation associated with a land and sea exposure by retreating glacier front and morphological changes along the freshly developing shorelines. Finally, I analyze the impact of recent storms on the stability of coastal barriers and erosional action.

This is a contribution to the 'ASPIRE - Arctic storm impacts recorded in beach-ridges and lake archives: scenarios for less icy future' project funded by the National Science Centre (UMO-2020/37/B/ST10/03074).

Looking into the future of Svalbard's atmosphere. State based on HERMOSA (SESS 2022)

Paulina Pakszys

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Keywords: Svalbard atmosphere, HERMOSA, air impurities, atmospheric pollution research and monitoring, recommendations

Abstract:

The Arctic acts as a global refrigerator by drawing warm ocean water from the south, cooling it, and ultimately sinking it toward the ocean floor. However, the interplay between water and the atmosphere, and also with other integrals of climate system, makes the atmosphere the core of climate research.

In recent years, atmospheric research in Svalbard has grown in variety and magnitude, with more comprehensive long-term observational efforts and numerous short-term intensive field experiments. These measurements has been reviewed by Hermosa, with a focus on long-term monitoring programmes that gather information from various sources on the state of the research and monitoring of priority pollutants and other impurities in the atmosphere over Svalbard, bridging the chemical, biological and supportive physical monitoring efforts.

Over Svalbard most of measured atmospheric characteristic, including levels of chemical pollution, dark dust connected to soot, and living organisms happens in Ny-Ålesund, preferred as a best hub that Svalbard offers. Climate-induced changes in spatial patterns and seasonality of parameters related to atmospheric impurities need to be studied at more than one site to be comprehensively understood, and the Arctic is likely to face multiple non-linear changes. Beyond the sites, also the methods at various proposed locations need to be harmonized and laboratories compared to obtain robust results.

Another important factor is interdisciplinary aspects, such as impacts on cryosphere and ecosystems, which is inherent in atmospheric impurity studies as are the well-known connections to human health, social science and economy.

You will learn that collecting information on many characteristics of the air at the same time helps solve long-standing scientific questions in Svalbard, such as the origins of pollution in the Arctic air and the future of the Arctic atmosphere in a changing world.

Still, some questions remain unanswered. What is the future of spatial distribution of key atmospheric impurities across Svalbard? How we can act to achieve harmonised picture across Svalbard? It is an attempt to present the complexity and problems of polar research as well as recommendations that we should apply in the near future.

Dendroecological response of Salix polaris from the two contrasting sites of Central Spitsbergen, Svalbard

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Keywords: Arctic, Climate change, shrubs, tundra, ecosystem

Abstract:

Arctic is warming four times more than the rest of the earth since 1970s. Since, this rising warming causing an unprecedented glaciers retreat, thawing permafrost, risk of avalanches and frequent mudslides. Moreover, its effects on the arctic vegetation, marked a huge recent changes. In Arctic, shrub expansion is very crucial and widely observed responses of high-latitude ecosystems to rapid climate warming. On the contrary; tundra browning, and their shift patterns from some native areas are another matter of concern. Hence, this diverse impact of climate change, under changing environment, has contributed to a complex set of soil–plant–atmosphere interactions. For a better understanding, the influence of a number of abiotic factors should be traced, such as topographic and soil conditions, altitude and exposure. Thus, the aim of this study is to analyze annual ring variability and wood anatomy features of Salix polaris Wahlenb. growing along an altitudinal transect. Additionally, to understand its interactions with the contemporary environmental conditions, we tried to find out its linkages with soil composition, species regeneration, sea ice rates, reindeer grazing, etc. Samples were collected from the two contrasting sites, northern slope of Breinosa fjellet in the vicinity of Foxfonna glacier (Adventdalen, Central Spitsbergen). Site 1 was located at an elevation of 451 m a.s.l, on the top of the massif covered with coarse-grained clasts. Whereas, site 2 at an elevation of 51 m a.s.l, on the gentle slope of the marine terrace where rock fragments in the soil comprised with a dominant sandy loam. Detailed anatomical analyses and measurements were carried out. Differences in the growth structure of the dwarf shrubs were found. This study will be helpful to understand the recent changes in Svalbard region and in filling out the gaps that dendroecological studies required in such sensitive areas. While in future, there is an urgent need of using multifactorial field experiments and multi-scale observations, that are designed to disentangle the relative impacts of multiple drivers and their interactions.

Spatial variability of ground surface temperature across scales and permafrost detection

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Keywords: permafrost, ground surface temperature (GST), landcover, Qinghai-Tibet Plateau (QTP), climate change

Abstract:

Ground surface temperature (GST, depth of 5 cm) is a key parameter for understanding the thermal evolution of the active layer and permafrost. A multiscale observation network of GST under different landcover types was established in an area of discontinuous alpine permafrost on the northeastern Qinghai-Tibet Plateau. The spatial scales range from fine (2 to 16 m) to local and landscape scales (2 and 50 km²) and along an 800-m elevational transect. GST was recorded using 72 iButton temperature loggers (DS1922L) at 39 sites from 2019 to 2020 under similar and different environmental conditions (e.g., elevation, landcover). A statistically significant correlation was identified between mean annual GST (MAGST) with landcover (0.37, $p < 0.05$) and elevation (−0.76, $p < 0.001$). MAGSTs in meadows (−0.6 to 0.6 °C) were higher than those in swamp meadows (−1.4 to 0.7 °C) and bare grounds (−2.0 and −1.2 °C). The decrease of MAGST with elevation was more pronounced for the sites in the bare ground ($R^2 = 0.83$) than vegetated ones (e.g., meadow: $R^2 = 0.64$). The negative MAGST was associated with a frost number > 0.5, indicating the probable presence of permafrost, and further validated by the boreholes measurements. Sites with a MAGST < –1 °C corresponded well with the stable permafrost, while sites with a MAGST > 1 °C matched the areas of seasonally frozen ground. The sites with a MAGST that ranged between –1 and 1 °C agreed with the lower elevation limits of discontinuous permafrost. These results help identify the patterns of permafrost distribution and thaw at a high spatial resolution and better understand their relationship with vegetation development.

Role of Surface Albedo for Differences in Modeled Ice Sheet Meltwater Runoff

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Keywords: Greenland, albedo, ice-sheet, mass balance, modeling, radiative heat fluxes

Abstract:

Since the 1990s, the Greenland Ice Sheet (GrIS) has had a net negative mass balance and it is currently the world's single largest cryospheric contributor to global sea-level rise. Accurate projections of ice sheet mass loss are therefore imperative. Although there already has been a number of regional climate models (RCMs) applied to forecast ice sheet mass loss, a recent intercomparison (GrSMBMIP) of surface mass balance (SMB) models demonstrated substantial discrepancies between their individual estimates. One likely explanation of model spread is inaccurate simulation of albedo, which determines the amount of shortwave radiation that is absorbed by the ice sheet surface.

In my research project, I seek to combine remote sensing products with a state-of-the-art surface energy mass balance model to investigate how different albedo schemes and cloud conditions impact meltwater runoff from the GrIS. In order to achieve this, I will develop benchmark meltwater runoff projections using a flexible process-based SMB model, "IceModel." It was designed to capture complex subsurface melt/refreezing processes in the glacier column, where most meltwater runoff is generated, and compares well with in-situ observations. IceModel will be used to evaluate different albedo parameterizations in RCMs and global atmospheric reanalysis products, which are commonly used for forecasting GrIS mass change. The implementation of both remote sensing observation and in-situ measurements in the development of IceModel will allow us to identify the physical mechanisms responsible for uncertainties and biases in current assessments of the ice sheet's contribution to global sea-level rise.

INVITED LECTURE

Svalbard coastal change - known knowns, known unknowns and unknown unkowns

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Abstract:

For many years the understanding of mechanisms controlling evolution of Svalbard coastal zones remained one of the neglected branches of environmental research in this key region for the study of climatic changes impacts on European Arctic environments. It is widely accepted that the research carried out on the archipelago over the last century brought major advances in the study of glaciers, permafrost, slope and fluvial processes operating in the High Arctic, but could we say the same about coastal studies? In my lecture I will make an approach to present to you the fascinating and diverse coastal landscape of Svalbard and highlight the main achievements obtained in recent years from coastal change observations. I invite you for the scientific journey from rugged and rocky coasts, through prograding beaches and deltas supplied by glacier rivers, to mysteries of coastal permafrost interacting with Svalbard seas. It is important to note that during the last century the rapid deglaciation activated number of new sediment cascades through which glacial and periglacial sediments are transported to the coastal zone. Using examples from studies carried out in Billefjorden, Recherchefjorden, Kongsfjorden and Hornsund I will show how those pulses of sediments were used to form new barrier and spit systems. We will also discuss the role of tidal flats in some of the inner fjord environments in storage of glacial sediments. Svalbard offers also excellent locations to study the development of rockly cliffs and shore platforms. New data on rock coast erosion rates and shore platform downwearing collected along the Svalbard coasts revealed number of intriguing patterns and questions about efficiency of marine and periglacial processes in rock weathering.

In my opinion, the biggest challenge for the future of Svalbard coastal research is to capture the way how coastal systems adapt to the shift from marine-terminating to land-based glaciers occurring in numerous Svalbard fjords and describe the initial phase of paraglacial transformation of freshly exposed shores from retreating glaciers. Coastal zone is a key interface were severe environmental changes impact directly on Svalbard community infrastructure. Recent studies showed that Svalbard heritage and settlement infrastructure sites are already seriously threatened by coastal erosion.

So, although we have observed a significant progress in coastal change studies in Svalbard there are still important gaps to be filled by future generation of Svalbard researchers.

The presentation is based on the research obtained from the Polish National Science Centre projects: POROCO, ASPIRE, SVELTA and GLAVE based at the University of Wroclaw

INVITED LECTURE

Microbial biodiversity as a biomarker of changes in polar ecosystems

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Abstract:

Climate warming increases glacier outflow, affecting water properties and providing changes in supraglacial and subglacial ecosystems. These are unique environments inhabited by various prokaryotes and eukaryotes that are capable of survival and proliferation at low temperatures. These microorganisms are essential for global microbial activity and nutrient cycling in permanently cold environments. Changes in glacier behaviour, such as the acceleration of ice melting, impact microbial communities, which is why microbial biodiversity is considered a sensitive biomarker for detecting changes in polar ecosystems. The development of modern, genetic-based methods like next-generation sequencing (NGS), a high-throughput sequencing technique providing much information, allowed us to study the community structure and changes in the microbial alpha and beta diversity.

NGS has proven to be a sensitive method in many studies, including polar environments, and it is worth looking more closely at the use of microbial biodiversity to assess environmental change. For instance, we used next-generation sequencing of bacterial 16S rRNA marker gene to study glacier microbiomes in the subglacial drainage system of the Werenskioldbreen glacier, Svalbard. Generally, studying subglacial microbial environments is quite challenging, and surface and deep drilling or analyses of water flowing out from glaciers are the most frequently used techniques. As a source of microbial communities, we used dome-shaped naled ice bodies forming and releasing subglacial water in the glacial forefield during the accumulation season. It prevented contamination from surface meltwater or rainwater, which can carry microbes from sources other than the glacier-bedrock interface. Our research showed that changes in the chemistry of naled water dependent on the local lithology of the drainage system were reflected in the microbial communities. The structure of the microbial communities was stable and specific for the sampling sites. In addition, analysis of the alpha and beta diversity of the microbial communities allowed us to verify glaciological models of subglacial drainage and confirmed that the meltwater transported through independent channels was a habitat of different microbial communities. Moreover, this study proved that when sampled during winter, it is possible to study glacier microbiome using naled ice bodies as a source of subglacial water. Similarly, other studies confirmed that microbial biodiversity is a valuable biomarker of polar ecosystem behaviour related to climate and, combined with other techniques, may help in the early detection of changes in these sensitive environments.

Upper ocean dynamics evolution in Fram Strait from SLA using the Surface Quasi-Geostrophic approach from 2010-2020

Marta Umbert

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Keywords: ocean dynamics, ocean currents, remote sensing

Abstract:

This study assesses the capability of surface quasi-geostrophic (SQG) approach to reconstruct the three-dimensional (3D) dynamics in a critical region of the Nordic Seas: the western coast of Svalbard, in the Fram Strait. Here, salty and warm Atlantic waters flow northward, entering the Arctic Ocean as the West Spitsbergen Current and feeding the Atlantic Intermediate Layer. This inflow is balanced by the cold and fresh Polar Waters, which flow southward along the western boundary of the Fram Strait. Since a non-negligible increase of the water temperatures reaching Svalbard has been reported over the last decade, changes in patterns, flux and rates of the Atlantic waters entering the Fram Strait might have strong impacts on glacier melting in Svalbard.

The difficult environmental conditions of the Arctic make remote sensing a good complement to in-situ measurements of ocean currents. Since 2006, Surface Quasi-Geostrophic (SQG) theory has been used to estimate subsurface dynamics and reconstruct the ocean interior from satellite observations. Here we present the application of the SQG approach to study the evolution of the ocean dynamics in the upper 400 meters of the ocean over the decade of 2010–2020 in western Svalbard.

We apply the SQG approach to reconstruct the 3D dynamics using the remotely sensed Sea Level Anomaly (SLA) data as input. Afterwards, we compare the 3D reconstructions with the geostrophic currents derived from the in-situ EN4 data in order to validate the reconstructions that were derived from the AVISO SLA data. A temporal analysis of the upper ocean currents from satellite information allows us to monitor changes in the north Atlantic current at a high temporal resolution and evaluate their potential impacts on Svalbard glaciers.

Freshwater discharge control seawater pCO_2 during the melt onset in fjord waters of Young Sound, Northeast Greenland

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Keywords: Northeast Greenland, fjord waters, sea ice, meltwater, glacier melt, pCO_2, sea-air gas exchange

Abstract:

Greenland is being disturbed by climate change. Major perturbations are associated with changes in the sea ice formation and melting cycles as well as glacier retreat. With more freshwater from melting ice, the exchange between the ocean and atmosphere, including the gas exchange at the sea-air interface may be altered. Greenlandic fjords are crucial for capturing carbon dioxide (CO_2) and counterbalancing sea-to-air emissions. However, the effects of meltwater on CO_2 dynamics in these fjords are poorly understood. To assess the effects of freshwater perturbations on CO_2 fluxes, we use Young Sound a fjord system in Northeast Greenland as a case study to i) estimate CO_2 fluxes at the atmosphere- sea ice- ocean interface and ii) investigate the sink capacity of the ocean for atmospheric CO_2. We conducted our study during late spring-early summer when sea ice begins to melt, and the fjord waters are still ice-covered. The partial pressure of CO_2 (pCO_2) combined with the physical properties of the seawater was continuously measured underlying the sea ice, while CO_2 fluxes were estimated using the Ogive Optimization method. Our preliminary results show CO_2 undersaturation in seawater, relative to the atmospheric equilibrium concentration, suggesting a disconnection between the ocean and atmosphere. The onset of melt and freshwater advection toward the inner fjord appear to be key processes controlling pCO_2 distribution in the marine environment. The addition of freshwater has also enhanced the water stratification that inhibits the CO_2 exchange between the subsurface and surface waters. On top, sea ice acts as a barrier for the gas exchange between the ocean and atmosphere in late spring-early summer, which highlights the potential sink capacity of fjord waters when the ice breaks up and water stratification is eroded.

Inter-annual Variability of Sound Speed Conditions in Hornsund Fjord, Svalbard

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Keywords: Hornsund, Sound speed conditions, Glacier melting, Climate warming

Abstract:

Arctic warming is highly pronounced in glacierized West Spitsbergen fjords due to the melting of glaciers and sea ice. The melting impacts on various components of the marine environment, including the vertical thermohaline structure of the fjord water column. The latter factor could impact on vertical sound speed profiles that affect the propagation of underwater noise. Consequently, changes in sound speed conditions have an impact on marine animals that rely on sound for their key biological functions: e.g. communication, navigation, and mating behaviour. To address this issue, we investigate the temporal and spatial variability of vertical sound speed profiles in Hornsund fiord, Svalbard together with its governing factors. We discuss the long-term variability of vertical sound speed profiles along the fjord axis: from its mouth (fjord outer part) through its main part to the Brepollen (its most eastern part, divided by sill from the main part). The archival CTD (Conductivity-Temperature-Depth) data collected during the AREX ship cruises from 2001 to 2019 has been used. Significant spatial and temporal variability in the vertical sound speed profiles in Hornsund has been shown. The main profile types have been defined for each part of the fjord. It has been shown that the processes like a glacier and sea ice melting, being under strong impact of climate warming, as well as Atlantic Water advection, govern the sound speed profiles. We suggest that climate warming changes the noise propagation conditions in Hornsund and therefore impacts on the level of acoustic noise in the fjord.

INVITED LECTURE

Enhanced heavy metal and ^{137}Cs discharges to marine deposits in glacial bay of an Arctic fjord (Hornsund)

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Keywords: Hornsund, Svalbard, pollution, glacier melting

Abstract:

The most important source of heavy metals and radionuclides in the Arctic is a long-range atmospheric transport. The pollutants carried by air masses deposit on the land, and glacier surfaces with dry and wet precipitation. Svalbard is warming almost four times faster than the rest of our planet, leading to increased melting of glaciers and permafrost, which in turn causes an increase in the supply of meltwater and pollutants to the marine ecosystem. The spatial and temporal variability of heavy metal and ^{137}Cs distribution was studied in Hornsund marine sediments. Six sediment cores were collected, sliced into 1cm layers and used for measurement of heavy metal (Hg, Pb, Cd, Cu, and Zn) concentrations and ^{137}Cs activity concentrations. Sediment layers were dated by the ^{210}Pb method to reveal the history of contamination. Isotopic lead composition was used to study sources of Pb. Loads of heavy metals and ^{137}Cs to fjord deposits were calculated based on mass sediment accumulation rates. Heavy metal discharge from the glaciers to the glacial bay were much higher compared to discharge in central and outer fjord parts. This may suggest that glaciers can be important secondary sources of pollutants to fjords.

Current landscape and ecosystem transformation in Sørkapp Land, Spitsbergen

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Keywords: glacial recession, landscape transformation, ecosystem development

Abstract:

Sørkapp Land, the southern Spitsbergen peninsula, is a land wedge (directed southward) between the warm and cold sea currents. Hence, its eastern coast is colder and almost devoid of continuous vegetation and herbivores. Moreover, the eastern and western coasts differ sharply in their abiotic environment. A completely new landscape – i.e., new landforms, deposits and water bodies – appears in areas abandoned by glaciers. These areas undergo animal colonization, plant succession, and soil formation. New bays (including fjords) have appeared due to recession of tidewater glaciers in the 20th century and expand. Recession of tidewater glaciers, set on bedrock below sea level at the base of the peninsula, leads to appearance of a new strait, and thus change the peninsula into a new island. Three vertical landscape zones (tundra, sub-nival, glacial-nival) lower their altitude from the west to east, what results in lack of a denser tundra in the east. However, climate warming determines a significant uplift of the upper vegetation limit and equilibrium line altitude on glaciers. The peninsula lessened by 15% due to recession of tidewater glaciers, from 1627 km² in 1899-1900 to 1386 km² in 2004-2005. Glaciers occupied 77% of its territory in 1899-1900 and only 54% in 2004-2005. During this period, the glaciated area decreased by 41,5%, from 1252 km² to 744 km², 47,5% of the deglaciated area (241 km²) was inundated by the sea. This transformation continues. Today, glaciers cover not more than a half of the peninsula. Sørkapp Land is a region with the most advanced landscape and ecosystem transformation in the European Arctic because: (1) deglaciation rate is very fast there, (2) this big and mostly glaciated peninsula is in the course of changing into a smaller and mostly unglaciated island, (3) there is an entire change in the region's ecosystems and biodiversity.

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