the Nansen LEGACY
Symposium

Towards the new Arctic Ocean – past, present, future

Abstract book 2023

Towards the new Arctic Ocean
– past, present, future

6 – 9 November 2023, Tromsø, Norway

Contents

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Welcome to the symposium «Towards the new Arctic Ocean – past, present, future»

Dear friends of the Arctic

Welcome to the international symposium "*Towards the new Arctic Ocean – past, present, future*" in Tromsø, 6-9 November 2023. These days, we approach the dark season in the north, but hope to shed light on the conditions and changes in the Arctic Ocean with shared new knowledge and good discussions.

The Arctic has been changing over the last 10-20 years at a speed beyond our imagination. There is increased geopolitic and socioeconomic interest due to increased accessability with reduced sea ice. This calls for joint efforts to build knowledge, understand changes and prepare for the future. This symposium aims to bring together new scientific knowledge across regions and across disciplines. Ocean and atmosphere currents as well as migrating organisms connect the Arctic Ocean across functionally different regions and national borders. We hope to inspire and facilitate integration of results across the international, pan-Arctic efforts to close central knowledge gaps in understanding the climate and the ecosystems in the Arctic.

At the time of the symposium, the Norwegian national project *The Nansen Legacy* (2018-2024) has reached the final phase. With a specific focus on the northern Barents Sea and adjacent Arctic and relevant drivers to the system, we hope to contribute regional knowledge to a larger Arctic context. We look forward to spend these days with an international science community to discuss and provide a larger Arctic perspective and look forward to exiting presentations and discussions that will inspire and strengthen our future Arctic research.

We thank all the session committees that have planned and reviewed abstracts for the theme sessions, and our keynote and plenary speakers and panel participants for their contribution to a symposium program. The administrative Nansen Legacy team with Ingrid Wiedmann in charge, has organized the practical work. You will find her and the other team members in Nansen Legacy T-shirts at the conference, ready to assist.

We welcome you all to Tromsø, and we wish you a great symposium.

Marit Reigstad, Tor Eldevik, Sebastian Gerland and Cecilie Mauritzen
The symposium organisation committee

	Monday 6.11 2023 UiT & Fram Centre	**Tuesday 7.11 2023 (Day 1)** The Edge	**Wednesday 8.11 2023 (Day 2)** The Edge	**Thursday 9.11 2023 (Day 3)** The Edge
9.00		**Introduction**	Keynote Talks 9.00 -10.30	Keynote Talks and Plenary: The Future Arctic Ocean 9.00 -10.30
9.30		Keynote Talks 9.30 -10.30		
10.00				
10.30		Coffee		
11.00		Plenary Talks 11.00 – 12.00	Plenary Talks 11.00 – 12.00	Plenary: The Future Arctic Ocean 11.00 – 12.00
12.00		Panel Discussion 12.00 – 12.30	Panel Discussion 12.00 – 12.30	**Perspectives & Closing**
12.30		Lunch 12.30 – 13.30		
13.00	Early Career Event 13.00 – 17.00 (UiT, Administration building room K1.04)			
13.30		Parallel Session A, B, C 13.30 – 15.00	Parallel Session D, E, F 13.30 – 15.00	Side Event “From Observation to Adaptation” 13.30 – 16.00
14.00				
14.30				
15.00		Coffee		
15.30		Parallel Session A, B, C 15.30 – 16.30	Parallel Session D, E, F 15.30 – 16.30	
16.00				
16.30		**Poster Session I (A, B, C) 16.30 – 18.00**	**Poster Session II (D, E, F, and The Future Arctic Ocean) 16.30 – 18.00**	
17.00				
17.30				
18.00	**Reception 18.00 – 21.00 (Fram Centre, Lysgården)**	Get some air 18.00 – 19.30		
19.30		Side event with APECS: Early career networking 19.30 – 22.30	**Conference Dinner 19.30 – 22.30**	
20.30				
21.00				
22.00				

Link to full program: https://bit.ly/Sym_ProgPDF

Link to abstract book: https://bit.ly/Sym_AbstractPDF

Keynote talks

Photo: Andreas Wolden

Physical Drivers in the Changing Arctic Ocean – the Larger Perspective

Igor V. Polyakov

University of Alaska Fairbanks, Fairbanks, USA

High-latitude atlantification is caused by increased warm, salty sub-Arctic inflows, which affect oceanic stratification, increase heat fluxes, and decrease sea ice in the Eurasian Basin of the Arctic Ocean. These inflows from the North Atlantic across the Nordic Seas are modulated by the atmospheric Arctic Dipole (AD), linked with anticyclonic winds over North America and cyclonic winds over Eurasia. The alternating atmospheric AD regimes establish a "switchgear mechanism". Switchgear decreased northward inflows across Fram Strait and increased inflows throughout the Barents Sea between 2007 and 2021, which was connected with the positive AD regime. A stronger Arctic Ocean circulation and freshwater redistribution into the Amerasian Basin associated with increased stratification and decreased oceanic heat fluxes are other consequences of the positive AD regime. These processes contributed to a hiatus in Arctic sea-ice loss after 2007. A transition to a new negative AD regime will likely accelerate the Arctic sea-ice decline, with consequences for the Arctic climate system.

Tuesday, 7 November 2023
10:00-10:30
Keynote 2

Primary Production and the Shifting Foundations of a Changing Arctic Ocean

Karley Campbell

UiT The Arctic University of Norway, Tromsø, Norway

Primary producers are the basis of ecosystems. Through their photosynthetic activity they provide the organic carbon necessary to support higher trophic levels while also influencing the movement of climate relevant gases like CO2 between the atmosphere and ocean. In the Arctic, sea ice is a prominent yet rapidly changing feature of the marine ecosystem that both hinders photosynthetic activity and provides new habitat opportunities. Here we review the current distribution of - and ongoing changes to - primary producers and their production in the Arctic Ocean. Important considerations for studying the production potential of sea ice are also investigated; including the need to represent a diversity of microhabitats within the ice and consider the role of respiration associated with them.

Wednesday, 8 November 2023
09:00-09:30
Keynote 3

Characteristics and Composition of Sea Ice in the Central Arctic Ocean

Marcel Nicolaus

Alfred Wegener Institute (AWI), Bremerhaven, Germany

Arctic sea ice has decreased in extent and thickness during all seasons. The ice cover changed to a younger and more seasonal ice pack with different physical properties. However, it is still challenging to characterize sea ice and snow properties and processes during all seasons in relation to feedbacks with the atmosphere and the ocean. As a result, numerical simulations and forecasts as well as satellite data retrieval algorithms still have large uncertainties. During the Multidisciplinary drifting Observatory for the Study of Arctic Climate, MOSAiC, sea ice and snow properties were observed over a full annual cycle in 2019/2020. In this presentation, I will summarize and review the sea ice and snow conditions over the annual cycle based on MOSAiC results. I will present mean properties of key parameters ranging from the lowest atmosphere, through snow and sea ice, into the upper ocean. The results indicate that the contrasts of different sea ice types in the Arctic Ocean diminish from autumn to spring. New sea ice types, pressure ridges and snow distributions need to be considered more explicitly when describing and modelling atmosphere-ice-ocean interactions. This will help to improve our understanding of the coupled Arctic system and lead to improved forecasts.

Freshwater Impacts on the Arctic Ocean Carbon Cycle, Views from Multiple Scales

Kristina Brown

University of Manitoba, Winnipeg, Canada

Unprecedented rapid changes in the Arctic Ocean are impacting its coupled physical and biogeochemical systems. Sea ice loss, together with increases in river input and coastal erosion, are altering both the Arctic's freshwater system and its carbon cycle in tandem. Such ongoing changes will play an important role in the global climate system, in particular impacting the Arctic Ocean's ability to act as a CO2 sink for atmospheric CO2. In this talk I will look at the impact of freshwater on the Arctic Ocean carbon cycle at a variety of scales to address the core question, "how does freshwater impact CO2 exchanges in the surface ocean?". At the pan-Arctic scale, I discuss the dual roles of regionality and seasonality of freshwater sources in establishing the backdrop for the biogeochemical processes that constrain carbon cycling in the surface ocean. Then I narrow the view to the regional frame, presenting new insights about the smaller northern rivers that drain the Arctic coastal margins. Lastly, I will discuss some of the challenges to freshwater and carbon monitoring in local river systems to demonstrate where community supported observational projects have been successful in filling critical gaps. Looking at this question from multiple perspectives allows us to see the importance of scalability in the design of observation systems and the absolute necessity for partnerships with northern communities to meet the challenges of Arctic research.

Wednesday, 8 November 2023
10:00-10:30
Keynote 5

Benthic Systems in Pacific and Atlantic Sectors of the Arctic Ocean

Monika Kędra

Institute of Oceanology Polish Academy of Sciences, Sopot, Poland

Arctic marine benthos and their food webs play an important role in overall ecosystem functioning including production and organic matter and energy cycling. Benthic organisms are considered temporal couplers of resources, especially in ecosystems with strong seasonality and seasonal organic matter pulses to the sea floor. In the Arctic predicted changes in primary production patterns are expected to impact pelagic-benthic coupling processes, and thus benthos and their food webs, and thus whole ecosystem functioning. In this talk I review and compare the benthic communities and their functioning in the Pacific and Atlantic sectors of the Arctic Ocean. I discuss the responses of benthic organisms and their trophic relations to the on-going and predicted changes in the quality and quantity of organic matter delivered to the sea floor. Potential consequences of possible changes in benthic communities for the ecosystem functioning are considered.

Thursday, 9 November 2023
09:00-09:30
Keynote 6

The Future Arctic Sea Ice: Key Drivers and Regional Variabilities

Marius Årthun

University of Bergen, Bergen, Norway

The Arctic sea-ice cover is currently retreating and will continue its retreat in a warming world. However, the loss of sea ice is neither regionally nor seasonally uniform. Sea ice conditions and associated drivers of variability differ substantially from region to region within the Arctic, and considering only pan-Arctic trends thus masks competing regional trends and makes the underlying drivers and implications difficult to ascertain. Arctic sea-ice loss is also not seasonally uniform. Whereas the overall pan-Arctic sea-ice loss has been largest in summer, the winter trends are of the same magnitude in the southernmost regions, and particularly in the Barents Sea.

In this talk, I will detail the seasonal and regional transition to an ice-free Arctic based on observations, large ensemble simulations, and CMIP6 models. The key drivers of present and future sea-ice variability and the relative contribution of internal (natural) and external forcing will be discussed.

Thursday, 9 November 2023
09:30-10:00
Keynote 7

- Science for use talk -
Turning science into use – where do we stand?

Marianne Kroglund

Norwegian Environment Agency, Oslo, Norway

Environmental problems are very often tricky problems: they are persistent, many are vast in scale with no clear end, and involve political decisions and struggles that are more about values, world views and ideology than they are about scientific facts. Even if it may seem crystal clear what environmental problems we are facing, the ecological and biological elements on the effect side of these problems are dynamic and complex, and the social and political elements on the solution side are constantly changing. And not the least; looking into the future, the complexity and uncertainty grows even larger. In a rapidly changing world, and in lack of linear patterns from science to action; what does it take to make decisions? Do we have the knowledge and knowledge systems we need to inform complex challenges? In this talk, rather than looking at the barriers I will focus on what I think are enabling factors for efficient uptake of science and knowledge in management and decision-making processes related to climate, nature and pollution.

Plenary talks

Photo: Algot Peterson

Tuesday, 7 November 2023
11:00-11:15
Plenary 1

Strong Seasonality and Advection Shape the Zooplankton Community in the European Arctic

Janne Søreide

University Centre in Svalbard, Longyearbyen, Norway

One of the distinct features of the European Arctic is the massive influx of warm Atlantic water, carrying huge amounts of nutrients and boreal plankton north. The result is a diverse and rich zooplankton community in the Svalbard-Barents Sea region, where a dominance of North Atlantic species mirrors strong influence of Atlantic water. The continuous supply of boreal zooplankton exposes the European Arctic zooplankton community to a severe borealisation, also referred to as “Atlantification”. However, the long, dark winter combined with the short summer make it hard for most of these boreal species to survive and thrive and we observe a reset to a more Arctic zooplankton community over the course of the winter. With global warming, sea ice extent and thickness are reduced while the primary production season in the high Arctic is extending. Whether this will increase survival rate and reproductive success of boreal species in the European Arctic is one of the key questions that will be discussed in this talk.

Tuesday, 7 November 2023
11:15-11:30
Plenary 2

Fishes in the Canadian Arctic, the Barents Sea, and Beyond

Maxime Geoffroy

Memorial University of Newfoundland, Saint John's, Canada

The Arctic is warming up to four times faster than the rest of our planet, resulting in a drastic reduction in sea ice cover and an increase in water temperatures. These changes strongly modify the habitat of the fish thriving under the extreme conditions prevailing in the Arctic and allow boreal species from the North Atlantic and Pacific to migrate further North, potentially opening new fishing grounds. However, these changes do not occur at the same rate across all Arctic regions. The Canadian Arctic remains mostly dominated by endemic species, while the Barents Sea experiences a rapid borealization of its fauna. Based on acoustic-trawl surveys conducted in both regions, this presentation will contrast the diversity and distribution of fish in the Canadian Arctic and the Barents Sea. It will further discuss current and future changes in their fish and fisheries ecosystems.

Biogeochemistry of the Holocene sediments in the Barents Sea, and what it might mean for paleoceanography

Christian März

University of Bonn, Bonn, Germany

Marine sediments are excellent recorders of past environmental conditions – but they are also biogeochemical reactors. This "duality" presents a challenge for paleo-environmental reconstructions: On the one hand, certain sediments are more prone to diagenetic overprint than others – on the other hand, certain depositional conditions give rise to more intense diagenetic reactions. Within the NERC-funded project ChAOS (The Changing Arctic Ocean Seafloor), and in collaboration with the Nansen Legacy project, an interdisciplinary team of scientists studied the shallow seafloor of the Barents Sea to unravel the diagenetic processes occurring in these deposits, and to inform paleo-environmental reconstructions on sediment cores from this Arctic shelf region. In this talk, I will present an overview of our findings, focusing on factors that control the degradation/dissolution versus preservation of various sediment components, including organic matter, biogenic carbonate, biogenic opal and metals like iron and manganese.

- Science for use talk -
Seasonal and climate change effects on pollution accumulation and effects in the Arctic marine food web

Khuong Van Dinh

University of Oslo, Oslo, Norway

Global warming, marine heatwaves, and ocean acidification can affect physical and ecological processes in Arctic marine ecosystems. These processes can have knock-on effects on the uptake, fate, and effects of persistent organic pollutants and contaminants of emerging Arctic concern in Arctic marine organisms. Conversely, toxicant exposure can affect species' adaptability to climate change. Here, we have summarized how climate change affect physical and ecological processes in Arctic marine biota and food webs.
1) Global use and regulations of pollutants still are the main drivers for levels in Arctic biota, increased incidents of positive states of the North Atlantic Oscillation (NAO+) result in the increased long-range transport of pollutants and biomagnification in Arctic food webs.
2) Northward range-shifting species act as biovectors for pollutants into Arctic marine food webs, leading to elevated levels.3) Dietary shifts can alter pollutant transfer in the food webs. Reductions in body condition are associated with pollutant increase in some biota.
4) The interaction of warming, ocean acidification and pollutants can result in antagonistic, additive or synergistic effects depending on the species, life stages, and the magnitude and duration of stressor exposure. Furthermore, multiple stressors studies have predominantly been conducted during summer months, however, we show that we show that effects and interactions of these stressors can often differ between winter and other seasons.
Studies that are performed across a series of stress levels, exposure conditions in multiple seasons will be particularly important to tease apart the effects of climate change on pollutant toxicity and accumulation. A step further is to identify the ecological tipping points of Arctic marine species and food webs in complex interactions of climate change and pollutants, which are crucial for more comprehensive ecological risk assessments and management.

Wednesday, 8 November 2023
11:00-11:15
Plenary 5

Large-Scale Atmospheric Drivers of Barents Sea Climate Variability

Camille Li

University of Bergen, Bergen, Norway

The Barents Sea sits in the main corridor of travelling weather systems, steered by the atmospheric jet stream, that carry warm air and moisture from the North Atlantic towards the Arctic. As such, conditions in the Barents are sensitive to factors that influence the speed, position and path of the jet. At the same time, ocean-driven changes in sea surface temperatures and sea ice cover may be felt by the atmosphere, with the possibility of teleconnections communicating these signals to other parts of the globe. Using observational and modelling results, this presentation will give an overview of how the atmosphere drives variability and change in the Barents region, and whether the Barents can affect climate and weather further afield. Open questions concerning the ability of climate models to capture the relevant processes and the implications for constraining future change in the region will be explored.

Wednesday, 8 November 2023
11:15-11:30
Plenary 6

Importance of Sea - Ice - Atmosphere Interactions for Kilometer-Scale Weather Prediction

Malte Müller

Norwegian Meteorological Institute, Oslo, Norway

The development of coupled Earth modeling systems on a kilometer-scale resolution is a new frontier for operational forecasting. However, accurately representing interactions between the atmosphere, snow/sea-ice, ocean, and waves is challenging due to the complexity of interactive mechanisms, the limited accuracy of the model components, and the availability of observations to resolve and assess relevant coupled processes. An overview of recent work will be given to assess the sensitivities of the model system to the representation of the sea-ice and snow by utilizing a multitude of observations, including field-campaign data, as well as satellite retrievals and standard in situ observations.

Microbial Communities in the Future Central Arctic Ocean – What Can We Learn From Present Observations and What's Next?

Oliver Müller

University of Bergen, Bergen, Norway

With its large interannual differences in ice extent, the Barents Sea is the ideal large-scale simulator to investigate how the Arctic marine ecosystem will respond to reduced sea-ice cover. By connecting seasonal studies in the Barents Sea (Nansen Legacy) with a year-long drift through the central Arctic Ocean (MOSAiC) we will reveal new insights on important microbial processes in the Arctic, how they differ from our expectations and set them into historical context (Nansen`s Fram expedition). We have focused on measurements of microbial abundance, including virus, bacteria and small phytoplankton and activity measured as bacterial production and our results clearly demonstrate the importance of sea ice in structuring microbial communities as response on phenological variability in primary production. To better understand the consequences of an ice-free future for Arctic microbial communities, we need to improve our knowledge on how sea ice is affecting microbial processes and whether our current paradigms on seasonal processes are more complex than previous thought. We need to compare our present observations with the past, e.g., by use of ancient DNA, to disentangle whether the new knowledge is a result of improved measurements or of a changed Arctic.

Wednesday, 8 November 2023
11:45-12:00
Plenary 8

- Science for use talk -
Ecosystem Modelling to Support Ecosystem-Based Management in the Barents Sea, Now and in the Future

Benjamin Planque

Institute of Marine Research, Tromsø, Norway

Conventional fisheries management relies on models that estimate how fish populations have changed in the past and how they might change in the future. The transition to ecosystem-based management has shifted towards considering multiple factors such as how different species interact, and how climate change and multiple human activities (e.g., fishing, shipping, tourism, energy) affect ecosystems and the services they provide. To support this approach, new models are needed that can consider all these dimensions together (rather than just considering one or few species at a time). While ecosystem models have been around for a while, they are not yet widely used in management. In this presentation, I will discuss existing ecosystem models and how they are, or can be, used in ecosystem-based management. I will also talk about some of the challenges that need to be addressed to make these models more useful. Finally, I will suggest how models can be developed to better support management in the future.

Plenary talks: the future Arctic ocean

Photo: Christine Gawinski

Plenary talks - Thursday 9 November

The future Arctic Ocean: projections, processes, implications, and uncertainties

Session Chairs: Marius Årthun, Céline Heuzé, Martí Amargant Arumí, Natalie Summers

Assessing the Spread of Atlantic Water Layer Temperature and Salinity in the Arctic Ocean in CMIP6 Model Ensemble Members

Devilliers M*[1], Olsen SM[1], Yang S[1], Langehaug HR[2]

[1]Danish Meteorological Institute, Copenhagen, Denmark, [2]Nansen Environmental and Remote Sensing Center, Bergen, Norway

In this study, we present a comprehensive analysis of the spread in temperature and salinity projections among the members of the Coupled Model Intercomparison Project Phase 6 (CMIP6) models, focusing on the Atlantic water layer in the Arctic Ocean. While this layer plays a critical role in the transport of salt and heat within the Arctic Ocean basins, its characteristics are not well represented in climate models, leading to divergent projections of future changes in the Arctic. To address this question, we analyzed a suite of CMIP6 models and assessed the realism of the Atlantic Layer characteristics including variability and trends in the historic period across all the available members in the multi model ensemble. By comparing the model results with available reanalysis, we aim to identify the biases within the model simulations and develop new metrics to constrain the models spread. Such metrics can be used to screen all members in the multi-model multi-member ensemble and construct a subsample with improved representation of the Atlantic water layer in the historical period which can be applied for projection of future changes in the Arctic region with reduced uncertainty.

Thursday, 9 November 2023
10:15-10:30
Talk Future Arctic Ocean 2

Climate-change driven terrigenous inputs decrease the efficiency of the future Arctic Ocean's carbon storage

Oziel L*[1], Gürses Ö[1], Torres-Valdes S[1], Koch B[1], Kuldenov N[1], Wang Q[1], Rost B[12], Hauck J[1]

[1]Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven, Germany, [2]University of Bremen, Bremen, Germany

Climate change is rapidly altering the whole Arctic system from the atmosphere, the cryosphere, the land and ocean. Here, we focus on the impact of terrigenous inputs, including rivers and coastal erosion, on the Arctic Ocean biogeochemical cycles, using model forecasts. Despite additional inputs of nutrients from land, the Arctic Ocean cannot cope with the massively increasing drawdown by phytoplankton and is inexorably shifting from a light-limited to a nutrient-limited. The cycling of nitrogen is becoming the bottleneck of carbon cycling and the biological carbon pump. If terrigenous inputs did not alleviate nutrient limitation, we show that they contribute more to the intensification of biogeochemical processes, such as remineralization, than scenario uncertainty (a change from a low to a high emission scenario). In a high emission scenario, we found that increased remineralization largely compensates the increase in Net primary production, reducing carbon export efficiency and the Arctic Ocean's ability to store carbon.

Present and Future Influence of Ocean Heat Transport on Winter Arctic Sea-Ice Variability

Dörr J*[12], Årthun M[12], Eldevik T[12], Sandø AB[23]

[1]University of Bergen, Bergen, Norway, [2]Bjerknes Centre for Climate Research, Bergen, Norway, [3]Institute of Marine Research, Bergen, Norway

The recent retreat of Arctic sea ice is overlaid by strong internal variability on all timescales. In winter, sea-ice retreat and variability are currently dominated by the Barents Sea, primarily driven by variable ocean heat transport from the Atlantic. It is projected that the future loss of winter Arctic sea ice spreads throughout the Arctic Ocean and, hence, that other regions of the Arctic Ocean will see increased sea-ice variability. It is, however, not known how the influence of oceanic drivers on regional winter sea ice variability will change. Using a combination of observations and simulations from large ensembles, we analyze and contrast the present and future regional drivers of the variability of the winter Arctic sea-ice cover using lagged correlations and a causal method. 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. Models agree on a gradual expansion of the footprint of the Pacific and Atlantic inflows, covering the whole Arctic Ocean by 2050-2079. This work highlights the combined importance of future Atlantification and Pacification of the Arctic Ocean and improves our understanding of internal climate variability which is essential to predict future sea ice changes under anthropogenic warming.

How can Functional Groups be Affected by Low and High Carbon Emissions Scenarios in the Barents Sea?

Nascimento MC*[1,2], Pedersen T[2], Fransner F[3], Primicerio R[2], Hordoir R[4], Skogen M[4]

[1]GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany, [2]UiT The Arctic University of Norway, Tromsø, Norway, [3]University of Bergen, Bergen, Norway, [4]Institute of Marine Research, Bergen, Norway

Polar regions are highly affected by the ongoing climate change and are expected to become profoundly different under all warming scenarios. Changes in the Arctic Oceans' ecosystem structure and species range shifts are expected. To evaluate the impacts of climate change on spatial distributions of functional groups in the Barents Sea in medium and long term, we simulated three plausible futures climate scenarios using the spatially resolved dynamic mass-balance food web model Ecospace for the Barents Sea (108 functional groups - FGs). We used the downscaled climate scenarios SSP 1-2.6, 2-4.5 and 5-8.5 from NorESM with Nemo NAA 10 km combined with three levels of fisheries exploitation regimes (low, "business as usual", and high fishing mortalities), running from 2020 to 2100. We applied environmental envelope limitations for many FGs and used environmental drivers such as temperature, ice coverage and phytoplankton primary production for each scenario. The model ran with monthly time steps and input of spatial environmental data. When simulating the scenarios with mitigation of carbon emission (i.e., SSP1-2.6 and SPP2-4.5), even though the FGs shift the distribution polewards for the period 2023-2050, in the long term from 2050-2100, the centre of gravity of the FGs distributions returns closer to the starting point. In the high-emission scenario (SSP 5-8.5), the shift poleward is intensified in the long term (2050-2100).

Thursday, 9 November 2023
11:30-11:45
Talk Future Arctic Ocean 5

Integrative Studies for Assessing Diversity, Distributions, Trophic Role and Range Shifts of Jellyfish in Tomorrow's Arctic Ocean

Havermans C*[1], Dischereit A[1], Murray A[1], Pantiukhin D[1]

[1]Alfred-Wegener-Institute, Helmholtz Centre for Polar and Marine Research (AWI), Bremerhaven, Germany

Gelatinous zooplankton are major drivers of ecosystem changes. Increases in biomass or "jellification" have been observed in several marine ecosystems, causing, amongst other factors, major fishery collapses. For the Arctic region, accurate diversity and abundance data on jellies are virtually non-existent, impeding our ability to detect impacts of a similar magnitude. We study current and future species distributions of dominant Arctic jellyfish under a growing influence of Atlantic waters. To do so, we combine net catches with environmental DNA and optical video systems to provide new information on the drivers of jellyfish distributions in Arctic environments. On these and public datasets, we apply species distribution models to understand species and community patterns and predict changes under climate-change scenarios. Based on predictive modelling, we project an Arctic "jellification" with range shifts of major Atlantic species into the Arctic Ocean on the pan-Arctic scale, and an increase of regional jellyfish abundances. By means of molecular diet studies, we reveal the importance of jellyfish as prey based on molecular diet studies of predator species such as fish and zooplankton predators. Finally, by investigating the species richness, abundances, and trophic role of jellyfish in fjords in which the influence of Atlantic water differs, we set a baseline to detect potential range shifts and predict the impact of jellyfish on local food webs in an Atlantified Arctic.

An Observing System that Serves Society's Needs in a Future Arctic

Karcher M*[1], Reigstad M[2], Sundfjord A[3], Wilkinson J[4]

[1]Alfred Wegener Institute for Polar and Marine Research (AWI), Bremerhaven, Germany, [2]UiT The Arctic University of Norway, Tromsø, Norway, [3]Norwegian Polar Institute, Tromsø, Norway, [4]British Antarctic Survey, Cambridge, United Kingdom

In the Arctic the warming already leads to fundamental changes, and projections for the future indicate them to intensify further. Arctic PASSION (EU funded) aims to support the co-creation and implementation of a more coherent, better integrated, and more useful Arctic observing system. We aim to overcome known flaws in the present observing system by refining its operability, improving, and extending pan-Arctic scientific and community-based monitoring and the inclusion with Indigenous and Local knowledge. Arctic PASSION has a pan-Arctic ambition and collaborate with other internal projects and programmes to forward the work on a future Arctic observing system on many levels. This includes how to shape an observing system to allow a monitoring of the most relevant environmental changes, the provision of data to improve numerical predictions and to serve decision making. We will present the status of the Arctic PASSION work in terms of improved coordination and enhanced observations, improving the Arctic data system, the use of modelling to support observational design, policy and decision-making support, and the development of services to cover relevant information needs regarding food security, emergency preparedness, wildfire and pollution risk reduction, environmental change information, infrastructure, transport, and safe shipping. We will also present our current understanding of Arctic Observing system elements needed for serving society's need in the future Arctic.

Parallel session A

Photo: Pernille Amdahl

Parallel Sessions - Tuesday 7 November

Parallel session A: Physical drivers: Causes and consequences of Arctic Ocean warming, freshening, and sea ice decline

Session Chairs: Frank Nilsen, Mary-Louise Timmermans and Laura Castro De La Guardia

Stormier Arctic Winters due to Surface Warming Amplification

Zapponini M*[1], Gößling HF[1]

[1]Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven, Germany

Surface air temperatures are rising faster in the Arctic than in any other region of the planet. However, the upper troposphere is not warming at the same speed, resulting in a weakening of the atmospheric stratification. Using reanalysis and CMIP6 model data, we show that an increased efficiency of tropospheric vertical transfer of horizontal momentum causes a winter strengthening of near-surface winds over the Arctic Ocean. For the winter season of the period 1950 - 2020, ERA5 and CMIP6 climate models show an approximately linear relationship between the decreasing atmospheric stability, measured through the 10 m – 850 hPa temperature gradient, and the increasing downward momentum transfer efficiency, measured through the 10 m/850 hPa wind speed ratio. In contrast, Arctic summers tend to change in the opposite direction. Here, as long as some sea-ice remains, the surface is constrained to the freezing temperature whereas the upper troposphere warms due to warmer air being advected from lower latitudes. The summer weakening of the downward momentum transfer efficiency is weaker than the winter decrease, and more pronounced in ERA5 than in CMIP6 data. However, the models show that the rate at which the winter momentum transfer efficiency shifts towards summer-like conditions is accelerating and projected to continue, resulting in almost no seasonality of the Arctic atmospheric stability and momentum transfer efficiency remaining by the end of the 21st century.

Sea Ice Fracturing Promotes Near-Inertial Atmosphere-Ocean Momentum Transfer during an Arctic Winter Storm

Crews L*[1], Lee C[1], Rainville L[1], Brenner S[2]

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Fluctuating wind stresses excite energetic currents in the mixed layer that oscillate at frequencies near the local inertial frequency. In polar regions, sea ice is fundamental to momentum transfer between the atmosphere and the ocean, and internal ice stresses can interrupt this momentum transfer. Despite the historical paradigm of inertial oscillation damping by a strong and consolidated ice pack, the impact of sea ice dynamics and characteristics on ocean near-inertial energy remains equivocal. Here we use observations collected by a Beaufort Sea mooring array during a February 2019 storm to show how a fractured ice pack with a recent history of lead formation permits inertial oscillation development whereas an intact ice pack selectively filters out high frequency motions. Prior to the storm, winds pushed the ice pack against the coast and opened a network of leads that traversed some of the study area. Following lead formation, a low pressure system excited ice and ocean near-inertial velocities that varied in accord with the history of lead activity, with stronger inertial oscillations at the fractured sites. Leads, which can extend hundreds of kilometers from coastal promontories into the ice pack, therefore link ocean dynamics to distant coastal boundaries. Consequently, efforts to predict future wintertime inertial motions in the Arctic may benefit from ongoing efforts to accurately model lead formation and floe size distribution.

Tuesday, 7 November 2023
14:00-14:15
Talk A3

A Coupled Ice-Ocean Framework to Investigate the Impact of Sea-Ice Deformation in the Winter Sea-Ice Mass Balance in the Arctic

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Sea ice is a critical component of the Earth's climate system as it modulates the energy exchanges and associated feedback processes at the air-sea interface in polar regions. These exchanges strongly depend on openings in the sea-ice cover, which are caused by fine-scale sea-ice deformations. Still, the importance of these processes remains poorly understood as most numerical models struggle to represent these deformations without using costly horizontal resolutions (~1 km). Here, we present results from a 12 km resolution ocean-sea-ice coupled model involving the ocean component of NEMO and the sea-ice model neXtSIM. This is the first coupled model that uses brittle rheology to represent the mechanical behaviour of sea ice. Using this rheology enables the reproduction of the observed characteristics and complexity of fine-scale sea ice deformations with little dependency on the mesh resolution. We investigate the sea ice mass balance of the model for the period 2000-2018. After carefully evaluating the modelled sea ice against available observations (extent, drift, volume, deformations, etc.), we assess the relative contribution of dynamical vs thermodynamic processes to the sea-ice mass balance in the Arctic Basin. We find a good agreement with ice volume changes estimated from the ESA CCI sea-ice thickness dataset in the winter, demonstrating the ability of brittle rheologies to produce a reasonable sea ice mass balance over long periods. Using the unique capability of the model to reproduce sea-ice deformations, we estimate the contribution of leads and polynyas to winter ice production. This contribution adds up from 25% to 35% of the total ice growth in pack ice in winter, showing a significant increase over the 18 years covered by the model simulation. This coupled framework opens new opportunities to understand and quantify the interplay between small-scale sea-ice dynamics and ocean properties that cannot be inferred from satellite observations.

Tuesday, 7 November 2023
14:15-14:30
Talk A4

Towards an Improved Representation of Arctic Sea Level, Ocean Currents and Tidal Modelling Using Multi-Mission Satellite Altimetry

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The Arctic Ocean is very sensitive to climate change. Its effects are seen in reduced sea ice cover, rising sea level and changes in ocean circulation. Satellite altimetry has allowed these changes to be accurately observed for about 30 years by steadily improving the determination of sea surface height (SSH) in the ice-covered ocean. This contribution presents 3 examples of how satellite altimetry can help provide an improved understanding of physical processes in the Arctic Ocean. The presence of sea ice requires special classification and retracking algorithms that make it possible to distinguish between radar observations from water or ice as well as to provide reliable ranges between the satellite and the sea surface. Here, it is shown how satellite altimetry data can be used to detect open water based on an automatic radar echo classification. Besides the computation of accurate SSH, the monitoring of ocean tides by altimeter satellites is of great interest to generate improved tidal corrections for sea level determination, but also to better assess the effects of tides on circulation. Therefore, recent results of the expansion of the ocean tide model EOT20 to the Arctic Ocean are shown. Finally, a combination strategy is presented to combine altimetry-derived SSH with simulated water heights to obtain spatiotemporally consistent representation of the circulation, even in sea ice covered areas. Results of this approach are shown for the Chukchi and northern Nordic Seas.

Assessing the Climate Change in the Arctic Region from Satellite Altimetry: A Comprehensive Analysis of Sea-Level Variability

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This study focuses on the sea level changes from radar satellite altimetry. Recent advancements in satellite altimetry have significantly improved our ability to observe and analyze climate-related phenomena in greater detail. Here, we present a comprehensive and uninterrupted 30-year time series of Arctic Ocean sea-level measurements, spanning from 1991 with the ERS-1 satellite to 2021 with the CryoSat-2 satellite. Our analysis primarily concentrates on the remarkably dynamic Arctic environment, with a particular emphasis on the pronounced changes observed during the most recent decade in comparison to the preceding 30 years of altimetric measurements. To achieve this, we employ a case study approach, examining the Beaufort Gyre region, the Russian Shelf area, and investigating the general circulation patterns of the Arctic Ocean. The sea-level dataset utilized in this research is part of the European Space Agency (ESA) Climate Change Initiative (CCI) Sea level initiative and has been updated with enhanced CryoSat processing, utilizing the ESA G-POD SARvatore Data Repository. Overall, this study sheds light on the substantial alterations occurring in the Arctic region due to climate change. By leveraging a comprehensive sea-level dataset and employing advanced satellite altimetry techniques, our research elucidates the key drivers of these changes, offering valuable insights into the complex dynamics of the Arctic Ocean system.

Tuesday, 7 November 2023
14:45-15:00
Talk A6

Mechanisms and Impacts of Arctic Ocean Freshwater Variability on Centennial Timescales

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Freshwater export through the Arctic Ocean gateways can have a strong influence on variations of the Atlantic Meridional Overturning Circulation (AMOC) on decadal timescales, as evidenced by the Great Salinity Anomalies of the 20th century. In turn, the AMOC can also influence Arctic Ocean freshwater content, for example by driving increased ocean heat transport into the high latitudes which leads to increased Arctic sea ice melt. From both mechanisms combined, a coupled Arctic Ocean–North Atlantic mode of variability can emerge on multi-decadal to centennial timescales, as first proposed by Jungclaus et al. in 2005 and recently identified as the driver of strong centennial-scale AMOC variability in two CMIP6 models. However, to our knowledge no systematic multi-model assessment of AMOC or Arctic Ocean variability on (multi-)centennial timescales has been conducted so far. Here, we investigate the co-variability of AMOC strength and Arctic Ocean freshwater content on centennial timescales in the CMIP6 ensemble of long pre-industrial control simulations. Our results show that Arctic Ocean freshwater content likely acts as a driver of significant centennial-scale AMOC variability in several CMIP6 models which all use the NEMO ocean component, and that the freshwater anomalies can persist within the central Arctic Ocean for several decades. We discuss the implications for modeled Arctic Ocean variability in past, present and future climates.

Tuesday, 7 November 2023
15:30-15:45
Talk A7

Understanding the Relative Roles of Diffusion and Mechanical Mixing in the Canada Basin's Upper Halocline Heat Budget

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Future regional and global climate change is tightly coupled to the fate of sea ice in the Arctic's Canada Basin. Rates of sea ice growth and melt are highly sensitive to relatively small upward fluxes of this stored ocean heat towards the base of sea ice. Crucially, stored ocean heat in the warm Pacific-origin waters of the Canada Basin halocline has more than doubled over the last three decades. Recent studies have further evidenced several critical trends in the Canada Basin's upper ocean halocline: a deepening of the mixed layer, a transition towards weaker stratification at the base of the mixed layer, and a changing mechanical energy input to the upper ocean. An essential motivation thus remains to better understand the mechanisms leading to the vertical transport of stored ocean heat within the seasonally complex Canada Basin halocline, and how these mechanisms will influence sea ice cover over the coming years to decades. In this study, we use Canada Basin water-column observations from the Ice-Tethered program to better quantify heat transports from two principal mechanisms: i) slow vertical diffusion and ii) wind-driven mixing. We combine the observational results with a numerical simulation approach which we use to diagnose the types of stratified shear-driven instabilities at the base of the mixed layer. Then, we compare the magnitude of vertical heat transport through wind-driven instabilities to estimates of the slow vertical diffusion of heat.

Tuesday, 7 November 2023
15:45-16:00
Talk A8

How Atlantic Heat Makes Arctic Sea Ice Retreat

Eldevik T[1], Steel M[2], Smedsrud LH*[1], Årthun M[1], Onarheim I[3], Dodd P[4], Muilwijk M[4]

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What sets the position of the ice edge downstream from Fram Strait? The answer involves a competition between warm Atlantic Water entering the Arctic Ocean and cold sea ice flowing out in the opposite direction, both of which are under the influence of atmospheric surface heat fluxes. In this study, we build on earlier work on this subject by using new in situ and satellite observations as well as long oceanographic time series maintained well south of Fram Strait. We also introduce a simple analytical model that includes the ocean salt balance to constrain the problem, using observed salinity profiles. We find that a high percent of interannual variability in the ice edge position can be simply explained by the upstream temperature of the Norwegian Atlantic Current one year in advance.

Retreating Sea Ice in the Barents Sea - the Arctic Hotspot Region

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Arctic climate change shows severe warming and declining sea ice. The Barents Sea stands out as a significant hotspot for the most dramatic sea-ice loss, with an annual warming rate being twice the Arctic's average. The Barents Sea warming pattern is highly consistent with the reduction in the sea ice. In the western Barents Sea (which more or less has become ice-free), the temperature trends no longer increase, while the warming trends continue to intensify in the east where the sea ice is still dense but melting at a high pace. The reduced ice cover has a crucial role in destabilising the ocean's upper layer stratification. With a weakened stratification, increased heat flux from the Atlantic Water towards the surface may prevent or postpone the sea ice from forming in autumn. More open water in autumn and winter allows the warmer sea surface to interact with the cold air above, raising the air temperatures. This demonstrates how the coupling between the atmosphere, ice, and ocean has contributed to the amplifying of recent warming in this region. This contribution presents recent findings of the exceptional changes in sea ice and warming in the Barents Sea over the past four decades, combining remotely-sensed data on sea ice and sea surface temperature, and observations of surface air temperature and oceanographic in-situ temperature and salinity.

Unprecedented Warming Rate over Northern and Eastern Svalbard

Isaksen K*[1], Nordli Ø[1], Køltzow MA[1], Aaboe S[2], Gjelten HM[1], Mezghani A[1], Eastwood S[1], Førland E[1], Benestad RE[1], Hanssen-Bauer I[1]

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The first automatic weather stations were established in the early 1990s in eastern and northern Svalbard. At the time, real time data were used in weather forecasting and for rescue missions. However, the initial recorded data were not stored in any databases and have not previously been available for scientific analysis. This new dataset documents the surface air temperature (SAT) development in the north and east that remained unexplored until now. Here, we present updated surface air temperature data to the year 2023 to study the recent warming and its spatial and temporal variability in Svalbard, and evaluate how well the most recent European Climate Medium Weather Forecast reanalysis data set (ERA5) and the recently released high-resolution Copernicus Arctic Regional ReAnalysis (CARRA) describe SAT-climatology and trends. We find an unprecedented warming rate of more than 2.5 °C per decade in northeastern Svalbard, with a high increase in autumn and winter, compared to other seasons. The observed temperature increase is in good agreement with the reanalyses. However, compared to ERA5, CARRA shows larger regional SAT trends and more spatial details. The warming is faster than hitherto known in this region and its spatial structure is primarily consistent with reductions in sea ice cover. The recent warming was punctuated by an increasing intensity of abrupt warming events, with far reaching regional effects related to e.g., extremes in heavy rainfall during winter.

Parallel session B

Photo: Adam Steer

Parallel session B: The Living Ocean: Understanding Ecosystem Structure and Function Across Seasons in a Changing Arctic

Session Chairs: Bodil Bluhm, Sławomir Kwaśniewski, Julia Giebichenstein

Tuesday, 7 November 2023
13:30-13:45
Talk B1

Seasonal Dynamics of Sea Ice Protists and Meiofauna in the Northwestern Barents Sea in Relation to Sea Ice Properties

Marquardt M*[1], Goraguer L[12], Assmy P[2], Bluhm BA[1], Patrohay E[1], Aaboe S[3], Down EJ[3], Edvardsen B[4], Smola Z[5], Tatarek A[5], Wiktor JM[5], Gradinger R[1]

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The rapid decline of Arctic sea-ice including that in the Barents Sea makes understanding sympagic biology an urgent task. Seasonal ice sampling (2019-2022) as part of the Nansen Legacy project focused on ice biota composition and abundance in the bottom 30cm of Barents Sea ice in relation to ice properties. In December and May we sampled growing first-year ice, while in July and August melting, older sea ice dominated, overall agreeing with ice trajectories. Abiotic ice conditions and Chla varied strongly seasonally, while POC values were unexpectedly homogenous. Low ice biota abundances in March could be related to late ice formation resulting in a short time for biota to build up biomass. Pennate diatoms dominated the bottom ice algal communities in all seasons, with highest biomass in May. Outside May, small-sized flagellates were co-dominant. Overall, ice meiofauna was comprised of harpacticoid copepods, copepod nauplii and rotifers, foraminiferans and highly abundant ciliates. While melting ice had released ice algal biomass in July, abundance of secondary producers remained high, indicating different life history traits. Unexpectedly abundant communities occurred in December, further strengthened the notion of an active biota in the dark Arctic winter. The data demonstrated a strong and partly unexpected seasonality in the ice biota, indicating that changing timing of ice formation and melt will significantly impact composition and phenology of sympagic communities.

Tuesday, 7 November 2023
13:45-14:00
Talk B2

Diversity and Distribution of Arctic Protists in Pelagic and Sympagic Habitats in the Northern Barents Sea as Revealed by Metabarcoding

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Protists have various crucial roles in the marine ecosystems and in a rapid changing Arctic it is important to address who´s there, when and where, for future management and research of the northern Barents Sea. The main objective in this study is to describe and compare the composition of the protist community in sea ice and pelagic habitats of samples collected along a S-N transect in the northern Barents Sea during in August 2018 with low sea-ice extent and 2019 with sea-ice extent high. By using metabarcoding targeting the 18S rRNA gene we revealed 3682 unique Amplicon sequence variants (ASV), a proxy for a species. The data shows a clear separation of ASV composition in the ice- and pelagic habitats. The pelagic community showed interannual differences along the sampling transect. In the year 2018 the community was dominated by dinoflagellates and nano- and pico-plankton such as *Micromonas polaris*. In the year 2019 a community with more centric diatoms was observed at station in the ice edge. Members of the class Chrysophyceae dominated in the melt ponds, whereas the community composition within the ice (dominated by dinoflagellates and pennate diatoms) changed from homogeneous to heterogeneous with increased ice cores thickness. Right below the ice other dinoflagellates ASVs were dominating, together with *Phaeocystis*. These results indicates that protist communities are distinct and specialized on habitat. With further ocean warming the pelagic community could shift towards smaller flagellates and thinning of the sea ice may result in loss of habitat niches diversity.

Tuesday, 7 November 2023
14:00-14:15
Talk B3

Phytoplankton Primary Production in the North-Western Barents Sea 1980-2021: No Obvious Trends but a Regime Shift Triggered by a Pulse of Atlantic Water

Castro de la Guardia L*[1], Hernández Fariñas T[2], Marchese C[3,4], Amargant-Arumí M[5], Myers PG[6], Bélanger S[7], Assmy P[1], Gradinger RR[5], Duarte P[1]

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The Barents Sea is a highly productive marginal shelf sea of the Arctic Ocean, where sea ice, Atlantic Water and Arctic Water create a heterogenous marine environment. We combined in situ measurements, remote sensing, and model simulations to estimate the primary production of phytoplankton in the Barents Sea (1980-2021). A biogeographical analysis based on phytoplankton chlorophyll-a identified three distinct oceanic regions: Arctic, Subarctic, and Atlantic. Long-term time-series of NPP and environmental characteristics highlighted the start of a warm regime in the NW Barents Sea around 2004, triggered by a pulse of Atlantic Water. This shifted the dynamics of phytoplankton growth limitation in the Atlantic and Subarctic subregions, decreasing temperature limitation and increasing the relative importance of light and nutrient limitation, which in the Atlantic subregion resulted in a step-like increase in net primary production. We identified photosynthetically available radiation and mixing layer depth as important physical predictors of net primary production in spring and autumn, respectively. Finally, the regional and seasonal multi-source estimates within the NW Barents Sea suggest that total net primary production in the study region ranged from 15 Tg C y^{-1} in the Arctic to 48 Tg C y^{-1} in the Atlantic subregion. We estimated that roughly 90 Tg C y^{-1} of primary production are required to sustain three of the most commonly harvested fish species north of 62 °N, highlighting the importance of allochthonous primary production in the NW Barents Sea for the sustainability of commercial fisheries.

Tuesday, 7 November 2023
14:15-14:30
Talk B4

Effects of Multiple Stressors on Overwintering Arctic Zooplankton

Dijkstra J*[1,2], Schott L[1,3], Thomsen N[4], Lutier M[5], Søreide J[2]

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Calanus glacialis is the dominating copepod species in the Arctic food web, accounting for up to 80% of the zooplankton biomass. Before the winter period *C. glacialis* builds up lipid reserves, allowing them to spend the winter near the ocean floor in a state of diapause, only resurfacing again in spring to feed and reproduce. The effects of ocean warming and acidification on *C. glacialis* during their overwintering period are unknown. In the present study *C. glacialis* individuals were exposed to four different acidification and warming scenarios for a period of 53 days. In this period the developmental stage, mortality, lipid content and respiration were monitored. Higher temperatures led to earlier higher oxygen consumption, earlier maturation of the individuals and higher mortality. These changes can lead to mismatch scenario and will likely negatively impact this key species reproductive success with possible cascading effects on the entire Arctic marine ecosystem.

Tuesday, 7 November 2023
14:30-14:45
Talk B5

Changes in the Life-History Strategy of Fish Communities from the Barents Sea in a Warming Environment

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In the Arctic, rapid warming causes large shifts in fish distributions. Which and how species are redistributing is related to their life-history traits. Previous studies have analyzed fish species range-shift according to few life-history traits, often considered separately. However, a more promising approach addresses multiple traits jointly to identify and characterize systematic changes. Following the equilibrium-periodic-opportunistic (EPO) life-history strategy framework, we aim to (i) describe how the Barents Sea fish species are positioned along the EPO continuum and whether their position can be related to other attributes (biogeography, feeding ecology, environmental preferences), and (ii) analyze the climate-driven spatiotemporal variation in fish community composition in terms of their life-history strategies (2004-2017). We used Archetype analysis to categorize the species within the three strategies based on their life-history traits. In contrast with other species pools, which are distributed between the opportunistic and periodic strategies, many fish species are distributed along the opportunistic-equilibrium axis in the Barents Sea. The equilibrium strategists were mostly generalist species at higher trophic levels, found in the western deep regions. The periodic strategists were boreal species with a generalist diet found in southern warmer areas. The opportunistic strategists were mostly Arctic or Arctic-boreal species with a specialist diet and low trophic level, found in the northern cold and ice-covered waters. In the central Barents Sea, where ice coverage has been declining and sea temperature has increased, the proportion of periodic species increased. In the Northeast, the proportion of opportunistic species remained stable, suggesting the presence of a cold Arctic water refuge. Equilibrium species increased eastward towards shallower waters. The fast warming of the Arctic has benefited periodic fish strategists, which are targeted by fisheries, over opportunistic species. The documented zoogeographic changes in life-history composition invite careful consideration in climate adaptation of management plans.

Tuesday, 7 November 2023
14:45-15:00
Talk B6

Feeding Preferences of Sea Urchins on Arctic Macroalgae Assemblages Changing with Depth

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The ongoing changes in the marine physical environment of the Arctic as well as the overall shift from sea- to land-terminating glaciers immensely impact shallow-water benthic communities, especially in fjords. The underwater light climate changes due to increasing sediment loads and a lower rate of scouring through icebergs causes less disturbances in shallow areas. In Kongsfjorden, Svalbard, the majority of kelp species (brown algae) is now found at shallow depths around 2.5 and 5 m, whereas the deeper areas around 10 and 15 m are dominated by red algae. We sampled the dominant grazers, the sea urchins *Strongylocentrotus pallidus* and *S. droebachiensis*, from the respective depth zones as well as the dominant macroalgae in summer 2021. Lipid and fatty acid analyses of gonad tissue revealed similarly high total lipid contents of 20-27 %dry mass as well as similar fatty acid profiles for both species from different depths. Thus, the energy-storing capacities and feeding preferences of sea urchins do not vary with depth and hence different macroalgal assemblages. As very mobile opportunistic grazers, sea urchins of the genus *Strongylocentrotus* apparently migrate routinely up and down rocky bottom slopes while foraging, which leads to similar dietary compositions, even if the grazers were sampled in different macroalgae assemblages. Furthermore, this illustrates that Arctic sea urchins are relatively independent from the ongoing changes in the depth distributions of macroalgae.

Tuesday, 7 November 2023
15:30-15:45
Talk B7

Seasonal and Spatial Variability in Macrobenthic Size Structure and Functioning in the Northern Barents Sea

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Climate warming is fastest and most intense in the Arctic regions, especially in the Barents Sea, which is influenced by both Arctic and Atlantic water masses. Large-scale simulations of global climate predict continuous increases in air and water temperature, leading to further reduction in ice-cover in the Arctic and results in cascading effects on the marine Arctic ecosystem. The initiation of ice melting is important for the timing, quality, and quantity of primary production and thus on the properties of organic matter reaching the seafloor. Changes in seasonality of organic matter pulses may led to changes in energy pathways and destabilization of the dynamics of food webs throughout the entire marine ecosystem, from pelagic to benthic compartments. The aim of our study is to identify seasonal and spatial variability of macrobenthic biomass size spectra, carbon demand, and respiration. Sampling and experiments were conducted in four seasons at seven stations in the Barents Sea and adjacent basin at depths ranging from 325 m to 3605 m and across gradients in ice extent and food supply to the seafloor and oceanographic regimes. The patterns of macrobenthic functioning and biomass partitioning among size classes are compared and assessed with respect to data on potential biotic and abiotic drivers. The basic metrics of functioning of macrobenthos in the ice-covered Arctic waters (north Barents Sea) were compared to those in ice-free regions at similar latitude/depth gradient (Greenland Sea) to explore the possible effects of environmental changes.

Tuesday, 7 November 2023
15:45-16:00
Talk B8

Blue Carbon Storage within Benthic Ecosystems across Multiple Habitats within the Barents Sea with Respect to Sea Ice Loss and the Anthropogenic Impact of Trawling

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Sustained intense warming has led to massive polar seasonal sea ice losses. This can cause new and longer phytoplankton algal blooms, and responsive growth increases of benthos, driving increases in zoobenthic blue carbon (carbon held within marine animals). This is important because it is a potential negative feedback on climate change (warming decreases marine ice, which increases algal bloom duration, benthic growth, and seabed carbon storage with sequestration potential). Does habitat type in the Barents Sea influence the quantity of zoobenthic carbon stored and the benthic functional groups present. This information could then feed into designation prioritization and management plans for protection of areas with high blue carbon values, as part of a suite of nature-based solutions to aid climate change mitigation. Secondly does the quantity of stored benthic blue carbon and functional biodiversity change with respect to trawling impact. Calibrated camera deployments perpendicular to seabed were made to get accurate replicate seabed images across 17 sites to calculate densities of epi-benthic functional groups. Three replicate Agassiz trawls were towed to collect specimens of zoobenthos which were also identified before measuring morphometrics, drying, weighing and ashing, and reweighing. Size spectra and carbon content of functional zoobenthic groups were calculated and analysed against physio-chemical factors measured at the time of collection. Scaling up from previous monohabitat benthic blue carbon assessments in the Norwegian Arctic would have massively underestimated quantity and ecosystem value. The Barents Sea is a highly productive and short-term predictable system that we would expect blue carbon storage to typically increase with changing Arctic conditions.

Biodiversity in the Northern Barents Sea and Adjacent Nansen Basin – Towards an Updated Inventory

Kwaśniewski S*[1], Altenburger A[2], Assmy P[3], Bluhm B[2], Dabrowska A[1], Edvardsen B[4], Goraguer L[23], Gradinger R[2], Grzelak K[1], Jordà Molina E[5], Kovacs KM[3], Lydersen C[3], Majaneva S[67], Marquardt M[2], Ormanczyk M[1], Reiss H[5], Renaud PE[8], Saubrekka K[9], Tatarek A[1], Vader A[10], Wernström J[2], Wlodarska-Kowalczuk M[1], Wold A[3], Øvreås L[11 10] and other collaborators

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Biodiversity patterns shape and drive ecosystem processes and functions in the global ocean. Given the changing climate and recent agreements to protect ocean regions, current estimates of biodiversity must be assembled. Here, we present new estimates and spatial patters of taxon richness from microbes to mammals from a shelf-to-basin transect in the northern Barents Sea and southern Nansen Basin from seasonal sampling in 2018-2022 by the Nansen Legacy project. We find that estimates of taxon richness are higher on the shelf than in the basin for pelagic protists, zooplankton, and benthic macrobenthos, nematodes, and prokaryotes, but not for sympagic protists. Taxon richness varied seasonally for pelagic prokaryotes, protists, and zooplankton, but little for sympagic meiofauna, benthic prokaryotes and macrobenthos. Unsurprisingly, taxon richness was generally highest for single-celled taxa. Taxon-rich groups included: sympagic diatoms; pelagic prokaryotes (e.g., Alphaproteobacteria), diatoms, dinoflagellates, copepods; and benthic prokaryotes (with abundant taxa, e.g., *Candidatus nitrosopumilus* and *Woesia*), nematodes, and polychaetes. Unexpectedly absent - though known from earlier studies - were, for example, nematodes in sea ice. Ironically, at top (and perhaps other) trophic levels species richness is likely to be enhanced regionally for some time, while losses of Arctic (endemic) species will impact global biodiversity, and potentially Arctic ecosystem functioning.

Ranges of Annual Production in the Barents Sea along Environmental Gradients

Gradinger R*[1], Amargant Arumí M[1], Assmy P[2], Bodur YV[1], Bratbak G[3], Castro de la Guardia L[2], Duarte P[2], Bluhm B[1], Eriksen E[4], Hop H[2], Ingvaldsen RB[4], Müller O[3], Pedersen T[1], Reigstad M[1], Svensen C[1], Wold A[2] and other contributors

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The Barents Sea is a highly complex system, influenced by strong environmental gradients between a relatively warm southerly Atlantic-influenced domain and the cold and seasonally ice-covered Arctic domain in the north. Within the system, organisms occur in distinct communities in three domains (sea ice, water column, sea floor), each with their own temporal and spatial dynamics. These systems are also linked through vertical flux, particularly during the spring production and subsequent ice melt, and during mixing events during autumn storms. The Nansen Legacy project resolved important patterns and drivers of biological processes in seasonal field expeditions at defined stations, augmented by remote sensing data, and regional monitoring and ecosystem modelling. The results of the individual cruises revealed substantial differences in biomass and productivity, tightly linked to the annual cycle of ice, light and primary production. Annual primary production estimates based on combined in-situ data, remote sensing and ecosystem model efforts revealed a strong latitudinal gradient from >100 gC m^{-2} y^{-1} in the south to <50 gC m^{-2} y^{-1} in the north. This contribution will extent such estimates to annually integrated values for the marine biological production on trophic levels from microbes to fish and for the sea ice, pelagic and benthic realms based on a combination of field data and modelling output.

Parallel session C

Photo: Pernille Amdahl

Parallel session C: Environmental Lessons from the Past

Session Chairs: Katrine Husum, Christian März, Christine Tømmervik Kollsgård

Unravelling the Link between Arctic-Atlantic Exchanges and Meridional Overturning Circulation during the last Deglaciation

Ninnemann U*[1], Irvali U[1], Lefevere SP[1], Liltved A[1], Nesbø J[1], Husum K[2], Kleiven K[1], Jansen E[1]

[1]Department of Earth Science and Bjerknes Centre for Climate Research, University of Bergen, Bergen, Norway, [2]Norwegian Polar Institute, Tromsø, Norway

The buoyancy (heat) loss by Atlantic Water (AW) along its horizontal circulation path is important for water mass transformation, contributing substantially to the Atlantic Meridional Overturning Circulation (AMOC). The Arctic, specifically sea ice and the Arctic halocline, represents the northern terminus of this water mass transformation. While AMOC is likely to weaken with future warming and freshening, declining sea ice may increase heat loss, complicating projections. To better constrain how sea ice, freshwater, and Arctic-Atlantic exchanges are linked to abrupt changes in AMOC and climate we reconstruct changes in AW inflow to the arctic across the last deglaciation. Using Barents Sea sediment cores, we show that changes in the properties of AW are tightly coupled to abrupt changes in North Atlantic climate and AMOC. Like previous work, we find that AW may have warmed abruptly during periods of weaker AMOC. Yet, our kinetic proxy suggests no associated increase in AW (in)flow as was previously suggested to explain this warming. New results from a site in the subpolar North Atlantic suggest that changes in AW inflow properties are out of phase with both surface outflow properties and North Atlantic climate. We show how Arctic-Atlantic exchanges were linked to abrupt climate and AMOC changes over the deglaciation and suggest that as the overall climate and cryosphere evolved so too did the relationship between AMOC, Arctic-Atlantic exchanges, and climate.

Tuesday, 7 November 2023
14:00-14:15
Talk C2

Holocene Natural Variability in Atlantic Water Inflow Properties to the Arctic

Irvali N*[1], Ninnemann U[1], Liltved A[1], Lefèvere S[1], Husum K[2], Jansen E[1]

[1]Department of Earth Science and Bjerknes Centre for Climate Research, University of Bergen, Bergen, Norway, [2]Norwegian Polar Institute, Tromsø, Norway

The recent decline in Arctic sea ice extent has been linked to increased ocean heat transport with the Atlantic Water (AW), i.e., the Atlantification of the Arctic Ocean. Here we evaluate how current changes compare in pattern and magnitude to the longer-term natural variability in AW properties and their relationship to sea ice through the Holocene. We use a sediment core from the northern Barents Sea (KH18-10-14-GC1; 80.68 °N, 28.95 °E; 552 m). Stable isotopes ($\delta^{18}O$ and $\delta^{13}C$) of planktonic (*N. pachyderma*) and benthic foraminifera (*N. labradorica*, *C. lobatulus* and *C. neoteretis*) are used to reconstruct the physical and chemical properties of the AW over the last ~12 000 years. Our *N. pachyderma* $\delta^{18}O$ values generally covary with the epibenthic *C. lobatulus* $\delta^{18}O$ values through the Holocene—suggesting there was always a presence of AW at the site and not a strong halocline dominance. Our planktonic and benthic stable isotope records indicate a sudden warming/freshening ($\delta^{18}O$ decrease by ~1‰) in AW properties at ~9 ka BP, in phase with an increase in sea ice concentrations (SpSIC %) in the northern Barents Sea (>80 °N). This indicates that natural variability in the region involved a close coupling between AW properties and sea ice extent. However, this past sea ice-AW coupling contrasts sharply to the recent changes suggesting modern changes are quite distinct from natural variability in the region and have a potentially different (anthropogenic) origin.

Reconstruction of Bottom Current Activity on the Northern Svalbard Margin on Orbital and Millennial-Scales during the late Quaternary

Lockwood-Ireland C*[12], Rasmussen TL[1], Noormets R[2], Junttila J[3]

[1]UiT The Arctic University of Norway, Tromsø, Norway, [2]The University Centre in Svalbard, Longyearbyen, Svalbard, [3]Multiconsult, Tromsø, Norway

The climate of the late Quaternary oscillated on orbital time scales between glacial and interglacial periods. Multiple, abrupt climatic fluctuations on millennial-scales, known as Dansgaard-Oeschger (D/O) events or Greenland stadials and interstadials occurred during The Last Glacial Period (115-11.7 Ky BP). D/O events are characterised by a prominent abrupt warming, to warm interstadial conditions with a gradual cooling, followed by a rapid decrease to very cold stadial conditions. Atlantic Meridional Overturning Circulation (AMOC) is a key component of our modern global climate system. Bottom current strength is associated with open ocean convection and the production of deep water that drives the AMOC. The D/O events are closely linked to the variations in the strength of convection in the Nordic Seas. The input of vast quantities of melt water during stadial periods and Heinrich events may have reduced deep water formation and subsequently weakened the AMOC in the past. Here, we present the results from an investigation of past bottom current activity in relation to climate change and meltwater input on orbital (glacial-interglacial) and millennial (D/O event) scales from a deep-sea sediment core recovered from the Sofia Deep on the northern Svalbard margin in the Arctic Ocean at 1031 m water depth. The area is part of the important Fram Strait gateway for the exchange of deep and surface water masses between the Nordic Seas and the Arctic Ocean. Atlantic water is currently transformed from a warm surface current into a colder subsurface intermediate water current. The results of the investigation are based on records of sortable silt, planktonic and benthic foraminiferal oxygen and carbon isotopes, planktic foraminifera counts, ice-rafted debris, and AMS ^{14}C dates. Mean sortable silt grain size (10-63 µm) is a reliable proxy used to reconstruct past bottom current strength. The results show fining of the sortable silt suggesting a weaker bottom current strength during periods of colder climate (Greenland stadials/Heinrich Events and the Last Glacial Maximum). The weaker bottom currents were possibly caused by increased meltwater input, leading to stronger stratification and a reduced exchange of the water masses. The outcome of the study aims to provide a further understanding into the causes of variations in the strength of bottom currents in relation to past climate change and the possible input of meltwater during the last 150,000 years. This is highly relevant with respect to the accelerated melting of Greenlandic ice caps that we are observing today.

Planktic Foraminifera in the Barents Sea: Reconstruction of Biomass and Biodiversity Changes during the last Three Millennia

Anglada-Ortiz G*[1], Rasmussen TL[1], Chierici M[2], Fransson A[3], Zamelczyk K[1], Ziveri P[4], Meilland J[5], Garcie-Orellana J[4]

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Anthropogenic CO_2 emissions are causing global environmental changes, such as ocean warming and acidification. Effects of ocean acidification have been observed in planktic foraminifera which contribute significantly to the ocean carbon cycle. When they die, they sink to the seabed and usually get preserved in the sediment recording the characteristics of the water column from when they were alive. Hence, their fossil calcareous shells can be used as proxies in paleoenvironmental reconstructions. The species composition and abundance of the faunas through time have been used to reconstruct past oceanography, climate and productivity, and the chemical composition of their shells, to reconstruct water mass properties. In this study, we have analyzed their abundance, size, and species distribution patterns together with δ13C, δ18O and total organic carbon (TOC), total carbon (TC) and calcium carbonate ($CaCO_3$) content in two sediment cores from the northern and southern Barents Sea. In the north, we observed low concentration of foraminifera (2.1 ind g^{-1}) dominated by *Neogloboquadrina pachyderma* (91%). This contrasts with higher abundances (20 ind g^{-1}) and biodiversity in the south, where *N. pachyderma* only constituted 22% of the fauna that was dominated by the subpolar species. The almost absence of foraminifera in the upper half of the northern site as well as the permanently low content of $CaCO_3$ were attributed to $CaCO_3$ dissolution in the sediment, possibly driven by the decomposition of organic matter, the presence of solely agglutinated specimens and the observed seasonal variability of living foraminifera in the area.

Delivery and Reactivity of Iron on the Eurasian Arctic Continental Shelf in the Holocene

Gray R*[1], Tessin A[1], März C[2], Husum K[3]

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Fe can act as a limiting nutrient for primary productivity and reactive Fe minerals play a key role in carbon, nutrient, and trace metal cycling. Delivery and reactivity of Fe can both be affected by glacial conditions, and glacial variations on Svalbard during the Holocene may have driven changes in Fe delivery and speciation. We analyzed sediment cores from the Barents Sea shelf and slope to determine the concentration and reactivity of Fe deposited during the Holocene. Gravity cores were collected from the Barents Sea during the Nansen Legacy Paleo Cruise in 2018. We used sequential extractions to determine the contents of Fe in four mineral phases: poorly crystalline Fe (oxyhydr)oxides, Fe associated with carbonate, crystalline Fe (oxyhydr) oxides, and Fe in magnetite. The most reactive phase, Fe in poorly crystalline oxides, showed the greatest variation across the shelf sites. Enrichments in reactive Fe in the upper 100 cm of the shelf sites suggest changes in Fe delivery during the Late Holocene. Based on preliminary age models, these results suggest that reactive Fe delivery to the continental shelf is enhanced during glacial readvance on Svalbard in the Holocene. However, the timing of increased reactive Fe intervals in the Holocene appears to differ between the shelf and slope sites. Further analysis of the slope site may offer insight into the pre-Holocene history of Fe delivery.

Glacial History of the Northern Barents Sea Reconstructed from Submarine Landforms – Nansen Legacy Results and Research Outlook

Rydningen TA*[1], Trælvik Eilertsen V[1], Tømmervik Kollsgård C[1], Husum K[2], Forwick M[1], Laberg JS[1], Lasabuda A[1], Ninnemann US[3]

[1]Department of Geosciences, UiT The Arctic University of Norway, Tromsø, Norway, [2]Norwegian Polar Institute, Longyearbyen, Norway, [3]Department of Earth Science, University of Bergen, Bergen, Norway

We have studied the ~300 km long Erik Eriksen and Kong Karls straits and the ~200 km long Kvitøya Trough and assoicated trough-mouth fan in order to reconstruct the last glacial history of the northern Barents Sea. Our findings include a major grounding zone wedge in the Kong Karls Strait, glacial lineations within the Kvitøya Trough, and several sets of cross-cutting moraines ridges. The trough-mouth fan formed from mass-wasting processes during repeated advances of the Svalbard-Barents Sea Ice Sheet to the shelf break, while contourites west and east of the fan deposited from eastward-flowing ocean currents. Our findings reveal that there were two different ice domes during the last glacial, one on Spitsbergen (draining eastwards) and one between Nordaustlandet and Kvitøya (draining northwards). We show several grounding events during a dynamic ice retreat, controlled by inflow of warm water masses, sea-level changes, and the seabed topography. This new reconstruction improves our knowledge of deglaciation and ice sheet evolution in northern Barents Sea during warmer-than-present conditions in the past. Yet, with vast areas still unexplored, including the continental slope, more research expeditions acquiring geophysical and geological data are required to fully constrain the regional ice-sheet dynamics, ocean current variability during the last glacial and Holocene, and the longer climate evolution of the Arctic Ocean.

Tuesday, 7 November 2023
16:00-16:15
Talk C7

Reconstructing Paleoenvironment and Sedimentary Processes of the Northern Barents Sea Continental Slope

Tømmervik Kollsgård C*[1], Laberg JS[1], Rydningen TA[1], Husum K[2], Lasabuda APE[1], Forwick M[1]

[1]UiT The Arctic University of Norway, Tromsø, Norway, [2]Norwegian Polar Institute, Tromsø, Norway

The northern Barents Sea continental slope is a key area for understanding the history of the northern Svalbard-Barents Sea Ice Sheet and the along-slope flowing ocean current in the area. The Kvitøya Trough Mouth Fan formed offshore of the Kvitøya Trough due to paleo ice streams that eroded and transported sediment during reoccurring glaciations of the trough, including the last glacial period. The ocean current is an extension of the West Spitsbergen Current and transports modified Atlantic Water to the Eurasian part of the Arctic Ocean northeastward along the upper continental slope. We reconstruct the past ice sheet dynamics and current regime by interpreting the sedimentary processes of the Kvitøya Trough Mouth Fan and the adjacent slope from six sediment cores (ranges from 0.43 to 5.45 m long). Based on grain sizes, sediment structures, color, and physical properties (wet bulk density, shear strength, and water content), we have identified three main lithofacies. These reflect different sedimentary processes including suspension settling, iceberg and sea ice rafting, down-slope sediment transport by gravity flows and sediment sorting from ocean currents. The timing of these events will be discussed based on radiocarbon dates of microfossils (planktic foraminifera) and correlations of magnetic susceptibility and paleomagnetism across the cores.

Depositional Environments in the Northern Barents Sea, from the Last Glacial to the Present

Eilertsen VT*[1], Rydningen TA[1], Forwick M[1], Laberg JS[1]

[1]Department of Geosciences, UiT The Arctic University of Norway, Norway

During the Late Weichselian glaciation, the Svalbard-Barents Sea Ice Sheet covered the central and northern Barents Sea and extended to the shelf break. Action of grounded ice resulted in formation of glacial landforms such as streamlined ridges/grooves, grounding-zone wedges, and recessional moraines. The action of grounded ice also resulted in deposition of muddy glacigenic diamicts. A cover of proximal glaciomarine deposits capped by Holocene marine muds overlies these diamicts. Analysing the landforms, as well as investigating the sediments can give information of past ice flow directions and the dynamics of the glacial retreat. This study aims to reconstruct the glacial dynamics and time the retreat of the northern part of the Svalbard-Barents Sea Ice Sheet, in addition to reconstruct the sedimentary environment on the northern part of the Barents Sea shelf from the last glacial to the present. A total of five gravity cores (1.15 to 5.05 m long) were retrieved from water depths of ca. 250-550 m in the Kong Karl's Trough, Erik Eriksen Strait and Kvitøya Trough during the Nansen Legacy Paleo-cruise in 2018. High-resolution sub-bottom profiles and multi-beam swath bathymetry were also acquired during the cruise. Results from multi-proxy analyses of the sediment cores including physical properties, grain size distribution, lithostratigraphy and XRF will be presented, combined with new multi-beam swath-bathymetry and high-resolution Topas seismic data.

Parallel session D

Photo: Luka Supraha

Parallel Sessions – Wednesday 8 November

Parallel session D: Caught in Transit – Key Processes on the Inflow Shelves and Their Regional Connectivity to Pan-Arctic Systems

Session Chairs: Randi B. Ingvaldsen, Jacqueline Grebmeier, Snorre Flo

Ocean Acidification Variability in the Northern Barents Sea during Years of Contrasting Sea Ice Conditions

Jones E*[1], Chierici M[12], Fransson A[23], Assmann K[1], Renner A[1]

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Atlantification with warming, loss of sea ice and increased influence of Atlantic Water, will impact biogeochemical cycling and ocean acidification in the Barents Sea. Variability and drivers of the carbonate system (inorganic carbon, alkalinity) were determined in summer (July, August) of three years (2018, 2019, 2021) of contrasting sea-ice conditions in the northern Barents Sea. In summer 2018, the region was largely ice free and the water column was generally warmer and more saline, representing Atlantic-like conditions. Greater Atlantic Water influence supplied the surface layer with nutrients and alkalinity, the natural buffer capacity of seawater. Primary production, biological carbon uptake and increased alkalinity enhanced calcium carbonate saturation states in the upper ocean in the ice-free, Atlantic-like regime. In summer 2019, greater sea-ice cover remained in the northern Barents Sea and created more Arctic-like conditions. Sea-ice meltwater was an important driver of biological carbon uptake, which was delayed in the ice-covered waters in 2019 relative to 2018. Summer 2021 represented an intermediate situation with retreating sea ice and meltwater input driving change in the carbonate system in surface waters. These findings indicate that future Atlantification may increase biological CO_2 drawdown, reduce dilution effects, and may partly counteract acidification in the Barents Sea.

Hydrography, Inorganic Nutrients and Chlorophyll a Linked to Sea Ice Cover in the Atlantic Water Inflow Region North of Svalbard

Renner AHH*[1], Bailey A[2], Reigstad M[3], Sundfjord A[2], Chierici M[1], Jones E[1]

[1]Institute of Marine Research, Tromsø, Norway, [2]Norwegian Polar Institute, Tromsø, Norway, [3]UiT The Arctic University of Norway, Tromsø, Norway

Changing Atlantic Water (AW) inflow promotes sea ice decline and borealisation of marine ecosystems and affects primary production in the Eurasian Arctic Ocean. North of Svalbard, the AW inflow dominates oceanographic conditions along the shelf break, bringing in heat, salt, and nutrients. However, interaction with sea ice and Polar Surface Water determines nutrient supply to the euphotic layer. We investigate the role of sea ice for hydrography, nutrients and seasonal dynamics of chl a, based on a combination of satellite data and in-situ measurements from a transect across the AW inflow at 31 °E, 81.5 °N, visited regularly since 2012. Large interannual variability in hydrography, nutrients and chl a indicates varying levels of nutrient drawdown by primary producers over summer. Sea ice conditions impact surface stratification, light availability, and wind-driven mixing, with a strong potential for steering chl a concentration over the productive season. In early winter, nutrient re-supply through vertical mixing varied in efficiency, again related to sea ice conditions. The re-supply elevated nutrient levels sufficiently for primary production but likely happened too late in the season when high-latitude light levels limited potential autumn blooms. Such multidisciplinary observations are key to gain insight into the interplay between physical, chemical, and biological drivers and to understand ongoing and future changes, especially at this entrance to the central Arctic Ocean.

Hotspot or Mismatch? - High Spring Productivity across the Barents Sea Polar Front

Leu E*[1], Campbell K[2], Lenss M[2], Miettinnen A[2], Gradinger R[2], Bedington M[1], Basedow S[2], Daase M[23], Renaud P[13]

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Oceanic fronts are considered hotspots of production due to different water masses meeting, which both may lead to upwelling of nutrient-rich waters and concentration of biota advected. In the Barents Sea, Atlantic water inflow is increasing with cascading effects throughout the entire ecosystem. Understanding how this Atlantification impacts primary production in the Polar Front area is key to assess climate change impacts on future ecosystem functioning. At high latitudes, pelagic primary production peaks during a few weeks in spring when the bulk of the annual new production takes place. As this happens in partly ice-covered waters, and most monitoring efforts are being carried out during the ice-free summer season, there is a lack of high-resolution data on primary productivity during this critical period. We report here unprecedently high phytoplankton biomass values from two cruises to the Barents Sea Polar Front in May (2021/2022), seemingly invisible by remote sensing, and combined with high production rates. Physiological measurements further indicate that nutrient availability was the main factor limiting production at this stage, while grazer abundances were surprisingly low. Absence of top-down control by grazing has likely contributed to the high biomass production we observed, but its underlying cause remains unclear. Increased Atlantification of this area may therefore lead to higher primary production – while additional data collected within the ongoing PolarFront project suggest that this high biomass is less available for pelagic zooplankton, with negative consequences for pelagic secondary production.

Wednesday, 8 November 2023,
14:15-14:30
Talk D4

Secondary Production at the Polar Front – the Role of *Calanus* spp. from Near and Far in Barents Sea Pelagic Productivity

Basedow SL*[1], Granaas T[1], Dunn M[2,3], Daase M[1], Sundfjord A[4], Leu E[2], Renaud P[2]

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The polar front ecosystem in the Barents Sea is markedly affected by Atlantification. Recent observations indicate that during the peak production period in spring there might be a spatio-temporal mismatch between primary production and pelagic secondary production. *Calanus* spp. copepods are important secondary producers in Atlantic and Arctic food webs and are advected in large quantities into the Barents Sea, however, the timing of peak advective input may not match local peaks in primary production. Here, we investigate spatio-temporal patterns of advection and secondary production in May/June (2011, 2022) based on a suite of optical and acoustic sensors (laser optical plankton counter, underwater video profiler, Sailbuoy equipped with active acoustics, ADCP) and experiments (egg production). Preliminary results indicate that *Calanus* spp. egg production accounts for between 5 and 15% of the total secondary production during the spring bloom and that the advective inflow of *Calanus* arrived too late (end of June) to fully utilize the peak in the phytoplankton bloom. Future scenarios are discussed.

Wednesday, 8 November 2023
14:30-14:45
Talk D5

Composition and Regulating Mechanisms of Downward Carbon Flux on Arctic Shelves

Bodur YV*[1], Renaud PE[2], Wiedmann I[1], Assmy P[3], Reigstad M[1]

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The Arctic Ocean is an important sink for atmospheric CO_2. The biological carbon pump is a substantial part of this mechanism, and vertical flux of organic matter is especially efficient on Arctic shelves. However, the Arctic is undergoing rapid change due to sea ice loss and increased inflow of Atlantic and Pacific Water. These changes will have consequences for the entire marine ecosystem, including processes that affect the biological carbon pump. We compare downward carbon flux in the Barents Sea from studies carried out during the last 25 years with other Arctic shelf regions in order to identify the differences and similarities of drivers of the biological carbon pump in the Arctic. Since export of organic matter is most efficient when high primary production is present, we expect highest downward flux of carbon on the productive inflow shelves. However, since investigations have been mostly carried out during summer, and less studies are present from interior and outflow shelves, overarching conclusions are challenging. It is important to evaluate vertical flux on a pan-Arctic level in order to assess how the biological carbon pump responds to drastic changes in this region.

The Effect of Ice-Free Summer Conditions on Benthic Food Web Structure and Pelagic-Benthic Coupling Strength in the Barents Sea

Ziegler A*[12], Jørgensen LL[2], Bluhm B[1]

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Reduced Arctic sea-ice cover has been shown to alter phytoplankton community composition and reduce the magnitude of vertical flux, thereby reducing the strength of pelagic-benthic coupling. It is predicted that Arctic shelf ecosystems, like the Barents Sea, will transition into sub-polar-like ecosystems under future climatic conditions. However, few studies have provided a benthic perspective to the question of how ice-free conditions in the Arctic will affect food web structure. In this study, we aim to test whether ice-free summer conditions in the Barents Sea and adjacent Nansen Basin alter benthic food web structure and the strength of pelagic benthic coupling. To do so, we used bulk stable isotopes of carbon and nitrogen measured in food sources and benthic consumers, demersal fish, and zooplankton collected during summers with contrasting sea-ice conditions: August 2018 – low sea-ice extent and August 2019 – high sea-ice extent. We compared benthic food web structure across three oceanographically distinct regions from the sea-ice free central Barents Sea shelf and the seasonally ice-free northern Barents Sea shelf to the slope extending into the Nansen Basin. The results of this work will not only improve our understanding of the impact that Arctic sea-ice loss has on benthic communities but also provide additional insight to the resiliency of Arctic benthic food webs.

Wednesday, 8 November 2023
15:30-15:45
Talk D7

Investigating Combined Effects of Climate Change and Fisheries on the Barents Sea Ecosystem Dynamics

Sivel E*[1], Planque B[2], Lindstrom U[23], Yoccoz NG[3]

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Species biomass in the Barents Sea display large fluctuations which can originate from internal processes, stochasticity, external drivers, or all three combined. Examining variability resulting from internal processes and stochasticity can help in better understanding the complementary role of external drivers, (e.g., climate change and fisheries) and thereby contribute to inform management policies. In this study, we use the dynamic stochastic model of the Barents Sea food-web named NDND (for Non-Deterministic Network Dynamics) to explore variability resulting from internal processes and stochasticity. We simulate the dynamics of the Barents Sea food-web under multiple scenarios of temperature and fishing mortality and measure how the stability of the food-web is altered under these combined scenarios. We measure the cumulated impacts of temperature and fishing on stability and assess if these are additive, synergistic, or antagonistic. Colder scenarios display synergism between temperature and fisheries while warmer scenarios show antagonistic effects. The conclusion of this study advocates for the importance of using approaches accounting for possible combined effects of multiple external drivers to define future management policies. This study is the only one explicitly looking at the response of food-web variability to impacts of human activities in the Barents Sea. It could open to the study of extreme events and become a useful tool for risk-based management.

Climate Driven Ecosystem Reorganization and Cumulative Risk in the Arctic

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Arctic marine ecosystems are undergoing rapid climate-driven reorganization fueled by species redistributions. The impact of climate warming on biodiversity and ecosystem organization affects exposure and vulnerability to multiple stressors, ultimately determining cumulative risk. The changes in biodiversity and food web structure observed during the last twenty years in the Barents Sea and along the North Norwegian coast help illustrate the pace and magnitude of the ongoing ecosystem reorganization in the High North. The rapid borealization of these Arctic marine communities, driven by poleward distributional shifts, has changed the functional character of species and the configuration of feeding relationships. The ecological changes are concomitant with the northward expansion of human activities such as fisheries, aquaculture and oil and gas extraction. The redistribution of species and human activities changes the character of exposure to multiple stressors in these ecosystems. In turn, the ecological reorganization affects the ecosystem internal stability, or robustness to perturbations, and its invasibility by new incoming species. The documented changes in ecosystem organization and exposure to multiple stressors provide the context for considerations of the ensuing cumulative risk and of its adaptive management.

Annual Replacement of Zooplankton Species in a Shallow Flow-Through Sea

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Water, and intrinsic plankton, in the Chukchi Sea originate in the Bering Sea and flow through the Chukchi Sea to exit the shelf to the basin. Thus, plankton populations in the Chukchi Sea likely are replaced annually and are not maintained as permanent residents. Here two case studies demonstrating the importance of the flow-through system to Chukchi Sea zooplankton populations will be presented. The annual replacement was observed from two bio-physical surveys, in early-winter 2011 and in late-spring 2014, that described the distributions of the dominant copepod *C. glacialis* relative to seasonal hydrography. Interannual variability in atmospheric forcing can have a substantial impact on spring evolution of the Chukchi Sea, including the timing of sea ice retreat, of northward expansion of springtime introduced Bering Sea water, and of the replacement of overwintering plankton populations with newly introduced animals. This interannual variability was observed in a late-summer 13-year study near Pt. Barrow, Alaska. The annual replacement has implications for whether plankton populations in the Chukchi Sea could ever increase in abundance and biomass substantially, since even if recruitment is high, the recruits are ejected into the Arctic basin where environmental conditions may be less favorable for persistence. The Chukchi Sea may remain benthically dominated, since the zooplankton populations never increase in biomass sufficiently to have a substantial grazing impact.

The Pacific Arctic: A Key Gateway Undergoing Ecosystem Changes with Climate Warming

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The Arctic ecosystem is undergoing change due to warming seawater temperatures and declining sea ice cover on regional to pan-Arctic scales. Changes observed in the biological system range from increasing primary productivity seasonally, but varying by region, changes in organic carbon cycling, trophic boreal species range expansion as well as Arctic species contractions, and impacts to upper trophic seabird and marine mammal populations and migration patterns. The Distributed Biological Observatory (DBO) is a successful example of a change detection array where international cooperation on a scientist-to-scientist basis is tracking the status and trends of the marine ecosystems of the Bering Strait region. Expansion of the DBO into a pan-arctic network is occurring with the developing Atlantic, Davis Strait/Baffin Bay and Siberian DBOs that will strengthen our ability to synergistically observe, track and model ecosystem impacts of a warming climate and ocean. Stressors in the Pacific Arctic associated with climate warming, such as increasing harmful algal blooms and ocean acidification, have a direct impact on food security for coastal communities as well as potentially commercial fisheries. This presentation will discuss key processes occurring over the inflow shelves of the northern Bering/Chukchi seas in the Pacific Arctic and the connections to processes in the high Arctic and beyond.

Parallel session E

Photo: Olaf Schneider

Parallel session E: Around and Out: Processes Along Interior and Outflow Shelves

Session Chairs: Paul Renaud, Zou Zou Kuzyk, Jakob Dörr

Inputs from Land Drive Complex Coastal Ecosystem Responses: Summarizing 5 Years of Research at Svalbard's Land-Ocean Interface

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Climate change is resulting in permafrost thaw, melting glaciers, and altered precipitation and runoff patterns; leading to altered inputs of freshwater and terrigenous material (sediments, nutrients, organic matter, and contaminants) from land to sea. However, there remain critical knowledge gaps related to how inputs from land shape Arctic coastal ecosystem structure and function, making it difficult to assess how future changes in these inputs could impact productive and important coastal ecosystems. Here we present results from recent interdisciplinary research in a river- and glacier-influenced high Arctic fjord system (Isfjorden, Svalbard) where a large team of collaborators has carried out extensive field-based research since 2017, focusing on riverine inputs of sediments, nutrients, organic matter and contaminants from land to sea and studying impacts of these inputs on physical and chemical conditions in coastal waters and sediments, and coastal ecosystem structure and function. These results reveal a broad range of physical, biogeochemical, and ecological responses to inputs from land. These responses are often shaped by the interaction between strong seasonality in magnitude and geochemistry of inputs from land and the strong seasonality inherent to Arctic marine ecosystem processes. In addition to summarizing key findings from recent research at Svalbard's land-ocean interface, we also identify key research needs moving forward, including opportunities for improved pan-Arctic collaboration to understand how predicted increases in land-ocean inputs to the Arctic Ocean are likely to impact coastal ecosystem structure and function.

Marine Heat Waves May Contribute to Ecological Change within the Hudson Bay System, Canadian Arctic

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Results from two recent interconnected studies are presented: (i) a comprehensive coastal habitat research program in Eeyou Istchee (eastern James Bay) that examined the coastal oceanography, health of eelgrass (*Zostera marina*), and Canada Goose (*Branta canadensis*) use of the coastal habitat, and (ii) a characterization of marine heat wave events in the region between 1982 and 2022 using sea surface temperature (SST) data from satellite remote sensing. James Bay is the most southerly extension of the large (~1.25 x106 km^2) Hudson Bay Inland Sea (HBIS) system, which lies along the outflow pathway of seawater from the Arctic Ocean. It experiences an annual sea ice freeze-melt cycle, that drives a feedback, in which the timing of ice breakup influences the amount of heat stored in surface waters during the summer months and a delay in fall freeze-up. Large and increasing additions of freshwater from both ice melt and river water maintain vertical stratification year-round in offshore waters and influence properties of surface and subsurface waters. Given the rapid loss of sea ice, the ice cover - SST interactions make the HBIS, and particularly James Bay at its southern margin, at risk of increasing frequency and severity of marine heat wave events. Of particular interest are the characteristics of a major marine heat wave event that occurred in spring 1998. Eastern James Bay experienced an unprecedented marine heat wave caused by early ice breakup. It is suspected to have played a role in transforming a gradual, probably localized decline of eelgrass ecosystems caused by hydroelectric development into a severe, large-scale decline, ultimately the largest scale eelgrass decline recorded in eastern Canada since the 1930s. It was one among many other large scale and local environmental changes discovered in the research program that likely jointly contributed to the eelgrass and goose declines.

Local Ice-Meltwater Drives Anticyclonic Circulation and Triggers Under-Ice Phytoplankton Blooms at the Entrance of an Arctic Fjord

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The onset of ice melt, while the ice cover remains, is a key period for physical and biological processes in the water column in the Arctic region. To assess the effects of local meltwater input we combined current and hydrographic data from moorings and CTD casts deployed in Young Sound Fjord, Greenland, during the transition from ice cover to ice free conditions. Our observations indicate that at the entrance of Young Sound melted, i.e., fresher water, generated a baroclinic instability and drove anticyclonic circulation. Fresher water was advected from the mouth into the fjord and seemed to recirculate back off the fjord. Furthermore, meltwater input onset stratification near the surface and triggered an under-ice phytoplankton bloom. This study suggests that most of the blooms occur prior to full ice break up.

Coastal Freshening Drives CO_2 Dynamics in Greenland Fjords

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High latitude marine waters are a large sink for anthropogenic CO_2. Global surface warming is accelerating the retreat of the Greenland ice sheet and increasing meltwater discharge into fjord waters. This freshening of fjord ecosystems causes biogeochemical changes affecting the carbonate system as well as changes to fjord circulation that may affect future productivity and rates of CO_2 uptake. Within Greenlandic fjords, the impact of freshwater discharge depends on local conditions, namely the position of the glacial terminus. Marine-terminating glaciers deliver freshwater partly through subglacial discharge. This incorporation of meltwater at depth leads to upwelling of nutrient rich, yet corrosive bottom water to the photic zone. Meanwhile, land-terminating glaciers deliver freshwater via rivers enhancing surface stratification and turbidity, leading to light and nutrient limitation. Glacial freshwater discharge is also extremely low in alkalinity. Freshwater incorporation from rivers or from subglacial discharge can therefore cause alkalinity dilution reducing the buffer capacity of water masses in fjords. Glacial meltwater therefore has the potential to drive CO_2 fluxes by modulating both carbonate chemistry and biological activity. Data from field campaigns between 2016-2023 evaluate the magnitude of CO_2 fluxes and elucidate the mechanisms by which freshening drives CO_2 dynamics in Greenland coastal waters.

Carbon Dioxide Flow and Acidification Rates at the Outer Shelf-Continental Slope Area of the Kara and Laptev Seas

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The water area of the Arctic Ocean is most of all in the World Ocean affected by global climate change, one of the important consequences of which is the change in the balance of carbon dioxide in the Arctic seas of Russia and the impact of its variability on the carbonate system of its waters. The Kara Sea and the Laptev Sea have the largest shelves areas. In addition, most of the continental runoff enters their water area, which determines the structure and, in part, the dynamics of waters on the shelf. The processes of transformation of organic matter occurring on the shelf and the variability of the balance of the carbonate system through the mechanism of cross-shelf and then cross-slope transport also have an impact on the waters of the Central Arctic Basin. The Shirshov Institute of Oceanology has been conducting research on the processes occurring on the shelf and slope under the program ""Ecosystems of the Seas of the Siberian Arctic"" since 2007. The results on the current state of the carbonate system of waters have been obtained, the intensity and spatial heterogeneity of the carbon dioxide flow at the water-atmosphere boundary have been studied, and long-term trends in the process of water acidification have been obtained. These results will provide a better understanding of the variability of the ecosystems of the Arctic seas against the backdrop of a changing climate in the Arctic and provide a forecast for their future development.

Does Terrestrial Runoff Alter Coastal Planktonic Community Structure in the Arctic?

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Higher temperatures in the Arctic are expected to increase permafrost soil thawing, leading to a larger discharge of muddy, carbon-rich water into coastal areas. Higher turbidity and increased levels of dissolved organic carbon (DOC) in nearshore ecosystems are likely to affect the biomass and community structure of phytoplankton and bacteria that form the base of the marine food web. Higher turbidity will reduce light intensity, thereby directly impacting phytoplankton growth. With DOC being an important carbon source for bacteria, increasing DOC levels might promote bacterial growth. Changes in bacteria and phytoplankton communities can have significant consequences for the marine food web and ultimately affect the functioning of coastal Arctic ecosystems. We conducted a mesocosm experiment to determine the relative importance of light reduction and DOC levels in altering phytoplankton to bacterial biomass ratios and phytoplankton community structure. Natural plankton communities from Herschel Island (Beaufort Sea, Canada) were exposed to four different treatments: 1) a control treatment, 2) a treatment with addition of a clear carbon solution (no light attenuation), 3) a treatment with addition of light-reducing pigment (no carbon addition), 4) a treatment with addition of natural thaw slump material (light attenuation and carbon addition). Preliminary results indicate DOC impacting growth of planktonic communities more than light reduction.

Biogeography and Connectivity of *Calanus* Copepods in the Arctic Ocean and its Peripheral Areas

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Copepods of the genus *Calanus* make the bulk of the mesozooplankton biomass in the arctic and subarctic seas and play a prominent role in the trophic transfer of energy and in the biogeochemical cycling of elements in the Arctic marine ecosystems. The Arctic *Calanus* complex of species is dominated by the two endemic *Calanus glacialis* and *C. hyperboreus*, and the smaller boreal-Atlantic expatriate *C. finmarchicus* transported by northward-flowing currents from the Atlantic Ocean over the Barents Sea and along the west Greenland coast. Due to the ongoing borealization of the Arctic through the main Atlantic and Pacific gateways, shifts in the composition of the *Calanus* complex have been observed with cascading effects on higher trophic levels. To address ecosystem disruptions with climate warming, the biogeographic patterns of these key pelagic species and ecological connectivity among the Arctic inflow, interior, and outflow shelves need to be better documented. Here we exploit a dataset of >500 zooplankton stations sampled from 1998 to 2021 to describe the spatial distribution of the dominant *Calanus* species over a vast expanse of the Arctic realm, from the Svalbard shelf and fjords inflow area to the western Labrador Sea outflow area. Interannual variability in the *Calanus* composition, populations' development, and abundances is explored at sites in the Canadian Arctic Archipelago and northern Baffin Bay to further identify the drivers of the current *Calanus* distribution.

Sympagic Carbon Uptake by Benthic Fauna: How Does it Differ between an Inflow and Outflow shelf?

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Organic carbon supply is an important factor determining benthic community structure. In the Arctic, sympagic (ice-associated) primary producers can be an important food source for the benthos, but it is unclear how rapidly changing sea ice conditions may alter their role in benthic food-webs. Here, we use highly branched isoprenoids (HBIs) to estimate the proportion of sympagic and pelagic carbon in benthic food-webs on two Arctic shelves at similar latitudes: the highly productive, warm-water influenced Barents Sea, and the less productive, cold-water influenced East Greenland shelf. Sympagic carbon was less important for Barents Sea benthos than for East Greenland benthos (23±28% and 91±7% sympagic carbon in diets, respectively). This is likely due to the shorter period of ice cover in the Barents Sea resulting in a lower sympagic contribution to total primary production. The contribution of sympagic carbon to Barents Sea benthos was greater at higher latitudes (62±23% at >78.5 °N), where annual ice cover was longer. The overall lower variability in East Greenland fauna suggests less patchy input of sympagic or pelagic carbon. These results indicate that sympagic carbon can contribute substantially to carbon assimilated by the benthos in regions with extended periods of ice-cover. Changing ice conditions will lead to shifts in primary production regimes, with implications for benthic diets and, potentially, community structure and function.

Epibenthic Communities in Northeast Greenland: Taxonomic, Functional, and Trophic Structure

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Arctic ecosystems are increasingly affected by climate change and anthropogenic exploitation. To better understand the consequences of these changes on ecosystem functioning, knowledge about trophic structure and feeding relationships is as central as thorough descriptions of the biota. As part of our efforts to describe and document the under-explored zoobenthic communities of Northeast Greenland, we provide a comprehensive assessment of community structure, including trait-based diversity, along an inshore-to-offshore gradient, from coastal fjords, shelf, to shelf-break and upper-slope habitats. Using carbon and nitrogen stable isotopes as well as lipid biomarkers (highly branched isoprenoids, HBIs), we also explore the trophic characteristics of the communities. The taxonomic composition varied among fjord, shelf, shelf break and continental slope communities. The spatial structuring was also evident in traits composition, but with less distinction among habitats. Community stable isotopic niches, on the other hand, showed significant overlap among habitats. Ice-algal carbon contributed substantially to the benthic food web as evidenced through HBI analysis. The relative importance of sea-ice algae and phytoplankton in diets of zoobenthos provides information about realized food web structure along environmental gradients and reveals insight into the capacity of consumers to adapt to changes at the base of the food web.

Exploring the Ecomorphology of Fishes from Northeast Greenland: Implications on Resource Use and Feeding Competition

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Changes in habitat, prey availability, and distribution of species are considered major threats to biodiversity and ecosystem functioning. In the Arctic, warmer seas, changing hydrography, and loss of sea ice have implications for all components of marine life, including fishes that are indispensable for transferring energy from lower to higher trophic levels and, ultimately, support the structure and functioning of ecosystems. Ecomorphology, i.e., the integration of form, function, and ecology of species, discloses the functional role of specific forms as well as performance implications. When applied on a given fish species it may provide insights on its actual feeding mode as well as how it may meet environmental changes. We studied Arctic fish communities from the Northeast Greenland fjords and shelf. Selected morpho-functional traits were analyzed to investigate the ability of fish species to cope with distinct environmental scenarios and changes in prey availability. Comparative ecomorphological analyses of two pelagic fish species endemic to the Arctic, *Arctogadus glacialis* and *Boreogadus saida*, exemplify actual trophic behavior and niche partitioning. *Mallotus villosus*, a sub-Arctic pelagic counterpart, whose distribution is expanding northward in response to the ongoing warming, is also considered and the potential implications for feeding competition explored.

Parallel session F

Photo: Luka Supraha

Parallel session F: A Shattered Mirror – Understanding a Rapidly Changing Central Arctic Ocean

Session Chairs: Mats Granskog, Igor Polyakov, Christine Gawinski

Wednesday, 8 November 2023
13:30-13:45
Talk F1

Arctic Sea Ice Changes - From Quiet to more Dynamical Regime

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Mass balance of the Arctic Sea ice depends on thermodynamical and dynamical factors. Thermodynamical and mechanical sea ice state variables are strongly coupled, but the strength of coupling varies in daily, seasonal, and climate time scales. When ice pack is thick, solid, and compact, this coupling is strong and large areas of pack ice are mechanically connected. In these circumstances, internal stress of pack ice is accumulating and reducing differences in ice motion. In these conditions drift speed of Arctic Sea ice decreases, age of ice increases and total mass of ice pack increases. On a contrary, thinner ice pack which includes cracks, leads or larger open water areas is in turn mechanically weakly connected, exhibits larger variations in motions in shorter time and length scales, drifts with higher speed and exhibits shorter residence time in the Arctic. In this talk, importance of ice dynamics on sea ice mass balance is reviewed and new findings based the MOSAiC campaign are discussed.

Turbulent and double-diffusive heat and nutrient fluxes in the Central Arctic Ocean

Randelhoff A*[1], Koenig Z[2], Muilwijk M[2], Dodd P[2], Renner AHH[3], Fransson A[2], Chierici M[3]

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Turbulent mixing in the Arctic Ocean is undergoing drastic changes. Some evidence is starting to appear for both increases in internal wave energy and basin-scale erosion of double-diffusive staircases, but the consequences for turbulent and diffusive mixing on a larger scale remain difficult to quantify. Here, we present ongoing work on measurements from the 2021 and 2022 R/V Kronprins Haakon missions to the central Arctic Ocean's Amundsen and Nansen basins, where we sampled hydrography, turbulent microstructure, and inorganic nutrient concentrations. Dissipation of turbulent kinetic energy was reliably sampled only in the upper approx. 50 m of the water column, whereas deeper in the water column, background dissipation levels were usually below the instrument noise floor ($O(10^{-9}$ W kg^{-1})). Accordingly, we found double-diffusive staircases occurring both in the Amundsen and Nansen basins, whose presence we used to constrain background turbulent dissipation to at most $O(10^{-10}$ W kg^{-1}). Upward double-diffusive heat fluxes are hence at least as important as turbulent ones at around O(0.1-1 W m^{-2}), and slightly larger in the Nansen than the Amundsen Basin. Upward turbulent nitrate fluxes both across the surface layer base are in line with previous estimates made during winter, suggesting that wind-driven mixing does not regularly penetrate the surface stratification enough to affect mixed layer nutrient inventories. Double-diffusive nitrate fluxes likely did not play a role, based on a tentative calculation using salt fluxes across double-diffusive steps. The modest fluxes presented here do so far not show an enhanced turbulence regime during our observations and may suggest a continued tight control of large-scale stratification on upward heat and nutrient fluxes.

Temporal Variability in Ventilation inside the Eurasian Arctic Ocean

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We evaluate changes in ventilation and circulation inside the Eurasian Arctic Ocean over three decades from 1991 to 2021, with the help of transient tracers (CFC-12 & SF6) measurements that constrain the transit time distribution (TTD), and by looking at changes in the Apparent Oxygen Utilization (AOU). The results show a decrease in ventilation (i.e., increasing mean age and increasing AOU) in the intermediate water between 250 and 1000 m in all areas of the Eurasian Arctic Ocean from 2005 to 2021. The vertical distribution of water showing this decrease in ventilation is increasing from south to north, being modest in the Shelf region (between 400 m and 1000 m) and most pronounced close to the Lomonosov Ridge (between 250m and 1000m). As this intermediate water is mainly fed by Atlantic Water entering from the Nordic Seas, our data indicate changes in the ventilation of this water mass. Analysis of the Arctic Ocean Boundary Current (AOBC) shows an increase in mean age and AOU over the years until 2021, suggesting a decrease in strength of the AOBC. The data from 1991 show comparable mean ages and AOU to the ones from 2021 in the intermediate water (except at the presence of the AOBC), being higher compared to 2005 and 2015. This indicates a slower ventilation being present in 1991 suggesting a decadal variability in ventilation in the intermediate water of the Eurasian Arctic Ocean.

There and Back Again: The Arctic Ocean during the MOSAiC Campaign

Schulz K[1], Koenig Z[2], Muilwijk M*[3], Bacuh D[4], Zurita AQ[5], Karam S[6], Tippenhauer S[5], Baumann T[7], Hoppmann M[5], Vredenborg M[5], Granskog M[3]

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In recent decades, the Arctic Ocean has garnered growing scientific attention, but it has also undergone significant changes attributed to climate change. From October 2019 to October 2020, the Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAiC) investigated the Eurasian part of the Arctic Ocean. This study presents the drift from a physical oceanography standpoint, examining water masses, currents, stratification, and the properties of the mixed layer. While the seasonal development of the upper water column is evident in our observations, the dominant changes we observed throughout the drift were spatial, rather than temporal. The mixed layer was found to be shallow in the Amundsen Basin, deep in the Nansen Basin, and its salinity was strongly correlated with the fraction of river water. Halocline heat fluxes were increased over the Gakkel Ridge and the Yermak Plateau. Additionally, thermocline heat fluxes were found to be higher in the Nansen Basin than in the Amundsen Basin, and higher over the Gakkel Ridge than over the Yermak Plateau. We compared the MOSAiC dataset with all available climatologies of the Arctic Ocean and found a good overall match. However, the MOSAiC observations showed a warmer and more saline Atlantic layer, as well as a shallower halocline and Atlantic Water core compared to climatologies. This comprehensive, one-year database of ocean properties is expected to serve as a reference for the Eurasian Arctic Ocean in 2020.

Turbulent Fluxes at the Ice-Ocean Interface in the Arctic Ocean

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Sea ice algae are at the base of the food web in the Arctic. With ongoing climate change and a shrinking sea ice cover, their habitat is compromised, and the sea ice algae communities are changing. With a more mobile ice pack, the physics at the sea ice – ocean interface is modified, influencing the turbulence in the ice-ocean boundary layer, the supply of oxygen and nitrate to the sea ice algae and fluxes of gases at the ice interface. Under-ice turbulence appears to be a key factor in controlling ice algal growth and should be parameterized in models to better represent the sea ice algae biogeochemistry. The under-ice turbulence was documented in 2020 in the Canadian Archipelago (Cambridge Bay in spring) and in the deep Arctic (Nansen and Amundsen Basin in summer). We used an eddy covariance system associated with fast Dissolved Oxygen (DO) sensors and nitrate sensors. We found that turbulent heat fluxes at the ice-ocean interface are about -2 W/m2, and DO fluxes vary from 0 to 150 mmol/m2/d. Variations will be linked to the sea ice algae productivity and current velocities, to try to understand the processes at the origin of these vertical fluxes.

Hidden in Plain Sight - New Insights on Arctic Sea-Ice Ridges from the MOSAiC Expedition – an Overview

Salganik E*[1], Müller O[2], Olsen LM[2], Gardner J[3], Lange BA[14], Gradinger R[3], Assmy P[1], Leu E[5], Bratbak G[2], Larsen A[6], Aberle-Malzahn N[7], Granskog, MA[1]

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Ridges compose a large fraction of the Arctic sea-ice volume but are still the least studied part of the ice pack, in part due associated methodological challenges. Our focused ridge studies during MOSAiC expedition allowed mapping of ridge physical properties, characterization of microbial communities associated with different ridge structures and biological rate measurements to assess the role of ridges for ecosystems. New insights include the significant contribution of either snow-slush or snow meltwater to rapid consolidation of ridge keels. The three-dimensional structure that provided microbial hotspots within ridges was drastically reduced through this summer consolidation. The overall more rapid melt of ridge keels compared to adjacent level ice is a significant but often overlooked contribution to the summer meltwater balance. Ridge keels affected the lateral extent of meltwater layers below the ice, and thus also exert indirect control of biologically important exchange between the ice and ocean. High ridge associated pelagic biological activity in winter could have originated from release of organic material during ridge formation, fueling winter activity. Unique vertical flux patterns and biodiversity and activity hotspots further demonstrate the unique biological signature of pressure ridges. Our focused studies provide new insights into the important role of ridges for the Arctic sea-ice system, ice mass balance and functioning of the ice-associated ecosystem.

The Variable Impact of Storms on the Surface Marine Biogeochemistry during the Onset of Freeze-Up in the Central Arctic Ocean

Droste E*[1], Nomura D[2], Tozawa M[2], Roden N[3], Bakker DCE[4], Hoppema M[1], Chamberlain EJ[5], Fong AA[1], Hoppe CJM[1], Webb AL[6], Schulz K[7], Ulfsbo A[8], Torres-Valdés S[1], Chierici M[9], Fransson A[10], Karam S[8], Koenig Z[10 11]

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The frequency of storms in the Arctic Ocean are predicted to increase with climate change. Storms play an important role in the variability of the ocean surface layer's physical and biogeochemical properties, as they cause turbulence and vertical mixing of subsurface water. Consequently, they alter the distribution and content of dissolved inorganic carbon (DIC), total alkalinity (TA), and partial pressure of CO_2 (pCO_2), affecting the sea-air CO_2 exchange. However, due to the strong seasonal variability of processes affecting the marine carbonate system, the contribution of storms may differ throughout the year. We investigate the impact of two storms on the marine carbonate system that passed through the Central Arctic Ocean during the onset of annual freeze-up in September 2020, using water column and under-ice data acquired during the MOSAiC expedition (Multi-disciplinary drifting Observatory for the Study of Arctic Climate). The first storm caused little change in the surface layer, while the second storm caused entrainment of subsurface water, increasing the DIC (~20 µmol kg-1), TA (>20 µmol kg-1), and p CO_2 (~10 µatm) underneath the sea ice. Elevated values persisted at least until the completion of the expedition one week later, indicating a pre-conditioning of the surface layer while transitioning into winter. Storms during freeze-up can therefore have long-lasting impacts on the biogeochemistry and are expected to be paired to changes in the marine ecosystem.

Contrasting Chemistry in the Central Arctic Ocean in a Pan-Arctic and Climate Change Perspective

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The Arctic Ocean is changing, with less sea ice, increased meltwater, and increased ocean CO_2 uptake. Data from the Central Arctic Ocean in 2021 (Nansen Legacy) and the 2022 (SUDARCO) cruises show contrasting chemistry in sea ice and seawater between the deep basins, focusing on the Amundsen and Nansen Basins. The chemical characteristics is affected by different water in the two basins; the Transpolar Drift current carries freshwater and carbon from the Siberian shelves to the Amundsen Basin and the Atlantic water on the other hand carries heat, salt, and nutrients to the Nansen Basin. Exchange of inorganic carbon and nutrients in sea ice and surface water is presented and discussed in relation to decreasing sea ice and increasing meltwater. The results are put into a pan-Arctic perspective, comparison with results from the Synoptic Arctic Survey.

Wednesday, 8 November 2023
16:00-16:15
Talk F9

Physical and Biological Observations from Ice-Tethered Observatories (ITOs) in the Arctic

Daase M*[1,2], Geoffroy M[1,3], De La Torre P[4], Berge J[1], Anderson P[5], Vogedes D[1], Schartmüller B[1], Zolich A[4], Johnsen G[4], Cottier F[5], Kopec T[1], Chawarski J[3]

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The Arctic Ocean remains one of the most poorly studied ecosystems while experiencing the most dramatic changes due to global warming. Advances in our understanding of Arctic marine ecosystem function are hampered by insufficient temporal and spatial sampling resolution. For example, the distribution and occurrences of acoustic sound scattering layers (SSL), indicating aggregations of macrozooplankton and small pelagic fish, are still poorly documented in the central Arctic Ocean. Autonomous, ice-tethered drifting platforms equipped with environmental sensors can remain in the Arctic for extended periods and help to fill important gaps in our understanding of the processes at work in the epipelagic layers of the Arctic. Here we present data collected with Ice-tethered observatories (ITOs) deployed between 2019 and 2022 in the Arctic polar basin and in land-fast ice in the Canadian Arctic. The ITOs consists of an automatic weather station, a specially designed Optical Chain And Logger (OptiCAL) for mapping the under-water light climate, a Sea Ice Mass Balance buoy documenting sea ice growth, and an Acoustic Zooplankton Fish Profiler recording temporal and spatial variability in acoustic SSLs. The drifting ITOs all followed similar trajectories through the polar basin and documented the presence of epipelagic SSLs throughout the deployment, with diel and seasonal changes strongly correlating with variabilities in the underwater light regime.

Status update of deep Arctic Ocean habitats and species diversity

Bluhm B*[1], Ramirez-Llodra E[2], Saeedi H[3], Meyer H[4], Brix S[5], and the Challenger-150 Arctic Working Group

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The global ocean is by far dominated by deep-sea areas; the ocean basin seafloor receives increasing attention due to it sequestering carbon, housing minerals, and its high - yet underexplored - biodiversity. As sea ice declines and access to the previously permanently ice-covered Central Arctic Ocean (CAO) opens, an update on its underappreciated habitat and taxonomic diversity becomes urgent - before the human footprint increases further. Under the framework of the Challenger 150 initiative and other efforts, an updated synthesis of CAO habitat and taxonomic diversity was attempted. The taxon inventory of metazoan fauna in the Central Arctic Ocean and Greenland-Norwegian and Iceland Seas, based on >170,000 taxon distribution records, yielded >1800 morphologically identified species for which >500 have COI barcodes available. As in most oceans, arthropods, annelids, and mollusks were the most (documented) taxon rich eukaryote groups. Part of the increase in taxa relative to earlier syntheses is related to sampling efforts of diverse, previously neglected habitats including vents, seamounts, oceanic ridges, and continental slopes – rather than to changing climate. Although large spatial and taxonomic gaps in deep-sea benthic biodiversity remain, and insights into functioning of these deep-sea systems are sparse, we present the state of art knowledge, summarizing a decadal increase of knowledge since 2011 as baseline for the UN Ocean Decade 2021 - 2030.

Poster presentations A

Photo: Malte Müller

Poster presentations
Tuesday, 7 November 2023
16:30 – 18:00

Parallel session A: Physical drivers: Causes and consequences of Arctic Ocean warming, freshening, and sea ice decline

Quantifying the Seasonal Cycle of Dissolved Oxygen in the Canada Basin Mixed Layer

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Quantifying the mechanisms driving seasonal variability of dissolved oxygen (O_2) in the surface Arctic Ocean is crucial to understanding how the seasonal cycle could be evolving or evolve in the future due to the effects of climate change. We model the primary processes that influence seasonal variability of mixed layer O_2 and compare the modeled O_2 variability to O_2observations from Ice-Tethered Profilers. This allows us to estimate the relative role of each process in driving the annual cycle of mixed-layer O_2. Our findings suggest that contributions to O_2 variability from vertical entrainment at the base of the mixed layer and exchange with the atmosphere are an order of magnitude smaller than contributions to O_2 variability from sea ice melt/growth. Given that sea ice melt/growth is the dominant factor for seasonal variations in mixed layer O_2, the rapid decline of sea-ice extent in recent decades inevitably influences the O_2 seasonal cycle, such that different driving mechanisms emerge in regions that are now ice-free for longer. By isolating the physical drivers, we are able to infer O_2 changes that result from production/respiration – changes which are challenging to measure directly. Our results provide further insight into how declining sea ice modifies Arctic marine primary production, and the consequences to ecosystems.

High Arctic Freshwater Input Reduces Sea Spray Aerosol Production

Dall´Osto M*[1]

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The rapidly warming Arctic opens on to changes in natural aerosol emissions, which have strong feedback effects on the climate system. One of the main primary sources of aerosols in the Arctic is the ocean, emitting sea spray aerosol (SSA). So far, climate models assume that, in a warming Arctic, loss of sea ice and higher wind speeds will lead to a large increase in the SSA emission, but no observational evidence is available to test this assumption. Here we show that SSA production is mainly modulated by the salinity in the freshwater layers covering the surface ocean, arising from melting sea ice. As a result, SSA aerosol fluxes from Arctic water with salinities <30 psu and <27 psu are reduced by factors of 3 and 6, relative to those in average oceanic water (35 psu). Future freshening of the Arctic Ocean - and associated surface salinity gradients - will significantly reduce SSA production, with important implications for the changing Arctic climate.

Sea Ice Studies in a Changing Northern Barents Sea within the Multidisciplinary Nansen Legacy Project

Divine D*[1], Steer A[1], Gerland S[1], Cristea A[1], Jones E[2], Fransson A[1], Chierici M[2], Itkin P[3], Raffel B[1], Granskog M[1]

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Northern Barents Sea is experiencing rapid changes manifested in a number of observable variables with receding sea ice being one of the major indicators of the ongoing warming. Both the northern Barents Sea and adjacent Arctic Basin have been in the focus of the Norwegian national project Nansen Legacy - a novel and holistic Arctic research project providing integrated scientific knowledge on the rapidly changing marine climate and ecosystem required to facilitate a sustainable management of the area through the 21st century. Throughout a series of research cruises conducted in 2018-2022 a dedicated interdisciplinary dataset on climate and ecosystem of the area representing entire seasonal cycle has been collected. This includes a large collection of data covering various aspects of the physics of sea ice for the range of spatial scales, from in situ acquired during on-ice station work to regional scales, based on helicopter-borne sea ice surveys and remote sensing. This dataset is presently being systematized and analyzed both for future dedicated publications on northern Barents Sea sea ice, as well as for aiding studies on regional ecosystem and biogeochemical cycles. We will present an overview of some of the first results summarized so far and discuss interdisciplinary linkages of the Nansen Legacy sea ice physics work to studies such as ecosystem research and environmental management.

CIRFA Cruise 2022: A Ship-Based Arctic Research Expedition with Focus on Satellite Remote Sensing of Floating Ice

Eltoft T[1], Gerland S*[2] and the CIRFA 2022 shipboard science team

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In April/May 2022, RV *Kronprins Haakon* was the platform for Norway's first ship-based Arctic research expedition with a focus on satellite remote sensing of floating ice, visiting the western Fram Strait to collect ground truth data for the validation of satellite remote sensing products. The cruise was a main activity of the Centre for Integrated Remote Sensing and Forecasting for Arctic Operations (CIRFA). The expedition's main goal was to collect ground-truth data for validating remote sensing products for sea ice, icebergs, and ocean. The science team consisted of 33 scientists and engineers from Norway and France. In addition to the planned studies in conjunction with satellite remote sensing, several other synergetic projects addressed changes in sea ice and ocean. Validation of sea ice remote sensing products tells us more about how accurate and reliable their information is. To retrieve ground-truth validation data at a multitude of spatial scales, especially for synthetic aperture radar (SAR) satellite imagery, the science team collected data and samples with surface information ranging in scale from micrometers, inferred from snow pits and sea ice coring sites, to kilometers, inferred from transects and drone data. In addition, autonomous sensors were deployed in sea ice and ocean to reveal sea ice and ocean changes and dynamics. Relevant validation parameters such as surface roughness, temperature, density, salinity, and internal microscopic structure of snow and sea ice were measured during stops in the ice. Ice and snow thickness was measured with transects walking along lines on the ice. A laser roughness profiler was used to reveal surface topography characteristics, and analysis of snow pit measurements and ice cores reveals physical properties of snow and sea ice. Validation of satellite remote sensing requires that the ground-based measurements are geographically co-located with satellite acquisitions and coincide in time. During the expedition, this was regularly achieved. A whole suite of satellite images was acquired, including scenes from the European Space Agency's Sentinel-1 and the Canadian RADARSAT-2 satellites. The combined ground truth and satellite measurements will allow future studies to address important research questions in Arctic remote sensing and development of new technologies. Here, we will give an overview on the expedition and show some preliminary results from the data and sample analyses.

Arctic Ocean Tidal Constituents Atlas

Hart-Davis M*[1], Ray R[2], Andersen O[3], Howard S[4], Padman L[5], Nilsen F[6] (presenter), Dettmering D[7]

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Ocean tides are a vital component of global ocean circulation. In the Arctic Ocean, tides affect ocean circulation and sea ice dynamics and thermodynamics. Significant advances have been made in global ocean tide models; however, difficulties remain in the Arctic due to the poorly-mapped bottom topography, the dynamical influence of sea ice, and limitations on satellite altimetry measurements due to the high latitudes and presence of sea ice. An additional factor is the limited network of in-situ tide gauges in the Arctic. In-situ measurements from tide gauges or ocean bottom pressure sensors are crucial sources of information that can be used to understand the spatial variability of tides and validate the advances made in modelled estimates. Global in-situ tidal constituent databases contain a limited number of observations in the Arctic with, for example, TICON-3 containing 111 above 60 °N and 21 above 70 °N, with the distribution of these measurements mainly being around North America. Here, we present the results of a concerted effort to produce a comprehensive dataset of tidal constituents in the Arctic region. This resulting dataset contains 691 measurements above 60 °N and 313 above 70 °N with a much greater spatial distribution across the Arctic Ocean. The dataset is quality assessed, appropriately flagged and compared to recent tide models to determine the reliability of the different data sources used and to allow for the ease of use of the dataset.

Towards Detection of Pressure Ridge Thickness and Consolidation by Electromagnetic Induction

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Sea ice pressure ridge thickness and their consolidation state are variables relevant for sea ice mass balance, melt processes and ecosystem habitat. We show how both variables can be detected by multi-frequency electromagnetic induction (EMI). We validated the EMI results by collocating them to sea ice topography from airborne laser scanner, underwater topography from multi-beam sonar, sea ice thickness and structure from drill holes and temperature measurements from the thermistor chains. Low frequency in-phase channels give good estimates of total thickness, while high frequency quadrature channels give good estimates of consolidated layer thickness. The EMI measurement footprint depends on the depth of layer in question. It is larger for the total thickness than for the consolidated layer thickness. The footprint size makes the method appropriate for detection of relatively shallow ridges (6 m). Snow depth is an important limiting factor for the winter ridge consolidation, when the ocean heat fluxes are low or even negative. In spring positive ocean heat fluxes erode the ridge keels fast. Our case study from the MOSAiC expedition also shows winter progression of ridge consolidation.

Albedo of Hummocks on the Surface of Sea Ice

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Significant areas of sea ice are being redistributed from relatively thick flat ice to thinner and heavily hummocky ice under the observed warming conditions. According to various estimates, hummocks already account for 25 to 40% of the total amount of ice in the Arctic Basin, and this number is predicted to only increase. «Grounde true measurements» do not allow one to study the processes of energy exchange through hummocky ice. As a result, it is impossible to correctly estimate the albedo, temperature, and radiation balance of large hummocky surfaces. The nature and intensity of energy exchange processes in the presence of hummocky formations differ from the conditions observed on flat ice. In the spring-summer period, solar radiation determines the total heat flux from the atmosphere to the ice surface. There are proven parametrizations of the thermodynamic failure of flat areas of sea ice, but no parameterizations of energy exchange processes for areas occupied by hummocks. Thus, understanding the processes of energy exchange over areas occupied by hummocks make experimental studies extremely necessary and relevant. First, this concerns the determination of the albedo values, taking into account the areas occupied by hummocky and flat ice. Albedo determines the intensity of sea ice melt and plays an important role in the positive feedback mechanism. The albedo of flat and hummocky ice remains the same in modern mathematical models, which contradicts our experimental estimates. The results of using UAVs to estimate the albedo and surface temperature of hummocky surfaces were obtained in the Barents Sea (the «Transarctic-2019» expedition), on land-fast ice near arch. Severnaya Zemlya (Laptev Sea, 2021) and on the Svalbard glaciers (2019). The albedo and the temperature of hummocky areas turned out to be lower than similar estimates for neighboring areas of flat ice, which confirms our assumptions about the need to take into account these features when estimating the total heat exchange in the Arctic under the conditions of the observed warming.

From Winter to Late Summer in the Northwestern Barents Sea Shelf: Sea Ice and Upper Ocean Evolution and Impacts on Nutrient and Phytoplankton Dynamics

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The northwestern Barents Sea has experienced broad environmental changes since the mid-2000s, including rapid sea ice loss, ocean warming, and weakened stratification, with strong impacts on the marine ecosystems, known as Atlantification. While the interannual variability of the Barents Sea is well-documented, the seasonal evolution of the physical and biological systems is less known, mainly due to poor accessibility of the seasonally ice-covered area in winter and spring. Here, we use an extensive set of physical and biological in situ observations from four scientific expeditions covering the seasonal evolution from winter 2020/21 to late summer 2021. We found that sea ice meltwater and timing of ice-free conditions in summer shape the environment, controlling heat accumulation, nutrient availability, and biological activity vertically, seasonally, and meridionally. In March and May, the ocean was ice-covered and featured a deep mixed layer. Chlorophyll-a concentrations were generally low during this time, but they showed an increase from March to May, indicating the beginning of the spring bloom despite the absence of surface stratification. By July and in September, sea ice meltwater created a shallow low-density surface layer that strengthened stratification. In open water, chlorophyll-a maxima were found at the base of this surface layer as nutrients were depleted, while in presence of ice, it was closer to the surface. Solar heating and the thickness of the surface layer increased with the number of ice-free days. The summer data showed a prime example of an Arctic-like space-for-time seasonal variability in the key physical and biological patterns, with the summer situation progressing northwards along with sea ice retreat. The amount of sea ice melt (local or imported) has a strong control on the conditions in the northwestern Barents Sea, and the conditions in late 2021 resembled pre-2010 Arctic-like conditions with high freshwater content and lower ocean heat content.

Impact of Atmospheric Rivers on Poleward Moisture Transport to the Arctic

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The projected increase in poleward moisture transport (PMT) towards future warming has mainly been linked to the larger moisture holding capacity of warmer air masses. However, the future of interannual fluctuations of PMT and associated driving mechanisms are fairly uncertain. This study demonstrates the extent to which atmospheric rivers (ARs) explain the interannual variability of PMT, as well as related variables such as temperature, precipitation, and sea ice. Such linkages help to investigate whether extreme precipitation or melt events over Arctic regions are sensitive to the occurrence and intensity of ARs. To robustly study trends and interannual linkages of ARs and Arctic Climate, we detect and examine Arctic ARs in large ensemble runs of one present and two future climates (+2 °C and +3 °C), simulated by the global climate model EC-Earth. We found that the additional PMT to the Arctic in warmer climates is almost exclusively due to atmospheric rivers. Further, the amount of ARs reaching any Arctic region strongly depends on the mid-latitude jet location southwest of the region. Accordingly, they have a strong local effect on Arctic temperature, precipitation, and sea ice.

Seasonal variability in hydrography and currents along a meridional transect crossing the Barents Sea

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The Barents Sea is an important inflow shelf to the Arctic Ocean where water mass modification and transformation processes take place that can have major impact on stratification and the halocline in the Eurasian Central Arctic. In this study, we analyse hydrographic conditions and circulation patterns on the Nansen Legacy (NL) main transect, a south-to-north section involving 25 stations across the central Barents Sea and the continental slope north of Svalbard. In particular, we examine seasonal variations in water mass characteristics and distribution, including properties and location of the Polar Front, and circulation patterns across the NL transect and their impact on water mass transformation. The dataset includes CTD, S-ADCP and L-ADCP profiles collected along the transect during 11 NL cruises between 2018-2022, with special focus on the NL joint cruises (JC2-1 and JC3) and the Q-cruises (Q1, Q2, Q3 and Q4). We investigate atmospheric drivers, such as wind and air temperature, and sea ice conditions, including concentration and other ice properties from remote sensing, to assess the physical drivers causing modifications of the water column properties.

Recent Sea Level Changes in the Barents Sea: Atmospheric, Thermosteric, and Halosteric Contributions

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Global sea level rise (SLR) is one of the most certain consequences of climate change. However, this rise is neither uniform in time nor in space but varies depending on both the time period considered and the geographic region. The Barents Sea (BS) is considered one of the most vulnerable regions to climate change, as it is expected to be ice-free by the middle of this century. In this context, this work aims to quantify relevant sea level changes in the Barents Sea over the period (1993 -2020) by calculating trends and variations in the main driving forces of sea level, including thermosteric, halosteric, and atmospheric contributions. To this end, we used gridded satellite-based sea level anomalies (SLA) provided by the Denmark Technical University (DTU) to estimate overall SLA variability, reanalysis of temperature and salinity profiles to estimate thermosteric/halosteric contribution, and ERA5 data for atmospheric contribution. Our preliminary results show that the basin's average SLR between 1993 and 2020 is about 2.35±0.45 mm/year. Significant spatial variability in SLA trends is observed, with the maximum trend (up to 5 mm/year) in the southern Barents Sea, while non-significant ($p > 0.05$) trends are observed in the northern Barents Sea. The thermosteric effect is the main factor contributing to sea level rise in most areas of BS, especially in the south BS, which is largely influenced by the inflow of warm Atlantic water. In the northeastern part of BS, the halosteric trend acts to increase the steric sea level, while in the western and southern parts, the halosteric trend leads to a decrease in sea level. The trend of the atmospheric component shows a very small and non-significant contribution to the trend of the sea level in the whole region.

A Recent Change of Relationships between the Barents Sea Climate System and Wintertime Atmospheric Variability in Eurasia

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Winter atmospheric variability in the Arctic-Eurasian region is investigated in relation to the previous summer anomalies of Atlantic Water temperature (AWT) in the Barents Sea using observations and reanalysis data from the period 1978-2018. The emphasis is on differences between the LATE and EARLY epochs selected based on a large sea-ice loss in the Barents-Kara Seas in the mid-2000s. It is shown that the linkages of Eurasian climate variability to the AWT anomalies that were significant in the EARLY epoch deteriorated in the LATE epoch. In particular, the detrended AWT anomalies explained 77% of the interannual variance of lower-tropospheric synoptic eddy activity (poleward eddy heat flux at 925 hPa) over northern Eurasia and 55% of the interannual variance of surface air temperature over midlatitude Eurasia in the EARLY epoch but a negligible fraction (<5%) of these variances in the LATE epoch. Analysis of sea surface temperature variability in the Arctic-North Atlantic region shows that the strong Arctic-Eurasian linkages in the EARLY epoch may have resulted from the atmospheric response to a large-scale surface re-emergence of ocean temperature anomalies. The features of winter Eurasian climate variability that have lost their connection to coherent ocean temperature anomalies in the Arctic-North Atlantic region have become related to other predictors.

Validation and Evaluation of Surface Heat Fluxes in Barents-2.5

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The Arctic sea ice has been undergoing a dramatic decrease in recent decades, in particular in September when the Arctic sea ice is at the minimum. The sea ice decline in the Barents-Kara Sea is responsible for one-third of the pan-Arctic winter sea ice loss over the past four decades. In particular, the northern Barents Sea hosts the most pronounced loss of Arctic winter sea ice. The Barents Sea is experiencing exceptional warming, which is strongly connected to the reduction of sea ice and increase of SST. Numerical simulations showed that the sea surface heat flux contributed 80% of the increase in energy of the upper layer of the Arctic Ocean. Thus, the surface heat flux plays an important role in the Arctic climate system. Barents-2.5 km is a primarily operational ocean and sea ice modeling and prediction system at met.no. It is a full coupled ocean (ROMS) and sea ice (CICE) model covering the Barents Sea and areas around Svalbard, and forced with a high resolution numerical weather prediction (NWP) system, Arome-Arctic. Using the remote sensing products of CERES-SYN and reanalysis data of ERA5, the surface heat fluxes in Barents-2.5 km were validated and evaluated.

Poster presentations B

Photo: Kay Jørgensen

Parallel session B: The Living Ocean: Understanding Ecosystem Structure and Function Across Seasons in a Changing Arctic

Water Column and Sea Ice Primary Production in the North-Western Barents

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The upscaling of pelagic and sympagic primary production (PP) over large ocean regions is challenging due to the lack of in situ measurements at high spatial and temporal resolution and the lack of remote sensing techniques for ice covered areas, or else, for areas with high cloud cover. We present results obtained with a coupled ocean and sea ice physical-biogeochemical model, implemented for a large region around Svalbard at 4 km horizontal resolution (S4K). The model is based on the two-way coupling of the Regional Ocean Modeling System and the Los Alamos Sea Ice Model. The ocean is resolved vertically in 35 terrain following coordinates, whereas 7 layers are considered for the sea ice and one for the snow. Biogeochemical (bgc) processes are computed for the ocean by a dynamically stoichiometric model including nutrients, dissolved oxygen, inorganic carbon, diatoms, flagellates, and detritus. In the case of sea ice, the bgc model includes nutrients and diatoms and corresponding processes are computed over the vertical extent of the brine network, using a bgc dynamic grid. Model results were used to compute phytoplankton and ice algal PP in the North-West Barents, with the former ranging between 20 and 60 gC m^{-2} yr^{-1}, and the latter ranging between 0.15 and 0.3 gC m^{-2} yr^{-1}, leading to a total production of ~9 TgC, of which 0.4% can be attributed to ice alga. We use the model results to quantify the relative role of different drivers on interannual PP variability.

From Midnight Sun to Polar Night: Understanding Copopods Seasonal Community Structures in the Arctic with a Trait-Based Approach

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Copepods are crucial in the Arctic marine pelagic ecosystem as they serve as a vital link between microbial processes and higher-level consumers. They are present in most aquatic environments and constitute a large fraction of mesozooplankton in the pelagic realm, approximately 70% of the total biomass. They also show a wide range of different ecological roles. Furthermore, copepods are good environmental indicators as they react strongly to changes in the water column. They also have high abundances and short life cycles; hence, they are excellent candidates for the study of ecosystem responses to climate variability because populations have the potential to reflect event-scale changes. However, our understanding of copepod assemblages and their functional roles is still limited, especially at high latitudes. Given that the Arctic shows extreme seasonality and a greatly variable oceanic environment and that such environmental variability affects the respective copepod community structures, it is crucial to address this gap in knowledge and evaluate copepod community structures in different seasons. A cutting-edge approach to unveiling the structure of planktonic communities is “trait-based ecology”. One of its primary goals is to predict how ecosystems function and how they will change in response to perturbations based on information about the distribution of traits within the species pool. This approach focuses on the individual and its measurable characteristics, known as functional traits. Functional traits are essential in capturing an individual’s Darwinian fitness, which refers to their reproductive success. In this approach, the individual is considered the primary level at which selection and adaptation occur. Therefore, the performance and responses of individuals affect those of populations, communities, and ecosystems. To study seasonality, it is not only important to relate abundances and distributions, but there is also a need to gain a functional understanding of how different seasons shape community structures and their ecological services. In order to do so, it is possible to group functionally similar species based on their functional traits. These usually occupy distinct ecological niches, and the ecosystem processes related to these groups are expected to vary across seasons. Defining the community structure in relation to seasonality is important to better understand the underlying seasonal environmental drivers. This approach is here used to model copepod community assemblages in the Barents Sea.

Phytoplankton in the Arctic Ocean - Species Composition and Biomass during the Nansen Legacy Arctic basin cruise, 24 Aug-26 Sep 2021

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At the southern-most station along the S-N transect, P7, the pelagic protist community was characterized by both high diversity and abundance. Large diatom species dominated the community, and large dinoflagellates and *Phaeocystis pouchetii* were also abundant. Moving north and into the ice, the protist community in the water column changed. Smaller organisms and heterotrophic species became more prominent. The larger diatom species became much scarcer but were still present. The community in the ice cores was dominated by pennate diatoms, but dinoflagellates and in particular the heterotrophic species were also abundant. In addition, green flagellates, cryptomonads, chrysophytes, and haptophytes were frequent. The sea-ice showed the highest chlorophyll-a values and had larger cells. In the melt ponds the salinity was low, but variable (2.8-5.7). The chlorophyll-a values there were low, and the species composition varied, and the taxa present were associated with brackish and freshwater as well as a benthic lifestyle.

Reproductive Features of the Ice Cod *Arctogadus glacialis* from Brede Fjord (Northeast Greenland)

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The ice cod *Arctogadus glacialis* is a gadid species endemic of the Arctic Ocean. It is mainly associated to coastal habitats and continental shelves, sometimes in brackish waters. Despite a circumpolar distribution, and coastal preference, information on the life history and reproductive features of *A. glacialis* is sparse. The time of spawning is controversial and both winter and summer spawning have been suggested. However, specimens with well-developed gonads have not been reported prior to the present work. In the frame of the international TUNU Programme (UiT The Arctic University of Norway), we studied the reproductive traits of *A. glacialis* collected in September 2022 during the TUNU VIII expedition to Northeast Greenland. *A. glacialis* occurred at all sampling locations, with peak abundances in secluded fjords such as Bessel Fjord and Brede Fjord. Here we report on the results of integrated macroscopic and histological analyses of gonads from 12 adult (female N=7, male N=5) A. glacialis collected in Brede Fjord. With a total length ranging between 225 to 355 mm, the analyzed specimens were larger than other conspecifics studied so far for reproductive traits. Macroscopic examination of the gonads showed only one immature female, whereas eleven specimens were clearly mature and in a pre-spawning state with gonadosomatic indices ranging between 8-15% for females and 7-10% for males.

Poster B5

Annual Estimates of Copepod Secondary Production in the Barents Sea and the Arctic Ocean

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Zooplankton show strong seasonal variations in abundance, biomass, and production in Arctic marine ecosystems, due to seasonal changes in food availability and quality. Because of the difficulties of conducting research in the Arctic in winter, copepod reproductive rates for this time of the year are poorly understood but are essential for assessing population dynamics and calculating secondary production in an annual context. Here, we present estimates of annual copepod secondary production, covering Atlantic to Arctic influenced domains in the northern Barents Sea (76 °N to 82 °N). In our calculations we used weight-specific egg production rates obtained from experiments conducted in August and December 2019, October 2020, and March, May, and August 2021 at temperatures between -1.5 and 3 °C aboard R/V *Kronprins Haakon*. We made comparisons with production estimates based on a widely used growth rate model by Hirst and Lampitt (1998). In spring most of the copepod secondary production was from large copepods of the genus *Calanus*, while in summer, autumn and winter the greater part of secondary production of copepods was from small-sized taxa.

Across the Seasons: Persistent Organic Pollutants in an Arctic Pelagic Food Web

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Arctic marine organisms are susceptible to multiple stressors, such as climate change, increased human activities such as fisheries and tourism, and pollutant exposure. Combined, these stressors are expected to alter food web composition and the transport, fate, and effect of pollutants within it. In a highly seasonal environment that can directly impact pollutant availability, storage, and transformation, knowledge of annual pollutant dynamics is crucial, particularly during the understudied polar night. We therefore analyzed chemical and dietary descriptors to determine how seasonal changes in energy acquisition and allocation impact annual dynamics of pollutant accumulation and transfer in the pelagic Barents Sea food web. Chemicals analyzed included a wide range of persistent organic pollutants such as DDT and PCBs in eleven different taxa, spanning from copepods (*Calanus spp., Calanus hyperboreus*) to macrozooplankton (*Themisto spp., Thyssanoessa spp., Meganyctiphanes norvegica, Chaetognatha, and Clione limacina*) to fishes (*Boreogadus saida, Mallotus villosus, Gadus morhua*). As diet is one of the main uptake routes of pollutants into biota, we measured stable isotopes of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$). These yield time-integrated information about an organism's carbon source and trophic position, to assess the food web structure and link pollutant levels with diet across the seasons.

Poster B7

Seasonality of Pelagic Protist Communities in the Barents Sea

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The Barents Sea experiences strong seasonal variability. The observed increase of warm Atlantic water inflow results in reduction of sea ice cover and influence the timing, duration, magnitude, and protists composition of the blooms. In this study, we assess the relationship between the spatial and seasonal variability in protist plankton biomass and taxonomic composition in the northwestern Barents Sea. Sampling was conducted during March, May and July 2021, August 2019, August 2018 and December 2019. Depth-integrated stocks of major groups of protists (diatoms, dinoflagellates, flagellates, and ciliates), and environmental factors as sea-ice extent, temperature, salinity, inorganic nutrients, chlorophyll a, particulate organic carbon and nitrogen concentrations were investigated. Spring bloom was recorded between May and July, which started earlier in Atlantic-influenced waters. Diatoms of the genus *Thalassiosira* were dominant, while mixotrophic flagellates, dinoflagellates and ciliates contributed significantly to protist biomass in August, with interannually difference due to earlier and more extensive sea ice retreat in 2018 compared to 2019. In winter, chlorophyll a concentrations were low. Dinoflagellates (especially genus *Gymnodinium*) dominated the community in December and March with ciliates being abundant at some regions in December. The observed succession differences reflected the water masses (Atlantic versus Arctic) and the duration of the ice cover ones.

Behavioral Response in *Calanus* Copepods to Change in Ambient Light in the Polar Night

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Light is the most important cue of life, regulating individual behavior and synchronizing behavior within and across species. Though the polar night is perceived as dark for the human eye, the light climate is highly dynamic with several ambient light sources detectable for the arctic organisms: Diffused light from the sun below the horizon, the moon which can increase the light by 100-fold from new to full moon, aurora borealis can be strong enough to be detected, and artificial light is becoming more abundant with increasing human activity in the Arctic. By acoustic measurements, it has been observed that the zooplankton perform vertical migration following the moon cycle during the polar night. In spring and fall when diel vertical migration is mediated by the sun, this is linked to optimizing feeding in the photic zone vs predator avoidance by hiding at depth at night. Preliminary results from the polar night indicate that the microplankton community is active and responding to light intensities similar to that of the full moon, thus locating the scarce food resources may potentially be less costly at certain phases of the moon cycle. In January 2023, experiments were conducted to investigate the activity level of *Calanus* copepods through the different moon phases by incubating them under light conditions imitating the moon cycle. Animals were observed in a dark room for video recording, with the aim of investigating if swimming activity changes through the moon phases.

Historical Changes in Biomass, Total Abundance, and Species Composition of Seaweed-Associated Fauna in Kongsfjorden, Svalbard

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Many parameters of the marine physical environment of the Arctic are rapidly changing. Especially in coastal areas the ongoing cryosphere loss has profound effects on shallow subtidal habitats and communities, including shifts in distribution of seaweed biomass and species composition along the depth gradient. The objective of this study was to assess whether and, if so, by how much biomass, total abundance, and taxon composition of the seaweed-associated fauna had changed concomitantly. In Kongsfjorden, Svalbard, the seaweed-associated fauna at Hansneset has been sampled at 2.5, 5, 10, and 15 m in 1996/98, 2012/13, and 2021. Taxonomic composition differed considerably between 1996/98 and 2012/13, while it remained similar to the latter in 2021. Taxonomic composition varied also with depth and this effect was independent on year of observation. The fauna biomass increased with depth between 2.5 and 15 m in 1996/98. Contrarily, it decreased with depth in 2012/13. In 2021, peak biomass was found at 5 m depth, while the remaining depths showed similar values of about 30-50% less. Overall, biomass and abundance of the seaweed-associated fauna increased about twofold, on average, between 2012/13 and 2021, returning to 1996/98 values. While mainly cirripeds caused this increase in biomass, the biomass of bryozoans decreased from 2012/13 to 2021.

Will Calcifiers Survive Rapidly-Progressing Changes in the Arctic Marine System?

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Calcifiers are organisms that produce calcareous skeletons. Their skeletal $CaCO_3$ consists of mainly Ca^{2+} and CO_3^{2-} but also a range of minor and trace elements. Due to warming, sea-ice retreat in the Arctic Ocean is leading to higher pCO_2 values in the surface waters reducing $CaCO_3$ saturation state. Carbonate undersaturation in the water may impact calcareous skeletons in many ways e.g., carbonate dissolution. Yet to what degree these changes will influence organisms depend on level of biological versus environmental control of their calcification processes. Organisms with a strong biological control will be able to withstand external environmental variations as they can adapt to changes over time. We analysed mineralogical and chemical content of all major calcifying benthic biota occurring in the Arctic waters including Bryozoa, Echinodermata, Brachiopoda, Mollusca and Crustacea from locations differing in environmental conditions. All together 1271 specimens belonging to 165 species were analysed. The mineralogy of skeletons was found to be group-specific e.g., echinoderms were exclusively calcitic while gastropods mostly aragonitic. Species-related differences in element concentrations were statistically significant and occurred regardless of environmental differences. This observation implies the dominance of biological processes regulating mineralogical and elemental uptake into the skeleton over factors related to the variability of abiotic environmental conditions.

Insights from Metatranscriptomics: Activity of Protist Communities between Seasons and along a North-South Transect in the Barents Sea

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Phytoplankton are the base of the Arctic food web, and changes here will be the first sign of ecosystem shifts, with unknown consequences for the Barents Sea ecosystem. Productivity patterns in Arctic phytoplankton are controlled by many physical and chemical factors where the availability of light and nutrients are deemed most important. The light climate in the Arctic is primarily controlled by seasonal changes in solar elevation, ranging from periods of midnight sun (polar day) to periods when the sun remains below the horizon (polar night). The duration of sea ice cover, ice thickness, snow cover, and mixed layer depths are also key parameters influencing the light climate in the Arctic. To cope with variable light climate, phytoplankton employ various mechanisms involving short- and long-term physiological changes. Each species of phytoplankton possesses distinctive adaptive characteristics that determine its distribution and activities. Increasing our understanding of these adaptations enables better prediction of their occurrence and the consequences of environmental changes on phytoplankton communities. To address this, we used metatranscriptomics, which involves transcript sequencing from the entire community, from different seasons and along a north-south transect in the Barents Sea. This approach provides a snapshot of the main active organisms and the predominant activities performed by a specific community in response to changing conditions.

The Missing Piece – the Gain of Including Gelatinous Zooplankton in Arctic Plankton Surveys

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Gelatinous zooplankton are a key component of Arctic communities, with central roles in trophic networks and the biological carbon pump. Yet, data on them remain scarce, and they are often neglected in zooplankton and benthic surveys due to perceived methodological challenges as well as identification difficulties. With the Arctic facing rapid anthropogenic changes, there is a dire need for baseline biodiversity and ecological data on the gelatinous zooplankton. We argue that simple measures to include these organisms in zooplankton and benthic surveys from the planning phase can substantially increase both data gain from the sampling effort and our understanding on the structure and functioning across the entire pelagic community, as well as benthic-pelagic coupling. Here, we show that engaging gelatinous zooplankton specialists and slightly modifying sample processing workflows can generate substantial data on gelatinous zooplankton diversity, distributions, and abundances without the need to necessarily increase sampling effort. Such data are fundamental for establishing a holistic baseline of ecosystem structure and functioning as well as a solid foundation for future work on metabarcoding and eDNA applications for monitoring biodiversity, ecosystem functioning, and climate impacts.

Poster B13

Benthic Diversity in an Arctic Glacial Fjord Assessed Using Morphology and Sedimentary eDNA

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Arctic coastal ecosystems are increasingly exposed to dramatic environmental changes and multiple stressors arising from climate warming. The effects of these stressors on benthic biodiversity have been well recognized for large size biota (macrozoobenthos) analyzed using traditional (morphology based) methods. In this study we applied sediment eDNA together with morphology-based species inventories to compare the effects of glacially mediated disturbance on benthic macrofauna, meiofauna and Foraminifera in a Svalbard fjord. Three genetic markers targeting metazoans (COI), meiofauna (18S VIV2) and Foraminifera (18S 37f) were used. Macrofauna (analysed morphologically) showed a clear change in taxonomic composition and a dramatic cline in diversity in response to glacially mediated disturbance. Such patterns were not observed for macrofauna taxa recorded in metabarcoding datasets. Nematoda and Foraminifera morphological and molecular data demonstrated a gradual change in both alpha diversity and taxonomic composition and more subtle responses to environmental changes along the fjord axis. These differences indicate that patterns of response described for macrobenthos (most commonly used in impact studies) should not be directly transposed to meiofaunal biota. The study also confirms the usefulness of sedimentary DNA metabarcoding as a complementary tool to assess the biodiversity changes in Arctic ecosystems, particularly suitable for analysis of meiobenthos.

Influence of Sub-Ice Turbulence Regimes on Sea Ice Net Community Production in the Canadian High Arctic

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The heterogeneity of sea ice microorganism communities presents a challenge in our understanding of sea ice primary production and its representation in modelling future scenarios. While most studies focus on the bottom centimeters of sea ice, less is known of how net community production (NCP), which is the balance between microbial photosynthesis and metabolic respiration, changes throughout the vertical profile of the ice column. In this study, two locations of land-fast first-year sea ice were routinely sampled 27 April to 4 June 2022 over a spring bloom near to the community of Cambridge Bay and the Canadian High Arctic Research Station (CHARS). Sample sites were selected due to their contrasting sub-ice turbulence regimes that are thought to promote differences in nutrient availability. Overall, comparatively low NCP and chlorophyll a values were observed in this region, however, variability in bloom magnitude and composition were found to be influenced by turbulence driven nutrient levels. Patterns within this inter-site comparison emerge as measurements of NCP, flow cytometry, DOC, POC and chlorophyll a are explored relative to turbulence driven nutrient availability. The study highlights the changes brought about by different turbulence regimes throughout spring melt and presents some of the first measurements of NCP throughout the ice column in the Arctic. The study is a component of the BREATHE (Bottom-sea ice Respiration and nutrient Exchanges Assessed for THE Arctic) research project funded by the Norwegian Research Council.

Seasonal Dynamics of Body Condition and Energy Content of Polar Cod (*Boreogadus saida*)

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A fundamental adaptation of many Arctic marine organisms is the development of large, lipid-rich energy stores, such as to withstand seasonal periods of low productivity. As a result, many species undergo pronounced seasonal changes in body condition, as energy stores are built up and depleted over an annual cycle. Polar cod (*Boreogadus saida*) is a key, energy dense, fish species in Arctic marine ecosystems, acting as a trophic connection between primary consumers and higher trophic levels. We collected polar cod from the Barents Sea during early spring (March), late spring (April/ May), late summer (August) and early winter (November/ December). We use morphometric parameters (length and weight) and condition indices (hepatosomatic and gonadosomatic index) to assess seasonal variations in body condition. Preliminary results show body condition varied seasonally, being significantly lower in spring months compared to summer and winter. We establish relationships of body condition, age, and sex, to assess potential seasonal variations occurring through a life cycle and associated with reproduction. We also directly measure energy content (kilojoules per gram, dry weight) using calorimetry, estimate seasonal changes in energy content and analyse relationships between body condition and energy content. Such seasonally resolved baselines will give insight into the resilience of this key species to intensified environmental and anthropogenic stressors expected in a future Arctic.

Poster B16

Towards Identifying Biological and Biogeochemical Data Products for Advancing Modeling of Carbon Sequestration in the Arctic Seas

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Significant knowledge gaps remain in mapping and forecasting future changes in marine carbon cycling. In particular, the changing role of biological processes in the uptake and sequestration of carbon from the atmosphere remains highly uncertain. At the same time, there has long been a mismatch between data needed to inform and evaluate climate and ecosystem models, and data products available from in-situ and remote sensing observations. The challenge is even bigger in the polar regions, especially in the Arctic, where we observe the greatest impacts of climate change while suffering from a scarcity of observations. Insufficient or ineffective communication among researchers across the observations-modeling interface as well as across the interface of inorganic-organic carbon variables exacerbates the problem. Here we will present the preliminary results of a working group action organized by the Horizon2020 project ECOTIP and EU4OceanObs projects. The action brings together a group of multidisciplinary experts from both the observing and modeling communities to agree on a priority list of biological and biogeochemical data products that are crucial for advancing the modeling of the biological carbon pump in the Arctic seas. We will also illustrate the integration of these data products with international efforts like the Integrated Ocean Carbon Research, the GOOS specification sheets, Copernicus Green Ocean, and IPCC reports.

Seasonal Variations in Food-Web Dynamics of Barents Sea Plankton Communities in a Changing Arctic

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Plankton are the basis of marine food-webs and are good indicators of the impact of climate change on marine ecosystems. It is ideal to study plankton in the Barents Sea as they are adapted to both the Arctic and Atlantic water flowing in. Phytoplankton usually forms intense blooms in the spring, but in winter the low irradiance due to ice-cover and deep mixing, lead to sparse biomass of plankton. Fall and winter seasons are times of the year where little knowledge about plankton dynamics exists due to limited access to these areas during the dark period. Here we present seasonal data from the Nansen Legacy cruises in August and December 2019 and March and May 2021 taken from stations P1, P4 and P7 in the Barents Sea, to study plankton dynamics and food-web interactions. The aim was to analyse seasonal growth and grazing rates of phytoplankton, micro-/mesozooplankton and copepods and to compare these between seasons. Based on dilution experiments, estimates on growth and grazing rates of plankton organisms were obtained. Data analyses showed that Bacillariophyceae were the most abundant phytoplankton group in spring, with the most abundant genus being *Fragilariopsis* spp. and *Thalassiosira* spp., while unspecified flagellates and the dinoflagellate *Gymnodinium* spp. dominated the plankton in the winter. Overall, a higher abundance and diversity of phytoplankton was found in the spring compared to the winter, an observation that is in line with previous findings from the Barents Sea ecosystem.

Diverse and Self-Sustaining Benthos of an Arctic Oil Seep

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Petroleum is well known to be highly prevalent in the Arctic, and arguably governs much of the commercial and political dynamics of the region. Though petroleum reserves tend to be located deep below the seafloor, recently the benthos in the Hopen Deep region south of Svalbard was observed to be saturated with petroleum; with oil even escaping into the water column and forming slicks on the sea surface. We used a highly interdisciplinary approach to characterize the ecology of the Hopen oil seep benthos and how the physical and chemical environment drives ecosystem function. Despite the presence of potentially toxic oil and gas, communities were diverse with high abundances of taxa. The local physico-chemical environment was measurably varied and heterogeneous, which drives site specific communities and species turnover, thereby increasing overall diversity. Chemosynthetically fixed carbon appears to be a major part of the food web, with contributions to higher level trophic levels surpassing what has been seen at Arctic gas seeps. The Hopen ecosystem appears thus to not be highly linked to photosynthesis which could suggest that oil seeps could affect pelagic benthic coupling (known to traditionally be tight on Arctic shelves). Since the Hopen seep covers a large area of the seafloor, and there is potential for similar systems to exist across the Arctic, the presence of such ecosystems should be considered in key processes within the Arctic marine ecosystem.

Newly Ice-Free Coastal Zones as Emerging Marine Habitats in the Warming Arctic Fjords (Svalbard, West Spitsbergen)

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The retreat of tidewater glaciers and them becoming land based is expected to decrease the productivity of the polar fjords as a result of, among others, changes in nutrient supply, stratification and transport of particulate and dissolved matter from land. However, as polar coastal waters expand due to the loss of marine ice, these newly ice-free areas are claimed by primary and secondary producers, and they might act as new and considerable sinks of atmospheric carbon. Thus, this work aimed to map the changes in the glacial bays' area in the West Spitsbergen fjords by using summer-time Landsat satellite images (1976-2022) and estimate gains in primary and zoobenthic production and carbon burial using existing regional data. In the period 1976 – 2022, the West Spitsbergen glacial bays with marine-terminating glaciers increased by around 200 km^2, with the highest contribution from Hornsund (around 100 km^2). Importantly, the surge event led to a decrease in the Van Keulenfjorden area by around 42 km^2. Due to the glacial dynamics, the net increases in primary production, zoobenthic production and organic carbon burial were estimated as 7.7, 1.6 and 2.0 Gg C per year, respectively. While these constitute only a fraction of the globally estimated rates, emerging marine habitats in the polar regions could gain more relevance considering the scale of marine ice loss and the high efficiency of organic carbon burial in fjords.

Poster presentations C

Photo: Andreas Wolden

Parallel session C: Environmental Lessons from the Past

Seasonal Sea ice in a warmer Arctic climate during the Holocene Thermal Maximum

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While climate model simulations provide valuable insight into potential future Arctic sea-ice scenarios, marine geological archives offer key information on how sea ice responded to substantial climatic warming in the past, particularly during periods characterized by warmer-than-present conditions. The HTM (Holocene Thermal Maximum), ~10.0-6.0 cal ka BP, was the last major period of warm climate expressed in warmer air and ocean temperatures across the globe. Although a result of orbitally-forced summer insolation, the HTM constitutes a valuable parallel to the greenhouse-gas-driven setting of a current (and near-future) warmer world. At higher latitudes in the Northern hemisphere, the HTM has been proposed as an interval of reduced sea ice and increased Atlantic water inflow, similar to a projected future warmer Arctic Ocean. Two sediment archives elucidate the early Holocene HTM evolution of high Arctic seasonal sea ice in the northern Barents Sea (>80 °N), a key area for Atlantic-Arctic Ocean water interaction in a hotspot of current climate warming. HBI (highly-branched) biomarkers (IP_{25}, $IPSO_{25}$, HBI III, HBI IV) unequivocally demonstrate the persistence of spring seasonal sea-ice as high as 55% between 11.7 and 9.1 cal ka BP. Concomitant high $\delta^{18}O$ in benthic foraminifera and elevated phytoplankton biomarker (HBI III, HBI IV) concentrations indicate the influence of warm Atlantic-derived bottom water and peak bioproductivity, respectively. Our results highlight the nuanced and complex cryospheric response to climate warming, showing High Arctic sea ice persisting in a setting of warmer-than-present spring and summer conditions under a concomitant increased inflow of subsurface Atlantic Water. This raises important questions about the fate of Arctic sea ice, oceanography, and ecosystems (including commercially important fisheries) in an increasingly warmer climate driven by anthropogenic factors.

Poster presentations D

Photo: Rudi Caeyers

Poster presentations
Wednesday, 8 November 2023
16:30 – 18:00

Parallel session D: Caught in Transit – Key Processes on the Inflow Shelves and Their Regional Connectivity to Pan-Arctic Systems

Sympagic and Pelagic Primary Production in the Northern Barents Sea: Seasonal and Spatial Variability in a Changing Inflow Shelf

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As an Arctic inflow shelf, the Barents Sea (BS) is a highly dynamic and productive ecosystem. Changes in Atlantic Water heat transport and sea ice extent, thickness and phenology have altered the marine ecosystem in recent decades, modifying stratification regimes and consequently microbial access to nutrients and light. The combination of these physical factors, as well as biological interactions within the food web, determine the seasonal succession in primary production. In this study, the seasonality in sympagic and pelagic primary production (PP) was assessed by revisiting a cross-latitudinal transect in four distinct seasons: late summer and late autumn in 2019, and winter and spring in 2021. PP strongly increased from the polar night to the polar summer. In the autumn-winter months, sympagic and pelagic production were consistently low throughout the euphotic zone in all sampled locations. In spring, the highest levels of production were detected in a pelagic diatom bloom at the southernmost station, and a sea-ice algal bloom in the Marginal Ice Zone (MIZ). Simultaneously, an under-ice phytoplankton bloom and an advected North Atlantic bloom were found in the Northern BS. In summer, PP was closely associated with the MIZ in the northern section of the transect, where sea ice algae contributed highly to the regional production. In more southern stations, pelagic PP was found over larger depth ranges. These results provide insights into future regime changes in the Arctic.

Stronger Influence of the Barents Sea Throughflow on the Arctic Basin Halocline and Pelagic Ecosystem

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The Barents Sea forms an important interface between the Atlantic and Arctic Ocean regimes. Part of the main circulation pathway, the northeastern Barents Sea has experienced rapid Atlantification becoming ice-free in winter, warming, and losing stratification. Recent changes in the Barents Sea have been well documented, but their influence on the effects of Atlantification in the Eastern Eurasian Basin (EEB), like the erosion of the cold halocline layer (CHL), remain unclear. In the EEB this has mainly been linked to a warmer Atlantic Water (AW) inflow north of Svalbard and enhanced winter mixing. However, using hydrographic observations we show that the salinity of the CHL in the EEB after 1999 is strongly influenced by salinity variations on the northeastern Barents Sea shelf. We argue that the changes on the Barents Shelf conspire with the fact that the Kara Sea now has a similar upper ocean structure to the northeastern Barents Sea due to the loss of a summer sea ice cover to allow the salinity variability of the through-flowing AW to survive into the CHL. Furthermore, stronger influence of the Barents Sea throughflow may also bring with it sub-arctic or boreal species into the Arctic. We use the available data base to speculate that the expansion of the Atlantic-Arctic domain into the Kara Sea has already led to the expansion of boreal species towards the Arctic Ocean. Our results highlight the importance of the Barents Sea throughflow for the physical ice-ocean system in the EEB and for the pelagic ecosystem in the Arctic Basin.

Poster D3

Changes in the Distribution of Marine Invertebrates in the Warming Barents Sea over the Last Century

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The Barents Sea, a shelf sea in the European Arctic, is influenced by warm North Atlantic and cold Arctic waters. Over the last century, its mean temperature has increased by 1.5 °C above and 0.5-0.8 °C below 60 m, a disproportionately high warming compared to other ocean areas. It is expected and documented only for a few taxonomic groups of marine organisms, that ocean warming has led to and will lead to changes in distribution. We used data on invertebrates mediated by the Global Biodiversity Information Facility to characterize species distributions and their shift over more than a hundred years. The data were separated into five periods covering 1861-2010 and three geographical regions. Over time distribution of invertebrates has changed in different ways. Overall, 71% of 364 species investigated with a log-linear model presented a change in occurrence numbers per region in at least one period. For the north-eastern and central Barents Sea, a turning point was 1980, after which a drastic change in taxon occurrence patterns was observed. Distributions in the southern area consistently changed through time. Examples of the temporal trajectory of distribution change for a few individual species comprising Arctic and boreal affinities are discussed. To conclude, in the Barents Sea's history, the distribution of invertebrates has shifted, most likely due to climate changes.

BREATHE field school goes with the floe: Insights from an early-career training program studying snow-covered sea ice and its physical-biogeochemical properties

Campbell K[1], McKay R[1], Koenig Z[1], Laber C[1], Osanen J[2], Itkin P[1] and participants of the 2023 BREATHE Field School

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In the spring of 2023, twenty early career researchers drifted with a sea ice floe north of Svalbard to study its physical-biogeochemical properties and the dynamics of the underlying water column. Participants were trained by researchers from UiT The Arctic University of Norway on related topics as part of a field school, and they collected a comprehensive dataset that characterised the floe over the ten-day drift. Here we present an overview of this successful training event and show first data from the fieldwork, which highlight the spatiotemporal variability of the microbiological communities present within the ice and their link with physical-chemical growth conditions. The field school represents an important contribution to the BREATHE (Bottom-sea ice Respiration and nutrient Exchanges Assessed for THE Arctic) and SIDRiFT (Sea ice deformation and snow for an Arctic in Transition) research projects, funded by the Norwegian Research Council. It is the first drift study conducted from the Norwegian research vessel Kronprins Haakon.

Poster D5

Longevity Estimates for Sea Anemones Inferred from Four Decades of Photographic Sampling in Svalbard and Northern Norway

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Information about the longevity of marine organisms is essential to understand ecological succession, stability, competition, and the ability of ecological systems to recover from disturbances caused by pollution and climate change. Longevity-information is primarily known for calcareous taxa and those containing hard structures but lacking in soft-bodied taxa. This study presents data on longevity for sea anemones based on underwater photography at two (Svalbard, northern Norway) hard bottom areas over 34-40 years. Individual *Urticina* sp. (likely *eques*) was followed 28 and 38 subsequent years in northern Norway and Svalbard, respectively, indicating a maximum longevity of ≥38 years. *Metridium senile* individuals, only found in northern Norway, were observed in up to 28 subsequent years. Despite the higher maximum persistence at Svalbard, 68% there were only found in a single year and few for >10 years; we suspect physical disturbance (ice scouring, rock movement) as the cause of the stronger dynamic at this horizontal bottom site. In contrast, at the vertical rock wall in northern Norway more (28%) individuals persisted for >10 years. The results indicate that the stability of sea anemone populations is dependent on angle of the substrate, and that individuals can become quite old. Sea anemones can be dominant at rocky bottom communities in northern areas, hence knowledge about their longevity is important to understand the ecological dynamics of such communities.

Seasonal Prey Composition of Three Small Arctic Copepods Assessed by Metabarcoding

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Although the small size-fraction of copepods (<1 mm) are important constituents of the Arctic food-web, their trophic interactions remain largely unexplored, partly due to methodological limitations. We here characterize the prey of the cyclopoid *Oithona similis*, harpacticoid *Microsetella norvegica* and calanoid *Microcalanus* spp. from the Arctic Barents Sea and Nansen Basin in March, April-May, August, and December using brute force prey metabarcoding of the 18S rRNA gene. Of the prey identified, chaetognaths were the most consistently identified taxa and composed 47% of all prey reads. Reads from diatoms (16%), dinoflagellates (11%) and urochordates (8%) were likewise abundant, but these taxa were more prevalent during specific seasons. Diatoms composed 43% of prey reads in April-May, dinoflagellates 15% in December and 17% in March, and urochordates 20% in August. Although some species differences were also discernible, we show that the dietary composition varied more among seasons than among species. This was observed despite the taxonomic and behavioural differences that distinguish the ambush-predator *O. similis*, chemosensoric particle-chaser *M. norvegica* and current-feeding *Microcalanus* spp. The results thus indicate that dietary plasticity is common in small Arctic copepods, regardless of their behaviours or strategies for finding food. We moreover hypothesize that such plasticity is an important adaptation in systems where prey availability is highly seasonal.

Development of Shipboard Automated Analysis for Nutrient and Trace Metals using Programmable Flow Injection in the Arctic Ocean

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Currently, our understanding of ocean biogeochemical data is limited needing increased coverage in both space and time. Our ability to obtain a large number of samples in the ocean is limited by complex analytical protocols, that are utilized both at sea and ashore. Areas like the Arctic Ocean are subject to rapidly changing freshwater inputs from increasing sea ice melt and rivers, which impact the surface ocean. Since the Arctic Ocean is surrounded by vast continental shelves, the geochemical transport of material from the continental boundary to the Arctic interior will also change with climate making it more important to understand the geochemical cycles in the Arctic. In our recent work [Hatta et al, 2021; 2023], we have developed methodologies for nutrient analysis using a miniaturized, automated, microfluidic analyzer. Through their robustness, minimal reagent use, and computer-controlled manipulations they meet the prerequisites for unattended operation. These methods use distilled water standards but eliminate the schlieren effect thus curbing matrix effects during seawater analysis. These newly developed methods can also be used to determine freshwater samples and pore waters. Furthermore, using their highly precise syringe pump system, these methods are capable of producing an automated standard curve from a single distilled water standard solution. We are now trying to adapt this technique to the shipboard trace metal analysis.

Tidal Flats, a Vulnerable Ecosystem in the Context of Climate Change

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The Arctic region has been well recognized as a place where the impact of climate change is noticed quickly. Ongoing melting ice cover and glaciers change the Arctic's landscape. Tidal flats consider areas with muddy/sandy surfaces that are periodically submerged and exposed to the air by changing water levels. The slope is slight, meaning the seabed area exposed during the low tide is considerable. One of the main goals of this research is to study how tidal flats can react to climate change. The synergy between seabed morphology and climatic influences has remarkable importance on living conditions. Water level change, ice cover, temperature and salinity change, and water dynamics in the shoreline zones as well as proximity to the open sea and freshwater inflow, are under observation. To know this habitat better, the samples are collected to make the following analyse: qualitative and quantitative macrofauna, meiofauna, and microfauna, eDNA, sediment chemistry, sediment chlorophyll, LOI granulometry. Samples are obtained from 2 tidal flats in the Svalbard archipelago and 3 tidal flats in the Tromsø area. The study's first results indicate a high heterogeneity of the habitat and biological assemblages depending on the location. Moreover, it has been found that in all Arctic tidal flats, the most significant stressor for life is the long-term ice cover. Based on accessible sea water level models, it seems that with melting ice cover, this habitat can be drawn in and change the character and role in the ecosystem.

Pacific-Arctic Connections: Assessing Flow through Bering Strait in context with Dynamic Ocean Topography

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The inflow of relatively warm and fresh Pacific Ocean waters through Bering Strait to the Arctic Ocean influences stratification as well as seasonal sea ice retreat. Mooring observations in Bering Strait show that over the last few decades, transport has increased at ~0.01 Sv/yr. Winds over the region have not increased comparably, suggesting that local winds are not the only factor influencing transport. The complex coastline and bathymetry in the vicinity of the strait, highly seasonally dependent buoyancy fluxes and buoyancy gradients, as well as large-scale atmospheric and ocean circulation patterns in the surrounding regions likely all influence transport through Bering Strait. We analyze Dynamic Ocean Topography (DOT) to investigate the fundamental dynamics governing flow through Bering Strait. Our findings support that flow through the strait is approximately in geostrophic balance such that the across strait DOT slope is proportional to transport through the strait. We explore how this across-strait DOT slope relates to different mechanisms, such as local surface stress and inter-basin DOT differences, to determine how these processes influence transport and ultimately gain a better understanding of how Bering Strait transport will be affected by a warming climate.

A new version of the Nansen Legacy metadata logging system

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A new version of the Nansen Legacy metadata logging system has been developed for use on cruises beyond the Nansen Legacy project. The aim is to simplify the process for scientists and reduce the workload, whilst improving consistency across cruises and projects. This will be achieved through 1) the development of a user interface through which all samples and sampling events can be easily logged into a single PostgreSQL metadata catalogue hosted onboard, 2) semi-automatic logging of most sampling activities and Niskin bottles thanks to integration with the onboard 'Toktlogger' and the .btl files, 3) reduction of copy-paste errors by allowing the user to simply click on which sampling activity they want to log samples for, 4) in situ propagation of metadata from 'parents' (e.g. sampling activities) to 'child' samples, 5) removing cases where users have to unnecessarily provide the same information multiple times. It will remain possible to log metadata in spreadsheet templates initially if desired, and users should be able to download whatever metadata they want with a few clicks of their mouse. The logging system will be developed and managed by a multi-institutional team so that it can be used by scientists for years to come. We hope that you will use this logging system, and we welcome all feedback and suggestions.

Developing a Pan-Arctic Network of Distributed Biological Observatories

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The Arctic climate system is in great distress, warming faster than the rest of the world and transforming more rapidly than previously anticipated. Sustained, focused, and harmonized multidisciplinary information is needed to fill knowledge gaps and evaluate the climate change impacts on the complex Arctic marine system. Since 2010, the Distributed Biological Observatory (DBO) has functioned as a "detection array" for ecosystem changes and trends in the Pacific sector of the Arctic Ocean. This long-term, multi-disciplinary initiative builds on active involvement of scientists with the main aim to systematically increase the scientific documentation of how biological systems are transforming with the environmental change. The DBO sampling concept is currently being expanded to other portions of the Arctic, including Davis Strait and Baffin Bay, the Atlantic Arctic gateway area, and the East Siberian Sea. Through increased collaboration and joint scientific objectives and methods, findings from such regional key areas can leverage to pan-Arctic perspectives and improve our understanding of the entire Arctic Ocean. Here, we present the latest developments in the process of integrating the regional networks into a pan-Arctic framework and how our efforts connect to other parallel processes aiming to strengthen the pan-Arctic observational system. A major part of these collaborative efforts is currently facilitated by the EU Horizon project Arctic PASSION.

Iron and Manganese-Driven Benthic, Organic Carbon Mineralization in the Northwestern Barents Sea

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Continental shelves and margins are hot spots for the cycling of iron (Fe) and manganese (Mn) cycling. At high latitudes, these depositional systems are experiencing rapid changes due to warming climate, glacial loss, and retreating sea ice that could significantly impact biogeochemical cycling. The availability and cycling of reactive Fe and Mn can drive changes in the mineralization versus preservation of organic carbon within the benthic environment. Here we use a transect of five sites within the northwestern Barents Sea shelf, slope, and rise to investigate the active recycling of organic carbon, iron, and manganese within surface sediments. Sediments and porewaters were collected in Fall 2018 on the Nansen Legacy Paleo Cruise on the R/V *Kronprins Haakon*. Porewater results suggest shallow, significant Fe and Mn reduction in the shelf sites, coupled to high levels of organic matter mineralization as evidenced by dissolved inorganic carbon δ13C values (as low as -7‰). By comparison, porewater profiles indicate that slope and rise sites to the north experience less extreme organic matter remineralization and metal reduction. Sediment results indicate that these sediments contain very high contents of the most reactive Fe and Mn mineral phases (up to 3.2% ascorbate extractable Fe and 0.8% ascorbate extractable Mn). Our results provide context for the importance of reactive Fe and Mn availability within sediments and the role that these metal oxides play in organic carbon cycling.

Poster presentations E

Photo: Rudi Caeyers

Parallel session E:
Around and Out: Processes Along Interior and Outflow Shelves

Epibenthic Community Structure in Young Sound, Northeast Greenland, over the Past Two Decades

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Extensive fjord systems are important areas of land-to-sea exchange, in parts of the Arctic. In Northeast Greenland, reduced sea-ice cover and increased run-off from the Greenland ice sheet are altering the physical environment, with consequences for the marine ecosystem. Epibenthic organisms in the Arctic tend to live long and can reflect long-term change, yet time series here are lacking. ROV derived under-water imagery from 2003-2010 and 2021-2022 offered a temporal comparison of epibenthic communities along three transects from 20-60 m depth in Young Sound, NE Greenland, to test if climate warming has altered the community structure. Preliminary results indicate the persistent dominance, though altered abundance, of brittle stars and bivalves, and the sudden appearance of a previously unrecorded large ascidian, in the most recent years. This indicates that change is already occurring in this fjord, which is concerning since the coast of Northeast Greenland is less affected by increasing ocean temperatures compared to the inflow regions.

Greenland Climate Trends and Marine Ecosystem Responses

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The Greenland coastline, spanning 24° latitude, harbors diverse marine ecosystems. Although there is a growing understanding of changes in Greenland marine ecosystems in response to climate change, the vast differences between regions and synergetic effects of different physical drivers are rarely addressed. Our study investigates regional trends in ecologically relevant physical drivers along the Greenland coastline and their impacts on marine organisms. Six subregions are delineated to identify spatial variations and interactions among drivers. We review available time series on changes in Greenland's marine communities and compare them with expectations based on synthesized physical driver changes. Our results identified strong regional differences in relevant drivers and the number of interacting drivers. Hotspots of climate change were identified between 67 – 76 °N, which were affected by large changes in the sea ice regime, run off and sea surface temperatures. We identified a limited number of consistent trends in biological communities from the literature. These findings emphasize the importance of considering synergistic effects of physical drivers when studying responses to climate change in Arctic environments. Greenland remains heavily understudied, although monitoring programs cover key areas. Our research contributes to comprehending the ecological dynamics in this critical region.

Poster E5

Patterns and Processes in the Kitikmeot Sea Estuary

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The Kitikmeot Sea of the southern Canadian Arctic Archipelago lies within the heart of the southern Northwest Passage and is home to five Indigenous communities. It is unique in the pan-Arctic system due to: (1) shallow bounding sills that are less than 30 m deep; (2) primary nutrient and salt supplies delivered over the sills from the Canada Basin; and (3) massive freshwater input from a watershed five-times its size. An estuarine-like circulation is maintained at the sills where exiting freshwater restricts replenishing inflow of salty, nutrient-rich oceanic water, and leads to a low-productivity ecosystem in the region. Observations from 1999-2019 suggest the Kitikmeot Sea functions as a nested estuary where exchanges of fresh and salt water are controlled at shallow interior and bounding sills. A system of four interacting estuaries (Coronation Gulf, Bathurst Inlet, Queen Maud Gulf, and Chantry Inlet) set up the predominant circulation, within which winds, tides, and boundary circulation control local conditions. We further propose a conceptual model of marine ecosystem function, one that supports an abundance of char and seals as top predators instead of the larger polar bears and whales found elsewhere in the Canadian Arctic Archipelago. Since climate change will impact critical social-ecological functions of the Kitikmeot Sea, understanding of connections within, and external to, this region is needed for its communities to prepare for an uncertain future.

Poster presentations F

Photo: Algot Peterson

Parallel session F:
A Shattered Mirror – Understanding a Rapidly Changing Central Arctic Ocean

The Polynya North of Greenland in Summer 2020: Insights on its Opening, Air-Ocean Fluxes and Ocean Properties from In Situ Observations

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North of Greenland is a region historically characterized by multi-year sea and high concentration of sea ice. At some occasions however, the sea ice concentration North of Greenland decreases and a polynya can open, in both winter and summer. In August 2020, the polynya North of Greenland opened. This area of open water up to 88 °N was used to relocate Polarstern northward at the beginning of leg 5 of MOSAiC (Multidisciplinary drifting Observatory for the Study of Arctic Climate), but also provided a unique opportunity to study this extremely undersampled region. Combining observations from the ship, in particular expendable hydrographic profiling probes (XCTDs), and atmospheric reanalysis, we investigate the dynamics of the opening of the polynya and its influence on the water column. The opening of the polynya is most likely caused by southerly winds lasting for nearly 10 days, from July 26 to August 4. In the polynya, surface waters are warmer than the freezing point, and the mixed layer is about 40 m deep. Hydrographic characteristics below the mixed layer (and above 200 m) indicate contributions from waters of Atlantic origin and glacial meltwater. Currently, we are investigating the impact of the polynya on the different such as heat fluxes between the atmosphere and the ocean.

An Overview of Underwater Hyperspectral Imagery of Sea Ice in the Central Arctic Ocean

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The impact of a rapidly shifting sea-ice cover on climate, ecosystem processes and biophysical habitat properties is not yet fully understood due to a lack of spatially and temporally representative observations within the Central Arctic Ocean. Sea ice coring is a standard sampling method in sea ice research, however, to overcome spatio-temporal sampling limitations, non-invasive methods are needed. Underwater hyperspectral imagery (UHI) is an emerging technology, which enables non-invasive biophysical characterization of the sea ice bottom. Here we will present a comprehensive dataset of UHI sea ice surveys from the central Arctic Ocean covering nearly the full algal growth season from May to Oct. Surveys were conducted with a ROV-mounted UHI, enabling survey lengths 50-200 meters with < 1 cm spatial resolution. UHI surveys were conducted during five cruises: MOSAiC (June-July 2020), Kronprins Haakon (KPH, May 2021, July-Aug 2022), Odin (May-June 2023), Polarstern (Aug-Oct 2023). UHI surveys included a one-month time series of the same ice. Overall, several ice types were surveyed including both MYI and FYI, ridged ice, and thin new ice. We surveyed a range of snow-covered and advanced melt ice conditions. Algal communities also varied from more typical bottom ice algal communities to algal aggregates and *Melosira* forests. We present some preliminary results from the ROV-UHI surveys and provide an overview of the regions, ice types, algal types and sea conditions surveyed.

Life at the Bottom of the Central Arctic Ocean: Epibenthic Composition at Lomonosov Ridge and Morris Jessup Rise

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Sea ice decline makes the central Arctic Ocean (CAO) increasingly accessible, sparking interest in potential seafloor resource use. The Fram-2014/15 ice drift expedition provided the unprecedented opportunity to obtain seafloor imagery at the Lomonosov Ridge and Morris Jessup Rise (84-89 °N). We investigated the acquired material to fill critical knowledge gaps of the epibenthic life at these deep Arctic ridges (800-2650 m). The megafaunal inventory revealed communities similar to those observed in other Arctic deep-sea regions – the Chukchi Borderland, Fram Strait, and Nansen and Amundsen Basins. Arthropods (amphipods and mysids) and echinoderms (*Pourtalesia jeffreysi*, *Bathycrinus carpenterii*, ophiuroids, and *Kolga hyalina*) showed a high occurrence across the study area. Most taxa were of Atlantic-boreal biogeographic affinity. Fish included the Glacial eelpout (*Lycodes frigidus*) and the currently known northernmost observation of Arctic rockling (*Gaidropsarus argentatus*) (86 °N). In addition, one station indicated seafloor seep activity with microbial mats and aggregation of large sponges. These observations share a high resemblance to previously described seep-sites in adjacent areas as well as nearby central Arctic Karasik seamount. This study expands the current knowledge of deep CAO ecology and supports the emerging picture of much higher habitat diversity in the Arctic deep-sea than previously appreciated.

Poster presentations

Photo: Kay Jørgensen

The future Arctic Ocean: projections, processes, implications, and uncertainties

Effects of Abrupt Ecological Change(s) on the Barents Sea Arctic Food-Web: Predictions from a Food-Web State-Space Model

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Arctic marine areas are facing rapid abiotic changes with decrease of seasonal sea-ice cover and increased sea temperature. The changing abiotic environment has several ecological consequences: changes in the population dynamics of sea-ice associated species and increased presence of sub-arctic generalist marine predator species in the Arctic area, i.e., borealization. In the Barents Sea ecosystem, two key fish species, capelin (*Mallotus villosus*) and polar cod (*Boreogadus saida*), link sub-Arctic and Arctic food-webs through shared preys and predators. Decrease in sea-ice has been predicted to negatively affect the population of polar cod. In addition, increase in the presence of sub-arctic marine predators in the Arctic part of the Barents Sea ecosystem may affect consumption rates of polar cod moderated by the condition of capelin stock. The consequences on Arctic marine ecosystem of both changes remain to be fully investigated. We hypothesize that both abiotic changes and borealization of the Barents Sea will significantly affect the stock of polar cod. To test this hypothesis, we combined recently developed statistical models: two age-resolved state-space models, for capelin and for polar cod, and a threshold model for predation rates in an integrated ecosystem state-space model for the Barents Sea food web. This approach allows us to predict the effect on the Barents Sea Arctic food-web of abrupt change(s), i.e., capelin stock collapse, in a rapidly changing environment.

Changing Nature of Polar Warming and Marine Extremes in High-Resolution Models for the 21st Century

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The Arctic is warming faster than any other oceans, a phenomenon known as Arctic amplification that has far-reaching implications for global climate. In contrast, the Southern Ocean (SO) and Antarctica have cooled in recent decades. The projection of these regions under global warming exhibits non-negligible model spread. Here we show that under a strong warming scenario from the mid-20th to the end of the 21st century, comparing a modern high-resolution climate model with a low-resolution model version, the warming in the Arctic is 1.5 °C greater and the warming of SO and Antarctica is 1 °C less. By a conceptual model, we attribute the changed polar warming to polar marine extremes, which are largely unknown. The marine heat waves (MHWs) in the Arctic and SO are twice as strong in the high-resolution model version, with the increasing intensity of MHWs in the Arctic accompanied by a large decrease in sea ice. The much stronger MHWs in the high-resolution model are caused by two orders of magnitude more turbulent energy in the ocean. They are less correlated with ocean stratification than those in the low-resolution models. We conclude that the Arctic amplification and MHWs are underestimated by the current generation of climate models with low resolution, while the SO and Antarctica warming is overestimated. Our eddy- and storm-resolving model is expected to open new possibilities for how the system responds to human activities in a high-CO^2 world by assessing the impact on past and future climate and environmental extremes.

Can We Even Predict the Future Arctic Ocean?

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The Arctic Ocean is a challenge to model accurately. Its exchanges with the rest of the global ocean occur through narrow gateways. Ventilation within the Arctic requires a realistic continental shelf hydrography and slope, interaction with the sea ice and atmosphere, and preservation of dense overflows. At all depth levels, an accurate bathymetry is needed to properly represent the circulation. The uppermost layers depend on both surface heat fluxes and freshwater fluxes from rivers, glaciers, sea ice, and the atmosphere, while the deepest layers are impacted by geothermal heating. Despite this, many parameterisations and tuning processes applied in the Arctic are not representative of the polar regions. In addition, observations used to constrain Arctic models are often limited to the summer season, ice-free regions, or upper ocean. Therefore, unsurprisingly, the coarse-resolution CMIP-type models are highly inaccurate in the Arctic Ocean. In this presentation, I will provide a non-exhaustive list of biases in Arctic Ocean water mass representation and circulation in CMIP6 models, with a specific focus on how these biases impact our ability to accurately project future Arctic Ocean and global changes. Key directions for improving the Arctic Ocean in climate models will be discussed, along with new results from the "future Arctic in CMIP6" workshop to be held this September in Bergen.

Will Atlantification Lead to a More Gelatinous Future of the European Arctic?

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Gelatinous zooplankton (GZ; pelagic cnidarians and ctenophores), are key players in marine ecosystems. Aside from their trophic importance, rapid reproductive cycles of GZ render their population size and structure tightly coupled to the environment, making them the ideal bioindicators for monitoring changes in the World's Ocean. Unfortunately, due to their delicate nature and convoluted taxonomy, data on their distribution are scarce and of poor taxonomic resolution. To tackle this paucity of data, here we re-analyzed zooplankton time series (2003-2014) run by the Institute of Oceanology (Polish Academy of Sciences), to investigate the future of GZ communities in the European Arctic under the scenario of progressing Atlantification. Specifically, we tested 1) whether oceanic fronts modulate the spreading of boreal GZ in the Arctic? and 2) how will the most abundant GZ in the region, *Aglantha digitale*, respond to ongoing changes? We found that the two fronts (Arctic and Polar), which flank the main inflow of the Atlantic waters to the Arctic, constitute a semi-permeable barrier for GZ distribution, maintaining distinct GZ community across fronts. Further, we found evidence, that year after year, *A. digitale* reproduced earlier in the Fram Strait, and in anomalously warm period (2005-2007) may have even reproduced twice per season. Overall, these findings may be interpreted as hinting towards more gelatinous future of the European Arctic.

Future Arctic Ocean Atmosphere-Ice-Ocean Momentum Transfer and Impacts on Ocean Circulation

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In recent decades, the Arctic has undergone extensive sea ice loss. The reduced ice cover affects the mechanical and thermodynamical coupling between the atmosphere and the ocean. One hypothesis suggests that a thinner and more mobile sea ice cover could lead to increased momentum transfer, resulting in an acceleration of upper Arctic Ocean circulation and enhanced vertical mixing. In general, sea ice protects the ocean from interaction with the atmosphere, and a shrinking ice cover implies a more direct transfer of momentum. However, previous modeling studies have demonstrated that seasonality plays a crucial role, and at times, more open water can lead to a decrease in momentum transfer due to the greater drag provided by the ice. Consequently, it remains uncertain whether the future sea ice cover will amplify or dampen the momentum transfer. To address this knowledge gap, we investigated future scenarios from an ensemble of CMIP6 models. We focused on examining the projected changes in momentum transfer in response to evolving sea ice and wind conditions, and how this depends on the formulation of drag. Our findings reveal that all models project an increase in ocean surface stress, primarily driven by a combination of intensified wind speeds and diminishing ice concentration. Although trends in wind speed are largest during late fall, the most substantial trends in ocean stress occur during winter, as reduced internal stress amplifies the impact of wind-driven changes.

Confined CMIP6 Estimates of Arctic Ocean Temperature and Salinity over the Next Three Decades

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Global climate models (CMIP6 models) are the basis for future predictions and projections, but these models typically have large biases in their mean state of the Arctic Ocean. Considering a transect across the Arctic Ocean (100-700 m), we show that the model spread for temperature and salinity anomalies ramp up during the next two decades (2025-2045). The maximum model spread is reached in the following decade (2045-2055) with a standard deviation 10 times higher than in 1993-2010. The CMIP6 models agree that there will be warming, but do not agree on the degree of warming. We therefore test a new approach to find models with good performance. We split the analysis in two typical layers; namely the Halocline Layer (100-300 m) and the Atlantic Layer (300-700m). We assess how CMIP6 models represent the horizontal patterns of temperature and salinity in these layers in 1993-2010. Based on this, we find four models with relatively good performance. However, these models show different degree of warming over the next three decades, which may be a result of their different climate sensitivities. The model with the overall best performance shows a warming of about 0.4 °C and 0.7 °C in 2045-2055 (compared to 1993-2010) in the Halocline and Atlantic layer, respectively, when considering the low end ssp126 scenario. This means reduced warming but larger freshening than the multi-model mean (MMM).


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