2018 ARCTIC FRONTIERS
CONNECTING THE ARCTIC
TROMSØ NORWAY 21-26 JANUARY

Arctic Frontiers Science 2018

ABSTRACTS

Chris S. Emblow and Katrin Bluhm
Editors
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About Arctic Frontiers 2018

Connecting the Arctic

In a world of increasing turmoil the Arctic is still a place for collaboration and peaceful communication. In maintaining peaceful relations across borders in the north the encompassing science collaboration has been particular important. The vast ocean that represents the bulk of the arctic area carries large potentials, but also threats. As increasingly larger parts of it will be utilized, how do we communicate and conduct search and rescue, how do we secure productive and healthy oceans? Sustainable development of the ocean is of particular importance in this matter. Sustainable business development is also key in securing resilient arctic societies. Connecting these societies together and closer to the rest of the world’s ideas, knowledge, technology and capital was an issue of special importance at Arctic Frontiers 2018.
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Introduction

Climate change and modernisation provide both enormous challenges and opportunities for the Arctic. Intense research and assessments document the impacts of human activities and climate change at regional and global scales, and help discover ways to conserve the ecological and cultural resources in the Arctic. Frontiers Science provides an arena for latest findings in environmental, technological and social research in the region. This part of Arctic Frontiers is organised by independent science committees.

Arctic Frontiers Science 2018 took place from Tuesday 23 January until Thursday 25 January 2018 and addressed the following four themes.

Aquaculture in the high north in times of change

Nature based industries are of particular importance in the High North. Increasing demand on area, good locations, ocean temperatures and other environmental challenges have brought forward an expansion of aquaculture further north and into the ocean. The United Nations estimate the world population will be near to 10 billion by 2050, thus an increasing demand for food and energy by 70 – 100%. Shortage of fresh water, fertile land and nutrients, including phosphorus, will enhance the need for biomass from marine sources. Sustainable development of aquaculture is on the agenda. On a global scale seafood production from capture fisheries has already been surpassed by aquaculture. The sessions in this theme highlighted the insights gained from recent research addressing challenges and opportunities in this field:

- Sustainable aquaculture in the high north in an age of climate change. Climate change can have a significant effect on global aquatic food production. Devising strategies to breed temperature-tolerant varieties combating existing and emerging diseases, reducing stress, and improving the welfare and health of farmed fish will help sustain the growth of the aquaculture sector. Thus, adopting new technologies for fish production and processing will be justified.

- Coexistence in coastal waters – benefits and challenges offered. Coastal areas are already subject to an increase in competing activities and protection and are thus subject to conflict for space allocation. Multidisciplinary research approaches are needed to ensure better integration, sustainability, and synergies among activities in the coastal zone.

- The use of new species in aquaculture. Norwegian aquaculture, for example, is synonymous with Atlantic salmon farming. The demand for salmon is expected to increase. However, the dependence on only one or a few species is not ideal for the economy of ‘the marine nation’. Efforts are underway to tap into new fish species for future farming and there is considerable increased interest to farm organisms lower in the trophic level, including macro and microalgae.

- Future Food and Feed from Marine Sources. The increasing demand for seafood is the result of the awareness on the beneficial effects of seafood consumption on human health. Through aquaculture the nutritional content of the farmed species can be modified, especially in terms of omega-3 fatty acid. This necessitates tapping into new sources of feed ingredients of marine origin.
• Safe and secure aquaculture farming operations in harsh conditions. Farming operations are moving into more exposed waters, and new farming systems are being developed in the northern hemisphere. As operations become complex there is a demand for new safe procedures which provide, health, safety, and environmental (HSE) challenges. To meet these new technologies for monitoring and surveillance, remote and autonomous operations need to be developed.

Scientific committee members:

• **Edel O. Elvevoll**, UiT The Arctic University of Norway (lead)
• **Ketil Eiane**, Nord University, Bodø, Norway
• **Arne Fredheim**, SINTEF Ocean AS, Trondheim, Norway
• **Geir Lasse Taranger**, Institute of Marine Research, Bergen, Norway
• **Albert Kjartanson Imsland**, Akvaplan-niva, Norway (Reykjavik office)

The New Arctic in the Global Context

The rapid changes taking place in the Arctic due to global climate change — e.g., the retreat of sea ice, a warming surface ocean and warming air masses — affect the physical and biogeochemical systems and ecosystems in the Arctic, but they also have the potential to influence weather and climate in mid-latitudes. The impacts of severe weather phenomena on commerce and infrastructure can be significant. It is therefore crucial to develop methods and tools to predict when and how changes in the Arctic will both affect the high latitudes but also densely populated regions such as Europe, Asia, and North America. Several projects and initiatives — such as the APPLICATE, MOSAiC, Nansen Legacy, N-ICE2015, GreenEdge and BAYSYS projects and the Year of Polar Prediction (YOPP) — are underway with the aim to better understand polar climate and ecosystem processes, to understand and forecast weather and environmental changes in the Arctic, how these affect global ocean and atmospheric circulation, ecosystems, and what are future societal impacts and requirements both in the Arctic and mid-latitudes.

This theme highlighted insights gained from recent research covering the following sessions:

1. Overviews: overview on projects and initiatives that aim to improve knowledge on the polar weather and climate system and ecosystem processes in order to enhance predictability of environmental parameters.
2. Observations: sea-ice changes and decline, snow changes, ocean warming and circulation, atmospheric circulation and weather, ecosystem changes, observing system design.
4. Prediction: from weather forecast to seasonal and subseasonal prediction and climate projections.
5. Linkages to mid-latitudes: how Arctic climate change influences weather and climate across the Northern Hemisphere.
6. Ecosystem processes: how the Arctic ecosystem functions from the interactions of its component species (humans included), habitats, and physical features as they affect one another, directly and indirectly.

7. User engagement: bringing together the forecast community and end users of polar prediction products.

8. Governance of the New Arctic: how policies and management procedures will change due to changing Arctic environment, e.g., regulations for new shipping routes, fisheries, communities in the Arctic that might be influenced by weather and environmental changes.

Scientific committee members:

- **Marcus Rex**, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany (lead)
- **Thomas Jung**, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
- **Sebastian Gerland**, Norwegian Polar Institute, Tromsø, Norway
- **Jackie Dawson**, University of Ottawa, Canada
- **CJ Mundy**, University of Manitoba, Canada

Organising committee members:

- **Luisa Cristini**, APPLICATE, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
- **Anja Sommerfeld**, MOSAiC, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
- **Kirstin Werner**, YOPP Office, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany

Resilient Arctic Societies and Industrial Development

The Arctic is in the midst of deep-seated change. Comprehensive changes in climate, transport and industry (mining, oil and gas, and more) will have a profound effect on the communities and the lives of the people living in this sparsely populated area. These transformative processes increase and broaden the interest in the area itself, making the Arctic more important strategically and economically in terms of globalization.

In addition to understand how to regulate and manage what is coming, a thorough understanding of the relationships between society, environment and business is crucial. Here international and national law and agreements play an important if not vital role.

There is a substantial variation in natural conditions in the Arctic (e.g. temperature, ice, weather conditions), and in the rate and extent of infrastructure development and telecommunications across the region. Subsequently, some parts of the Arctic are more densely populated than others. Indigenous people are an important part of the Arctic population and their rights are increasingly supported by the UN system and international law which itself has an influence upon what can be done and how.
The call will mainly focus on how changes in climate and industry development in the Arctic influence different types of societies. To what extent are communities, population centres and individuals resilient and able to adjust to change, or recover from such deep-seated shifts influencing and even transforming their way of life? If they are not able to adjust and recover, why, and to what extent does it matter?

This theme highlighted insights gained from recent research covering the following sessions:

- **Demographic and socio-economic changes.** People are gradually moving in and out of the Arctic and within the Arctic – from small communities to cities and areas that are more central. The socio-economic circumstances are also of increasing concerns in the Arctic especially in the case of the indigenous people. What are the short and long time consequences for Arctic life of these deep-seated structural changes? Are there any systematic differences between indigenous and non-indigenous people when it comes to demographic and socio-economic processes?

- **Industrial activities in the Arctic.** Where do we see industries coming in and what kind of industries are we talking about? What do we know about the short and long-term impacts of these new industries? To what extent is this type of change particularly challenging for indigenous communities, and if so, why? Case studies are very welcomed here.

- **Trust, legitimacy.** Who is heard and who has a say in these types of large-scale changes? What kind of role and impact do those already living in the area (indigenous people and settlers) have on these types of transformative processes in which much of the input is coming from the outside? Do people have trust in what is going on and is local democracy playing an important part? Will it strengthen or weaken the role of indigenous people in the Arctic?

- **Corporate social responsibility, Social license and free, prior and informed consent.** Corporate social responsibility and social license are increasingly the benchmark of industrial development in the Arctic, but how to implement it so it alleviates conflict around development? In the case of indigenous people, with the endorsement of the UNDRIP by all circumpolar countries, free and prior informed consent is becoming increasingly relevant in the relation between indigenous people and resource development companies. But here again, how this international norm can be put into place in the Arctic is a challenging matter.

- **New governance structures and institutional development.** What kind of new governance structures are developing in the Arctic and what exactly are the relationships between the different levels, local, regional, national and global? Are there actually more global governance structures that are taking the lead at the cost of the national and local level? What is the role of international business here? Do we see the building of new institutions that really help in improving food security, health and other deep-seated social challenges in the Arctic?

- **Science, technology and indigenous knowledge.** Western science plays a core role in the processes we are looking into here. However, over the years there has also been an increased emphasis on indigenous knowledge in the Arctic as indigenous people, in particular, become more visible in these processes. How can indigenous knowledge, if at all, improve decisions and solutions, and how do western science and indigenous knowledge interact?
Scientific committee members:

- **Per Selle**, University of Bergen and UiT The Arctic University of Norway (lead).
- **Thierry Rodon**, Université Laval, Québec, Canada
- **Julie Decker**, Anchorage Museum, Alaska
- **Stephan Schott**, School of Public Policy and Administration, Carleton University, Canada
- **Toril Inga Røe Utvik**, Statoil, Norway

Circumpolar Safety, Search and Rescue Collaboration

Search and rescue (S&R) in cold waters is a short race against time. Low temperatures, poor visibility and bad weather, as well as vast distances, conspire to make S&R operations challenging. Although ice floes can keep people afloat for longer periods, and modern communication systems means there is less search and more rescue, even with the best survival gear the odds are decidedly poorer than in warmer waters.

With the advent of dramatically reduced summer ice coverage, human activity in the Arctic Ocean ranging from petroleum exploration and drilling to shipping and cruise traffic is set to increase significantly. Mass rescue operations (MROs) must be handled differently in the Arctic, and to understand how the risk of a large accident in this sparsely populated area should be assessed we must draw on our understanding of the weather conditions, the changing climate, and the limited resources available in this region.

This theme highlighted insights gained from recent research covering the following sessions:

- **Risk Assessment of Arctic Operations.** The risk associated with human activity in the Arctic differs from that found in other marine regions due to the paucity of resources, the adversity of the environmental conditions and lack of crew experience from sailing in Arctic waters. How should risk, both dynamic and static, be assessed for Arctic operations?
- **Pan-Arctic S&R Collaboration.** Arctic S&R is essentially international. How the S&R services around the Arctic Ocean organize their resources matters to our preparedness. Which scenarios face the S&R services as the ice cover retreats and human activities are ramped up?
- **Forecasting for Arctic S&R.** Weather matters before and after an accident. Forecasts are more uncertain in the Arctic due to a lack of observations and the presence of small polar lows further decreases the predictability of Arctic weather. Here we will explore how weather, waves and currents affect the fate of a drifting object, and how ensemble forecasts can lead to more efficient S&R operations.
- **Satellite Monitoring and S&R.** A range of new satellite services are coming online. How can remote sensing be used to monitor the environmental conditions essential to S&R operations, and how can modern satellite communications reduce response times for operators in the Arctic?
- **Cold Water Effects on Humans.** Hypothermia is the major concern with accidents in polar waters and essentially determines the time span of the rescue operation. How
does the human body react to immersion in cold water and how efficiently can equipment or a choice of action help reduce heat loss?

Scientific committee members:

- Øyvind Breivik, Norwegian Meteorological Institute and University of Bergen, Norway (lead)
- Arthur A Allen, United States Coast Guard, USA
- Tor Einar Berg, SINTEF, Norway
- Kjetil Bilic Michaelsen, Norwegian Space Centre, Norway
- Penelope Wagner, Norwegian Meteorological Institute, Norwegian Ice Service, Norway
Oral presentations

Aquaculture in the high north in times of change

KEYNOTE: Sustainable aquaculture in northern Europe under Climate Change

Michaela Aschan¹, Elisabeth Ytteborg²

¹UiT The Arctic University of Norway, Norway, ²Nofima, Norway

Climate change happens at a faster rate than predicted. The temperature increases, extreme weather events intensify, and the ocean pH declines. In a world where the demand for food is constantly increasing, climate change threatens the overall food production and limits the growth potential. Aquaculture is expected to increase and serve as one of our main sources of food, and species farmed in the oceans are exposed to climate change; the question is how to adapt to these changes. How can the industry prepare for the climate change that is coming, and how can they reduce negative effects while at the same time exploiting possible positive outcomes?

In this paper we briefly present the history of aquaculture in the north, identify the main threats and opportunities caused by climate change, and look at future prospects. We identify the most vulnerable species and countries when it comes to aquaculture production in Europe and present preliminary forecasts for case studies in marine and freshwater aquaculture in the Arctic. These forecasts allow for risk assessments and preparation for climate adaptation. Farmers view on current problems and future challenges and opportunities related to climate changes will also be presented. It is the responsibility of each nation to develop climate adaption plans to prepare also the aquaculture industry for climate change, but not all counties have such plans.

The EU financed H2020 project ClimeFish, Co-creating a decision support framework to ensure sustainable fish production in Europe under climate change, aim at estimating the effects of climate change on fisheries and aquaculture in Europe from today until 2050. To forecast production, we use two climate scenarios from the International Panel of Climate Change (IPCC), RCP4.5 and RCP8.5, and simulate the future of 15 cases, including some of the least resilient and the most important fish species in Europe. The outcome of the project will help to improve decision making for a sustainable aquaculture in Europe in the future.

For more information www.climefish.eu and Twitter @climefish, or contact us at climefish@uit.no
The importance of current and environmental variability for dispersion of waterborne pathogens along the Norwegian coast

Lars Asplin, Ingrid A. Johnsen, Bjørn Ådlandsvik, Anne D. Sandvik, Jon Albretsen, Mari S Myksvoll, Jofrid Skardhamar

Institute of Marine Research, Norway

The Norwegian salmon aquaculture produce 1 million tonnes of salmonid fish annually at almost 1000 fish farms located along the 2000 km long Norwegian coastline. The number of individual fish is more than 200 million, which is significantly higher than the wild salmonid fish stock (2-5 million individuals).

Although the farmed fish are monitored and treated for parasites and diseases, a substantial amount of waterborne pathogens are being released from the fish farms to the natural ecosystems. The Norwegian authorities has decided recently that the growth of the salmon aquaculture will be based on sustainability of the wild ecosystems, and at present the infection pressure of salmon lice from farmed to wild fish is the most critical measure of sustainability.

To estimate regional distribution of pathogens with high resolution in time and space, we use a combined set of numerical models. A high resolution atmosphere model, a coastal ocean model and a hydrological model all feed a fjord model producing current and hydrography on a spatial scale of O(100m) every hour for any period the last 50 years. Based on results from the fjord model we simulate particle dispersion where particles will have vertical behaviour, mortality and infectivity depending on the pathogen. Observations for model validation are taken from e.g. current measurements.

We find that the currents are highly variable when realistically forced by wind, tide, freshwater runoff and the interaction with coastal water. Thus the regional distribution of pathogen concentrations will also have a large variability (hourly to daily) and potentially a long dispersion distance from the source (several tens of km).

It is necessary to include the effects of the current and other environmental variables like salinity and temperature in order to determine precisely the regional distribution of pathogens in Norwegian coastal waters. This will be increasingly important in a future climate, which is projected to include stronger forcing of the fjord and coastal water.
Developing dispersal modelling tools to predict regional environmental impacts of finfish aquaculture

**Raymond Bannister, Ingrid A. Johnsen, Pia K. Hansen, Tina Kutti, Lars Asplin**

*Institute of Marine Research, Norway*

The ability to achieve environmentally sustainable Atlantic salmon aquaculture in coastal ecosystems is presently constrained by our limited knowledge of the regional interactions and fate of organic effluents on benthic ecosystems. A first step in addressing this limitation is to establish verified predictive modelling tools to understand better local and regional dispersion of organic effluents in the wider ecosystem.

By combining settling velocity of faecal waste from different sizes of Atlantic salmon, a 3D hydrodynamic model coupled with a particle tracking model and farm management data, this presentation will demonstrate the accuracy and reliability of a generic far- and near-field effluent dispersion model to predict the spread of particulate organic waste into fjord ecosystems. Simulations predict that more than 75% of organic effluents are dispersed to near-field sites (< 500 m from the release point); while a small proportion of particulate organic effluents (up to 2.7%) are dispersed to far-field sites (> 2 km) (Figure 1).

Modelling dispersion of organic material dispersed from fin-fish farms in a whole fjord system (i.e. 50 000 tons of organic loading per year), demonstrates that organic effluents from fish farms may be spread over large areas of fjord systems with the potential for overlapping between multiple fish farms, potentially leading to hotspots of organic accumulation. This modelling tool has the potential to be used as a premise for selecting optimal sites for monitoring regional benthic impacts of finfish aquaculture.
Recent advances in spotted wolffish (*Anarhichas minor*) reproduction at the Nord University

Jose Beirao 1, Oddvar Ottesen 2, Mette Sørensen 1, Bjørnar Eggen 1, João Santana 3, Sylvie Bolla 1

1Nord University, Norway, 2Akvatik AS, Norway, 3University of Algarve, Portugal

Spotted wolffish (*Anarhichas minor*) has been considered one of the most promising species for species diversification in cold-water marine aquaculture. Nevertheless, there are some challenges in this potential successful story. Reproduction in captivity is dependent on *in vitro* fertilization, however, the low sperm volume with low cell concentration, the lack of gametes synchronization (simultaneous availability of mature eggs and sperm) and the long period of eggs incubation, up to 1 000 day-degrees, represent a challenge for the aquaculture industry. At the Nord University, we have been working to overcome some of these bottlenecks. First, we optimized a step-by-step *in vitro* fertilization protocol that allows maximizing the use of the limiting amount of gametes, particularly semen. Second, we developed a sperm cryopreservation protocol to store sperm and overcome the lack of gametes synchronization. Finally, we are working to establish spawns quality indices that correlate in first place with fertilization rates but also with hatching and larvae survival rates during the first weeks.

For the fertilization protocol development sperm concentration could be accurately measured by spectrophotometry. The highest coefficient of determination with the direct cell counting was obtained with the spectrophotometric reading when the sperm was pre-diluted 1:99 (sperm: extender) and the absorbance set at 300nm, $r^2 = 0.9185$. No improvement in the percentage of fertilized eggs was observed using ratios of sperm: egg above $5 \times 10^5$ for a 2h contact time. On the other hand, the longer contact time, i.e. using 6h instead of 2h, significantly increased the percentage of fertilized eggs when lower volumes of sperm were available.

To cryopreserve spotted wolffish sperm the best results were obtained with sperm diluted in an extender containing 10% DMSO, loaded on 0.5ml straws, freeze at a height of 4.5 or 7.5cm from liquid nitrogen for 10min and thawed for 1min at 5°C. To obtain fertilization ratios equivalent to those obtained with fresh sperm with similar sperm: egg (5x105), *in vitro* fertilization needed to include a 4h contact time. We are presently optimizing this protocol with the use of different sperm membrane stabilizers and antioxidants.

Finally, we are also analysing different spawns for basic egg quality parameters and biochemical parameters (fatty acids, phospholipids, amino acids and carotenoids). These results will help build evaluation schemes that can be used to select rearing protocols, breeders and gametes for *in vitro* fertilization.
Applying molecular tools to assess the environmental impact of aquaculture

Melissa Brandner ¹, Truls Moum ¹, Henning Reiss ¹, Paul Renaud ²

¹Nord University, Norway, ²Akvaplan-niva, Norway

The Arctic Aquaculture industry is expanding rapidly with a current contribution of 2% to global production, a volume equal to the total production from the European Union. There will be further expansion of the aquaculture industry, and it is vital to grow sustainably with the safety of the environment in mind. The most widely documented environmental consequence of aquaculture farming is degradation of the seabed. Both deposition of waste products, contributing to eutrophication, and contaminant releases, such as copper from antifouling paint, supply quantifiable changes in benthic communities under fish farming nets. With a rapidly expanding industry in the Arctic, it is vital to apply methods that are rapid and cost effective to assess these changes. Biodiversity has been shown to be useful indicators in terms of assessing environmental impact. Traditional methods for species identification are extremely time consuming and require highly skilled taxonomic expertise. Species identification using DNA is an attractive alternative, which is currently supported by a global initiative to generate DNA barcodes. We can potentially determine the species composition of complex communities, e.g. benthic communities, from reading the barcodes of the total DNA content of a sediment sample (DNA metabarcoding). Our study applied newly developed DNA metabarcoding tools to quantify the diversity changes in benthic communities from Salmonid farming in Hardanger fjord, Norway. This method is rapid, cost effective and less labour intensive than traditional methods. It also has the added benefit of whole community quantification that is difficult to achieve with traditional morphological methods. New metabarcoding tools could be applied to assess environmental health around aquaculture installations. The development of new tools to assess and mitigate environmental impact, are essential as we expand aquaculture further into the Arctic.
Impacts of climate change on the prospects for macroalgae cultivation in Northern Norway

Ole Jacob Broch, Ingrid Ellingsen, Aleksander Handå, Dag Slagstad

SinTEF Ocean, Norway

Although Norwegian aquaculture production is dominated by Atlantic salmon, there is currently great interest in the cultivation of marine macroalgae, in particular kelps. According to the Norwegian Directorate of Fisheries, there were 108 licences for macroalgal cultivation awarded in Nordland as of December 31, 2016. Despite many potential areal conflicts with fisheries, aquaculture, fairway and tourism, there is a great potential for cultivation of macroalgae in Northern Norway. Some reports (the DKNVS scenario report) have indicated a 3 to 5 time increase in Norwegian aquaculture output, with a value increase from 1.2 billion NOK today to almost 40 billion NOK of the macroalgae industry by 2050. At the same time, global atmospheric temperature will continue to increase, with a further amplification in the Arctic and Northern regions. In this perspective, it is of interest to investigate what, if any, the effects of increasing air temperature will have on the prospective and potential for macroalgal cultivation in Northern Norway.

In this talk we investigate such questions by using a coupled physical-biological ocean model system (SINMOD) enhanced with modules for macroalgal growth and production for the coast of Nordland and Southern Troms. Scenarios including the present situation (as it is today) and with increased temperatures will be described. Both direct effects of increased temperature and secondary effects like the timing of the phytoplankton spring bloom and hence the availability of nutrients on physiological responses will be considered.
How is Ecosystem-Based Management entering Norwegian Coastal Zone Planning, and how will it affect Aquaculture Development?

**Arild Buanes** ¹, Eirik Mikkelsen ¹, Håkan T. Sandersen ²

¹Norut, Norway, ²Nord University, Norway

New or expanded space for aquaculture production is in Norway set aside through municipal-led coastal zone planning (CZP) according to the Planning and Building Act (PBA). Ecosystem-based approaches has increasingly been emphasized for marine resource management. This paper analyses the extent to which ecosystem-based management considerations are present in Norwegian CZP; in planning documents and/or processes. Our analysis is based on a study of recent inter-municipal CZP in Nordland and Troms counties in North Norway. Many Norwegian municipalities cover rather small areas. Because of this, inter-municipal planning may be seen as “scaling-up” coastal zone planning to an ecologically more relevant scale. Inter-municipal planning may be said to represent an “ecosystem shift” compared to single-municipality planning.

The PBA does not mention ecosystem or ecosystem-based management. Still, some have seen it as an already established demand also on CZP, for example in the 2012 conclusions of the largest (to date) Norwegian research project on integrated CZP. Through coastal zone planning the territorial regulations of municipalities is aligned with the functional management of national sectoral policies, some of which pursue more explicitly stated EBM ambitions. Since 1990 there has been a continually evolving demand for environmental impact assessments, including for establishing larger aquaculture facilities since 1997. From 2015, environmental impact assessments must be done in the CZP phase for proposed aquaculture areas. Such knowledge is introduced into the planning process that is mandated by the PBA to include broad popular participation, but also a growing reliance on presumably expert knowledge on ecosystem function and structure. In the absence of properly facilitated science communication, this may, exacerbate “knowledge wars” in planning and management.

The experiences from the recent planning processes will serve as a background to highlight challenges and possibilities emanating from a recent revision (2017) of the environmental impact assessment regulations, now demanding that also impacts on “ecosystem services” must be assessed. Due to the novelty of this requirement, it remains to be seen what this entails in practice. To clarify the probable implications of this is important for assessing the potentials for further aquaculture development in the north, and elsewhere in Norway.
Unlocking exposed locations for sea aquaculture activities with autonomy and remote control technology

**Walter Caharija, Leif Magne Sunde, Arne Fredheim**

_SINTEF Ocean, Norway_

Current state-of-the-art technologies and operations for sea-based aquaculture farms are highly dependent on manual labour, where the need for personnel to operate on fish farms is a risk factor for safety matters as well as a significant economic cost. Hence, new reliable technological solutions with more autonomy and remote control features by means of unmanned vessels can minimize personnel exposure time, reduce cost and improve regularity and planning of operations. Moreover, motivated by good water quality and lack of available sheltered locations, the industry is moving to more exposed areas and this renders manual work difficult and highlights the need for autonomous vessels, teleoperations and remote control. Autonomy and remote control technology can hence deliver the key to open areas that are exposed to harsh weather conditions to sea aquaculture activities.

Some automation and remote control solutions are already employed by the Norwegian salmon farming industry, resulting in higher yields and higher safety standards. For example, remotely operated vehicles (ROVs), deployed from manned service vessels, are now used to inspect and clean cage nets as well as inspection of mooring lines and anchors on a regular basis. Special ROV intervention tools for net repair exist as well, but these are very dependent of low wave state, and could not be considered as proven technology that are widely acquired by the industry.

This talk will present the ongoing activities within SINTEF Ocean in the fields of autonomy, remote control and robotics for sea aquaculture, since SINTEF Ocean has been investigating unmanned vessels and remote technology for application in aquaculture sites for the last 10 years where the most relevant concluded project is MerdROV (The Research Council of Norway project num. 217541). The scope of the MerdROV project was to develop navigation and station-keeping control systems for ROVs, for aquaculture specific operations such as net cleaning, inspection and repair. The results from full scale attempts indicate that a navigation system based on acoustic measurement principles can be used for navigation in full scale farms with large biomass and that holes in the net can be detected via computer vision algorithms. Given the promising results, a new generation of ongoing projects within autonomy and remote control followed: ARTIFEX (RCN project num. 256241), CageReporter (RCN project num. 269087), RACE and EXPOSED.
FEATURED TALK: Microalgae cell factories on the rise, trick or treat?

Hans Christian Eilertsen

UiT The Arctic University of Norway, Norway

The recent years we have witnessed increased focus on industrial mass cultivation and utilization of photoautotrophic microalgae. One conclusion that can be drawn from this is that there is a large diversity in the range of (suggested) products and applications, while unfortunately innovative bioreactor concepts are rather scarce or missing. In sum most mass cultivation initiatives must today be considered “pilots” or “well advanced plans”. If mass cultivation of microalgae shall have success, large scale industrial units (> 20 000 tons/year) must, for market reasons, be set up and must be profitable as well as environmental sustainable. Unfortunately such initiatives are, in our opinion, largely lacking from the scene.

One of the main reasons for the lack of progress here is that todays cultivated species have too low photosynthetic efficiencies. This can partly be improved by selection of species that allows for long light depths, i.e. large cells with high optical package effects, this combined with selection for efficient CO2 uptake. Also it is important that the reactor is cheap and favours efficient utilization of photons, and that the water that the algae are cultivated in are devoid of light absorbing dissolved organic material. Further the choice of species to cultivate suffers from the belief that “the safe thing to do is to cultivate the same species utilized by others”, e.g. small well-known green or bluegreen ones! Considering the large species and thereby size and chemical diversity that microalgae represents, this is a pity and a culprit that in many ways hinders further development towards profitable mass cultivation concepts. This can, we mean, be overcome by engaging traditional educated taxonomists and algae physiologist in the selection of species and strains, and encourage closer cooperation between biologists, biochemists and technological competence.

A potential profitable production scenario will here be illustrated with results from an ongoing mass cultivation research project integrated in the production line at the ferrosilicon producer Finnfjord as. The initiative is set up to sequester CO2 and NOx from the factory smoke by cultivation of lipid rich light efficient cold water diatoms, while the diatom biomass will be used as fish feed. Finally it will be focused upon that large biotechnology initiatives utilizing live organisms potentially are, by state environmental authorities, considered as being potential environmental treats, e.g. by release of “alien species”.

Arctic Frontiers 2018
Small creatures, big trouble - do jellyfish induce aquaculture losses in arctic fjords?

Claudia Halsband, Sanna Majaneva, Aino Hosia, Per-Arne Emaus, Frank Gaardsted, Qin Zhou, Ole Anders Nøst, Paul E. Renaud

1Akvaplan-niva, Norway, 2UiT The Arctic University of Norway, Norway, 3University Museum of Bergen, Norway

Blooms of jellyfish are becoming more common in many marine ecosystems worldwide, including the Nordic Seas. Despite rising concern, there is insufficient research into how this will impact the structure and function of marine ecosystems, or Norway's maritime industries, including aquaculture, a cornerstone of Norway's national economy and social development. Jellyfish can cause high mortality of farmed fish and hence significant economic losses for the aquaculture industry, but scientific documentation of this and regional economic loss statistics are sparse. On the other hand, jellyfish do provide ecosystem services: they are food for fish and other organisms, enhance the biodiversity of marine ecosystems, and are a source of bioactive compounds for the medical industry. Despite their socio-economic importance, distribution and diversity data on gelatinous plankton are scarce from Nordic marine systems, and jellyfish are not mentioned in most national and international marine management frameworks.

Intense blooms of jellyfish have repeatedly been observed in Ryggefjord, Finnmark (Norway), sometimes concurrent with severe health problems of salmon. Here, the jellyfish community of this fjord was studied in summer 2015. In July, at least 13 species were identified using a combination of morphological and molecular techniques. High densities of small Beroe spp. and ctenophore larvae in cydippid stage dominated the surface waters. Adult Beroe cucumis were also present. Molecular identification revealed the presence of juvenile Euphysa tentaculata, as well as two species of Clytia and Obelia, respectively. O. longissima was identified from both its pelagic (medusa) and benthic (polyp) stages, suggesting that some local populations can complete their entire life cycle in the fjord. Fish farms may in fact provide substrate for the benthic life phase and thus contribute to bloom formation. Location within the fjord and prevailing wind direction had significant influence on jellyfish abundances. A dense bloom of the hydrozoan Dipleurosoma typicum in September coincided with high mortalities of farmed fish, suggesting a causal relationship. Polyps of this species are obscure and have not yet been located. We conclude that the jellyfish assemblage in Ryggefjord is dynamic on short time scales and structured by both oceanographic conditions and local reproduction. A better understanding of seasonal population development and the relationships between hydrography, abundance and species composition is required to develop mitigation strategies for aquaculture operations.
SUSTAINable AQUAculture in the North: identifying thresholds, indicators and tools for future growth

Nigel Keeley 1, Astrid Harendza 2, Pia K. Hansen 1, Reinhold Fieler 2, Lars Asplin 1, Frank Gårdsted 2, Liv Plassen 3, Raymond Bannister 1

1Institute of Marine Research, Norway, 2Akvaplan-niva, Norway, 3NGU, Norway

The Norwegian salmon farming industry is expected to grow substantially in the near future with the largest expansion likely to occur in Northern Norway. It is critical for both, the national economy and the global reputation of the industry, that this is planned and managed effectively and sustainable. Benthic environments in these northern regions are thought to largely comprise hard and mixed bottom habitats dominated by epibenthic species assemblages. Unlike for infauna dominated soft-sediment habitats, tolerance levels of epibenthic species to farm-derived wastes are poorly understood, and currently, there is no approach for monitoring aquaculture related effects. This situation is compounded by a lack of basic information about the specific organisms present and their distributions along the Norwegian coastline. Thus, there is a clear and pressing need to increase our knowledge about potential interactions between farm wastes and the mixed and hard-bottom habitats of Northern Norway.

This presentation details a 4-year (2017-2020) research project, funded by the Norwegian Research Council, with the goal of identifying biological indicators and thresholds for organic enrichment on mixed and hard bottom ecosystems to aid the development future monitoring tools. An overview of the project will be given, highlighting its multidisciplinary approach, from habitat mapping and characterizing structure and function of mixed and hard bottom habitats to elucidating their responses to organic enrichment from fish farming. We will also demonstrate the use of dispersion models, specifically developed for Norwegian coastal waters, as suitable tools for the assessment of environmental influence on mixed and hard bottom habitats. In addition, we will present some preliminary results from the first research cruise in 2017 in Finnmark, which describe the dominant habitats and epibiotic organisms to facilitate selection for Phase 2 investigations.
Dispersion of salmon lice along the Norwegian coast

Ingrid Askeland Johnsen, Lars Christian Asplin

Institute of Marine Research, Norway

The Norwegian coastline is a complex system of fjords, narrows and sounds. Relatively warm water is transported northwards along the coastline by the Norwegian coastal current, providing favourable conditions for aquaculture of Atlantic salmon. The coastline is currently housing almost 1000 salmon farms that annually produce more than to 1 million tons of Atlantic salmon.

The infective parasite salmon louse (Lepeophtheirus salmonis) is a reoccurring problem for most salmon farms. In the well circulated fjords and coastal system the louse is rapidly transported between farms, where they can attach to a host fish from about 5 to 15 days past hatching.

A hydrodynamic salmon lice dispersal model has been developed as a part of the management strategy. The model covers the full coastline and by particle tracking, it predicts the dispersal of salmon louse to be highly variable. The transport is often several 10 of km during the planktonic life stages. The spatial and temporal variability in the water masses creates particles with positive buoyancy, or swimming ability, to converge in areas creating filaments with high particle density. Salmon lice swim towards the surface. They are therefore influenced by this mechanism and occur in spatially uneven fields with patches of higher concentrations.

By increasing knowledge of the aggregation of salmon lice close to the surface, and map the areas of where the high concentrations occur frequently, we believe that the aquaculture of Atlantic salmon along the coastline can be made strategic with minimization of lice infestations at farm sites by selective positioning of farm locations.
FEATURED TALK: Coexistence in coastal waters - benefits and challenges offered

Karin Kroon Boxaspen

Institute of Marine Research, Norway

The Norwegian coastal zone is a challenging area to govern. The variance form inner fjords to outer coastal areas and the south to north axis and differences from temperate to boreal environment means that not all approaches fit everywhere.

The pressure from human activities increases and raises important fundamental questions regarding management of biological values and nature habitats in the coastal zone. Focus areas like pollution, climate changes and overall effects on fish populations, plankton, macroalgae, crustaceans and sea mammals are all studied to address the issue.

There are many different user groups for any given area. Commercial and leisure fisheries, transport, aquaculture, tourism and leisure activities do all need space. There is a general challenge to let these coexist and area conflicts do easily arise. Access and use need to be regulated in an optimal way.

What kind of activities can coexist and where, where do we need one user area, where can they overlap and especially where can they interact in a beneficial manner?

To answer these questions, we need a toolbox with appropriate methods to describe and study the effects of human activities over time. The successive development of suitable indicators or proxies and politically agreed upon thresholds for acceptable impact is a vital part of the process towards a legislative framework for good management practise.

The benefits of optimal use of area in our coastal zone are high and need our full attention to be taken to its fullest potential. The challenges thus need to be addressed by all in a fruitful manner.
KEYNOTE: The early ontogeny of an eco-sustainable Nordic aquaculture sector: a strategy, some possibilities, common and uncommon pitfalls

Nathalie R. Le Francois

Biodôme de Montréal/Espace pour la vie, Canada

1. The challenges and opportunities facing the Canadian and Scandinavian aquaculture industry are very similar. However, striking differences exist that can for the most part explain the deceiving performances of the Canadian aquaculture sector. All provinces were not created equal and consequently have not relied on similar regulatory strategies and regulations to harness the potential of aquaculture development. Accusing a late start in fully grasping the challenges and opportunities, Québec claims to do thing differently. Eco-sustainability and social acceptance have been major obligations early in our short aquaculture history. However, these are remarkably in line with the social and environmental concerns of the new generation of consumers and the trends in the seafood industry. I will briefly present,

1. Québec’s aquaculture strategy and scope for development,
2. Examples of successful "soft aquaculture" initiatives that could very well become the much sought after "success stories" that will enable our aquaculture sector to reach a state of maturity that could lead us to successful finfish aquaculture initiatives and,
3. Why identified eco-sustainable, exclusive, well-adapted niche species such as the Arctic charr and the spotted wolffish should logically be the recipients of a significant fraction of our investments and efforts.
Aquaculture in the context of global food security -- what to feed the fish?

Erik-Jan Lock, Rune Waagebø, Livar Frøyland, Gro-Ingunn Hemre

NIFES, Norway

World per capita fish supply continues to increase due to vigorous growth in aquaculture, which now provides half of all fish for human consumption (FAO 2016). Aquaculture will likely play an even more important role in providing food security and adequate nutrition for the growing global population. To facilitate this growth, aquafeed producers require increasingly more raw materials. In salmon farming, the inclusion of fishmeal and fish oil per kilogram of aquafeed has decreased dramatically over the past decades and now the majority of the diet is from plant-based sources. Whilst this is a positive development when it comes to the amount of wild fish needed to produce farmed salmon, it has shifted the dependence of salmon farming from marine fish stocks to terrestrial production and hence competing with food producing industries for arable land. Moreover, the dietary content of specific micronutrients required by marine fish and most often found in the marine food chain have reduced. New nutritious feed ingredients that do not compete with already limited resources are required in order to grow the aquaculture industry sustainably. We will discuss feed ingredients that can come from fisheries, e.g. use of by-catch, slaughterhouse waste, krill and zooplankton; or from novel farming methods, e.g. insects, yeast, seaweed and microalgae. These resources either harvest biomass at a lower trophic level or make better use of waste streams in existing production chains. The latter is referred to as ‘upcycling’ of nutrients and is a central part of the circular economy. When placing aquaculture in the context of global food security, it is important to consider the whole production chain, from the raw materials to the composition of the fish fillet. Whilst fish have the ability to very efficiently refine feed resources into a highly nutritious food resource, the contribution of aquaculture to global food security will largely be determined by the sourcing of the feed raw materials.
Assessing the Functional Diversity of Benthic Communities using Metatranscriptomics

Amalia Mailli, Truls Moum, Henning Reiss

Nord Universitet, Norway

Marine benthic communities constitute an important part of the marine seafloor environment, as they are involved in a multitude of important ecological processes such as geochemical cycling and the distribution of pollutants. Studying these communities in situ and exploring their activity down to the gene level can reveal insights into their functional role within the benthic ecosystems. Our aim is to investigate the molecular profile of benthic communities exposed to organic effluents from aquaculture farms by comparing the expression levels of selected genes at impacted and non-impacted sites. We use a metatranscriptomic approach, i.e. the analysis of the complete RNA contents of benthic organisms contained within environmental samples. We hypothesize that the effect of organic effluents will be reflected in the metatranscriptome of the benthic community; indicators such as stress signals and metabolic pathways will vary between affected and controlled sites as a response to environmental stress. While bacterial communities of environmental samples have previously been studied by similar approaches, our study includes both the prokaryotic and eukaryotic constituents of the benthos.

We collected sediment samples from two locations that are affected by salmon farm effluents in a Norwegian fjord. We extracted the total RNAs from sediment samples and obtained adequate amounts of the prokaryote and eukaryote communities for functional analyses. The sequencing and bioinformatics part of the study is currently underway and preliminary results show that there are sufficient eukaryotic mRNA sequences for the subsequent functional diversity analysis. A successful workflow established by this project could facilitate future studies of ecosystem functioning as it can provide accurate, detailed and fast insights into the functional responses of benthic communities.

In addition, we are investigating the effect of aquaculture effluence on two model organisms, the polychaetes Capitella capitata and Scoloplos armiger. The former is a widespread polychaete that commonly dominates areas with high organic load, while the latter has a life mode similar to C. capitata (e.g. subsurface deposit feeder), but is mainly found in habitats with lower organic input. Under experimental conditions, both species will be immersed in organically enriched conditions that simulate natural (algae-derived) and aquaculture (fish waste-based) organic enrichment. Using the polychaetes' transcriptomes, we will analyse their gene response to the different treatments. The latter project will serve as a “focus-species” model in comparison to the “community” model of the former, assessing the strengths and weaknesses of those two approaches.
Kelp cultivation above the Arctic Circle

Sanna Matsson 1, Anna Metaxas 2, Bodil Bluhm 3, Hartvig Christie 4, Reinhold Fieler 1, Silje Forbord 5, Aleksander Handå 6

1Akvaplan-niva, Norway, 2Dalhousie University, Canada, 3University of Tromsø, Norway, 4NIVA, Norway, 5SINTEF/NTNU, Norway, 6SINTEF Ocean, Norway

In the future, there will be an increased demand for human food, animal feed and biofuels as well as a need for new cultivation areas. Kelp cultivation offers a potential for all three products, without needing fresh water, land areas and fertilizers. At the same time, kelps have one of the highest growth rates in the world. The MACROSEA project is a Norwegian Research Council-funded 4-year project designed to build a knowledge platform for industrial macroalgae cultivation in Norway that is combining biology, technology and modelling tasks. As part of the MACROSEA project, we have been collaborating with local kelp farmers to explore the potential for Saccharina latissima cultivation along the Norwegian coast at a total of ten sites from 58 °N to 69 °N. We used local genetic material pre-cultivated at the same lab, transferred to all study sites at the same time and cultivated in similar rig set-ups in the sea. Here growth and biofouling were quantified each 2nd to 3rd week throughout the whole growth season of 2017. S. latissima produced highest biomass furthest north due to a combination of later settlement of biofouling organisms settling or grazing on the biomass and good growth conditions. The preliminary results from this co-operation show that there is a good prospect for biomass production along the Norwegian coast, with an extended growth season north of the Arctic Circle.
Promises, promises... The use of licences to manage Norwegian Salmon Aquaculture

Eirik Mikkelsen ¹, Bjørn Hersoug ²

¹Nofima, Norway, ²UiT The Arctic University of Norway / Nofima, Norway

Norwegian salmon aquaculture has come a long way since its beginnings in the 1960s and 70-ies. From small-scale operations run by one person to today’s industry dominated by international companies with hundreds of millions of Euro in turnover. Along the way, the industry’s impacts have also changed a lot. This includes on local and national economy and employment, and not least the environmental impacts and risks. To try to manage the impacts and risks, salmon aquaculture requires a license from the state. These have been issued in license rounds. With increasing profitability in the industry, the competition for the licenses have increased. The rounds have been announced with varying objectives or concerns that the authorities want to achieve and the licensees to contribute to. These have included to combat fish disease or salmon lice, or to promote innovation, rural development or small companies, to name some.

The cost of getting a licence has varied over time, geography and type of license. Some actors have obtained large windfall gains by selling their granted license to others. This has clearly influenced later license rounds. Auctions have supplemented the previous praxis of fixed licence prices, and limitations on moving licenses have sometimes been set.

We present an analysis of the objectives in the licensing rounds announced from 2002 to 2013. We consider how each round of licenses have incorporated various central concerns, and how political motivations of shifting governments have influenced this. We also investigate to what extent conditions for awarded licenses are controlled and monitored by the authorities and if and how any breaches have been sanctioned. We conclude by discussing if the licencing system is a suitable instrument for meeting the objectives that the authorities have for the aquaculture industry in Norway.
Impact assessments in Norwegian Coastal Zone Planning

Eirik Mikkelsen \(^1\), Patrick Berg Sørdahl \(^1\), Sanne Bech Holmgaard \(^2\), Bente Sundsvold \(^3\)

\(^1\)NOFIMA, Norway, \(^2\)NIKU, Norway, \(^3\)UiT The Arctic University of Norway, Norway

Coastal zone planning (CZP) processes in Norway must since 2015 include impact assessment of proposed aquaculture areas (and similar which may have "significant impact on environment and society"). The assessments must consider possible impacts on resources, interests and stakeholders. In academic and government publications, this is increasingly often coined ecosystem services. There is not a standard method to do impact assessments in CZP in Norway. Various IA guidelines and methods have been used for different CZP processes. Impact assessments should be structured and transparent to ensure legitimacy of the process and its outcome. For efficiency in the prioritizations and trade-offs made, the methods to determine and value possible impacts must be harmonized. This should be across proposed aquaculture areas/localities in one CZP process and across different CZP processes.

This paper analyses the methods and outcomes of impact assessments in two inter-municipal CZP processes in Norway. They involved 13 and 5 municipalities, and 109 and 34 aquaculture areas that were impact assessed, respectively.

We consider the systematic approach described for these two CZP processes. We analyse the methods to assign value to various resources and interests and to consider impacts (of aquaculture) to see if some classes or types of ecosystem services are considered more or less objective, that is, based on verified or verifiable data, and with clear valuation/assessment rules. Further, we also analyse the overall outcome of the IA process for each area/locality, to assess to what degree there seems to be consistency in each CZP process and across the two processes regarding valuation, prioritization and trade-offs.
Heterotrophic microalgae - the potential for cultivating cold - adapted varieties

Daniela Morales-Sanchez 1, Alfredo Martinez 2, Christopher Hulatt 1, Rene Wijffels 3, Viswanath Kiron 1

1Nord University, Norway, 2Instituto de Biotecnologia, Mexico, 3Wageningen University, AlgaePARC, Netherlands

Algae are photosynthetic organism that can convert CO2 to a variety of compounds that could be used as food, feed, high-value chemicals and biofuels. The growing interest in cultivating microalgae for new bio-based industries in Norway has spurred research interest in identifying algae species suitable for the local climatic conditions. During winter season when the light efficiency is low, the microalgae productivity may be poor. Therefore, it is important to consider cultivation of heterotrophic microalgae, which use dark conditions and sugar as carbon and energy sources, as an alternative. In comparison with phototrophic growth and under heterotrophic conditions, growth rates, final cell number, cell mass and lipid content, including DHA and EPA, can be significantly increased depending on the selected strain of microalgae.

We present here the optimization of the cultivation of Neochloris oleoabundans (UTEX 1185), a freshwater edaphic microalga, as a concept for application to cold-water microalgae species. As an example of a successful process under heterotrophic conditions, the performance of growing in batch and fed-batch cultures with glucose as the only carbon source was characterized.

Batch and fed-batch cultures were carried out in shake flasks and dark stirred tanks with N. oleoabundans, using a mineral medium and glucose at different concentrations. N.oleoabundans was able to grow using glucose. Batch cultures with an initial glucose concentration of 3g/L allowed increasing the cell number 3.5-times in comparison with phototrophic cultures. Under these conditions, there was no nutrient limitation and the major cellular component was protein. At high glucose concentration (50g/L) and nitrogen limitation in batch cultures there was a four-fold increase in dry cell weight (DCW), cell mass productivity was 1.03g DCW/L/day; and lipid accumulation was enhanced up to 50% of the DCW. Exponentially fed-batch cultures controlling the microalgal growth rate allowed us to optimize the process and obtain the highest cell mass productivity (1.9g DCW/L/day) and global lipid productivity (1.02g LIP/L/day) reported to date for N. oleoabundans under phototrophic or heterotrophic conditions.

The experience gained from this study will enable us to develop suitable culture strategies for cold adapted microalgae, to develop them especially as feed sources for the aquaculture industry.
Can the cod farming in Norway be resurrected?

Atle Mortensen, Velmurugu Puvanendran, Øyvind J. Hansen

Nofima, Norway

Farming of Atlantic cod (Gadus morhua) in Norway had a tremendous development from year 2000 to 2008. Twenty commercial hatcheries with a production capacity of at least 70 million juveniles were established during the first two years of this period. The optimism for cod farming was based on the trust that the major production challenges were solved and that low quotas for wild cod and corresponding high prices for cod would prevail. None of these assumptions proved to be true. The intensively produced fish had high mortality at larval stage and the mortality continued in the sea cages, in some cases exceeding 50%. Growth rates were lower than expected and occurrence of skeletal deformities were high. Escapes from the sea cages were common, and losses due to diseases like vibriosis, atypical furunculosis and fracisellosis were severe. Because of these issues, the cod farming industry did not have the strength to resist when the financial crises appeared in 2008 together with lower cod prices (due to higher quotas for wild cod). Hatchery production of cod peaked in 2008 at 22 million juveniles and slaughter volume in 2010 at 20000 tons. The last commercial cod farm stopped production in 2014.

The National Cod Breeding Program was established in 2002. It is financed by the Ministry of Trade, Industry and Fisheries and managed by Nofima in Tromsø. Unaffected by the turmoil in the commercial cod farming industry, the breeding program has improved production traits of farmed cod from 2002 and until today. The results are a more domesticated farmed cod with higher growth rate, less deformities and higher disease resistance. Concurrent improvements of the production protocols for juveniles have resulted in substantially higher survival rates during the larval and juvenile stages. Losses during the cage production phase is now equal or less than that of farmed salmon, and experience from the market indicates that farmed cod can achieve higher price than wild cod. Thus, many of the factors that caused the disaster of the cod farming some years ago have now subsided. Three commercial companies in Norway have started small-scale cod farming again in the last two years. Experience from these companies will indicate if cod farming can be feasible in the future, but the prospects are better than ever before.
Forecasting the impact of salmon lice on wild salmonids, setting the stage for sustainable growth in salmon aquaculture

Mari Myksvoll, Anne Sandvik

Institute of Marine Research, Norway

The Norwegian government has decided that the aquaculture industry shall grow, given that the growth is environmentally sustainable considering the impacts of salmon lice on wild salmonids. The salmon-lice-infestation-pressure has traditionally been monitored through catching wild fish on specific predefined locations. Despite that, a substantial dataset has been collected this way over the years; the Norwegian coast is too long and the variations too large for efficient sampling of the entire coast. We have therefore developed an operational salmon lice model that calculates the infestation pressure all along the coast in near real-time based on a hydrodynamic ocean model and a salmon lice particle-tracking model. Concerning quality, we will show good comparisons between model and observations for both hydrographic properties and salmon lice dispersion when evaluated against observations on wild caught trout. By using two complimentary data sources, the operational model and wild fish data, we can provide an improved monitoring system for assessing risk and sustainability that forms the basis for knowledge-based advice to management authorities.
Modelled salmon lice dispersion and infestation patterns in a sub-arctic fjord system

Jofrid Skarðhamar, Jon Albretsen, Anne D. Sandvik, Vidar Lien, Mari S. Myksvoll, Ingrid A. Jonhnsen, Lars Asplin, Bjørn Ådlandsvik, Elina Halttunen, Pål Arne Bjørn

Havforskningsinstituttet, Norway

Salmon lice infestation is a major challenge for the aquaculture industry in Norway, threatening wild salmonid populations and causing welfare problems for farmed salmon. The planktonic phase of salmon lice larvae lasts more than two weeks in sub-arctic fjords, and a louse has the potential to be transported far from where it hatched. Lice dispersion and infestation patterns can be estimated with numerical models, and a model system combining a high resolution numerical ocean circulation model with an individual-based model for salmon lice, has been developed for the Norwegian coast and fjords. We present model results from the fjord Altafjorden in Finnmark, Northern Norway. The fjord hosts several fish farms, and is an important area for large stocks of wild salmon, sea trout, and char. The inner part of Altafjorden is therefore protected as a National Salmon Fjord, where no salmon farms are allowed. The model simulations demonstrate how the ocean currents can disperse lice from aquaculture farms and into the protected part of the fjord. Our results show that the present regulations regarding salmon lice is not sufficient to protect wild salmonids from lice in a future with increased salmon production, not even in the protected part of the fjord. Further, the model illustrates how farms in different parts of the fjord contribute to lice dispersal and potential infestation of each other, depending on their locations relative to the circulation patterns in the fjord. Knowledge of how the highly variable water currents disperse salmon lice within fjord systems is necessary for managing farm locations and production quotas if the goal is to minimize infestation pressure on wild salmonids and between fish farms.
Potential of the microalgae *Scenedesmus sp.* in feed for Atlantic salmon

Mette Sørensen 1, Tharindu N B Herath 1, Yangyang Gong 1, Mark Huntley 2, Zackary Johnson 2, Viswanath Kiron 1

1Nord University, Norway, 2Duke University, USA

Availability of high quality protein and lipid ingredients to support future growth of Atlantic salmon farming is a challenge. In recent years, fishmeal and fish oil is largely replaced with plant-derived ingredients in feeds for salmonids. Plant ingredients in carnivore fish diets have nutritional limitations and sustainability is also debated. There is an increasing interest in use of novel marine ingredients to supply both lipid and valuable amino acids in feeds for fish. The aim of the present study was to investigate the potential of using the microalgae *Scenedesmus* sp. in low fishmeal diets for Atlantic salmon.

Three diets were formulated with microalgae *Scenedesmus* sp. incorporated at zero (Ctrl), 10% (SCE 10) and 20% (SCE 20) partly replacing fishmeal in low fishmeal diets. Effect of inclusion level was studied on growth, feed utilization, nutrient digestibility and physical quality of feed. Fish with an initial average weight of 229.1 ± 1.5g were fed the experimental diets in six replicates for 65-days, in a combined growth and digestibility study.

The results showed that fish fed with SCE 20 had significantly lower weight gain and specific growth rate and feed intake than those fed with the Ctrl. Retention of lipid differed among all groups while retention of protein and energy was significantly lower in fish fed SCE 20. Digestibility of dry matter, protein and energy was significantly different among all the three dietary treatments.

In conclusion, *Scenedesmus* sp. can be used at 10% inclusion in diets for Atlantic salmon without negative effect on growth, nutrient retention and physical quality of feeds.

Acknowledgment: This work was partly funded by project Marine Algae Industrialisation Consortium: Combining biofuel and high-value bio products, granted to Duke University by the US Department of Energy (Grant DE-EE0007091).
Hydrodynamic Model as Tool for Better Management of Aquaculture in North Conditions

Alena Timoshina, Valery Chantsev

Russian State Hydrometeorological University, Russia

Nowadays, aquaculture is one of the fastest growing industries. Aquafarms are complex systems that include biological, physical, chemical, technical and anthropogenic components. In areas of high latitudes, it is much more difficult to monitor the stable functioning of the system, especially in condition of a changing climate. Each seemingly insignificant detail could be a determining factor for the successful development and growth of healthy aquatic organisms. The hydrodynamic regime of waters plays a vital role at all stages of the fish and other aquatic organism’s lifecycle. The values of the flow velocity and the turbulent vorticity, which formed inside cages, affect the processes of the vital activities of fish, their ability to move, to respiration and bioproductivity in general. On the other hand, the construction of the aqua farm also can affect the hydrodynamic regime in coastal area. Therefore, at the initial stage of planning the aqua farms several calculations are needed to estimate the impacts of new installations in the area of interest. The use of numerical modelling is best suited for solving this problem, supporting the optimization of location, size, shape and type of underwater constructions. Due to size of farms vary within tens of meters, a small-scale model is needed (that can perform simulations with spatial steps equal to several centimetres or one meter).

The authors developed a new three-dimensional small-scale hydrodynamic model. The purpose is to identify features of hydrodynamic regime in coastal area considering the existence of submerged structures. The present model is not hydrostatic allowing more accurate assessment of vertical movement processes. It also uses deterministic differential Reynolds’s equations of averaged turbulent flow. The complete parameterization of Smagorinsky is applied to describe the coefficients of turbulent vorticity. The explicitly implicit scheme is used for the time numerical solution, while the finite difference method is considered for the spatial solution.

Such kind of study helps to establish an improved strategy for creating the best conditions for aqua farms and this ultimately leads to an increase in the bioproductivity of each crop, as well as to an increase in the efficiency of the installation of underwater structures intended for aquaculture.
FEATURED TALK: Future Food and Feed from Marine Sources

Bente E. Torstensen

Nofima, Norway

Global demand for food increase with increasing world population, and modern aquaculture is part of the solution for global food security. Today, fish and seafood account for less than 10% of the global protein sources produced. This stands in contrast to that 70% of the earth is oceans. Seafood is a source of protein but in addition, seafood contributes with essential minerals, vitamins, and omega-3 lipids necessary for good human health. Thus, we need to explore increased use of known and new sources of food and feed ingredients to meet future demand for safe and nutritious seafood.

Growth in food from marine sources require full flexibility in choice of feed ingredients to meet increasing feed volume demand. To meet this challenge, we need knowledge on nutrient requirements, raw material properties and feed technology.

Traditionally, farmed Atlantic salmon protein, energy and essential nutrient requirements were met by using fish meal and fish oil as the main feed ingredients. However, these are resources with a stable (at best) and limited supply. In aquaculture of Atlantic salmon, the need for increased feed and feed ingredients have so far been met by replacing fish meal and fish oil with plant proteins and lipids. This has been possible through research on nutrient requirements and feed technology, and developing ingredients to meet these requirements. However, to meet the increasing feed demand for future aquaculture new sources of proteins, energy, and essential nutrients including marine omega-3 lipids is required.

Atlantic salmon is a good source of omega-3, and this is maintained when feed ingredients change since salmon have their own minimum requirements of marine omega-3 fatty acids to ensure good growth, health and product quality. The omega-3 lipids in fish feed have traditionally been supplied by fish oil produced from pelagic species such as anchoveta, herring and menhaden. The supply of omega-3 from fish oil will not be able to meet future demand, and therefore we need to look beyond the traditional omega-3 sources and develop new plant and animal sources. Today, marine micro- and macroalgae, mesopelagic fish species, insects, GM oils, and PAPs are only some examples of developments towards future food and feed from marine sources.
Interactions of salmon farming on Atlantic cod spawning grounds

Terje van der Meeren, Jon Egil Skjæraasen, Mari S. Myksvold, Geir Dahle, Esben M. Olsen, Ørjan Karlsen, Raymond Bannister

Institute of Marine Research, Norway

There is increasing focus on finding optimal areas for fish farming of Atlantic salmon and rainbow trout in open cages in Norwegian fjords, along the coast and in Northern Norway. The potential for overlapping fish farming installations with areas that are important spawning/nursery areas for commercial fish species (i.e. Atlantic cod) may have implications for the success of these spawning and juvenile nursery grounds and subsequently may influence the long-term health and fitness of commercial fish species. Atlantic cod is one of the species that can be influenced by the presence of the aquaculture industry. With the growth of aquaculture, it is anticipated that the competition for use of coastal area between aquaculture, fisheries, and other interests will escalate in the coming years and it is important to understand the potential interactions.

This presentation details a large 5-year (2015-2020) research project focusing on understanding if the establishment of fish farming activities near a known spawning ground of Atlantic cod will affect the migration of adult cod and their spawning and recruitment success. This project is multidisciplinary in nature, using a combination of research methodologies to disentangle the effects of fin-fish aquaculture on cod spawning grounds. Here we discuss the use of 1) acoustic telemetry to study adult spawning cod behaviour, 2) spatial and temporal sampling of cod eggs and juvenile fish, 3) DNA identification of spawning cod, cod eggs and juvenile cod and 4) sampling of benthic environmental health. This data is combined using state-of-the-art-modelling tools to increase our understanding of the interactions of coastal aquaculture with cod spawning grounds, and to predict changes in spawning and juvenile populations. This presentation will present recent data on observed changes in cod spawning/juvenile nursery grounds and shifts in benthic environmental health due to the establishment of the fish farm.

The project results presented here are important new knowledge that are essential for addressing the needs for managing natural resources and environments along the Norwegian coastline with the development of the aquaculture industry, as outlined by the Norwegian authorities.
FEATURED TALK: Current challenges and future opportunities for exposed salmon farming in Norway

Hans Vanhauwaert Bjelland

SINTEF Ocean AS, Norway

Significant parts of the Norwegian coast are today unavailable to industrial fish farming due to remoteness and exposure to harsh wind, wave, current and ice conditions. Regular as well as infrequent operations are challenging. The Exposed Aquaculture Operations research centre (EXPOSED) draws upon its industrial and research partners to enable safe and sustainable seafood production in exposed coastal and ocean areas.

Firstly, this presentation will give an overview of challenges with farming at current exposed locations with dominant production technology. Our research has uncovered key risk factors to fish welfare, workers health and safety, and operations. Shortcomings in current knowledge and design methods will be described.

Secondly, the presentation will present general trends in a current surge of development projects exploring novel production technologies. These technologies cover both floating closed containment systems and large-scale rigid offshore units. The high rate of innovation is driven by a combination of:

1. An ambition to increase salmon production and utilise the whole coast, given that key environmental and wellbeing challenges are addressed
2. High salmon prices and low oil prices and suppliers to the oil & gas sector looking for other industries
3. A new opportunity for farmers to apply for development concessions regime that drives innovation towards technological concepts for more exposed farming.

Thirdly, research on how to obtain reliable quantitative descriptions of the physical environment on exposed locations for use in design and dimensioning of fish farms will be presented. Various analytical and experimental methods have been used to study the degree of exposure at Norwegian farms. It has been shown that the existing methods give large variations in estimates.
FEATURED TALK: Future Food and Feed from Microalgae

Rene Wijffels $^1$, Chris Hulatt $^2$, Mette Sørensen $^3$, Viswanath Kiron $^3$

$^1$Nord University & Wageningen University, Norway, $^2$Wageningen University & Colorado School of Mines, Netherlands, $^3$Wageningen University, Netherlands

Currently fish feeds rely on marine proteins and oils of animal origin. The dependence on these sources is not sustainable as these ingredients are also human food sources. Hence, it is important to identify new ingredients, preferably from non-conventional aquatic sources, as potential components for feed.

Microalgae are single-cell factories that offer excellent opportunities for producing fish feed ingredients. Currently we are summarizing results from several experiments testing defatted marine microalgal species, biomass from bio-refineries, in feed for Atlantic salmon. The results are promising.

Yet there remain a number of technical challenges for their widespread commercial implementation. At present, relatively few species of microalgae have been studied for large-scale biomass production. We present our on-going studies illustrating the potential value of cold-adapted species of polar microalgae for biotechnology, including synthesis of novel products and potential for increased growth rates under cold-climate conditions. In our first experiments, extremophilic Arctic microalgae were tested to establish whether satisfactory growth and lipid production could be obtained at very low water temperature.

The maximum productivity reached was comparable to mesophilic strains and lipid content up to 39% was attained with the snow alga *Chlamydomonas pulsatilla*. The neutral lipids of each species were comprised by a large proportion of mono- and polyunsaturated fatty acids, which may find applications in industrial production. Overall, the results indicate that selection of varieties of microalgae from polar environments may provide great opportunities.
The New Arctic in the Global Context
Observation and model synthesis: Combining observations and radiative transfer modelling to analyse penetrating shortwave radiation through sea ice within the Community Earth System Model

Alexandra Arntsen, Donald Perovich

Dartmouth College, USA

An important goal of large-scale global climate models is to incorporate observational data from multiple platforms into a comprehensive and rigorous description of interacting processes that can be used as a powerful predictive tool. To improve the functionality and precision of these models, parameterization and configuration considerations for a changing Arctic should be prioritized in the analytical framework of observational experiments in this region. In this study, we examine the partitioning of penetrating shortwave radiation within Arctic sea ice and observe how seasonal and spatial variability of the in-ice and under-ice light fields can have an impact on total surface energy budget, ice algae bloom dynamics, and overall primary production. Our analysis is guided by output from the Community Earth System Model (CESM) and utilizes a multiplatform observation suite as well as independent radiative transfer modelling to assess and scale optical properties of sea ice in the Beaufort and Chukchi Sea regions. We characterize light available to springtime algal blooms and bio-optical feedbacks related to a younger ice cover. Incorporated into CESM, our results demonstrate how pronounced physical changes associated with a warming Arctic can have an effect on both regional ecology and the greater Arctic energy budget.
Emerging physical and biological properties in a new Arctic ice regime

Philipp Assmy¹, N-ICE2015 team²

¹Norwegian Polar Institute, Norway, ²N-ICE2015, Norway

One of the most prominent manifestations of climate change is the drastic decrease in Arctic sea-ice thickness and summer sea-ice extent. These fundamental changes in the physical properties of the ice pack will have unforeseen consequences for the entire Arctic marine food web. During the Norwegian young sea ICE (N-ICE2015) drift expedition from January to June 2015, we studied ice-algal and phytoplankton blooms under the new ice regime in the Arctic Ocean north of Svalbard, consisting of young ice, first- and second year ice. The most pertinent emerging physical properties observed during N-ICE2015 were the thinner and more dynamic ice pack, relatively thick snow cover, and the frequent formation of leads and ridges due to a more dynamic thin ice pack. This regime shift was reflected in the fact that light penetration through the open leads allowed for a phytoplankton bloom to develop in late May despite the snow-covered sea ice. On the other hand, ice-algal assemblages that developed in the high-light young ice environment of a refrozen lead were characterized by elevated levels of UV-protecting compounds, indicative of light stress by the shade-acclimated ice algae. The ice algal bloom of the young lead ice was apparently facilitated by recruitment of ice algae from adjacent older ice, highlighting the importance of the older ice for seeding of the ice algal bloom. Empirical and model results suggest that maximum growth rates of ice algae will increase whilst vertically integrated NPP and biomass will decrease under the thinner ice regime, as a result of the predictable increase in the area covered by refrozen leads in the Arctic Ocean. Furthermore, we have identified pressure ridges as biological hotspots which merit further investigation as the probability of their formation is expected to increase under the new, more dynamic Arctic sea ice regime. The heavy snow load on the sea ice caused negative ice-freeboard throughout the drift. In early June this led to infiltration of seawater through cracks in the ice and growth of phytoplankton at the snow-ice interface. These snow-infiltration communities have rarely been reported from the Arctic and could be another harbinger of a new Arctic sea ice regime. The observed changes in ice algal and phytoplankton bloom dynamics will potentially have cascading effects on the entire Arctic food web and may alter the uptake and release of climate-relevant gases from ocean and sea ice.
The AmP project: a Framework for integrating Eco-physiological data into marine ecosystem-based management tools

**Starrlight Augustine**¹, Konstadia Lika², Laure Pecquerie³, Goncalo M. Marques⁴, Sebastiaan A. L. M. Kooijman⁵

¹Akvaplan-niva, Norway, ²University of Crete, Greece, ³IRD, France, ⁴Instituto Superior Técnico, Portugal, ⁵VU University, Netherlands

The role of biodiversity in ecosystem structure and functioning is crucial for conservation and environmental quality management, as well as biospheric and system earth studies. Scientists are turning towards trait based approaches to tackle this issue by investigating for example which traits make a particular species invasive, or else make it resistant (or sensitive) to pollution or climate change, which traits co-exist under what circumstances...

We present in this talk a rigorous trait based approach that aims to: (i) find the simplest organisation principles for metabolism upon which all life is based and (ii) understand taxon-specific patterns as variations on this common theme. This approach is the AmP project: ‘Add-my-Pet’ database of Dynamic Energy Budget (DEB) models, parameters and referenced underlying data for animals. AmP started in 2009 and, to date, 120 authors submitted entries to the collection. In the context of the NFR project "Framework for integrating Eco-physiological and Ecotoxicological data into marine ecosystem-based management tools" we included many new arctic species like snow crab, shrimps. Auks, reindeer, seals, whales, Greenland shark etc.

The DEB models proved to fit data well, the mean relative error is less than 0.1, for 785 animal species at 2017/09/06, including some extinct ones, from all large phyla and all chordate orders, spanning a range of body masses of 16 orders of magnitude. Each DEB parameter has a clear link with one underlying physiological process and the combination of parameters covers all aspects of energetics throughout the full life cycle of organisms, from the start of embryo development to death by aging. These aspects include feeding, digestion, storage, maintenance, growth, development, reproduction, and aging.

DEB models apply to all life on earth and allow us to compare species on the basis of (functions of) parameters of that model. AmP comprises the methodology and code that allows estimating the parameters for any animal species. This talk presents the rapidly extending AmP collection on the web, presents new code that analyses patterns in parameter values of species and discusses the application of AmP as a framework for integrating eco-physiological data into ecosystem-based management in the Arctic.
KEYNOTE: On the Complex Implications of Melting Arctic Sea Ice

David Barber

University of Manitoba, Canada

The Arctic continues to experience an unprecedented reduction in the thickness and extent of sea ice; a transformation from a multiyear to first-year dominated ice type; and increased mobility of sea ice through a range of time and space scales. Polar nations are challenged not only by the magnitude and rate of this change, but also by counterintuitive effects. In this paper I provide examples from the recently completed Snow, Water, Ice, and Permafrost Assessment (SWIPA – 2017) as they pertain to physical, biological and geochemical implications of current and near future changes in sea ice. I provide examples of how complexity in changing sea ice thermodynamics affect sea ice dynamics creating counterintuitive effects in terms of climate feedbacks, polynya processes, ice hazards and marine shipping. I conclude by presenting some new major programs recently funded in Canada that will significantly increase our ability to engage internationally in Arctic Science.
The EU Arctic Cluster - Implementing the European Arctic Policy

Nicole Biebow 1, Jeremy Wilikinson 2, Stein Sandven 3, Steffen Olsen 4, Thomas Jung 1, Hugues Lantuit 1, Margareta Johansson 5

1Alfred-Wegener-Institut, Germany, 2British Antarctic Survey, UK, 3Nansen Environmental and Remote Sensing Center, Norway, 4Danish Meteorological Institute, Denmark, 5Lund University, Sweden

In April 2016, the European Commission (EC) and the High Representative published an integrated European Union policy for the Arctic, outlining the European Union’s interest in playing a key role in the region. With this strategy, the European Commission identified three priority areas: Climate change and safeguarding the Arctic Environment; Sustainable Development in and around the Arctic; and International Cooperation on Arctic Issues. In addressing these areas, the EU states its intent to attach particular importance to research, science and innovation and as such to continue to function as a major contributor to and funder of Arctic research.

As a result of this intention, the EC is investing in a broad package of Arctic research activities in Horizon 2020, which are called the EU Arctic Cluster. All projects belonging to this cluster contribute with societal relevant knowledge, which enables informed decision making within the framework of the European Arctic Policy and operate in close cooperation with international partners.

The EU Arctic Cluster comprises seven projects. EU-PolarNet, which as a coordination and support action supports the EC in all questions related to Polar issues and will develop a European Polar Research Programme co-designed with all relevant stakeholders. ICE-ARC, which looks into the current and future changes in Arctic sea ice – both from changing atmospheric and oceanic conditions. The project also investigates the consequences of these changes on the local and global economy, and their social impacts on for example indigenous peoples. Furthermore, four large research projects focussing on developing an integrated Arctic Observing system (INTAROS), on the effects of Arctic change on lower latitudes (APPLICATE and Blue Action) and on the effects of climate change on Arctic permafrost (Nunataryuk). The Arctic Cluster is completed by the two infrastructure projects INTERACT and ARICE. The International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT offers trans-national access to 79 terrestrial field bases in northern Europe, Russia, US, Canada, Greenland, Iceland, the Faroe Islands and Scotland as well as stations in northern alpine areas. The Arctic Research ICEbreaker Consortium (ARICE) aims at providing the Arctic research community with better research icebreaker capacities for the Arctic and will offer trans-national access to six research icebreakers working in the ice covered Arctic Ocean.
Participatory risk and vulnerability assessment to decrease uncertainties in Arctic weather and sea-ice forecasting

Berill Blair, Machiel Lamers

Wageningen University, Netherlands

We are witnessing significant temperature shifts and sea-ice loss in the Arctic. While Arctic weather and sea-ice predictions have been the focal point for a number of recent partnerships and projects, significant gaps remain between scientific observations and user needs. Maritime operational and tactical planning greatly depend on weather and sea-ice forecasting information, while it is becoming increasingly challenging to model the spatial and temporal variability of Arctic weather patterns and sea-ice hazards. Aside from the uncertainties inherent in met-ocean models, the saliency and usability of information greatly impact the level to which forecasting data and tools may act as decision support for users. On the user side, several attributes impact what pathways are most effective in receiving, analysing and utilizing forecast information products and tools. For example, vulnerabilities to users’ long-term interests that stem from uncertain weather and sea-ice forecasts and impact the focus of planning and risk-avoiding behaviours. These vulnerabilities may differ cross-sectorally, as does the resolution at which information is useful. In short, it is vital that available information –long-term and operational planning tools – are maximized to improve safety, identify uncertainties, guide decisions; while being interoperable across sectors.

Through analysing the network of data users and producers, their linkages and interactions; SALIENSEAS (Enhancing the saliency of climate services for marine mobility sectors in European Arctic seas) undertakes mapping the network connections that underpin Arctic information systems. It probes existing arrangements for users to receive information, the margins that define uncertainty for users, how these risk thresholds impact risk assessment and planning, and ways to use these insights to improve tools and services. This paper reports on the first phase of the project, and progress made on a risk and vulnerability assessment of key stakeholders. The assessment integrates spatial and temporal variables that impact stakeholder interests, delineates the critical infrastructures and key resources that drive risk-informed decisions, and identifies key information that may increase certainty in decision making. The vulnerability assessment is discussed as an avenue to extract target variables for observation, and implement an iterative, participatory product development process.
Improving Met Office seasonal predictions of Arctic sea ice using satellite thickness observations with application to shipping

Ed Blockley, Drew Peterson, Nicolas Fournier

Met Office, UK

Met Office seasonal predictions are made daily using the GloSea coupled forecasting system. The ocean and sea ice are modelled using the NEMO and CICE models and are initialised using the FOAM ocean-sea ice operational analysis system. FOAM assimilates satellite and in-situ observations of temperature, salinity, sea level anomaly and sea ice concentration using the NEMOVAR 3D-Var scheme. Sea ice thickness is not yet assimilated but the Met Office are currently developing capability to assimilate sea ice freeboard and thickness observations from CryoSat-2 and SMOS sensors within the NEMOVAR 3D-Var framework.

Here we present the findings of a recent study undertaken to assess the impact on the evolution of sea ice seasonal forecasts of initialising with CryoSat2-derived thickness observations. We will show that the initialisation of thickness leads to improved skill for seasonal predictions of Arctic summer sea ice extent and ice-edge location whilst highlighting persistent biases in the modelled thickness distribution.

Details will also be provided of user engagement activities underway to improve the relevance of model predictions for industry end users such as shipping.
Modeling Arctic sea-ice algae: Physical drivers of spatial distribution and algae phenology

Giulia Castellani 1, Martin Losch 1, Benjamin A. Lange 2, Hauke Flores 1

1Alfred Wegener Institut (AWI), Germany, 2Fisheries and Oceans Canada, Canada

Algae growing in sea ice represent a source of carbon for sympagic and pelagic ecosystems, and contribute to the biological carbon pump. The biophysical habitat of sea ice on large scales and the physical drivers of algae phenology are key to understanding Arctic ecosystem dynamics and for predicting its response to ongoing Arctic climate change. In addition, quantifying potential feedback mechanisms between algae and physical processes is particularly important during a time of great change. These mechanisms include a shading effect due to the presence of algae, and increased basal ice melt. The present study shows pan-Arctic results obtained from a new Sea Ice Model for Bottom Algae (SIMBA) coupled with a 3D sea-ice–ocean model. The model is evaluated with data collected during a ship-based campaign to the Eastern Central Arctic in summer 2012. The algal bloom is triggered by light, and shows a latitudinal dependency. Snow and ice also play a key role in ice algal growth. Simulations show that after the spring bloom, algae are nutrient-limited before the end of summer and finally they leave the ice habitat during ice melt. The spatial distribution of ice algae at the end of summer agrees with available observations, and it emphasizes the importance of thicker sea-ice regions for hosting biomass. Particular attention is given to the distinction between level ice and ridged ice. Ridge-associated algae are strongly light-limited, but they can thrive towards the end of summer, and represent an additional carbon source during the transition into polar night.
The importance of giants in a world of dwarfs

Pedro Duarte, Andrew Lowther, Philipp Assmy, Geir Gabrielsen, Kit Kovacs, Christian Lydersen, Gary Griffith

Norwegian Polar Institute, Norway

The main goal of this study was to explore the importance of higher trophic levels (HTL) in Arctic marine ecosystems functioning. Hereafter, HTL are defined as organisms in or above the fourth trophic level. Notwithstanding the fundamental importance of these organisms as a food source for the Arctic societies, their cultural and aesthetic values (and tourist appeal), their role in biogeochemical processes and top-down control within Arctic marine ecosystems is yet to be quantified. What will happen if these organisms decrease in abundance or are replaced by their temperate equivalents? We are seeing evidence of declines and substitutions in several bird and fish species in the Svalbard Archipelago. We argue that there is a deficiency in the scientific debate of this question in the Arctic in comparison with the Southern Ocean, where the role of HTL have been discussed in connection with iron recycling for primary production and the decline in krill populations. HTL organisms have an important role in the exchange of nutrients between terrestrial and marine environments, from deep sea to surface waters and from nutrient hotspots to oligotrophic areas. These species may also exert a significant top-down effect on prey populations, thus shaping the ecosystem. Importantly, the long life span of some of these organisms makes them a nutrient buffer, dampening the loss of nutrients to the deep ocean through the typical boom and bust cycles of the Arctic phytoplankton and ice algal blooms. Instead, HTL species keep nutrients available at the surface, where they are partially released through fast recycling excretion pathways that may be used readily for regenerated production. Birds and mammals are thought to consume up to 13% of the net primary production in Kongsfjorden, Svalbard, which suggests that they play an important role in coastal ecosystem functioning. It is likely that this role decreases from coastal to open ocean environments. Current ecosystem models show a dichotomy between lower and HTL based approaches, reflecting difficulties in coupling processes at spatial and temporal scales that span over several orders of magnitude. This dichotomy limits our capacity to evaluate bottom-up and top-down ecosystem effects and their biogeochemical feedbacks. We discuss the need and the methods to overcome these limitations in a context of climate-induced ecosystem restructuring.
Temporal variability in surface water pCO2 in Adventfjorden (West Spitsbergen): physical and biogeochemical drivers.

**Ylva Ericson** 1, Eva Falck 1, Melissa Chierici 2, Agneta Fransson 3

1The University Centre in Svalbard, Norway, 2Institute of Marine Research, Norway, 3Norwegian Polar Institute, Norway

Surface water pCO2 and air-sea CO2 fluxes in a West Spitsbergen fjord (IsA Station, Adventfjorden) were studied using marine CO2 system data collected between March 2015 and June 2017. The surface waters were undersaturated in CO2 with respect to the atmosphere all year round. The variability in pCO2 correlated significantly with the calculated effects of both biological activity and thermal forcing, of which the former explained more of the observed variability. The estimated impacts of surface water freshening, turbulent vertical mixing and air-sea exchange on pCO2 were generally small in comparison. The annual air-sea CO2 fluxes, as estimated from the month of April, were -36 ± 2 and -31 ± 2 g C m⁻² year⁻¹ for 2015-2016 and 2016-2017, respectively. Waters of a freshened Arctic source dominated the first nine months of the study and were replaced in 2016 by waters of a transformed Atlantic source. The uptake rates over the period of Arctic origin waters were significantly higher than the rates of the corresponding period of the following year. If wintertime atmospheric forcing continues to facilitate the transport of Atlantic waters into the West Spitsbergen fjord systems, as observed frequently over the last decade, the CO2 uptake capacity could be reduced in this region.
Small-scale spatial patterns of soil organic carbon and macro-nutrients in northern Siberian permafrost-affected soils

Alevtina Evgrafova 1, Tilman de la Haye 2, Ina Haase 3, Olga Shbishstova 4, Georg Guggenberger 4, Nikita Tananaev 5, Leopold Sauheitl 3, Sandra Spielvogel 6

1University of Bern/University of Koblenz-Landau, Germany, 2University of Bern, Switzerland, 3Leibniz University of Hannover, Germany, 4Leibniz University of Hannover/VN Sukachev Institute of Forest, Russia, 5Igarka Geocryology Laboratory, Melnikov Permafrost Institute SB RAS, Russia, 6University of Bern/University of Kiel, Germany

Thawing permafrost, driven by climate change, alters pedogenic processes and properties as well as soil-plant-atmosphere interactions in high-latitude regions. Increased plant-available macronutrients, i.e. nitrogen (N) and phosphorus (P), may induce vegetation growth and further vegetation community shifts in polar climate regions. However, the influence of permafrost thaw on the spatial distribution and variability of permafrost-affected soil properties remains unclear.

This research studied the changes in spatial patterns and relationships between soil organic carbon (SOC), N and P stocks (0-30 cm) and active layer thickness (ALT), soil acidity, pedogenic (hydr)oxides, and plant-derived C inputs and neutral sugars as a result of permafrost degradation within the six study grids (16 m²) using the principles of geostatistics. The study grids, characterized by various ALT and under different vegetation communities, were located within the forest-tundra ecotone underlain by warm and discontinuous permafrost at the Little Graviyka Creek catchment (67°28.933’N, 86°25.682’E). The soil samples were collected from two depth increments, top- (n=61) and subsoil (n=61) for each study grid, with a sample spacing of 0.2, 0.5 and 1.0 meters.

The results showed that permafrost thaw caused a decrease and homogenization of SOC, N and P stocks and increase in P availability for plants within the studied small-scale grids. Moreover, declining permafrost table led to the formation of soil organic matter (SOM) accumulation “hot spots” in thawed soil horizons, associated with the development of organo-mineral associations and deeper root systems. The semivariogram ranges for SOC and N stocks were estimated at less than 3.1 m. The nugget-to-sill ratios were estimated between 29 and 52% for shallow AL soils and between 19 and 34% for intermediate AL and non-permafrost soils. Based on vegetation analyses, higher grid-specific vascular species abundance was observed for grids with a deeper ALT likely due to the increased availability of macronutrients, while species diversity was lower likely due to more homogeneous distribution of macronutrients. Hence, the changes in vegetation communities in high-latitude regions could be an indicator of permafrost thawing linked to possible vegetation shifts and changing carbon sequestration potential in the Arctic regions. Combined research on vegetation structure and ecosystem carbon storage capacity can be seen as a key approach for estimating carbon and biodiversity losses driven by permafrost degradation.
Mesopelagic layers in the European Arctic: seasonal migrations and trophic interactions.

Maxime Geoffroy 1, Malin Daase 2, Jørgen Berge 2, Martin Graeve 3, Marine Cusa 2, Nestor Hernandez 2, Stig Falk-Petersen 4

1Fisheries and Marine Institute of Memorial University of Newfoundland, Canada, 2UiT, Norway, 3AWI, Germany, 4APN, Norway

A mesopelagic sound scattering layer (SSL) was detected with a multifrequency echosounder in the European sector of the Arctic Ocean, both during the polar night and the midnight sun periods. The SSL was located within Atlantic water masses, and pelagic trawling suggested that it was mainly composed of age-0 fish (mainly *Sebastes mentella* and *Leptoclinus maculatus*) as well as macrozooplankton (mainly *Cyanea capillata*, *Themisto libellula*, *Meganyctiphanes norvegica* and *Thysanoessa inermis*). Most abundant species were analysed for total lipids and fatty acid trophic markers. We present data on the total available energy expressed as lipids available for higher trophic animals in these mesopelagic layers. By combining new data on fatty acid trophic markers with published data, we are presenting a new approach to describe the energy transfer from phytoplankton and ice algae to apex predators. We suggest that the prevalence of a high-energy SSL when the ice edge retracts northwards might explain the large Dutch bowhead whaling that took place in Whalers Bay between 1670 to 1800, as well as recent observations of whale aggregations. This study is a part of the RCN funded Arctic ABC project (http://www.mare-incognitum.no/) and of the Arctic Size project at UiT The Arctic University of Norway.
The ice-water interface - new approaches to investigate a crucial node in the Arctic ecosystem

Hauke Flores ¹, Barbara Niehoff ², Ilka Peeken ¹, Fokje Schaafsma ², Nicoloe Hildebrandt ¹, Jutta Wollenburg ³, Erin Kunisch ³, Rolf Gradinger ³, Marcel Nicolaus ¹, Christian Katlein ¹

¹AWI, Germany, ²Wageningen Marine Research, Netherlands, ³ UiT, Norway

The Arctic sea ice environment is changing faster than we can gain knowledge about its role for biodiversity and ecosystem functions. In the present Arctic Ocean sea ice plays a crucial role as a habitat hosting a unique diversity of life, and supporting major life stocks through the primary production of ice algae. Which ecological role sea ice played in the past, and how it may develop in the future, is largely unknown. Major carbon transmitters of the food web, such as *Calanus* spp., ice amphipods and polar cod, depend on the ice-water interface as a habitat and foraging ground. This makes the ice-water interface a functional node in the Arctic ecosystem. Sampling this environment, however, has been a challenge due to its inaccessibility to traditional sampling tools, such as nets, flasks and sensors. The rise of automated under-ice profilers and recent technological developments have made it possible to obtain a more quantitative view of the life in the ice-water interface layer, from microscopic protists to polar cod. This presentation will review recent developments in under-ice sampling with under-ice nets and ROVs, and the scientific knowledge that has been gained with them. A special focus will be laid on first experiences newly developed ROV-operated sampling devices suitable to be used during MOSAiC and other drift stations.
Review on status and changes of the Barents Sea System

Sebastian Gerland¹, Tor Eldevik², Marit Reigstad³

¹Norwegian Polar Institute, Norway, ²Geophysical Institute, University of Bergen, Norway, ³UiT The Arctic University of Norway, Norway

As a part of the new Norwegian research project “Nansen Legacy”, involving eight Norwegian governmental and two private research institutions (https://site.uit.no/nansenlegacy/), a scientific review about the status and changes in the Barents Sea System is developed. We will present first results from this synthesis, focusing on the physical, biological and biogeochemical systems. The review is based on recent peer-review publications about the region, with additional use of publically available long-term monitoring data, such as satellite-based sea ice extent. The Barents Sea represents both geographically and temporarily a gateway to a changing Arctic: It is connected to the Arctic Basin in the central Arctic and ocean currents, sea ice drift and ship traffic illustrate this connection. One question scientists work with is to what extent the Barents Sea can be seen as a sentinel for current changes that in a similar way could happen in the future in other Arctic regions. The Barents Sea is highly relevant as a part of the climate system, as a habitat, and within socio-economics. It is exposed to natural forcing and direct or indirect human impacts, and it is changing relatively fast, compared with other Arctic regions. We will present examples of such changes and relevant processes, including results from numerical modelling.
Direct observations of atmosphere -- sea ice -- ocean interactions during Arctic winter and spring storms

Polona Itkin 1, Robert Graham 1, Mats Granskog 1, N-ICE2015 team 2

1Norwegian Polar Institute, Norway, 2N-ICE2015, Norway

To study the thinner and younger sea ice that now dominates the Arctic the Norwegian Young Sea ICE expedition (N-ICE2015) was launched in the ice-covered region north of Svalbard, from January to June 2015. During this time, eight local and remote storms affected the region and rare direct observations of the atmosphere, snow, ice and ocean were conducted. Six of these winter storms passed directly over the expedition and resulted in air temperatures rising from below –30°C to near 0°C, followed by abrupt cooling. Substantial snowfall prior to the campaign had already formed a snow pack of approximately 50 cm, to which the February storms contributed an additional 6 cm. The deep snow layer effectively isolated the ice cover and prevented bottom ice growth resulting in low brine fluxes. Peak wind speeds during winter storms exceeded 20 m/s, causing strong snow redistribution, release of sea salt aerosol and sea ice deformation. The heavy snow load caused widespread negative freeboard; during sea ice deformation events, level ice floes were flooded by sea water, and at least 6-10 cm snow-ice layer was formed. Elevated deformation rates during the most powerful winter storms damaged the ice cover permanently such that the response to wind forcing increased by 60%. As a result of a remote storm in April deformation processes opened about 4% of the total area into leads with open water, while a similar amount of ice was deformed into pressure ridges. The strong winds also enhanced ocean mixing and increased ocean heat fluxes three-fold in the pycnocline from 4 to 12 W/m2. Ocean heat fluxes were extremely large (over 300 W/m2) during storms in regions where the warm Atlantic inflow is located close to surface over shallow topography. This resulted in very large (5-25 cm/day) bottom ice melt and in cases flooding due to heavy snow load. Storm events increased the carbon dioxide exchange between the atmosphere and ocean but also affected the pCO2 in surface waters through mixing. Finally, the combination of a higher lead fraction and thinner ice cover, driven in part by storms, helped facilitate an early under-ice phytoplankton bloom in May, far inside the ice pack. In summary the storms entail significant effects on the ice pack that may last much longer than the short-lived storm events.
Impact of Sea Ice Thickness and Freeboard Products on Forecast Performance

Thomas Kaminski 1, Frank Kauker 2, Leif Toudal Pedersen 3, Michael Vossbeck 1, Helmut Haak 4, Laura Niederdrenk 4, Stefan Hendricks 5, Robert Ricker 5, Michael Karcher 2, Hajo Eicken 6, Ola Grabak 7

1 The Inversion Lab, Germany, 2OASys and Alfred Wegener Institute, Germany, 3EOLab.dk, Denmark, 4Max Plank Institute for Meteorology, Germany, 5Alfred Wegener Institute, Germany, 6University of Alaska Fairbanks, USA, 7European Space Agency ESRIN, Italy

The A+5 study belongs to the STSE ARCTIC+ cluster of ESA projects and contributes to the Year of Polar Prediction (YoPP). The project has constructed a flexible system for Arctic Mission Benefit Analysis (ArcMBA) that evaluates in a mathematically rigorous fashion the observational constraints imposed by EO data products in using the quantitative network design (QND) approach. The assessment of the observation impact (added value) is performed in terms of the uncertainty reduction in a four-week forecast of sea ice volume (SIV) and snow volume (SNV) for three regions along the Northern Sea Route by a coupled model of the sea ice-ocean system.

The assessments covered seven EO products, three real products and four hypothetical products. The real products are monthly ice thickness, ice freeboard, and radar freeboard, all derived from CryoSat-2 (AWI). These are complemented by two hypothetical monthly laser freeboard products (one with low accuracy and one with high accuracy), as well as two hypothetical daily snow depth products (again one with low accuracy and one with high accuracy). In total 15 (groups of) products were assessed, and their performance compared with each other and a reference case without any observations (prior).

On the basis of the per-pixel uncertainty ranges that are provided with the CryoSat-2 ice thickness (SIT), ice freeboard (SIFB), and radar freeboard (RFB) products, the SIT achieves a much better performance for SIV than the SIFB product, while the performance of RFB is more similar to that of SIT. For SNV, the performance of SIT is low, the performance of SIFB higher and the performance of RFB yet higher. A hypothetical laser freeboard (LFB) product with low accuracy has a similar impact as RFB on both SIV and SNV. A reduction in the uncertainty of the LFB product yields a significant increase in performance.

Combining either of the SIT/freeboard products with a hypothetical snow depth product achieves a significant performance increase. The uncertainty in the snow product matters: A higher accuracy product achieves an extra performance gain. The provision of spatial and temporal uncertainty correlations with the EO products would be beneficial not only for QND assessments, but also for assimilation of the products.

The ArcMBA can be extended to cover further EO products and target variables. With the setup used here, the model would be able to simulate a range of ice-ocean variables in addition to those considered in the present study (e.g. ice drift). Even other modules (e.g. biogeochemical) could be coupled to the systems.
Global warming impact on Arctic Marine Operations

Andreas Kjøl

Viking Ice Consultancy, Norway

To safely and effectively perform an Arctic marine operation many risks must be evaluated and mitigated. Remote locations, rapid changing met ocean conditions, high mobile pack ice and icebergs are the most challenging factors of operations in Arctic and Sub Arctic regions. In most regions it requires high specification on vessels, with its equipment, and well trained experienced personnel.

This presentation is based on long operating experience in performing marine operations in Arctic. The presentation should primarily reflect how the global warming, retracting ice cap and general ice thickness reduction have an influence on the season’s operational period, vessels and equipment used. It will also give a short description of the types of marine operations which is performed in the Arctic the last Decade by Viking and how we see the possibilities for future prospects in this warming trend. The various regions and operations will be described with a brief view on Ice/Met ocean Conditions from an operational point of view. General trends and future will be described, with emphasis on increased ice mobility, increasing fetch and wave interaction impacting marine operations.
Co-production and user engagement in weather and sea ice forecasting for the European Arctic marine areas

Maaike Knol ¹, Machiel Lamers ², Peter Arbo ¹, Anders Doksæter Sivle ³

¹UiT the Arctic University of Norway, Norway, ²Wageningen University, Netherlands, ³Norwegian Meteorological Institute, Norway

The Year of Polar Prediction (YOPP) aims to improve polar environmental monitoring and forecasting. YOPP also aims to strengthen interaction and communication between polar forecast providers and users. This paper aims to understand the diversity of users of forecast information, their information needs, and their engagement in processes of co-production in a European Arctic context. In particular, we focus on weather and sea ice forecast information for the marine areas.

There is a great diversity of users of forecast information, including researchers, government agencies, and 'end users' like fishers, and shipping- and cruise tourism operators. These end users have a variety of information needs throughout different phases of their activities. A variety of forecast services serves these diverse needs. Based on qualitative interviews and literature studies, this paper generates insight into the actual services that are provided and how and why they are used in decision-making practices through various phases – from planning up to several months ahead to short term operational decision-making.

It is commonly agreed that user engagement is vital to enhance the user-friendliness of forecast services. This paper therefore also explores practices of user engagement and processes of co-production in forecasting activities. Examples from Norway and Denmark will be described and analysed. Since many users also produce information, we will explore the notion of user beyond the dualistic notions of user and producer. In order to strengthen interaction and communication between forecast providers and users, it is important to be better aware of the fluidity of the notion of ‘user’, and to improve understanding of their decision-making patterns, preferences and needs. Such knowledge will be a basis for strengthening user engagement in the process towards more user-friendly forecast services.
FEATURED TALK: Evaluating impacts of the Arctic sea ice loss and variation on the northern hemisphere climate

Torben Koenigk 1, Yongqi Gao 2, Guillaume Gastineau 3, Noel Keenlyside 4, Tetsu Nakamura 5, Fumiaki Ogawa 4, Yvan Orsolini 5, Vladimir Semenov 7, Lingling Suo 2, Tian Tian 8, Tao Wang 9, Jonathan J. Wettstein 10, Shuting Yang 8

1Swedish Meteorological and Hydrological Institute, Sweden, 2Nansen Environmental and Remote Sensing Center, Norway, 3Sorbonne Universites, France, 4Geophysical Institute, University of Bergen, Norway, 5Hokkaido University, Japan, 6NILU - Norwegian Institute for Air Research, Norway, 7A. M. Obukhov Institute of Atmospheric Physics RAS, Russia, 8Danish Meteorological Institute, Denmark, 9Nansen-Zhu International Research Center, China, 10Oregon State University, USA

Arctic sea ice loss during the recent decades of global warming could have contributed to Arctic amplification and colder winters over Eurasia. However, recent reviews suggest that the impact of sea ice changes in the Arctic vary regionally and seasonally, and the results from individual modelling studies differ widely, which led to a debate on the role of sea ice in the polar amplification and Eurasian cooling trend. Here we show that the impact of the recent sea ice decline is rather limited to the high-latitude lower troposphere, through coordinated experiments with six atmospheric general circulation models (AGCMs) forced by observed and climatological daily sea ice concentration and sea surface temperature (SST). The Arctic amplification is strongly coupled with sea ice loss over the Arctic lower troposphere throughout winter, while the warming aloft is mostly associated with remote SST changes. Sea ice changes do not significantly lead to colder winters over Eurasia. The observed temperature trends and corresponding circulation trends are reproduced in a small number of ensemble members but not by the multi-model ensemble mean, suggesting that atmospheric internal dynamics could have played a major role in the observed trends. Further, we show that Arctic sea ice variations are important for the interannual two meter air temperature (T2m) variations in northern Europe but have limited impact on all other mid and high latitude land regions. In particular, sea ice variations do not contribute to the observed opposite variations in the Arctic and mid-latitudes. The spread across ensemble members is large and many ensemble members are required to reproduce the observed T2m variations over northern Europe in our models. The amplitude of T2m anomalies in the coldest observed winters over northern Europe is not reproduced by our multi-model ensemble means, but the sea ice conditions in these respective winters lead to an enhanced likelihood for occurrence of colder than normal winters and extremely cold winters. However, the main reason for the observed extreme cold winters seems to be related to internal atmospheric dynamics. The coldest simulated northern European winters between 1982 and 2014 reproduce the large scale T2m and atmospheric circulation anomaly patterns in the observed coldest winters, indicating that the models are well able to reproduce the processes, which cause these cold anomalies. The results are robust across all six models used in this study.
Short range weather forecasts in the European Arctic; recent work and experiences with AROME Arctic.

Morten Køltzow, Malte Müller, Teresa Valkonen, Yurii Batrak, Eivind Støylen

MET Norway, Norway

Over the past decades the Arctic warmed more than any other region in the world with profound socio-economic consequences. Thus, our current weather forecasting systems are challenged by increasing interest in accurate forecasting products. There are many challenges for Arctic weather prediction, e.g. the sparse observation network, atmospheric data assimilation, the representation of sea-ice, and the high-latitude representation of many sub-grid scale parameterizations.

The limited area model Arome Arctic, employed in the European Arctic, is a particular MET Norway configuration of the HARMONIE system. Arome Arctic has been in operational use since autumn 2015. It provides four daily forecasts up to +66 hr lead time on a 2,5 km horizontal grid and with 65 vertical levels. The full model output is openly available to the public. It is the source of the forecasts on Yr.no in the European Arctic, and is used actively by the on-duty meteorologists, researchers and downstream users.

The Arctic forecast and research activities at MET Norway focus on use and further development of this particular system. In addition to the core activities at MET Norway, Arome Arctic is a part of a variety of research projects (i.e. APPLICATE, CARRA, Nansen Legacy, NORDNWP PGD)

In this presentation we will give an overview of current developments and recent results of Arome Arctic. Topics we will touch on are: added value of limited area models compared to global coarser resolution models, challenges in Arctic verification with high observational uncertainty, the importance of surface forcings like sea ice description and glacier masks at Svalbard.
FEATURED TALK: Understanding user needs: Enhancing the saliency of weather and sea ice services for marine mobility sectors in European Arctic seas

Machiel Lamers

Wageningen University, Netherlands

The rapid warming in the Arctic ocean environment has profound socio-economic consequences, which generates a strong call from local communities and various marine sectors for more user-specified weather and sea ice services. Currently, there is limited availability of, and accessibility to, high-quality Arctic climate information for operational and strategic decision making. Moreover, little is known about what and how these information services are used, and what are the information needs of maritime sectors. This presentation will discuss how the SALIENSEAS project tackles these two interrelated issues. First, I will discuss ways to increase our understanding of the current mobility patterns and challenges, as well as the uptake and need for climate services in several mobile Arctic ocean end-user groups. Second, I will present how tailored Arctic forecast products can be co-produced with key marine stakeholder groups meeting their social, environmental and economic needs. During SALIENSEAS we will conduct in-depth social science research in relevant end-user practices, disseminate forecast products to end-users of climate information, and develop a more participatory, flexible and tailored approach to developing forecast products. Moreover, Arctic sub-seasonal and seasonal prediction capabilities and climate projections in the Arctic will be systematically exploited, in order to establish baseline expectations for predictive power and to guide advances in predictive capability. The SALIENSEAS project brings together a strong consortium of international research institutes, whereby high-level experts on Arctic socio-economic sectors and governance processes, weather and climate prediction, and data dissemination will work in line with stakeholder representatives. The developed tailored forecast products will be merged into Norway’s and Denmark’s met-ocean and sea-ice forecasting infrastructures and maintained and developed beyond the lifetime of this project.
Tight coupling and distinct differences: Ecophysiological traits of sea ice algae blooms vs. pelagic under-ice blooms in Arctic landfast sea ice

Eva Leu 1, Ane Cecilie Kvernvik 2, Sander Verbiest 3, Thomas Brown 4, Hoppe Clara Jule Marie 5, Jozef Wiktor 6, Tove Gabrielsen 7

1Akvaplan-niva, Norway, 2UNIS/ UiT, Norway, 3University of Utrecht, Netherlands, 4Scottish Association of Marine Sciences, Scotland, 5Alfred-Wegener-Institute, Helmholtz Centre for Polar and Marine Research, Germany, 6Institute of Oceanology, Polish Academy of Science, Poland, 7UNIS - The University Centre in Svalbard, Norway

Decreasing Arctic sea ice changes the environmental conditions that control timing, quantity and quality of future Arctic algae blooms. In the FAABulous project, we try to gain a mechanistic understanding of how these changes will alter algal production regimes. In spring 2017, we observed a strong sea ice algal bloom occurring simultaneously with a pelagic algal bloom in Van Mijenfjorden in Svalbard. We found strong indications for a tight cryo-pelagic coupling in the bottom part of the sea ice, as indicated by species composition and biochemical tracers. At the same time, sea ice algae and phytoplankton seem to have distinct differences in their photophysiological traits, even if their surrounding conditions with respect to light and nutrient availability are very similar. These findings were confirmed by field experiments with natural communities, as well as laboratory experiments with unialgal cultures of dominating diatom species. Sea ice algae are superior in their ability to take advantage of even very low light intensities – whereas they are much more sensitive to high light stress, and have a lower maximum photosynthetic rate. Such intrinsic differences indicate that a transition from predominantly sympagic to more pelagic algal bloom regimes at high latitudes might have complex implications for ecosystems.
FEATURED TALK: Arctic sea ice prediction from days to decades: are we there yet?

François Massonnet

Université catholique de Louvain, Belgium

The Arctic is currently undergoing dramatic changes that have profound impacts on populations, ecosystems and the climate of the High North. Sea ice forecasting has established itself as an emerging discipline of climate sciences since 10 years, thanks to its potential benefits for societies, industries and stakeholders. But just how good are these forecasts, and how useful are them? During this presentation I will review the past and ongoing efforts to advance Arctic sea ice prediction, discuss its inherent limitations and suggest ways forward. In particular, I will (1) review the physical mechanisms that are thought to provide sea-ice predictability from days to decades, (2) discuss the reliability of sea-ice reanalyses, (3) describe the current limitations in observational networks and possible improvements and (4) review the knowledge on long-term sea ice projections and what controls their uncertainty (a timely issue as the Coupled Model Intercomparison Project phase 6 (CMIP6) is about to start).
Performance of a high-resolution 58-year hindcast experiment

Arne Melsom ¹, Vidar Lien ²

¹Norwegian Meteorological Institute, Norway, ²Institute of Marine Research, Norway

Hindcast results from a simulation of the ocean circulation and sea ice for the last 58 years are available on a domain with 4km horizontal resolution which includes the Barents Sea and adjacent seas (Nordic Seas, Kara Sea, Arctic Sea sector). These results are referred as the SVIM ocean hindcast archive, with results being available as daily averages. A comparison between various observational data sources and several model products has revealed that the SVIM archive is a leading quality model product for the Barents Sea (Lien et al., Ocean Mod., 2016).

We present comparisons of results for sea ice concentration with both ice chart data and data from microwave sensors. The ice chart data have advantages in being available throughout the SVIM period, on a very high horizontal resolution (1 km), and being produced by staff with expertise in the regional conditions in the Barents Sea. However, the data sources used for the ice charts are not uniform in time. Hence, we supplement the validation vs ice chart data with a corresponding comparison vs microwave data from instruments on satellite platforms, available since 1979.

A preliminary validation of SVIM results for sea ice area in the Barents Sea for a two year period indicated that the experiment captures variability on short time scales (weeks) and also changes from one winter to the next (Lien et al., Fisken og havet, 2013). Here, we present validation results for various time scales for the full experiment period. The results will also be discussed in the context of variability of oceanic heat transport into the Barents Sea. This analysis is performed on behalf of the Nansen Legacy project. The objective in Legacy is to subsequently perform an analysis of the sea ice budget for the Barents Sea on time scales ranging from days to decades, taking into account lateral oceanic heat transport and ocean-ice-atmosphere heat fluxes.
Atlantic Water and sea ice variability in the 20th century Arctic Ocean from a global ocean model and observations.

Morven Muilwijk 1, Lars Henrik Smedsrud 1, Mehmet Ilicak 2, Helge Drange 1

1University of Bergen & Bjerknes Centre for Climate Research, Norway, 2Uni Research & Bjerknes Centre for Climate Research, Norway

Both historical observations and outcome from a fully coupled earth system model show a warming trend in core temperature of Atlantic Water entering the Arctic Ocean over the last few decades (1977-2015). The Atlantic Water is also observed to rise systematically in the water column since the 1990’s. This suggests an “Atlantification” of the Arctic Ocean, i.e. an ongoing expansion of the Atlantic domain. A portion of this “Atlantification” and recent warming has been attributed to the current global warming and possibly anthropogenic activity. However, past periods of warm Atlantic Water (1930-1940) have been documented, a period often termed “Early Warming”. We believe that the Atlantic Water warming trend in the Arctic Ocean may be part of long-term multidecadal variability, which is influenced and reinforced by strong anthropogenic forcing.

We have therefore investigated the interannual, decadal and multidecadal variability of Atlantic Water and sea ice in the Arctic Ocean using a global ocean model. Here we present simulations for the period 1871-2009 with the ocean-sea ice component of the Norwegian Earth System Model (NorESM-O) forced by a Twentieth Century Reanalysis data set. These are compared with available Atlantic Water and sea ice observations in the Fram Strait and north of Svalbard.

The simulation and observations show several periods of relatively warm Atlantic Water and “Atlantification” to a certain degree, also before the 1970s. In the Eurasian Basin, north of Svalbard there appears to be a direct correlation between Atlantic Water heat and Arctic sea ice volume. We find, for example, that the 1930s warm period was followed by a loss of Arctic sea ice volume.

In addition, passive tracers were released in the model simulation to explore the circulation pattern of Atlantic Water, the variability of recirculation of Atlantic Water in the Fram Strait and distribution of freshwater from different river sources. These tracers show that most Atlantic Water either circulates in the Nansen Basin or recirculates back to the Fram Strait relatively quickly, and that only a very small portion crosses over to the Canadian side of the Lomonosov Ridge.
Benthic foraminifera as proxies of brine-enriched shelf waters cascading: promising tools for reconstructing historical changes in sea-ice production in the Storfjorden polynya (Svalbard)

Maria Pia Nardelli 1, Arbia Jouini 2, Hélène Howa 1, Bruno Lansard 3, Elisabeth Michel 3, Thierry Garlan 4, Frédéric Vivier 5, Agnès Baltzer 6, Meryem Mojtahid 1

1UMR CNRS 6112 - LPG-BIAF, University of Angers (France), France, 2University of Angers, France, 3UMR CNRS 8212 – LSCE, Université de Versailles (France), France, 4Service Hydrographique et Océanographique de la Marine (SHOM), Brest, France, 5UMR CNRS 7159 - LOCEAN, Université Paris 6 (UMPC) (France), France, 6LETG - UMR6554 CNRS, Université de Nantes (France), France

Nowadays, the Storfjorden (Svalbard) is a first-year sea-ice production zone characterized by intense production of brine and cascading of brine-enriched shelf waters (BSW). Brine formation, and the consequent injection of salty and relatively acid dense water into the deepest ocean, was likely more important during the cold climatic periods of Holocene, because of the higher sea-ice production. In this study, we explore the potential of benthic foraminifera (fossilizing meiofauna), as indicators of brine water circulation on the sea floor. Consequently, the identification of benthic foraminiferal species sensitive to brine waters properties would allow the reconstruction of the extent and the temporal variability of Arctic sea-ice cover, and therefore a better understanding of the ongoing climatic change on historical time scales (hundred to thousand years). Therefore, this study aims at calibrating the ecological response of living benthic foraminifera to sinking brine waters, and estimating the taphonomic loss during early stages of test fossilization. Sediments from 7 interface cores sampled along a N-S transect across the Storfjorden were analyzed for living and modern dead foraminiferal assemblages. Results from the living fauna show two major biozones: an “inner-basin” fauna characterized by the dominance of calcareous species, with more or less dissolved tests; and an “outer-basin” fauna, characterized by a strong dominance of agglutinated species, potentially due to persistent relatively low pH conditions hampering the development of calcareous species. Down-core dead faunas from the inner-basin show low amplitude temporal changes, while in the outer-basin some abrupt changes in agglutinated/calcareous ratios occur. High ratios suggest large brine production and higher BSW residence times in the inner basin, whereas low ratios (more calcareous) might correspond with low to no sea-ice cover periods due to warmer and organic enriched Atlantic water intrusions into the fjord. Indeed, the ratio between agglutinated and calcareous benthic foraminiferal species is potentially a good bio-indicator of BSW circulation in Arctic shelf areas.
Methane genesis in massive ground ice on Central Yamal - the Key to catastrophic gas emission events on the peninsula?

Dmitry Nekrasov

Lomonosov Moscow State University, Russia

Pioneer studies of gaseous inclusions in massive ground ice on Central Yamal took place in 2016. Geographically area or research is located in the Southern part of Bovanenkovo gas field. Five outcrops with exposed ground ice were sampled. In 2016, basic investigation happened - the goal was to detect high concentrations of methane in massive ground ice and to study isotopic composition of this ice to understand climate conditions when it was formed. The goal was achieved. In five samples (out of thirty) high concentrations were detected - 0.18-0.33%, although the distribution of methane in the ice body was uneven.

The results showed the high potential of this area to investigate methane concentrations and possibly do isotopic analyses for methane itself. Methane isotopic composition can say about the genesis of gaseous inclusions - is it bacterial or catagenetic? This information can lead us to a better understanding of the source of the methane in permafrost sediments on Central Yamal and reveal the nature of gas emission craters (GECs) formation catastrophic events.

First detected GEC formed on Yamal peninsula in autumn, 2013. By now we know the location at least six of them on northern peninsulas of Russian Arctic: 4 on Yamal, 1 on Tazovskiy and 1 on Gydan. There is evidence of even more such formations in Russian Arctic. To get the better understanding of local permafrost scientists from Earth Cryosphere Institute RAS SB accruing data each year about permafrost conditions on research station Vaskiny Dachi located on Central Yamal. We joined the expedition in August 2017 to perform complex studies of massive ground ice on two local thermokarst outcrops with exposed ice, which became active last year. Totally 134 samples were collected during this season: 17 ice monoliths, 38 (with duplicates) isotopic composition samples from melted ice, 50 gaseous inclusion samples from ice and host sediments, 11 granulometric samples from host sediments, 10 C14 samples from buried peat, etc.

These studies can help us to understand the nature of massive ground ice on Central Yamal and possibly find the connection with GEC formation catastrophic events.
Using the Lagrangian Ice Tracking System (LITS) to respond to risks in a warming world

Robert Newton 1, Stephanie Pfirman 2, Bruno Tremblay 3, Patricia DeRepentigny 4

1Columbia University, USA, 2Barnard College, USA, 3McGill University, Canada, 4University of Colorado, USA

Starting from satellite-based estimates of sea ice drift vectors we have developed a user-friendly system for tracking sea ice forward and backward in time from an arbitrary set of locations and start times between 1979 and 2015. We have used the system to analyse changes in sea ice exchanges between the exclusive economic zones of the Arctic nations, as well as changes in ice formation and melt rates; formation and melt locations; and the timing of open water in the Arctic peripheral seas. We are extending LITS by integrating climate model outputs so that users can track ice formation, transport and melt as projected through the twenty-first century.

In this contribution we will summarize previous results on inter-EEZ transport and present initial results on shifting transport projections over the next 100 years. We apply LITS to several critical societal issues, including: transports forward in time from the locations of oil leases on the Siberian shelves, which localize, and highlight, risks due to oil exploration, recovery and transport; backward tracking of ice from a proposed marine protected area (the Last Ice Area), which demonstrate the need for Arctic-wide policy processes to protect local resources; and ways that hemispheric-scale atmospheric changes impact Arctic regional and local sea-ice conditions in the Arctic.

Global climate change is making dramatic changes in the distribution of thick, multi-year, vs thin, first-year, ice—a critical environmental basis for current Arctic eco-zones. Not only are the overall size and thickness distribution of ice cover important; so too are the timing and location of formation and melt, along with transport patterns. Sea ice transport moves freshwater, sediments and living organisms, which are critical to ice-obligate species from diatoms to polar bears. In addition, ice formation and melt patterns impact the distribution of buoyancy and dense waters, which modulate deep water formation and affects global climate. Visualizing current trends and likely future shifts in sea ice dynamics is fundamental to policy formulation and implementation. The results from LITS, both retrospective and projections, will be placed in the context of our earlier work on diverging stakeholder interests in the Arctic (White Arctic vs Blue Arctic; Newton et al. 2016). Earth’s Future, DOI: 10.1002/2016EF000356). That is: we provide input for analysts to think concretely about how stakeholders are likely to align and where openings may occur for consensus building and policy development as the global climate, including the Arctic, warms.
On the statistical properties of sea ice lead fraction and heat fluxes in Arctic

Einar Olason, Pierre Rampal, Sylvain Bouillon

Nansen Environmental Remote Sensing Center, Norway

Heat flux through leads and polynyas is an order of magnitude larger than that through unbroken ice. In this presentation we explore some statistical properties observed in Arctic sea ice lead fraction, showing that our model (neXtSIM) does a good job at reproducing the observed statistics. Given the importance of heat flux through leads we then use the model to explore the statistical properties of the modelled heat fluxes. We show that the model reproduces well the probability density function (PDF) and the mono-fractal spatial scaling of observed lead fluxes in the Central Arctic. We then explore the PDF and spatial scaling of simulated heat fluxes, showing that the heat fluxes have a multi-fractal scaling in the Central Arctic, which we attribute to lead formation, while coastal polynyas destroy the scaling in the wider Arctic. Finally, we show that the scaling of simulated lead fraction is preserved for different model resolutions, while further work on a sub-grid scale parametrisation of surface heterogeneity is required to preserve the scaling of heat fluxes for different model resolutions.
FEATURED TALK: Seasonal and regional manifestation of Arctic sea ice loss

Ingrid H. Onarheim 1, Tor Eldevik 1, Lars Henrik Smedsrud 1, Julienne Stroeve 2

1University of Bergen and Bjerknes Centre for Climate Research, Norway, 2University College London and National Snow and Ice Data Center, UK

The Arctic Ocean is currently on a fast track towards seasonally ice-free conditions. Although most attention has been on the accelerating summer sea ice decline, large changes are also occurring in winter. This study assesses past, present, and possible future changes in regional Northern Hemisphere sea ice cover throughout the year by examining ice concentration from satellites since 1979 and reconstructed from observations since 1850. At present, summer sea ice variability and change dominate in the perennial ice covered Beaufort, Chukchi, East Siberian, Laptev, and Kara seas, with the East Siberian Sea explaining the largest fraction of September ice loss (22%). Winter variability and change occur in the seasonally ice covered seas further south; the Barents Sea, Sea of Okhotsk, Greenland Sea, and Baffin Bay, with the Barents Sea carrying the largest fraction of loss in March (27%). The distinct areas of summer and winter sea ice variability and loss have generally been consistent over the 160 years of observations, but appear at present to be in transition due to the rapid ice loss in all seasons. As regions become seasonally ice-free future ice loss will be dominated by winter. The Kara Sea appears as the first currently perennial ice covered sea to become ice-free in September. Extrapolation of current trends suggests that the Arctic shelf seas may become seasonally ice-free in the 2020s, that their winter ice extent decreases onwards from the late 2040s, and that the seasonally ice covered seas further south become ice-free year-round from the 2050s.
Subseasonal-to-Seasonal Forecasts with the Norwegian Climate Prediction Model

Fei Li, Yvan Orsolini

Norwegian Institute for Air Research, Norway

There is now a renewed concerted international effort to tackle the time scales that fall between weather and climate, i.e. between 10 days and one season, the so-called subseasonal-to-seasonal (S2S) time scale. We present first results of S2S forecasts with the Norwegian Climate Prediction model (NorCPM), with a focus on mid and high northern latitudes. As an initialized prediction system for seasonal-to-decal prediction, NorCPM developed from the Norwegian Earth System Model (NorESM), a state-of-the-art climate model, and advanced data assimilation techniques based on the Ensemble Kalman Filter approach. The initialisation of land is carried out by using the Community Land Model (CLM), in which the initial and boundary data is taken from the NCEP (National Centers for Environmental Prediction) reanalysis. The initialisation of ocean is carried out by an ocean analysis using the Miami Isopycnic Coordinate Ocean Model (MICOM), in which sea surface temperature anomaly and temperature and salinity profiles are monthly assimilated into the ocean component. The atmospheric component of the model is the Whole Atmosphere Community Climate Model (WACCM), a “high-top” chemistry–climate model that extends from the Earth’s surface to the lower thermosphere, and is run with interactive stratospheric chemistry. The initialisation of atmosphere is via nudging WACCM towards the ECMWF (European Centre for Medium-Range Weather Forecasts) ERA-Interim reanalysis. One of the focus is the role of land initialisation, and snow cover and depth in particular. Pairs of 3-month ensemble forecasts were started on every 1st November in the years 1980–2010, with either realistic initialization of snow variables based on CLM/NCEP, or else with “scrambled” snow initial conditions from an alternate year.
Observations of methane over the Arctic Ocean

Stephen Platt 1, Ove Hermansen 1, Norbert Schmidbauer 1, Ignacio Pisso 1, Sabine Eckhardt 1, Benedicte Ferre 2, Sunil Vadakkepuliyambatta 2, Pær Jansson 2, Anna Silyakova 2, Juergen Mienert 2, Cathrine Lund Myhre 1

1NILU - Norsk institutt for luftforskning, Norway, 2UiT The Arctic University of Norway, Norway

The release of methane (CH₄) presently stored in vast hydrate deposits under the seafloor is a potential climate tipping point and a major uncertainty in the global CH₄ budget. Significant methane hydrate deposits are located in shallow waters in the Arctic where they may destabilise, releasing CH₄ to the atmosphere due to ocean warming. To address this issue the Methane Emissions from Arctic Ocean to Atmosphere (MOCA, http://moca.nilu.no/) project was established in cooperation with a Centre of Excellence (http:cage.uit.no/).

State-of-the-art atmospheric measurement techniques are ongoing over a large area of the Arctic including northern Norway, the Barents Sea, and areas of shallow water around Svalbard since summer 2014. Oceanographic measurements, during intensive measurement campaigns in 2014 and 2015 included the deployment of measurement stations (temperature, salinity, density, oxygen, fluorescence, turbidity, etc.), water column sampling (CH₄, nitrate, phosphate, silicates), and echo sounding (mapping the seafloor and revealing locations where streams of gas bubbles are vented). Ongoing atmospheric on-line measurements are performed aboard the research vessel Helmer Hanssen (CH₄, CO₂, CO, meteorological parameters). Finally, atmospheric measurements are compared with long term data sets from the nearby Zeppelin Mountain monitoring station (Ny Ålesund, Svalbard). Back-trajectory analysis and FLEXPART modelling are used to rule out non-local sources and combined with emission inventories to estimate the effect of terrestrial emissions from anthropogenic activities, wetlands, and biomass burning.

Here we present an overview of all of these activities and results from MOCA in cooperation with CAGE - Centre for Arctic Gas Hydrate, and Climate at UiT, The Arctic University of Norway. We demonstrate that terrestrial emissions are sufficient to explain most large CH₄ excursions in the Helmer Hanssen atmospheric time series, although high concentrations north of Svalbard, not replicated by the emission inventories, suggest the presence of a highly localised hotspot of ocean-atmosphere emissions. In general, there was no observable effect of known subsea CH₄ seep sites on atmospheric concentrations, demonstrating the remarkable capacity of ocean processes to mitigate the effect of subsea CH₄ emissions on the atmosphere and climate, at present.
The Nansen Legacy: A new project for scientific exploration and sustainable management beyond the ice edge

Marit Reigstad ¹, Tor Eldevik ², Sebastian Gerland ³

¹UiT the Arctic University of Norway, Norway, ²University of Bergen, Norway, ³Norwegian Polar Institute, Norway

A summer sea ice-free Arctic is gradually emerging, and winter-time sea ice retreat is to date most pronounced in the Barents Sea, the Atlantic gateway to the Arctic. The knowledge basis for sustainable management of this changing environment and associated resources is therefore an urgent scientific challenge. This challenge inspired the Norwegian Arctic research community to initiate the Nansen Legacy project. The new project represents a collaborative effort among ten Norwegian research institutions to carry out a holistic investigation in this marine region utilizing the expertise and infrastructure across all institutions. With a multidisciplinary approach including improved technological platforms to increase observational capabilities, the Nansen Legacy team will increase the understanding of how a changing physical climate and increased human activity impact the living Barents Sea. Using an integrative approach, the Nansen Legacy aims to understand responses to change and increase the predictive capabilities and constrains to enable a sustainable management in the north. Involvement of end-users will ensure dialog and knowledge transfer. The Nansen Legacy has developed from an initiative started in 2012 to a major research project with a budget of 740 mill NOK, funded by the Norwegian government, The Research Council of Norway and a 50% in-kind contribution from the participating institutions. With a pre-project in 2017, the six yearlong main project starts in 2018, and includes > 370 days in field, > 130 researchers, > 50 recruitment positions, and represents a historic Norwegian effort to prepare for a new Arctic future. The Nansen Legacy will also represent a hub for collaboration across nations and across the Arctic, aiming for improved Pan Arctic integration.
Arctic Sea Ice Characterization for Navigational Assistance using Space-borne Fully Polarimetric SAR

Suman Singha ¹, Malin Johansson ², Nicholas Hughes ³, Sine Hvidegaard ⁴, Henriette Skourup ⁴

¹German Aerospace Center (DLR), Germany, ²UiT The Arctic University of Norway, Norway, ³Norwegian Ice Service, Norway, ⁴National Space Institute, Denmark

Satellite images are an essential parameter for sea ice products such as the daily sea ice concentration maps issued by the Norwegian Ice Service. In this regard, Synthetic Aperture Radar (SAR) is especially valuable given its all-weather capabilities and that it does not require sunlight. Recently launched missions such as Sentinel-1 acquire data in dual-polarimetric mode, something that has been proven to be more useful than conventional single polarization SAR in terms of characterizing different sea ice types. Within this study we further investigate the usefulness of fully polarimetric SAR. Here we employ an automatic sea ice classification algorithm developed for Near Real Time (NRT) services on two sets of spatially and temporally near coincident fully polarimetric acquisitions from the ALOS-2, Radarsat-2 and TerraSAR-X/TanDEM-X satellites acquired during the N-ICE2015 sea ice drift study.

Overlapping coincident sea ice freeboard measurements from Airborne Laser Scanner (ALS) data are used to validate the classification results. We analysed the usefulness for the classification results of 18 different polarimetric parameters. In order to deliver sea ice products in NRT efficient computation is very important and by reducing redundant or overlapping parameters we can speed up the delivery time. Among the most useful features for classification were the geometric intensity, the scattering diversity and the surface scattering fraction. We also found that we can halve the number of parameters from 18 to 9. In our study, the ALS data show that 100 % of the open water is separated from the surrounding sea ice and that the sea ice classes have at least 96.9 % accuracy. This analysis reveals analogous results for both X-band and C-band frequencies and slightly different for L-band. In particular, the overlapping image portions exhibit a reasonable congruence of detected sea ice when compared with high resolution airborne measurements.
Simulating variability in the Fram Strait sea ice export and related Arctic sea ice response

**Lars H. Smedsrud** 1, Morven Muilwijk 2, Mehmet Ilicak 3

1University of Bergen & Bjerknes Centre, Norway, 2University of Bergen, Norway, 3Uni Research, Norway

The long-term annual Fram Strait sea ice area export is about 880 000 km², representing about 10% of the sea-ice-covered area inside the Arctic basin. This export has large inter-annual and multi-decadal variability, but apparently no long-term trend. However, during the last decades, the amount of ice exported has increased, with several years having annual ice exports that exceeded 1 million km². This large recent export has likely played an important role in the recent Arctic sea ice loss, explaining some of the observed summer ice loss and some of the general thinning (ice volume loss) occurring throughout the year.

Generally, simulations only capture parts of the recent sea ice loss, and the role of natural variability in the ice loss remains a somewhat controversial issue. Because changes in the larger scale wind forcing is the primary cause of the ice export variability one would expect that regional and global ice-ocean models forced by observed (re-analysis) winds should reproduce the variability quite well. The global coupled air-ice-ocean models (CMIPS type) have well documented correlations between large export anomalies and thinning, but generally export too much sea ice area.

This work evaluates simulated Fram Strait sea ice area export in a range of models used for the coordinated FAMOS (Forum for Arctic Modelling and Observational Synthesis) Climate Response Functions (CRF) set-up. Our initial focus is on the Greenland Sea wind forcing perturbations. Initial evaluation of the Norwegian Earth System Model (NorESM) shows that there is a large simulated variability correlating well with observations for 1935 - 2015. However, the mean export is about 10% larger than observations, which may explain a low bias in sea ice area. We anticipate that an increased ice export during winter results in new ice growth and contribute to thinning inside the Arctic Basin, while increased summer or spring export will contribute directly the following September minima. Preliminary analysis suggest that the wind perturbation indeed decreases sea ice export, with the main response being a larger Arctic sea ice volume and ice covered area, with largest response in the Atlantic sector during winter. Creating a response with increase in export appears more challenging, and the wind patterns driving this response will be discussed.
The Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC)

Markus Rex 1, Matthew Shupe 2, Klaus Dethloff 1, Anja Sommerfeld 1

1Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Germany,
2University of Colorado, Cooperative Institute for Research in Environmental Sciences, USA

MOSAiC is an international initiative under the umbrella of the International Arctic Science Committee (IASC) designed by an international consortium of leading polar research institutes.

Rapid changes in the Arctic lead to an urgent need for reliable information about the state and evolution of the Arctic climate system. This requires more observations and improved modelling over various spatial and temporal scales, and across a wide variety of disciplines. Observations of many critical parameters have, to date, not been carried out in the central Arctic for a full annual cycle.

MOSAiC will be the first year-around expedition into the central Arctic exploring the coupled climate system. The research vessel Polarstern will drift with the sea ice across the central Arctic during 2019 to 2020. The drift starts in the Siberian sector of the Arctic in late summer. A distributed regional network of observational sites will be established on the sea ice in an area of up to 50 km distance from Polarstern, representing a grid cell in climate models. The ship and the surrounding network will drift with the natural sea ice drift across the polar cap towards the Atlantic.

The focus of MOSAiC lies on in-situ observations of the climate processes that couple atmosphere, ocean, sea ice, biogeochemistry and ecosystem. These measurements will be supported by weather and sea ice predictions, and remote sensing operations to aid operational planning and extend the observational results in time and space. The expedition includes aircraft operations and expeditions by icebreakers from MOSAiC partners. All these observations will be used for the main scientific goals of MOSAiC: enhancing the understanding of the regional and global consequences of Arctic climate change and sea ice loss, and improve weather and climate prediction. In particular, the results are needed to advance the data assimilation for numerical weather prediction models, sea ice forecasts, climate models and ground truth for satellite remote sensing. Furthermore, the understanding of the energy budget and fluxes through interfaces, sources, sinks and cycles of chemical species, boundary layer processes, and primary productivity will be investigated during the expedition. MOSAiC will support safer maritime and offshore operations, and contribute to an improved scientific future fishery and traffic along the northern sea routes.
How to ensure seasonal forecasts are useful to a broad user community

Julienne Stroeve ¹, Lawrence Hislop ²

¹University College London, UK, ²CliC, Norway

Increasing uncertainty about future sea ice conditions presents a distinct challenge to industry, policymakers, and planners responsible for economic, safety, and risk mitigation decisions. The ability to accurately forecast the extent and duration of Arctic sea ice on different timescales provides significant implications for the operation of wide ranging Arctic maritime activities. While the Arctic sea ice prediction community has advanced rapidly in the past decade with many new sea ice forecast approaches, products and services currently provided may not be as useful as they can be for different user groups. Furthermore, it remains unclear how well end users are able to utilize current products and services into their planning. Thus, there is a need for better engagement with a broad range of Arctic stakeholders and a need to tailor new products and services to end user-specific requirements. This talk will report on preliminary outcomes of a community-engagement workshop held in conjunction with Arctic Frontiers with specific focus on stakeholder needs and limitations of current forecasting systems on seasonal time-scales.
Heat loss in the Atlantic Water boundary current on its way into the Arctic Ocean - insights from observations north of Svalbard

**Arild Sundfjord**¹, Angelika H.H. Renner ², Markus Janout ³, Randi Ingvaldsen ⁴, Agnieszka Beszczynska-Möller ⁵

¹Norwegian Polar Institute, Norway, ²Institute of Marine Research, Norway, ³Alfred Wegener Institute, Germany, ⁴Institute for Marine Research, Norway, ⁵Institute of Oceanology- Polish Academy of Sciences, Poland

Atlantic Water (AW) entering the Arctic Ocean along the shelf break around Svalbard is the largest oceanic heat source for the Arctic Ocean. A mooring array has been deployed since 2012 north of Svalbard to track this AW inflow as it follows the upper continental slope as a topography-following boundary current. Heat content varies significantly throughout the year with largest heat transport and highest heat loss in autumn and winter. Along the slope north of Svalbard, we estimate an annual mean heat loss of about 16.5 W/m² in the upper 200 m between 22 and 31°E, the longitudes of the moorings. A large part of the AW heat is thus lost to the atmosphere during the eastward journey. In autumn, upward heat flux can be an order of magnitude larger over periods of days to weeks, and the large volume of incoming warm water appears to keep the slope area ice free well into winter, even during episodes when sea ice is advected into the region. Local vertical processes in the ocean such as wind-driven and tidal mixing and shedding of mesoscale eddies contribute to the spatial and temporal variability in heat loss.
FEATURED TALK: Sea-ice phenology in a warmer Arctic

**Letizia Tedesco** ¹, Marcello Vichi ², Enrico Scoccimarro ³

¹Finnish Environment Institute, Finland, ²University of Cape Town, South Africa, ³Euro-Mediterranean Center on Climate Change, Italy

Future projections of Arctic sea-ice changes are alarming, but the response of the ice-associated biological community is still uncertain. Here we investigate future changes in timing and intensity of primary production in Arctic first-year ice using a combination of climate and sea-ice biogeochemistry models. Overall, model results suggest a general increase in sea-ice primary production at all latitudes during this century. However, the projected phenological changes are not as quasi-monotonic as the changes in physical drivers. Three latitudinal clusters are identified and distinctly explained by snow cover thinning at the lowest latitudes, biological time windows narrowing in the mid latitudes, and ice seasons advancing towards more favourable photoperiods at the highest latitudes. When considering the changes in ice extent, the increase in sea-ice production at the highest latitudes is boosted due to significant first-year ice expansion at the expense of multiyear ice. The projected changes in sea-ice primary production suggest potential far-reaching consequences for the whole Arctic marine food web.
Norwegian Climate Prediction Model

Yiguo Wang 1, Francois Counillon 1, Noel Keenlyside 2, Ingo Bechke 3, Madlen Kimmritz 1

1Nansen Environmental and Remote Sensing Center, Norway, 2University of Bergen, Norway, 3Uni Research Climate, Norway

Recently it has been demonstrated that the slow fluctuations of the climate can be predicted up to a decade in advance in region such as in the North Atlantic. Prediction of near-term climate changes is of great interest to stakeholders e.g., fisheries, energy, shipping, farming, and insurance sectors. The Bjerknes Centre has developed climate prediction capability (the Norwegian Climate Prediction Model, NorCPM) that makes use of existing observations to control the internal variability of the climate that drives these slow fluctuations. The NorCPM combines the Norwegian Earth System Model (NorESM) with the ensemble Kalman filter (EnKF) data assimilation method and assimilate observations of ocean and sea ice. We will present the system and the skill of the most recent system for seasonal to decadal time scales. It is for instance shown that NorCPM can predict variability of the temperature in the Nordic Sea up to one year in advance, which has been shown to influence temperature and precipitation over Norway and the migration of the cod. The system shows also skill in predicting Arctic sea ice extent from January and April up to one year in advance, in particular in the Barents Sea and the Labrador Sea.
The Year of Polar Prediction - From Research to Improved Environmental Safety

Kirstin Werner, Thomas Jung, Helge Goessling, Winfried Hoke, Katharina Kirchhoff

Alfred Wegener Institute, Germany

In May 2017, the World Meteorological Organization (WMO) officially launched the Year of Polar Prediction (YOPP). From mid-2017 to mid-2019, scientists and operational forecasting centers worldwide are working together to observe, model, and improve forecasts of the Arctic and Antarctic weather and climate systems. This international effort aims to close gaps in polar forecasting capacity. Improved forecasts of weather and sea-ice conditions in polar regions are also expected to result in better weather and longer-range prediction at lower latitudes where most people live.

During two Special Observing Periods in the Arctic (1 February – 31 March 2018 and 1 July – 30 September 2018), routine observations will be enhanced, for example by additional radiosonde launches and buoy deployments. Scientists will intensely observe the Arctic system as part of coordinated field campaigns. Coordinated aircraft campaigns, satellite observations, and newly installed automatic weather stations will provide new insights into the processes governing the Arctic climate and related impacts on global weather systems.

The WMO’s Information System will house the majority of the data collected across the initiative, making them available for operational forecasting centres to feed into their forecasting systems in real-time. Social scientists will assess the practical needs of stakeholders from the transport, shipping, and tourism sectors and how better polar forecasts could affect the outcomes of socio-economic decision-making.

The International Coordination Office for Polar Prediction (ICO; hosted by the Alfred Wegener Institute in Germany) supports the Polar Prediction Project by supporting the planning and implementation of YOPP activities as well as ensuring international coordination between a variety of involved partners and collaboration with related WMO and other international programmes.
Polar Prediction Matters - A Dialogue Platform to Engage with Forecast Users

Kirstin Werner 1, Helge Goessling 1, Winfried Hoke 1, Dragana Bojovic 2, Luisa Cristini 1, Jackie Dawson 3, Gerlis Fugmann 1, Halldór Jóhannsson 4, Thomas Jung 1, Machiel Lamers 5, Daniela Liggett 6, Raeanne Miller 7, Marta Terrado 2

1 Alfred Wegener Institute, Germany, 2 Barcelona Supercomputing Center, Spain, 3 University of Ottawa, Canada, 4 Arctic Portal, Iceland, 5 Wageningen University, Netherlands, 6 University of Canterbury/Gateway Antarctica, New Zealand, 7 The Scottish Association for Marine Science (SAMS), Scotland

The Year of Polar Prediction, initiated by the World Meteorological Organization (WMO) and taking place between mid-2017 and mid-2019, attracts considerable attention to polar forecasting. However, our knowledge of what information is really needed at the end of the forecast chain is rather limited. In particular, important insights into the use of environmental forecasts by users operating in polar regions are often restricted to relatively small audiences, such as the participants of specific science meetings. Together with partners from the EU-funded Horizon 2020 projects APPLICATE and Blue-Action, the International Coordination Office for the Polar Prediction Project (PPP) and the PPP-subcommittee on “Societal and Economic Research and Application” have initiated a non-peer reviewed forum titled Polar Prediction Matters with the main aim to strengthen the dialogue between polar forecast providers and users. The platform facilitates discussion between those that research, develop, and provide polar environmental forecasts and those that use (or could use) polar environmental forecasts to guide socio-economic decisions. Polar Prediction Matters features written contributions that provide a range of individual views on how polar environmental forecasts (and other environmental information such as satellite imagery) are actually used, what additional information is needed, and what factors might limit the effective use of forecasts. The majority of contributions offers perspectives from forecast users, but contributions by providers (meteorological and sea-ice services and climate scientists) and social scientists concerning the creation, delivery, and utilization of forecast information and services are also included. Collectively, these diverse perspectives will contribute to a better understanding of the actual needs of users, thus helping guide research towards significantly improved prediction capabilities in polar regions in a way that is meaningful to a wide variety of stakeholders. In this presentation, we will report on first contributions and experiences with the forum.
Spatial and temporal patterns of sea-ice leads in the Arctic Ocean during winter: Observations from MODIS thermal infrared imagery, 2002-2016.

Sascha Willmes, Günther Heinemann

University Trier / FB VI, Germany

The occurrence of sea-ice leads represents a key feature of the Arctic sea ice cover. Leads promote the flux of sensible and latent heat from the ocean to the cold winter atmosphere and are thereby crucial for air-sea-ice-ocean interactions. We use the thermal signature of leads in the MODIS ice surface temperature product and a subsequent cloud artefact filter to infer daily and monthly composite lead maps for the Arctic Ocean during wintertime (Jan-Apr), 2002-2016. Our results highlight the marginal ice zone in the Fram Strait and Barents Sea as the primary region for lead activity. The spatial distribution of the average pan-Arctic lead frequencies reveals distinct patterns of predominant fracture zones along the Arctic Boundary Current, in the Siberian sector of the Arctic Ocean as well as in the well-known polynya and fast-ice locations. Additionally, a substantial inter-annual variability is indicated. We further discuss the potential asset of this data set for an operational high-resolution sea-ice monitoring.
Resilient Arctic Societies and Industrial Development
Growing resilient arctic societies through strategic partnerships

Karen Barnes, Bronwyn Hancock, Shelagh Rowles, Tosh Southwick, Michael Hale
Yukon College, Canada

Drawing on examples across Yukon, this paper focuses on the social and economic changes occurring in this northern Canadian territory over the past decades, despite continuous booms and busts within the mine industry. Yukon College and its partners in industry and First Nation governments are now working together to support the resilient communities of Yukon through these cycles using innovative programming and new partnerships. Federal and territorial investments jointly support these initiatives.

In the early 1990s the last thriving mines in Yukon closed. The impact was felt across the territory. Population decreased and unemployment rose. Particularly hard hit were those from the 14 Yukon First Nations who chose to remain in their traditional territories. At same time, many Yukon First Nations were in the final stages of settling their land claims and self-government agreements with Canada and the Yukon. In 1993, four of the first agreements were signed. By 2005, 11 of Yukon’s 14 First Nations had signed agreements.

During an industry contraction and the economic downturn in the Yukon in the 1990s, Yukon College evolved from being solely a vocational school serving industry to broadening its programming into professional degrees and research. Although student enrolment dropped, this new programming meant that the College continued to serve Yukoners with entry level career programs, university transfer and two degrees. In 2009, the economy in the Yukon began to improve. Mining exploration reached an all-time high in 2011. With this exploration came jobs, with opportunities from entry labour positions to highly skilled professional roles. Importantly, First Nations governments in the Yukon also had a much stronger voice in mine permitting and development. Concurrently, Yukon College recognized the need to take a stronger role in the territory’s resilience, and reached out to its partners in government and First Nations to co-design a new entity that would not only begin training for the needs of industry, but would establish a collaboration that would ensure that training, education and research would continue through the next contraction. This became the Centre for Northern Innovation in Mining and the Yukon Research Centre at Yukon College.

This paper will describe how this different context is working by providing examples of innovative projects built from these new partnerships. Presenters come from various areas of Yukon College including senior leaders from the Yukon Research Centre, Centre for Northern Innovation in Mining, First Nations Initiatives, and Community Innovation and Development.
FEATURED TALK: Imbalanced power? Indigenous-industry relations in Arctic renewable energy

Else Grete Broderstad ¹, Hans-Kristian Hernes ¹, Greg Poelzer ²

¹UiT The Arctic University of Norway, Norway, ²University of Saskatchewan, Canada

Industrial resource development on Indigenous lands is often a venue for the clash between traditional use of renewable resources and large-scale economic development of non-renewable and renewable resources. The past two decades have demonstrated that industrial resource development does not always mean a zero-sum game; indeed, Indigenous peoples in some counties have entered numerous benefit sharing arrangements that have not only generated increased wealth at the community level, but also facilitated greater opportunities to pursue traditional harvesting. With greater efforts made by national governments to mitigate global warming and to meet targets of the Paris Agreement, national and regional governments are increasing investments in the development of new, and the expansion of existing, renewable energy projects. The generation, transmission, and distribution of green electrical power is leading, in many instances, to new clashes between Indigenous land users and industrial development. Can the lessons from the extractive industries, particularly the concept of benefit-sharing, also apply to electric power sector?

This paper[1] focuses on the question of benefit sharing and electric power through an examination of two cases – the state-owned utility company, SaskPower Corporation in Saskatchewan, Canada and the privately owned Finnmark Kraft AS in Norway. The empirical analyses will be structured around the concepts of benefit and equity sharing. Benefit sharing, referred to in international hard and soft law, has been linked to indigenous peoples’ rights to land and resources. By drawing on the Equity Framework of McDermott et al (2012), we will discuss the process by which equity is defined, the goal of equity, who counts, and what counts in evaluating equity. Dimensions as “procedural”, equal access to decision-making, “distributive”, concern fair distribution of resources with regard to the conditions of benefit sharing in indigenous-industry relations.

[1] This work is part of the research project The Arctic governance triangle: government, Indigenous peoples and industry in change (TriArc), funded by the Research Council of Norway.
Visual reporting: an approach to sharing context-rich information in environmental planning and decision-making

Tracie Curry

University of Alaska Fairbanks, USA

Iñupiat communities on the North Slope (the northernmost region of Alaska) are facing numerous challenges and opportunities related to the current and projected effects of climate change, and resource development activities with potential for far-reaching impacts on indigenous ways of life. Though these changes have significant local impacts, most planning and decision-making activities happen outside the local scale, and involve numerous other actors such as government agencies, Industry, and NGOs. A major challenge within this transdisciplinary dynamic is cultivating a meaningful understanding among outsiders of the personal experience of change and its local impacts for Arctic communities. Additionally, among information sources generated, shared, and used for decision-making, local and indigenous knowledge are often underrepresented due to conventions that privilege Western science. This leaves decision-makers with imperfect or insufficient information, and may lead to biased decisions that ultimately harm North Slope communities.

There are strong arguments for the inclusion of local and indigenous knowledge in research and decision-making. However, methods to achieve meaningful inclusion of this information in practice are not well-documented. In response, the focus of this project is the content and format of information transmitted from local communities to outside entities, and the potential for context-rich images within this information to help convey qualitative and experiential detail. Through a case study of the Native Village of Wainwright in North Slope, Alaska, this research draws from semi-structured, in-depth interviews with Elders from the community to identify major themes of social-environmental change. It also incorporates input from agency decision-makers involved in North Slope environmental planning to understand desirable characteristics of visual reporting methods. The project and its methodology are the outcome of an iterative process in partnership with the Wainwright Traditional Council and with guidance from a project steering committee comprising local leaders from the community.
Recognized by postcolonial writers as "state creatures" serving the purpose of assimilation but viewed by others (specifically indigenous elites) as an empowering tool serving indigenous interests, indigenous institutions are still at the centre of a number of debates. If we agree with the postcolonial thinkers’ perspective about these institutions, we consider that their normative position has blocked all attempts to understand the real effect of these institutions in the long run. My research attempts to do so by examining how these institutions are changing the relationship between Aboriginal peoples and the state. We want to see this relationship with the citizenship regime analysis tool that we can define as "all the institutional arrangements, rules and understandings that guide and shape the political decisions and common spending of States, definitions of problems by States and citizens and claims by citizens "(Jenson and Saint Martin 2003, 5). Therefore, the citizenship regime is a useful analytical tool to understand how relations between the state and indigenous peoples are framed. For this I am establishing a comparison between Nunavut territory in Canada and the Sami parliament in Norway. Why this comparison? Because these institutions, if they are not structurally similar, they represent the interests of a population with the same contemporary problems (climate change, language protection, economic sustainability, etc.) and are part of a global indigenous movement that began in the 1970s to redefine indigenous citizenship and establish a more egalitarian relationship with states. These movements have changed the boundaries of citizenship and it can be assumed that the indigenous institutions within these movements, and as a reaction of the state (in Canada and Norway), contribute to these changes.

My research studies the evolution and transformation of Inuit and Sami citizenship systems (I divide the citizenship regime into three indicators: the acquisition of rights (the history of indigenous rights and their exclusion or assimilation in dominant societies), democratic participation (the evolution of the participation of Inuit and Sami in the dominant society) and identity (see the transformation of Inuit and Sami identity, the way they define themselves, are defined by society dominant and finally define the others) since the implementation of the territory of Nunavut and the Sami Parliament (created in 1999 and 1989 respectively).
Designing, forming, implementing a serious game "Artic Climate in Society" (ARctIS) to elucidate intra- and intergenerational decision-making under scenarios of climate change for communities of Norway

**Dorothy Dankel** ¹, Rachel Tiller ², Yajie Liu ³

¹University of Bergen, Norway, ²SINTEF Ocean, Norway, ³NTNU-SØF, Norway

Climate change is anticipated to have a variety of effects on the provision of marine ecosystem goods and services, and these effects could have profound impacts on the people, including affecting life's basic needs (Millennium Ecosystem Assessment 2005). Climate change affects marine ecosystems and their services directly among others through marine resources (e.g., species), including their biomass, distributions and interactions. By assessing ecosystem services and the natural marine system and the effects of value of the services that the natural system provides, we can assess the potential impacts when climate changes. But what good are climate change forecasts of impacts if they are not used or deemed useful by stakeholders and decision-makers and managers?

The primary goal of the REGIMES.no project funded by the POLARPROG of the Research Council of Norway is in light of this to promote outstanding climate research to the benefit of society. In this paper, we therefore outline a unique method that directly links climate modelling and society, focusing on stakeholders of today as well as the stakeholders of tomorrow. The link is visualized through the development and testing of a unique serious game. In this paper, we describe the bold intra- and inter-generational approach to climate change communications by involving high school students, their parents, and retired and elderly citizens (from local chapters of the Grandparents Climate Campaign) in our stakeholder gaming workshops in Bergen. Through the climate scenario game, the multi-generational stakeholders will interact with decision-making scenarios, and elucidate ethical and philosophical discussions of trade-offs in the Arctic under a changing climate. We describe the set-up and protocol of the game as well as how results will be analysed, as well as the potential for game replication in Trondheim, Tromsø, Oslo and Longyearbyen.
FEATURED TALK: Environmental Refugees and Migrants: Planned Relocation as an Adaptation Strategy to Climate Change

Livia de Conciliis

SIOI, Italy

Climate change combined with the world population increase and less sustainable resources exploitation, affect population movement and distribution (Warner et al., 2003), as already pointed out in 1990 by the Intergovernmental Panel on Climate Change (IPCC) in its first evaluation report[1]. Either as a key factor or as an accelerator to other trends, climate change is going to affect our life conditions in the future: indeed, it can represent a threat to the sustenance of entire populations and modify the exposition of others to natural disasters, forcing people to migrate. According to the International Displacement Monitoring Centre (IDMC), only in 2015, 19.2 million people were displaced by disasters [2]. This figure is likely going to increase in the next years [3]: considering that human mobility is affected by – as much as affects itself – the ways national States adapt their selves to climate change alterations, it is suitable and necessary that they apply mitigation and adaptation policies. In this regard, the planned relocation of those communities exposed to the impact of climate change – as it is already taking place in some areas of the world, often upon requests of the involved populations – could represent an example of good practice combining humanitarian protection and sustainable development.

In the light of the guidelines set by the United Nations High Commissioner for Refugees (UNHCR), the International Organization for Migration (IOM), the European Commission, the national States and research institutes as the IDMC, this paper aims at describing characteristics, potentiality and risks of planned relocation as an adaptation strategy to climate change, taking into account that thinking, talking and planning about relocation, does not automatically mean carrying it, rather it represents an exercise of responsibility, necessary in order that relocation is carried out respecting human rights and on the basis of previous experiences.


[2] In the same year, half of the people were displaced by conflict and violence (8.6 million). Source: IDMC, http://www.internal-displacement.org/globalreport2016/#home

[3] Future forecasts vary from 25 million to 1 billion environmental migrants by 2050, moving either within their countries or across borders, on a permanent or temporary basis, with 200 million being the most widely cited estimate. This figure equals the current estimate of international migrants worldwide. (Sources: IOM, https://www.iom.int/complex-nexus#estimates)
Coastal Indigenous Peoples in the Arctic and the protection of marine environment

Lara Fornabaio ¹, Margherita Poto ²

¹University of Ferrara, Italy, ²K. G. Jebsen Centre for the Law of the Sea, UiT, Norway

The article identifies the main challenges that climate change and environmental threats pose to the population living in the Arctic, especially looking at the indigenous peoples whose survival depends on the marine environment.

The analysis starts from some considerations on the need to provide special protection to the Arctic marine environment and its coastal indigenous peoples (CIPs), taking into account food security issues. Indeed, the linkage between indigenous food systems and seascape means that climate change and food security are interdependent, as abundance or scarcity of food respond to temperature fluctuations. Then the paper shifts to the analysis of the different regulatory answers to the threats posed by climate change on the Arctic environment and on the indigenous population, as provided by international, regional and national actors, and namely: 1. the Arctic Council’s activity addressed to establish marine protected areas (MPAs); 2. the European Union’s attempts to preserve the Arctic Sea; 3. the national establishment of MPAs with the consultation of the indigenous groups.

The objective of the contribution is to investigate on effectiveness of the current legal tools to guarantee an adequate level of protection for the both marine environment and the coastal population, as well as on the possible ways to improve it. The vulnerability of all the actions undertaken so far lies in the scarce level of participation of the local peoples as well as by the lack of a political will to effectively decentralise the decisions that are connected to the management of marine protected areas. Potentially fruitful research lines will have to focus on a systematic mapping of the virtuous co-management regimes, where the participation of all the stakeholders is effective and the dialogue with the indigenous peoples and their local knowledge is lively and open.
Analysis of the solar energy potential on buildings in Tromsø

Clara Good, Tobias Boström

UiT - The Arctic University of Norway, Norway

Solar energy is a little used resource at high latitudes. This is partly due to the misconception that the solar resource is not sufficient in the north. On the contrary, there are conditions that make the northern regions highly suitable for solar energy utilisation, such as low temperatures, which increase photovoltaic (PV) efficiency, and solar reflection from snow, which can increase the available radiation.

The number of solar energy systems in Tromsø today is negligible. This study presents a potential analysis for building integrated photovoltaic (BIPV) systems or building added photovoltaic (BAPV) systems in Tromsø. The purpose of the study is to quantify the contribution that solar energy could make to the local energy system.

A major benefit of PV systems on buildings is that roofs and facades are typically “unused” spaces. These types of PV installations will therefore not occupy any additional areas and potential land use conflicts can be avoided. In addition, solar energy systems are silent, require no fuels and do not produce emissions. Using a local network of distributed renewable energy sources, such as solar energy systems, can also contribute to a more resilient energy system.

The analysis presented here performed using statistical data on the building mass. It is assumed that the PV systems are installed on buildings (private homes as well as office or industrial buildings) and the analysis is therefore based on an estimation of available areas on roofs and facades. The suitable area for PV installations is determined using the simplified method proposed by IEA PVPS Task 7, which is based on the ground floor area of the buildings and relative factors for architectural and solar suitability.

The focus of this study is PV systems that generate electricity. The energy output of different types of PV systems on specific buildings are simulated using PVsyst, but rule-of-thumb values are also used in the urban-scale analysis.

Since the potential analysis presented here is based on statistical data, it can only provide an estimate of the actual potential. Future, more detailed studies will utilise GIS in combination with LiDAR data to analyse the potential on actual buildings in Tromsø, existing as well as planned.
FEATURED TALK: Advancing the governance system for Arctic shipping: role of the Arctic Council in facilitating institutional interplay

Piotr Graczyk

UiT The Arctic University of Norway, Norway

Negotiations on the binding International Code for Ships Operating in Polar Waters (Polar Code) adopted in 2014/2015 by the International Maritime Organisation (IMO) revealed a network of various institutions and actors interested in regulating shipping activities in Arctic waters. The Arctic Council (AC) has significantly stepped up its role in governing shipping activities in the Arctic, primarily through the follow-up actions on the 2009 Arctic Marine Shipping Assessment (AMSA) recommendations. This presentation examines the key interplay mechanisms between different levels of the governance system of shipping in the Arctic, primarily between AC and IMO. The objective is to explore the AC’s institutional impact on Arctic shipping governance through the analysis of its role, which is conceptualised through institutional tasks, functions and “pathways of influence”. In a three-step analysis the presentation addresses relevant AC’s functions and measures at its disposal applicable to Arctic shipping. Firstly, it defines AC’s position within the system and summarises its relevant work pertaining to shipping such as already undertaken initiatives. Secondly, it identifies areas in which AC may have impact on regulations on both national and international levels. Thirdly, the presentation explores the mechanisms of interaction between AC and IMO and other international institutions. Three distinct channels for interplay are analysed to systematically specify principal “pathways of influence” through which AC may sway the shipping governance system in the Arctic. The focus is not, however, on areas on which the impact may be exerted as these have been identified by others (e.g. Stokke 2013), but rather on definite mechanisms and instruments at the disposal of the Arctic states to be used through AC. In that sense, AC is seen as a tool in international diplomacy, negotiations and policy-making and an instrument of influence on individual members. The study uses cases from actual work of the AC’s working groups, the Norway’s involvement in both within AC and IMO as well as bodies such as the newly established Arctic Marine Shipping Best Practices Information Forum. The latter case is further an example of shipping industry (including insurance business) involvement in decision-shaping procedures and their own interest in development of new international bodies. In particular, the AC’s work on coordinating international regulatory and policy activities related to Arctic shipping and efforts to incorporate perspectives from a broad range of actors, such as indigenous peoples, NGOs, IGOs and industry are central for this presentation.
Concerns about a resource curse in Arctic regions have been raised in response to rapid growth in the extractive industries in the circumpolar North. Yet, the contemporary resource curse debate that examines the linkages between resource extraction and socio-economic development is largely focusing at the national level. This paper gives consideration to how symptoms of the resource curse are experienced at a regional scale, among others, by Indigenous communities. Our data covers seven regions of the Russian Arctic: Murmansk Oblast’, Nenetskiy AO, Komi Republic, Yamalo-Nenetskiy AO, Krasnoyarsk Krai, Sakha Republic (Yakutia), and Chukotskiy AO. We empirically examine the four main interpretations of resource curse, including 'Dutch disease', (negative) correlation with economic growth, 'staples trap', and political rent-seeking, and assess their applicability at the level of an extractive Arctic region. First, we show that the “Dutch disease” type of argument, which highlights the roles of state-level institutions (resource ownership, exchange rate, industrial policy), can only be made at the national level. Second, we apply correlation analysis and find no evidence of systematic negative association between economic growth and the added value of production in extractive industries. Third, we compare the regions in terms of their economic diversification and per capita GRP and find that more specialised regions enjoy higher economic performance. Fourth, we demonstrate that due to the Russian federal taxation regime resource rents do not stay within the extractive regions, prompting their governments to rely on regional taxation rather than rents. Finally, we explore the relationship between a range of indicators of socio-economic development and resource extraction in these seven regions and conclude that while regions vary in the patterns of their socio-economic development, we cannot attribute these differences to growth in extractive industries.
Building corporate trust and credibility in a politicized resource region: The story of the oil company North Energy

Vegar Lunde Hafnor, Peter Arbo

University of Tromsø – The Arctic University of Norway, Norway

New extractive industries entering the Arctic often face strong expectations of creating ripple effects and contributing to local and regional development. To acquire a social license to operate, the companies have to demonstrate that they are concerned with the environmental and social aspects of their industrial activities, and not just their own profits. The major oil companies have long experience in dealing with such conflicting considerations as they move into new petroleum provinces. Nevertheless, oil and gas exploration and exploitation in the Arctic are becoming increasingly controversial.

In this paper, we analyse the oil company North Energy, which was established in 2007 by regional entrepreneurs who aimed to create a fully North Norwegian petroleum company. We present the story of North Energy and explore the attempts to build corporate trust and credibility in a politicized resource region. How did the regional oil company define its identity and role? How did it seek to balance the expectations of being both a professional company and a community builder? The paper shows the ways in which North Energy endeavoured to be a different oil company, rooted in the region, but at the same time serving as a door opener for the petroleum industry in the north. This double track did not succeed, and we summarize important lessons from the case of North Energy.
Consultations and FPIC - new tools for indigenous peoples?

Hans-Kristian Hernes

UiT The Arctic University of Norway, Norway

States and indigenous peoples have a troublesome relationship, not least due to uneven resources and a history of colonialism and the majority suppressing the minority. This is a challenge in the Arctic and Northern areas where new industrial development increase the challenges on indigenous peoples. Efforts to improve the relationship and secure the role of indigenous peoples have been thriving, not least by international law and conventions. The 2007 UN Declaration on the Rights of Indigenous Peoples (UNDRIP) continues to be a hallmark, also by renewing the emphasis on tools like free, prior and informed consent (FPIC) and consultations.

Norway is among the few countries that have ratified ILO Convention no 169, a convention that has been important in the development of consultations between the Norwegian state and the Norwegian Sami Parliament. Consultations have become a crucial part of the relationship, and given the Sami Parliament an important tool to participate in political and administrative processes. Consultations are however also challenging, not least in cases related to new industries.

In the paper, I first make a presentation the formalization of consultation as part of Sami politics in Norway. The following discussion has two paths. One where consultations – in the ILO 169 framework – are discussed from a principal, or theoretical, point of departure. Based on this, the second part is an effort to summarize the strengths and weaknesses on consultations as a tool for indigenous peoples. By doing this, the intention is to put forward some general experience of relevance for implementation of UNDRIP and the principle of free, prior and informed consent, but also to illuminate challenges for development in Arctic and Northern areas.
Socio-economic implications of energy subsidies removal in the Russian Arctic (the Sakha Republic case study)

Mariia Iakovleva

University of Saskatchewan, Canada

In the proliferous environment of the Arctic these days, fuel dependency remains one of the vital problems based on complex transport systems and remoteness of communities in the North. This problem leads to a large economic burden not only on the state budget but on industries. The feasible solution is seen in the deployment of renewable energy technologies that have had a noticeable update in the last half-decade. However, this has been in a context of the policy of energy subsidies, namely cross-subsidization - an approach of price equalization between industrial and residential consumers for on- and off-grid communities - in the Russian Far East. In recent years, the volume of cross-subsidies has significantly grown and become a very serious problem in Russia. In 2016, the amount of cross-subsidization in the Sakha Republic/Yakutia, the largest federal entity of Russia, was equal to 6.8 billion RUB (118 million USD). Cross-subsidization in Yakutia exists since almost half of the territory is above the Arctic circle with 125 diesel stations united into regional islanded microgrids (ITAR TASS Far East, 2016). Preservation of the mechanism of cross-subsidization has led to distortions in the economy, non-compliance with the basic principles of pricing in the electricity industry. At the regional level, cross-subsidies lead to a shortfall of financial assistance from the federal budget. At the municipal level, there is a distorted formation of power generation costs which leads to the wasteful and inefficient use of energy resources (Elyakova & Elyakov, 2015).

However, according to a decree of the President of Russia (2016), cross-subsidization of the diesel generated energy is to be consistently phased-out in the Sakha Republic within ten years. Thus, this raises an important question: what are the socio-economic implications of the phasing-out of cross-subsidies?

Removal of cross-subsidies is particularly important for economic stability, which is aggravated by the threat of social insecurity due to the absence of economically effective competition in the energy industry in the Far East. At the same time, cross-subsidization of the residential consumers adversely affects the competitiveness of a number of branches of Russian industries. Cross-subsidization creates incentives for large-scale industrial consumers (diamond, gold, oil companies Yakutia economy based on), to invest in creating self-generation or joining the national grid by opting-out from the regional grid. Therefore, it is essential to research and expose the implications of energy subsidies removal for the society and industries based on national, regional, and municipal policies.
The Norwegian Barents Sea-Lofoten Ocean Management Plan: How Have The Valuable & Vulnerable Areas Been Protected From Maritime Vessel Activity?

Onni Irish

Jebsen Center for Law of the Sea, UiT / Center for Coastal & Ocean Mapping, University of New Hampshire, USA

The Norwegian Barents Sea-Lofoten integrated ocean management plan (plan) was designed using an ecosystem based management architecture, an approach that examines an ecosystem holistically, accounting for both human and natural uses. The plan identifies seven areas where the environment and natural resources are considered valuable and vulnerable. To determine these spatial areas, scientific assessments were conducted to assess hotspots for biodiversity and productivity. According to the Norwegian Government, however, “the designation of areas as particularly valuable and vulnerable does not have any direct effect in the form of restrictions on commercial activities, but indicates that these are areas where it is important to show special caution” (Meld.St.20 (2014-2015), p.24). This statement begs the question, what constitutes “special caution”? Specifically, what precautions must commercial activities give to the valuable and vulnerable areas? Although the plan’s original intent was to protect the valuable and vulnerable areas from one form of commercial activity in particular (i.e., petroleum industry), other commercial activities are growing in the region, namely maritime vessel traffic. Maritime vessel activity encompasses all forms of traffic, from cruise ships and fishing vessels to bulk carriers and petroleum industry supply ships. All of these vessel types present a series of risks to the Barents Sea, including the introduction of potential hazardous pollution and alien species or physically disturbing the environment during transit and scarring the seafloor (e.g., anchoring or fishing gear). Additionally, the declining extent of Arctic sea ice is opening up new navigation routes. Five of the seven potential Arctic Ocean shipping routes pass through the Barents Sea; indeed, three of these routes pass near Svalbard, a critical archipelago in the northern section of the Barents Sea that enjoys strict marine protection. This research will investigate whether measures taken by Norway to regulate maritime traffic have an effect on vessel movement within the valuable and vulnerable areas. The first step to complete this research is to review domestic policies and international agreements Norway has adopted that are applicable to maritime traffic in the Barents Sea. Secondly, AIS (vessel) data will be analysed using GIS software from 2005 to 2017 to determine if the adopted measures have affected maritime traffic patterns with respect to the valuable and vulnerable areas. Such research is timely given the growing risks maritime commercial activity pose to the Barents Sea, including the impact climate change is having on Arctic maritime shipping routes.
The NPA project URCHIN - Utilising the Arctic sea urchin resource

Philip James

Nofima, Norway

Nofima are the lead partner in the three year URCHIN project, funded by the Northern Periphery and Arctic Program (NPA). The project aims to utilise the sea urchin resource present in the northern arctic regions and develop the sea urchin industry in Norway, Greenland, Ireland and Iceland. Each of these countries have quite specific challenges regarding sea urchin fisheries. Therefore, the project is diverse and addresses a number of challenges experienced in isolated and environmentally harsh and challenging areas in the Northern and Arctic region.

The project research areas include the following. The development of fishing techniques appropriate for the arctic regions. Implementation of fisheries management and legislation, including suitable methods of stock assessment, to enable sustainable fishing in arctic areas. The use of roe enhancement as a means of utilizing urchins from Arctic areas that are present in very high numbers (urchin barrens) but are too low quality to fish commercially. The ecological benefits of roe enhancement have been investigated in a complimentary project ECOURCHIN. Storage and transport of sea urchins in arctic areas is problematic and has been an area of research in the URCHIN project. Finally, market value and placement is crucial in order to develop new, or to expand existing industries. How sea urchins products from the Arctic area fit into existing, or new markets has been investigated.

The URCHIN project has created a platform for the development/expansion of sea urchin fisheries in the NPA area and has had a positive impact on small business and local communities in remote areas of the Northern Periphery. This talk describes how the sea urchins industry looked in the NPA area prior to the URCHIN project. How it will look at the conclusion of the project (April 2018) and some examples of the economic and social impact the project has had in the NPA area.
Variation in commercial fish stock abundance and geographical distribution and commercial fisheries in a warming Arctic.

Jan Erik Stiansen, Geir Odd Johansen, Endre Moen

Institute of Marine Research, Norway

This paper would fit a proposed session in the Resilient Arctic Societies and Industrial Development segment based on the STOCKSHIFT project (see paper proposals by Hønneland, Molenaar, and Stokke) but can also be a freestanding contribution.

Marine ecosystems are under continuous change, both due to natural and anthropogenic pressures. Such changes influence both the abundance and geographic distribution of marine organisms. The mechanisms involved are diverse and they often interact. Different mechanisms influence different parts of the life cycle of the organisms. There are also strong interactions between abundance and distribution shifts.

Since mid-1970s, we have witnessed a warming of the Norwegian and the Barents Seas. This have had pronounced effects on the abundance and spatial distribution of marine organisms, on the biological communities, and on the functionality of the ecosystem. Along with these changes we have observed major changes in the abundance and distribution of commercial resources, such as Northeast Arctic cod and Northeast Atlantic mackerel. The Northeast Arctic cod now exhibit its largest abundance and widest geographic distribution on record.

The presentation draws upon on a new database under development in the STOCKSHIFT project, which combines time-series of (i) survey data on abundance and geographic distribution of important commercial fish stocks in the Norwegian and Barents Sea, (ii) data from the commercial fisheries on the same stocks from the same period, and (iii) temperature data. We summarize the observed changes in abundance and geographic distribution and analyse the variation in catch and distribution of fishing effort.

The objective is to evaluate and understand the potential responses in the commercial fisheries to the changes in abundance and distribution of these species. This will serve as a basis for understanding the potential effects of climate change on commercial fisheries in Arctic waters in the future, as well as feed into the analysis of socio-economic implications and intergovernmental management challenges also examined in the STOCKSHIFT project.
Using Traditional Arctic Games to Promote Sustainability and Peace in the North

John Kilbourne

Grand Valley State University, USA

With climate change expanding trade routes in the Arctic and the resultant pursuit of oil, gas, mineral deposits, and fish, it is imperative that the eight Arctic countries find paths towards sustainability and peace in the region. Revisiting and understanding the traditional games of the indigenous people of these regions can go a long way towards helping those determining the region’s future to work cooperatively towards these goals.

Throughout history the games we have played have been a testament about who we were, and are. From early Inuit bone and hunting games, to the gladiator contests of Ancient Rome, to the modern American game of baseball, the games we play have served as a statement of and a rehearsal for the life-world of that period and place. By reconnecting with and understanding the games of our past, we can build meaningful bridges between our past and present, and hopefully gain a better understanding of our modern world. The aforesaid are timely and important, especially as they relate to indigenous people throughout the world who are trying to preserve their traditions in a fast changing modern world.

This presentation/paper will offer, based on my research and experiences in the Arctic, lessons learned from traditional Sámi and Inuit games that may help promote sustainability and peace in the Arctic world. Hopefully, by acknowledging these lessons we can pursue a path forward, together reconnecting with the traditional games of the Arctic with the hope of building meaningful bridges between the past and present and moreover, helping to enhance our understanding of the important role traditional games can play in shaping an Arctic where sustainability and peace flourish.
Magnetic North: Resilience in the Changing Urban Arctic

Mara Kimmel ¹, Julie Decker ²

¹University of Alaska Anchorage, USA, ²Anchorage Museum, USA

This paper examines how northern cities integrate newcomers to build environmental, social and economic resilience. It focuses on the efforts underway in Anchorage Alaska to embed values of equity, inclusivity and justice into a resilience framework. Anchorage is the most ethnically diverse city in the United States, and foreign-born Alaskans contribute greatly to the city's and state's economy. Yet many immigrants, refugees and rural Alaskans remain at the margins of the city's social and economic life. Anchorage leaders are currently constructing a data driven policy framework focusing on building the capacity of that city to address environmental, economic and cultural change through partnerships between local government, universities, the business community and the city's museum. The city's effort is multi-disciplinary, including migration law and policy, economics, political science, climate science, social and environmental justice, and urban design theory and practice. This presentation examines these efforts with an eye toward assessing the applicability of this model to other urban centres in the circumpolar north.
Invasive Crustaceans in the Arctic: On the verge of ecological and socio-economic transformations in Northern Finnmark

Melina Kourantidou, Brooks Kaiser

University of Southern Denmark, Denmark

The introduction and establishment of invasive species in Arctic ecosystems is a key component of environmental change that has drawn the attention of both resource managers and stakeholders in the Arctic in recent years. Invasive species often enter human preferences in both positive and negative ways. The Red King Crab invasion in Northern Norway has already gained a significant foothold and has been commercially exploited since the early 2000’s. The introduced crab has acted as a noteworthy driver of change in the ecosystem as well as in the socioeconomic landscape of Northern Finnmark. The flourishing and now firmly established crab fishery, coupled with the uncertain ecological impacts from the invasion, make the current management policy in Norway contentious, since the crab is viewed as an asset by some and as a liability by others. The political desire and willingness to support local coastal communities and livelihoods in the Arctic provides significant impetus for maintaining a long-term stock in Eastern Finnmark. Increasing capital investments in the fishery, as well as in crab processing plants across Finnmark, are pressuring regulators to support the upcoming industry through institutional and governance structures that promote economic stability in the long-run. We highlight the role of environmental economic and bioeconomic tools in identifying suitable compromises among different stakeholders with interests at odds. Identification and management of the introduced species in a socially optimal fashion requires reconciliation of contrasting views on the invasion. To that end, we analyse how environmental- and bio-economics can create common understanding of the trade-offs inherent in the ecological features of the invasion and market characteristics of Finnmark’s transitioning fisheries industries. This common understanding can provide both the information and the incentive structures needed to optimize the use of Arctic benthic natural resources in creating stable and prosperous communities in Finnmark.
Piliriqatiigingniq in Practice: a look at common governance principles in Inuit Land Claims Organizations between 2006 - 2016

Katherine Minich, Piers Kreps

McMaster, Canada

Inuit land claim organizations are increasingly consulted for Indigenous representation and political positions at regional, national and more recently, international forums. The public policy learning from Indigenous Peoples has shifted power sharing and coalitions, for example Inuit land claim organizations have greater involvement in wildlife planning and protection in Canada. In our work we analysed three Inuit land-claim organization’s annual reports between 2006-2016 using an Indigenous informed framework. The framework was two-fold including an institutional lens of UNDRIP and the Inuit-specific cultural lens of Inuit Qaujimatuqangit (IQ). We reviewed each annual report’s leadership statements, organizational trends, and self-directed activities. Findings were analysed by region and by category. Characteristics from each region and topic will be presented.
Local resources, international climate policies and salvaging the welfare state: Peat production at the symbolical core of Finnish energy-economy-society interface

Hanna Lempinen

Arctic Centre, University of Lapland, Finland, Finland

While much of the debates over the Arctic energyscape are dominated by the pros, cons and prospects of northern oil and gas extraction, this presentation takes a focus on another Arctic non-renewable energy resource that sits uncomfortably between regional economic development and international climate policy priorities: peat. While at the official level the national climate and energy policies have shifted from “peat promotion” to gradually phasing out its use in favour of more climate-friendly energy alternatives, local and industry efforts to define peat as a “slowly renewable biomass fuel” continue.

Although the share of peat in Finland’s national energy mix has gradually decreased to around five percent, the importance it still has in terms of supply security and regional economics and employment, the adverse environmental and climate impacts of peat production, and the colorful lobbying campaigns of peat producer associations make sure that the attention that peat receives in political and popular agendas remains larger than its size. This presentation takes an empirical focus on the most recent public peat promotion campaign in Finland with an aim to highlight the fundamental intertwine of “the idea of peat” and the Finnish society. As such, it provides a case study approach to the often complex discursive interplay of northern local "realities" and shifting international policy priorities in the era of accelerating global warming.
Participation in Regional Fisheries Management Organizations: A Case Study on the Arctic

Erik Molenaar

Netherlands Institute for the Law of the Sea, Utrecht University, Netherlands

This paper would fit a proposed session in the Resilient Arctic Societies and Industrial Development segment based on the STOCKSHIFT project (see paper proposals by Hønneland, Johansen/Stiansen, and Stokke) but can also be a freestanding contribution.

The issue of participation in regional fisheries management organizations (RFMOs) is of crucial importance for the performance, credibility and legitimacy of international fisheries law. States and entities may have several reasons for participating in RFMOs. In most RFMOs, States and entities mainly participate to obtain the socio-economic benefits derived from engaging in fishing or fishing related activities (e.g. provisioning of fuel, water etc., and transshipment of catch) under an RFMO’s auspices. There are nevertheless also instances in which participation is predominantly motivated by the ability to participate in an RFMO’s decision-making process, and thereby influence the substance of individual decisions as well as the evolution of the RFMO and its constitutive instrument. Participants could, for instance, be mainly concerned with strengthening an RFMO’s performance on conservation in general or on minimizing the impacts of fishing on (iconic) non-target species or ecosystems in particular (i.e. ‘non-user States’). Moreover, a State or entity could value a participatory status with a particular RFMO due to the prestige associated with the status (in particular for RFMOs that are relatively ‘closed’) or the evidence it provides of that State or entity’s commitment to, and efforts towards, responsible fishing. The latter can be of crucial importance for avoiding restrictions on access to important market States or entities (e.g. the United States or the European Union (EU)) and other measures taken against States and entities whose vessels and nationals are involved in illegal, unreported and unregulated (IUU) fishing.

This presentation will examine the rules on participation in RFMOs that are laid down in the UNCLOS and the 1995 Fish Stocks Agreement, and provide a concise overview of the rules and practices within RFMOs. The case study on the Arctic will offer a more in-depth analysis on the North-East Atlantic Fisheries Commission, the Joint Norwegian-Russian Fisheries Commission, and the currently ongoing negotiation-process on high seas fishing in the central Arctic Ocean between the five central Arctic Ocean coastal States (Canada, Denmark, Norway, Russia and the United States; also: Arctic Five) and China, the EU, Iceland, Japan and South Korea (Five-plus-Five process).
Industrial development in the North - Sami indigenous interests between globalization and self-governance

Vigdis Nygaard ¹, Per Selle ², Elisabeth Angell ³

¹Norut, Norway, ²University of Bergen, Norway, ³Uni research, Norway

Sami local communities and livelihoods in Norway have experiences tremendous changes. Increased mobility act as driving forces for change. An increasing number of Sami people experience a decoupling from their traditional territories and specific Sami industries like reindeer herding, and small-scale fjord fishing and agriculture. Change is also evident in the traditional rural Sami areas. Here we find a weak private sector but increased employment in public sector made possible by the growth of the Norwegian welfare state. The inland communities with a majority of Sami population furthermore benefit from a strong Sami institutional building and work opportunities. Others, and particularly Sami coastal communities, do not have such institutions and diversity of work opportunities. Subsequently, such communities are in urgent need of new industrial activities to survive and develop in a sustainable way. The question is; can development of new resource based industries form an alternative path of development for these Sami communities?

Global demand of natural resources and the Norwegian Northern policy of increased extraction of natural resources goes hand in hand. Offshore petroleum development, new mining projects and wind power developments are all examples of novel industrial initiatives on territories of traditional Sami land and sea use. Sami reindeer herding utilizes almost all land, and traditional Sami fjord, river and sea fishing depend on access to the resources, as well as a clean water and environment. This is a typical conflict were new industrial development with the potential of supporting new employment and diversified business milieu in a fragile local society, clash with the interests of and conditions for future traditional Sami livelihoods. To study such a conflict between global industrial development and sustainable business development in Norwegian rural areas of indigenous people, is of particular interest due to the strong legal position of the Sami indigenous people in Norwegian law without territorial rights.

This paper reveals the tension between modernity and tradition in Sami local communities meeting new industrial development. The spatial context of the study is Finnmark County where were the traditional reindeer herding is most extensive. I have selected a typical traditional Sami coastal community of Kvalsund municipality as a case to exemplify tensions spelled out in politics and arguments for future sustainable local communities when a new mining project is under planning. The purpose of this study is to reveal different Sami positions on future business development in rural Sami areas.
Swimming Away: International Cooperation on fisheries in the Arctic

Geir Hønneland

Fridtjof Nansen Institute, Norway

In 2009, Iceland and the Faroe Islands unilaterally decided to increase their annual catch quotas of the Northeast Atlantic mackerel by 6500% and 340%, a move not supported by the other coastal states harvesting that stock (i.e. the EU and Norway). The ensuing conflict over the management of the Northeast Atlantic mackerel stock has become a frequently evoked example of how international cooperation fails when under pressure from a changing climate. Similarly, in the Barents Sea a conflict over snow crab has developed between Norway and the EU. The snow crab is new to the Barents Sea, moving westwards from the Russian Arctic. From 2016, the EU has licensed vessels to catch the crab in the maritime zone around Svalbard, despite Norwegian jurisdiction in these waters. These two cases highlight growing tensions over marine resources, as changes in the distribution of the resources challenge international cooperation between states. Yet, how accurate are such depictions?
Governance and norm dynamics in the Arctic: an assessment of the role of the United Nations

Cécile Marie Lucie Pelaudeix

Aarhus University, Denmark

In the context of the analysis of transnational norm dynamics and their impact on institutional change, the proposed paper looks into the role of the United Nations in shaping norms impacting the development of economic activities in the Arctic region. The academic literature has focused on instruments like the UNCLOS or the UNDRIP, but the role of the UN as an international organization has not been examined in the context of the governance of the region, the main focus being on the primary intergovernmental body, the Arctic Council. Not only a recent decision of the Supreme Court in Canada about the respect of UNDRIP principles in the development of offshore activities stands as an important decision, but many other instruments have contributed to shape norms applying to the Arctic. Soft instruments include important declarations such as – the Stockholm Declaration (1972), the Rio Declaration (1992), the Johannesburg Declaration on Sustainable Development (2002), the UNDRIP (2007), the Rio +20 Declaration (2012). Hard Instruments include the UNCLOS, the Convention on Biological Diversity (CBD), and the United Nations Framework Climate Convention (UNFCCC) - with their relation to the Rio Conference in 1992 and its declaration. Furthermore, the UN has also launched two new instruments which have a potential to impact the Arctic: the under-discussion binding Convention on Biodiversity Beyond National Borders, and the recently adopted non-binding Sustainable Development Goals. The paper first adopts a historical approach to introduce to the negotiations of some of these major UN instruments. The paper then takes a more critical view to put in perspective the UNCLOS and the UNDRIP, compare some of their – potentially conflicting – provisions, in particular with regard to sovereignty - and then analyses the ways Arctic actors manoeuvre at various levels of governance, from regional to local, with the interpretation and implementation of the global instruments’ provisions. The paper then concludes on the extent to which the UN has so far contributed to shape the institutional framework governing the future of the region.
May Traditional Reindeer Herding Knowledge help in counteracting climate sensitive infections (CSIs)?

Jan Åge Riseth ¹, Hans Tømmervik ²

¹Northern research institute (Norut), Norway, ²Norwegian Institute of nature research (NINA), Norway

The rate and magnitude of climate change (CC) are greater in northern regions than elsewhere. CC is likely to push the geographic boundaries of climate sensitive infections (CSIs) northward, thereby increasing the potential for inhabitant humans and animals to be exposed to new and/or existing CSIs. Most CSIs are zoonoses, i.e. transmitted both-ways between animals and humans, and may be carried by vectors and reservoir organisms such as ticks, badgers and deer, which are expanding their ranges northwards. For many northern societies depending on animal husbandry or on other nature-based activities this means to deal with complex consequences of increased exposure to CSIs, which generates a dynamically interlinked scenario of societal, economic, political, and cultural change.

The Nordic research project “Climate-change effects on epidemiology of infectious diseases and impacts on societies” (CLINF) addresses these challenges, and aims to improve adaptive capacity, essential to ensure socio-economic development and viable communities in the changing North. One aspect of the project is to put emphasis on traditional knowledge (TK) and its risk management potential. TK is culture- and experience-based, transferred across generations, and includes empirical facts, social institutions and management, as well as inherited world views; it is often focused on practical application and provides a basis for cultural and community continuity. The authors study how reindeer herders’ traditional knowledge (TK) may provide a reservoir of precaution and adaptation possibilities to counteract the threats by CSI. The methods are document studies (herder narratives) and interviews of TK-holders. Preliminary results will be presented.
KEYNOTE: Alternative Arctic Economies

Thierry Rodon

Université Laval, Canada

The Arctic is seen as a periphery and mostly portrayed as a resource region. As a result of climate change, it has become a new frontier for resource development, from mining and oil and gas extraction to commercial fisheries. In this keynote, I would like to emphasize the need to change this narrative. The Arctic is not only a resource rich hinterland; it is the homeland to indigenous and non-indigenous communities that benefit only marginally if not at all from big resource development projects. However, through a mix of creative and traditional economies, Arctic people and communities attempt to elaborate their own models of economic development.
Submarine communications cables: A case study of Arctic decision-making and institutional development

Juha Saunavaara

Hokkaido University, Japan

Some years ago, the Arctic Ocean was still described as one of the last oceans that were not crisscrossed with submarine communications cables. This situation is now changing. The Quintillion Subsea Holdings has just laid a submarine cable around Alaska and is ready to proceed with its plan to lay a data cable between East Asia and Europe through the Northwest Passage. In the meantime, the Finland-based project aiming at the submarine communications cables between northern Europe and East Asia through the Northeast Passage is advancing under the leadership of Cinia Group. While these projects are linked, for example, to questions concerning the digitalization of the Arctic and regional development of the North, they can also be approached as a case study of Arctic governance and decision-making. Besides being compact and concrete (i.e. discussion focuses on a few ongoing projects), the Arctic data cables are also complex (i.e. a great number of actors, forums, aims and means and resources to achieve one's objectives) and highly politicized topics. This study challenges the tradition of focusing on the framework of Arctic national states and the Arctic Council and pays attention to the role of Arctic Economic Council, non-Arctic states (especially in East Asia), regional authorities in Arctic and non-Arctic states, private and governmentally owned companies, funding agencies and investors both inside and outside the Arctic. In other words, this case study is expected to demonstrate the versatility of actors involved in the Arctic decision making and introduce the main forums where discussion and decision-making concerning the Arctic data cables take place.
Missing stories from Nunavut’s wall hanging: Confronting access to justice issues in the employment law system in the Canadian Arctic in the quest for economic development

Gloria Song
Polar Knowledge Canada, Canada

Economic development is an important priority for strengthening Arctic communities in the Canadian territory of Nunavut. And yet, one crucial aspect that has not been adequately addressed in academic discussions about Canadian Arctic economic development is the ensuring that workers have the necessary legal protections and mechanisms to address their work-related problems, and generally improving the Canadian Arctic territory’s employment law system. Employment law in Nunavut has generally received little if any academic attention in the past.

This paper constitutes one of the first legal scholarly analyses of Nunavut’s employment law system in relation to economic development. This paper explores the state of employment law in Nunavut by reviewing the Arctic territory’s relevant employment laws and reports, and analysing employment law court cases from the Nunavut Court of Justice, the Nunavut Court of Appeal, and the Nunavut Human Rights Tribunal to identify issues that occur during the legal process and general barriers for employment and economic development in Arctic communities.

In doing so, the paper identifies a number of access to justice issues, indicating the shortcomings of the current Western-based employment law system operating in a predominantly Inuit context. Given the limits of the formal legal system, other innovative culturally-sensitive solutions incorporating traditional Inuit Qaujimajatuqangit values are recommended.

This paper concludes that although some attention has been paid to Nunavut’s criminal justice system, legal reform in the Canadian Arctic must be further explored, in particular with respect to Nunavut’s civil law issues, including employment law, in order to support economically healthy, sustainable and resilient Arctic communities in the territory as envisioned by the Nunavut Land Claims Agreement.
Stock Shifts, Value Chains and Arctic Fisheries Management: Making regime complexes more coherent

Olav Schram Stokke

University of Oslo, Norway

This paper would fit a proposed session in the Resilient Arctic Societies and Industrial Development segment based on the STOCKSHIFT project (see paper proposals by Hønneland, Johansen/Stiansen, and Molenaar) but can also be a freestanding contribution. Climate-induced shifts in the abundance or migratory pattern of commercial fish stocks pose severe challenges to three tasks of resource management – building scientific knowledge, adopting agreed regulations that reflect the state of knowledge, and ensuring compliance with those rules. This paper argues that fisheries management in the European Arctic is better placed to handle such challenges than before because the relevant institutional complex has grown. Responding to the near-monopoly on regulation and enforcement that flag states have on the high seas, coastal states and other players have developed supplementary measures, targeting links in the seafood value chain that are either prior to harvesting (e.g. liability insurance, bunkering) or subsequent to it (e.g. transhipment, landing, processing or distribution). Those measures have proven helpful also to management of fisheries conducted in exclusive economic zones. This presentation examines the still evolving institutional complex for managing high-seas fisheries in the Norwegian Sea, the Barents Sea, and the Arctic Ocean. In focus are not only national fisheries agencies and Regional Fisheries Management Organizations and Arrangements (RFMO/A) but also international institutions specializing in areas other than resource management, such as international trade or the combat of trafficking or money laundering, as well as private governance initiatives like fisheries certification schemes. The paper speaks to a broader debate on institutional interplay in environmental governance by examining the coherence of these various contributions to knowledge building, regulation and compliance – including whether such coherence requires explicit coordination among the component institutions.
Application of classifications of settlements to cities of Arctic Circumpolar region.

Ivan Tarasov 1, Olga Russova 2

1Northen Arctic Federal University, Russia, 2Northen Arctic Federal University, Russia

In modern world of variability and mobility, the Arctic is not an exception. Climate conditions, market conditions, political alignment and the declared role of the Arctic are changing. To determine the real role of the region, it is sufficient to describe fully the main places of people’s lives-urban settlements. The article points to the fact that the Arctic, on the average, is a highly urbanized region, although this value can vary considerably from country to country. So, consideration should be made at the city level. The presented article analyses all the largest settlements in the region using the following classifications: basic historical “background” by V.G. Davidovich, city functions by C. Garryson, organizational and planning structure, economic role and classification by number of population. The result is a summary table that showing the total values assigned to each city for each classification. Stable patterns are found at the intersections of these characteristics, which makes it possible to talk about the economic role of certain parts of the Arctic, and characterize the differences between regions and cities. A conclusion is drawn on the role of industry for different parts of the region and its impact on the structure of resettlement.
Climate change, disasters and community resilience in light of uncertain responsibility coordination - the case of Svalbard avalanches

Rachel Tiller 1, Elizabeth Nyman 2, Ashley Ross 2

1SINTEF Ocean, Norway, 2Texas A&M University at Galveston, USA

While much of the attention on climate change focuses on coordinated agreements made by the international community, natural hazards related to global warming present complex disasters issues that states must manage. This is particularly acute in the Arctic, where climate-related hazards test the coordinated response of emergency management in remote areas. We consider the case of Svalbard, an archipelago that is not considered Norwegian territory but is assigned by treaty as the administrative responsibility of an appointed governor. Longyearbyen, the largest settlement of Svalbard, is a former "company town", where a single organization, Store Norske Spitsbergen Kulkompani, was responsible for all employment, housing, supplies and services, organizing both the social and working lives of the inhabitants. This started changing in the mid-70s, when the coal company was nationalized and a normalization process started. In 2002, this process was finalized with a new local democracy (Longyearbyen Lokalstyre) taking over the functions previously held by the Company. In addition, though, the town also has a Governor, that represents the interests and responsibilities of the national government. The weak coordination between actors on multiple levels of government is endemic to Norway; however, the negative ramifications of poor coordination are exacerbated in this case by the lack of community capital for resilience with the town's high turnover in residents, at 25% per year, which hinders the development of collective memory that aids disaster preparedness and response. This has led to the community recently suffering from preparedness failures, with avalanches that have had resultant fatalities. We examine resident questionnaires and in-depth interviews to explore how community capacity and disaster governance intersect to affect resilience in this complex context. The findings will highlight where improvements in disaster preparedness, response, and recovery can be made in Svalbard. The findings also have implications for the coordination action needed, by government and society, to address the hazards presented by a rapidly changing climate.
FEATURED TALK: Anger and the built environment: reflection on youth and the housing situation in Nunavik

Anne-Marie Turcotte

Concordia University, Norway

Inuit of Nunavik represent Canada’s youngest and fastest growing population. The Inuit population’s experience of larger sedentary settlements on their territory is quite recent, and was precipitated through the hydroelectric project that led to the James Bay and Northern Quebec Agreement (JBNQA) in the 1970s. In less than a century, Inuit have experienced rapid social changes that have impacted the transmission of cultural skills and values and contributed to a significant intergenerational divide where elders sustained a land-based way of life that younger generations will not experience. The purpose of my doctoral research, which is done in collaboration with the Nunavik Youth House Association (NYHA) an organization I have been involved with for the past 15 years, is to examine acts of juvenile delinquency, more precisely the breaking of windows, and to verify the extent to which destructiveness can be used as an indicator of youth distress. The investigation will centre on Inuit youth who struggle to create a stable identity in communities where cultural continuity has been disrupted and assimilation processes have rendered endemic different forms of violence. In addition, I would like to investigate if (and how), youth breaking windows can been regarded as the embodiment of adults’ projections of unconscious anxieties, such as the ones surrounding the complex and difficult housing situation in Nunavik.

Few studies have focused on the meaning of acts of property destruction among Nunavik youth. Moreover, acts of vandalism like the breaking of windows have not received any attention by researchers, mainly because they have been regarded as a children’s game without any particular significance. Yet, in many Northern Villages of Nunavik, windows of specific buildings are systematically smashed by youth who throw rocks at them. Broken windows are replaced by plywood, leaving opaque structures where natural light cannot be seen from the inside. According to Bachelard, the built environment and spaces like houses cannot be perceived as purely material. They are places where imagination and dreams can be deployed freely. Houses are intimate spaces both inhabited by and inhabiting people. Spaces are filled with memories linked to senses, which make them irreducibly embodied.
Re-use of mining legacies: A comparative study in the Arctic.

Camilla Winqvist

KTH Royal Institute of Technology, Sweden

In this paper I will present my dissertation project. The aim of my project is to find out how, why and under which circumstances that legacies of a resource extractive past can be re-used. Re-use can be many things: re-opening, cultural heritage, use of the historical mining operations to promote new ones etc. I will examine some historical cases of re-use of mining legacies from different parts of the Arctic; Sweden, Svalbard and Canada. Mining operations always come to an end, and how to handle the remains of a mine is an important question that demands consideration. The historical handling of mine closures can hopefully guide present mining companies to think differently about what a mine should become after operations have stopped, and what that mine meant to the mining community.

In my dissertation, I am comparing cases from the Arctic, of which I will present one of my cases from the Gällivare area in Northern Sweden at the conference.

My project is a part of the larger Resource Extraction and Sustainable Arctic Communities (REXSAC) project.
Arctic urbanisation: how does it possible?

Nadezhda Zamyatina ¹, Ruslan Goncharov ²

¹Lomonosov Moscow State University, Russia, ²National Research University Higher school of economics, Russia

Arctic urbanization became one of the popular researching frontiers. Arctic human development report shows that the majority of the Arctic territories of the world (except the Faroe Islands, Nunavut and Northwest territories of Canada) have more than ¾ of urban population.

The literature review shows us by the way that the main socio-economic condition of Arctic settlements development is the condition of remoteness (Huskey, Berman etc.). Remoteness hinders the agglomeration effect and other advantages of urban development.

So the phenomenon of Arctic urbanization poses three puzzles for us: 1) is Arctic urban population really increase so fast as it seemed, 2) are Arctic cities "real" cities comparable to non-Arctic analogues, and 3) what are the mechanisms of urban resilience in Arctic conditions. Re-evaluation of the degree of Arctic urbanization using the same criteria for different countries showers that the current estimations of Arctic urbanization are over-stated. Nevertheless, Arctic urbanization is an established phenomenon. Within Russia the Arctic paradoxically is the most urban part of the country (at the beginning of 2016 89% of the Arctic zone of the Russia population live in urban areas). We attempted to compare the Arctic and non-Arctic cities of Russia searching differences in specialisation, the level of amenities etc. using official statistical data. The findings is that there are no statistically significant differences in the structure of employment or amenities but there are great difference in the level of mobility of Arctic urban population. We suggest the high level of mobility as the main factor of Arctic urban resilience. It could be the base for knowledge spill-over and thus the base of innovative process which is the core process of urban development. The high level of mobility and temporal proximity (Torre et. al.) compensate the absence of agglomeration effect and other negative factors of development of Arctic cities derived from the conditions of remoteness.
Circumpolar Safety, Search and Rescue Collaboration
Towards ensemble forecasting and data assimilation in the Arctic using a Lagrangian sea-ice model

Ali Aydoğdu, Matthias Rabatel, Alberto Carrassi, Pierre Rampal, Laurent Bertino

Nansen Environmental and Remote Sensing Center, Norway

neXtSIM is a novel sea-ice model designed to tackle the challenges in modelling the extreme fracturing events and acceleration of the sea-ice drift associated with the drastic changes in the Arctic sea ice cover. It is a continuous Lagrangian numerical model that uses a Maxwell-Elasto Brittle rheology to simulate the ice response to external forces. We present first a sensitivity analysis and the probabilistic forecast capabilities of neXtSIM as a response of the model to the uncertainty on winds using probabilistic forecasts of ice trajectories. The performance is also evaluated using the IABP buoys’ trajectories, and compared to the free-drift model formulation, in which the rheology of the ice does not play any role on the modelled physics of the ice. An assessment of the model for search-and-rescue (S&R) operations has been performed. We will discuss then our ongoing efforts and some preliminary results for the development of an ensemble-based data assimilation system with neXtSIM. The nature of the Lagrangian mesh of neXtSIM, which also includes the possibility of re-meshing, constitutes the main issue related to the use of data assimilation, and particularly ensemble-based, methods. While this property is essential to the skill of the model in describing the mechanics of the sea ice with great details, it brings a challenge in developing compatible data assimilation schemes, as the dimension of the state space can change over time when these re-meshing occur. Some solution to overcome this challenge and its outcomes for better forecasting, which will directly serve to improved S&R operations, will also be discussed.
Drifting path prediction and search for missing vessels

Tor Einar Berg 1, Ørjan Selvik 1, Raymond Prestøy 2, Øyvind Bech 3

1SINTEF Ocean, Norway, 2JRCC Bodø, Norway, 3Norwegian Coast Guard, Norway

In Arctic waters, it will be important to have a good starting point and efficient search patterns in the search phase of a SAR operation. Time is a critical factor for all Arctic SAR operations. It is thus necessary to have reliable tools for prediction of drifting patterns based on the last confirmed position of the drifting vessel. This paper will investigate the following topics that influence the reliability of tools for defining the search area and search patterns for missing vessels in Arctic waters:

- Uncertainty in the last reported position of a missing vessel
- Quality of metocean data for Arctic waters
- Quality of motion models for drifting vessels
- Optimized search patterns based on estimation of vessel drifting motion

The first part will discuss existing systems for position reporting from different types of vessels operating in Arctic waters. Late information of abnormal operational conditions for commercial vessels has in many cases resulted in emergency situations needing SAR operations to save crew members.

The second part will review quality of metocean data for Arctic waters. As an example the findings from a study done by Øyvind Bech as part of his MSc thesis in nautical science will be presented to highlight difference between estimated and observed position of a drifting object in a SAR scenario.

The third part presents experience from use of a specific drifting vessel model in SAR like operations involving smaller fishing vessels. Further, this part will present a comparison of estimated drifting tracks for a modern 120 m cargo vessel (generated by different simulation tools). The need for better prediction of paths of drifting vessels will be discussed.

The final part of the paper will discuss how drifting path prediction outcomes can be used to optimize search patterns in Arctic maritime search and rescue operations.
OpenLeeway - a new S&R forecast tool

Øyvind Breivik, Knut-Frode Dagestad, Stian Anfinsen, Tor Christian Bekkvik

1MET Norway, Norway, 2Christian Michelsen Research (CMR), Norway

The recently developed OpenLeeway S&R model has been implemented is now the operational S&R forecast tool for the Joint Rescue Coordination Centres in Norway. The openly available code utilizes global and local forecast fields and meshes seamlessly with the S&R planning tool at the RCC (HRS). The model and its implementation are major steps toward more interactive use of flight data and updated interactive searches where previous searches are used to inform the next round. The flexibility with which various meteorological and oceanographic forecast products can be ingested means that the uncertainty in wind and current fields can now in principle be handled by using ensemble forecasts, thus providing more realistic search areas.
FEATURED TALK: Peripheral Cold Water Exposure and Manual Performance

Heather Carnahan, Matthew Ray

Marine Institute, Canada

Cold exposure has the potential to limit an individual’s ability to perform occupational and survival skills in the cold ocean environment due to impairments in tactile sensitivity, grip strength and dexterity. Developing an understanding of how cold exposure impacts manual performance is critical for the safety and efficiency of those working in cold ocean environments. Depending on the time of the year and the geographical location, cold ocean temperatures hover around 0°C; despite this reality, research is rarely carried out using water this cold. To develop evidence based occupational time management practices it is imperative to understand how long individuals can maintain hand function after being exposed to extremely cold water. We investigated the length of time that tactile sensitivity and fine manual dexterity could be maintained following exposure to 2°C water. Participants immersed their hands in 2°C water and fine manual dexterity and tactile sensitivity were assessed every 30 s until index finger temperatures dropped below 8°C (skin temperature associated with severe impairments in hand function). After 90 s of cold-water exposure tactile sensitivity and fine manual dexterity showed impairments and after 120 s index finger temperatures dropped below 8°C and severe deficits in tactile sensitivity and fine manual dexterity were observed. This finding can be used to inform performance criteria (i.e. critical manual tasks should be performed < than two minutes) and occupational time management practices. An additional concern for those working in the cold ocean environment is that they are exposed to both cold and moisture. The slipperiness caused by moisture may add to the impairments caused by cold due to the fact that cold impairs tactile sensitivity and tactile sensitivity is critical for grasp maintenance. A second study was conducted to help understand how the combined effect of cold and moisture impacts manual performance. Individuals performed tests of tactile sensitivity and manipulative ability with thermoneutral dry hands, thermoneutral wet hands, cold dry hands, and cold wet hands. The results showed that the additive effect of cold and moisture was greater than cold or moisture alone and that intrinsic object properties have the potential to reduce the combined effect of cold and moisture to that of cold alone. This finding highlights the fact that solutions for working in the cold ocean environment need to focus on reducing the impact of both cold and moisture on manual performance.
FEATURED TALK: Finnmark ocean currents field experiment

Kai H. Christensen ¹, Harald Johnsen ², Ann Kristin Sperrevik ¹, Johannes Röhrs ¹, Breivik Øyvind ¹

¹Norwegian Meteorological Institute, Norway, ²NORUT, Norway

We report from a field experiment that will take place in Northern Norway in October 2017. During the experiment, several methods for measuring ocean currents will be compared: (i) radial velocity components from High Frequency (HF) radar, (ii) drift of floats with and without drogues, (iii) currents from moored acoustic Doppler velocity profilers (ADCPs), and (iv) radial velocity components derived from satellite Synthetic Aperture Radar (SAR). The analysis of the data will focus on the vertical and horizontal variability of the currents, and validation and improvements of the geophysical model function for deriving the radial surface current from the radial velocity measurement of SAR. We will also comment on the potential for using the various observation types in ocean data assimilation.
FEATURED TALK: Meteorological Cooperation in the Arctic - Enhancing monitoring, services and arctic climate science

Juhani Damski

Finnish Meteorological Institute, Finland
Planning, coordinating and implementing maritime SAR-operations in the North

Kay Fjørtoft 1, Even Holte 1, Bent-Ove Jamtli 2, Ole-Magne Kolstad 3

1SINTEF Ocean, Norway, 2JRCC, Norway, 3Nordland Fylkeskommune, Norway

"Norway shall be the world leader in planning, coordinating and implementing maritime SAR-operations in the North."

Search and rescue operations are demanding. In the Arctic, one strikes several additional challenges such as long distances, limited infrastructure and demanding climatic conditions. This places high demands on equipment, expertise and, not least, cooperation between the involved emergency preparedness actors. For major actions in the Arctic, very different emergency preparedness actors, stakeholders and institutions will be involved in SAR operations, including private and state actors, civil and military, and volunteer and professional aid organizations. In some case, it will also be a close cooperation with other countries’ rescue services.

With this as a starting point, we need to address demands for new functions that can improve SAR capacities at the JRCC (Joint Rescue Coordination Centre). A concept study was released in September-17 where we identified gaps as well as the needs for new functions. One main findings were the need for an analytical centre that reviews, analyses, and validates data from previous accidents and training exercise. The establishment of such an analysis centre will make a significant contribution to strengthening national interoperability skills, as well as ensuring good safeguarding of international obligations and interests. A central function will be the ability to maintain a systematic and continuous approach to analysis and processing of data from various incident reports.

The report confirms that an analytic centre will give important value to both JRCC itself, but also to other external emergency actors. Analyses from past events are presently missing and are being given a lower priority because the work pressure on employees at the JRCC is very high. In this material, a lot of lessons could be learned from past events, and a large amount of data are thus available for analysis. The results of an analysis will provide increased expertise and understanding, which can be used in new learning and development of new training programs as an example. An analysis centre will mean a lot for Norway to achieve its political aspirations to be world leader in SAR in the High North, and the centre will be important when preventive measures are to be designed and implemented.
Risk Management in the Arctic: Risk & Uncertainty

Hannah Hernandez

University of Copenhagen, Norway

The Arctic is experiencing significant change as ice free waters become a reality and we see an increase in industrial development and activity. As this activity expands across the region, risk management is purport as the most responsible way to manage the uncertainties ahead. Throughout this presentation, I shall share my research on what methods are used to assess risks, what measures are in place to address them, and whether they are sufficient to manage the dynamic challenges of developing the region. I will discuss the processes of taking unknowns and uncertainties and translating them into calculable, manageable risks that can be quantified and acted upon. I will also describe at what techniques are being used to identify, analyse, classify, mitigate and manage the risks in this Arctic. In order to develop the region safely and responsibly, it is important to analyse and assess these practices to determine if the existing procedures are sufficient against the full scope of challenges facing the region. Backed by theory, the primary purpose of this presentation is to highlight some of the potential shortcomings within risk management and will focus specifically on forecasting and risk assessment. I will conclude by offering some insight into my research for addressing these shortcomings and a discussion on my research for embracing the uncertainties the future holds.
10 years of fixed-wing unmanned aircraft (UAV) operations in Norway - history, status and future.

**Vegard Evjen Hovstein** ¹, **Rune Storvold** ²

¹Maritime Robotics AS, Norway, ²NORUT, Norway

Both NORUT and Maritime Robotics have been the national pioneers within fixed-wing unmanned aircraft (UAV) beyond-line-of-sight (BLOS) operations in Norway. The presenters met already in 2005 and start fixed-wing operations in their respective environments. It is now over 10 years since we started the first fixed-wing operations in Norway, at a time when the civil aviation authorities had barely started its work on regulations. We can look back at RnD and scientific missions in coastal and arctic climate over more than 10 years. The evolution has taken place and the lecture will look back on this with some examples highlighting important lessons. We will also consider how we believe that fixed-wing BLOS operations in the high-north and arctic areas will develop over the next 10 years.
FEATURED TALK: Emergency Preparedness Collaboration and Continuous Improvement

Sigurd Robert Jacobsen, Anne Gro Løkken, Jan Erik Jensen

Petroleum Safety Authority, Norway

The purpose of this paper is to examine collaboration between the many stakeholders in the Norwegian petroleum industry, national and international organisations and the effect it has on emergency preparedness in the Barents Sea and potentially the broader Arctic region.

The paper also considers initiatives, including ones “hidden” in acronyms like AORF, BaSEC, EPPR, SARINOR and SAREX, which are vital to development of emergency preparedness for personnel in the Arctic.

We elaborate on interaction and collaboration between stakeholders and illustrate the positive effects the combined efforts have on emergency preparedness in the petroleum industry and for other users of the Barents Sea.

There has been petroleum activity in the Barents Sea since 1980. The area has experienced renewed interest since 2005 and the opening of the Barents Sea South East for petroleum activity in 2013. Areas further from the coast have been explored introducing emergency response challenges that have required careful consideration.

The Petroleum Safety Authority (PSA) regulates safety in the petroleum industry and is a catalyst promoting collaboration and maturing awareness regarding challenges and requirements for prudent operation. PSA has challenged the stakeholders in the industry on numerous issues pertinent to safety of personnel working in the Barents Sea. Issues related to ice accretion on lifeboats, provision of medical evacuation services (MEDEVAC), performance requirements and capacity to rescue personnel from the sea due to a helicopter incident, have been the topics of much debate.

Norwegian Oil and Gas, with considerable participation from stakeholders, including PSA and representatives of the workforce, studied topics regarding safety of operations and emergency preparedness in the Barents Sea. Work continued in Barents Sea Exploration Collaboration (BaSEC) maturing performance requirements related to emergency preparedness.

In addition to work performed by companies and stakeholders directly involved in the petroleum industry, there are numerous other initiatives where both PSA and the petroleum industry have participated. The results of the efforts are additional resources in the Barents Sea. These are mainly SAR helicopters, facilities to land on and refuel helicopters and vessels supporting operations. In addition, there is an improved awareness of the challenges, access to competent personnel and willingness to collaborate and share knowledge.

We demonstrate that, with broad involvement of stakeholders and PSA participation continually challenging industry, there is “cross pollination” of ideas and expectations lubricating the process of continuous improvement within emergency preparedness in the Barents Sea and the Arctic.
FEATURED TALK: The Search and Rescue preparedness and response in the Norwegian Arctic, status and challenges

Bent-Ove Jamtli

JRCC NORTH-NORWAY/Norwegian Mission control Center (NMCC), Norway

The Arctic is a region characterized by long distances, harsh climate and relatively few rescue resources. Three factors are therefore essential;

Firstly, the **prevention** of accidents is important because the consequences for people and the environment will often be greater with accidents in the North. It is therefore necessary with particularly stringent maritime safety requirements.

Secondly, **cooperation** between nations is essential for the effective utilization of available rescue resources in order to come to the rescue as quickly as possible.

Finally, it is important to note that the **time** factor, **distance** and **climate** can make certain operations impossible, no matter how much is spent on emergency services. It is therefore important, that anyone travelling or operating in the Arctic systematically work to reduce the risk of accidents and strives to be able to handle crises to a greater extent than is necessary in other areas.

But, as a final positive note; although more activity will increase the chance of an incident to happen, there will also be more resources available to assist in SAR.
Leadership and competence in a survival situation - experiences of a "survivor"

Jan Erik Jensen 1, Knut Espen Solberg 2, Sigurd Robert Jacobsen 1

1Petroleum Safety Authority, Norway, 2University of Stavanger, GMC Maritime AS, Norway

SARex I and II were rescue exercises carried out by industry, regulators and academia north of Spitzbergen during spring of 2016 and 2017, respectively. The Norwegian Coast Guard, University of Stavanger and GMC, Stavanger organized the exercises. The experiences from participation in an exercise in the Arctic through SARex I and II have given valuable experiences relevant from a regulator’s point of view.

Firstly, the importance of testing the viability of new regulatory requirements and secondly the dependence of leadership and competence enabling group survival and the use of cold climate survival equipment. This article will focus on the latter.

There are many heroic accounts of sealers and fishermen being stranded in their rescue crafts for prolonged periods. Knowledge and equipment have been key factors for their survival. Technology related to Arctic survival equipment has evolved and improvements made. We raise the question: to what extent has the importance of leadership skills and ability to utilize this equipment been considered in order to ensure survival for prolonged periods in a cold marine environment?

The regulations governing the Norwegian offshore oil and gas industry are mostly functional requirements. The Petroleum Safety Authority found it important to participate in SARex I and II to better understand the factors enabling success in a cold climate survival situation.

The survival tests in lifeboats and life rafts during SARex I and II, showed the necessity of having a trained and competent leadership on-board. This issue has perhaps been neglected compared to development of equipment to avoid hypothermia, where technology has made considerable progress. Some key factors for survival success were:

- Maintaining warmth and mental awareness and motivation.
- Operating the rescue craft at sea, watch routines, operating hatches/venting routines.
- Organizing water and food rations.
- Organizing and teaching the function of various safety equipment onboard the rescue craft.

The rescue craft leader used effective techniques to engage the survivors on-board the life raft, e.g. giving each individual responsibilities and tasks. He also ensured mental awareness by creating activities throughout the time on-board.

Overall learning from SARex I and II is that survival is dependent on active participation from the survivors. That means that there needs to be sufficient competence amongst survivors to micro-manage all the details required for survival. The mental factors following fatigue and seasickness, in addition to hypothermia, make leadership and competence in cold maritime climate essential for survival.
An update on Polar Lows in the European Arctic

Gunnar Noer

The Norwegian Meteorological Institute, Norway

Polar lows are forecasted at MET-Norway throughout the winter season. Currently the Arome-Arctic NWP model with 2.5km resolution is the main tool for this purpose, but also the ECMWF NWP is used for longer forecast ranges. In coastal regions of Norway, the Arome-Hirlam MetCoOp ensemble prediction system is used.

The weather in the Arctic is under constant monitoring by the meteorologists at the forecast centre in Tromsø. Polar Lows are recorded with dates, positions, centre pressure and wind speed, and this database now consists of 233 events from 2000 until 2017. The list is a valuable reference for further studies on polar lows.

The speech presents an update on MET-Norways current capabilities of forecasting Polar Lows, and the channels that are used to convey forecasts of Polar Lows to the public. An updated climatology from the Polar Low database is presented, as well as other recent additions to our knowledge on the topic of Polar Lows.
Challenges of Collaborative Oil Spill Response and Sustainability of Recovery Methods in the Arctic Ocean: Case of the Norwegian and the Barents Seas

Victor Pavlov ¹, Ensieh Kheiri Pileh Roud ²

¹University of Oulu, Finland, ²Nord University, Norway

The rise of maritime activity in the Arctic due to oil and gas exploration and exploitation and tourist cruise shipping also generated concerns for sufficient and adequate oil spill response and search and rescue capacities and capabilities. The Arctic sea region has one of the most pristine, yet inhospitable environments on the planet, and any minor event in this environment can easily become a major disaster not only for the people and companies involved, but also for the local environment and its ecosystem. Due to long distances, unfavourable weather conditions and scarce resources for effective oil response in the Arctic, inter-organizational collaboration is required. Large-scale emergencies are even more challenging tasks and demand extra competence for collaboration between emergency preparedness organizations due to its complexity.

This paper looks at Arctic waters in the Norwegian and the Barents Sea with focus on large-scale oil spill consequences on the environment and the economy as well as the technology for sustainable recovery. Oil spill response methods at sea, in particular, are mutually compared based on a set of sustainability indicators. Moreover, this work focuses on the need for competencies related to large-scale oil spill response and the challenges of inter-organizational collaboration. The paper has qualitative research approach and the data is collected from semi-structured interviews, exercise observations in addition to secondary data. The secondary data consists of governmental reports, protocols, organization website and logbooks.
Norshelf: A data assimilative ocean model for the prediction of surface currents on the Norwegian Shelf

Johannes Röhrs, Ann Kristin Sperrevik, Kai Håkon Christensen

Norwegian Meteorological Institute, Norway

Ocean circulation models are commonly used to study oceanic transport and as forecasting tool for contingency preparedness. We will release the “Norshelf reanalysis”, a new ocean circulation model simulation for the Norwegian Sea with a 4D-var data assimilation scheme on 2.4km resolution. Therein, satellite and in-situ observations of the oceanic state in terms of temperature and salinity are used to constrain the ocean circulation model. We will present a validation of the model and the performance of the data assimilation scheme, and show some of the key dynamic processes that appear in this region with focus on surface currents.

The Norshelf model covers the shelf sea around Norway, i.e. the Skagerrak, the northern parts of the North Sea, the shelf slope off western Norway and the southern parts of the Barents Sea. In this domain, the model resolves the hydrodynamics and hydrography of the Norwegian Coastal Current, the Atlantic Current, and mesoscale fronts and eddies permitted by the intermediate resolution of 2.4km. In addition to the reanalysis, an operational forecast with daily analysis of the ocean’s state is run at the Norwegian Meteorological Institute. Both the reanalysis and forecast are open available data sets.
Liberties and obligations in the law of Arctic search and rescue

Erik Røsæg

University of Oslo, Norway

Search and rescue as well as preventive measures in respect of pollution are subject to international agreements. To some extent, these agreements allows actions that would not otherwise be allowed under international law, and impose new obligations on states. The paper analyses such legal effects of the international agreements relevant to the Arctic, and discusses why the liberties and obligations differ so much between them.
Pan-Arctic search and rescue (SAR) collaboration is essential as the Arctic region poses significant challenges, for which robust international coordination is the most effective strategy. In many parts of the Arctic region, long distances and scarce physical and communications infrastructure make effective mass rescue operations (MRO) and SAR difficult; the effects of the polar climate pose challenges around the entire region and in adjacent sub-Arctic areas. These challenges are heightened in the maritime areas of the Arctic, where sea ice poses an additional significant challenge.

In response to these operational challenges, and furthering the robust international cooperation already present among Arctic states, the Arctic Coast Guard Forum (ACGF) was established in 2015 to strengthen multilateral cooperation and coordination among member states within the Arctic maritime domain. Member states include Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, and the United States. Finland currently holds the chairmanship of the ACGF.

The goal of the ACGF is to gather knowledge, develop and enhance transnational collaboration, and demonstrate the ability to conduct SAR operations in the Arctic. The ACGF meets regularly to consult, exchange information, agree on core principles, and develop joint practical measures to maintain safety and security at sea. As part of these efforts, in September of 2017 the ACGF held its first live exercise, Arctic Guardian 2017, to gain experience with combined SAR operations and demonstrate practical implementation of the Agreement on Cooperation in Aeronautical and Maritime Search and Rescue in the Arctic. Lessons learned and best practices developed during the Arctic Guardian exercise provide for a solid foundation for developing future joint SAR exercises within the Arctic domain.

The presentation will introduce the Arctic Coast Guard Forum, as well as describe its achievements towards improving SAR in the Arctic region, including the Arctic Guardian 2017 exercise’s contribution. The presentation will also refer to the recently conducted survey, written in cooperation with the ACGF, mapping the key challenges of Arctic SAR and compiling recommendations for enhancing international cooperation.
KEYNOTE: Search and Rescue in the Alaskan region and its challenges

Paul Webb

U.S. Coast Guard, USA

Search and Rescue in the Alaskan region and its challenges. I will present and discuss the differences in the Alaskan environment from Southeast to the Arctic regions and how that effects how we respond and how we deal with the distances and communications issues that we encounter within the region. A brief overview of the types of cases we have encountered in the Arctic region will be displayed and how we have had to approach the response and planning. I will discuss how using ice flows as a way to survive when stranded and how we determine where to search using local information and our technology (SAROPS). Present the searching techniques for fast ice for the Great Lakes and Arctic. Finally, the presentation also includes discussion on the future of technologies and SAROPS and the incorporation of latest data into SAROPS for the Arctic.
Methane release at underwater mounds in the Barents Sea (76° N) and its impact on Arctic benthic faunal communities

Emmelie Åström 1, Arunima Sen 1, Michael Carroll 2, Helge Niemann 3, William Ambrose 4, JoLynn Carroll 2

1CAGE - Centre for Arctic Gas hydrate, Environment and Climate, UiT - The Arctic University of Norway, Norway, 2Akvaplan-niva, FRAM - High North Research Centre for Climate and the Environment, Norway, 3Aquatic and Stable Isotope Biogeochemistry University of Basel, Switzerland, 4Department of Biology, Bates College, USA

A large part of the Arctic seafloor consist of continental shelves and slopes, which are recognized as regions of interest for fisheries as well as for the petroleum sector. Recently, hydrocarbon emissions have been localized offshore Svalbard. Hydrocarbons and other reduced compounds emitted from such sources can form chemosynthetic ecosystems recognized as ‘cold seeps’. Cold seeps are known to host specialized faunal communities that are associated with active seepage, fuelled by microbial chemoautotrophs through oxidation of reduced compounds. Generally, there is a paucity of studies at Arctic cold seeps with respect to ecology. Here, we present results from one of the few biological studies in a high-Arctic cold seep system. Methane seepage has been localized in association to gas hydrate bearing mounds (~380 m water depth), at the western Barents Sea shelf (76° N). We used an underwater camera system and a remotely operated vehicle (ROV) for imaging and collecting benthic samples for community analysis and for studying functional guilds and trophic interactions among fauna present around the seeps. Additionally, sediment and water measurements for environmental characteristics were analysed.

Soft sediments mixed with methane-derived carbonate formations, patches of microbial mats and, dense aggregations of obligate chemosymbiotic worms characterized the sea floor where seepage occurred. The density of the chemosymbiotic worms was on average 8000 ind. m-2 in areas of active seepage. In addition to the high densities of chemosymbiotic worms, a high density of megafauna was observed including aggregations of various heterotrophic epifaunal species and commercially important fishes (e.g. cod, saithe, various flat fishes) and crustaceans (e.g. shrimps and snow crab) that were seen associated with seep features such as microbial mats, carbonates, as well as the worms themselves.

The highly localized seepage drives strong community-level effects over small spatial scales at these methane seeping mounds. Gas seepage creates a heterogeneous habitat resulting in chemosymbiotic organisms co-occurring with conventional fauna at the scale of the overall region. The aggregation of high trophic-level predators around specific seep features indicate that such habitats can be of high importance; Carbonate formations provide a 3D structure, adding complexity and heterogeneity to the site, which provide shelter and substrate to both sessile epifauna and motile fauna. We aim further to elucidate the role of Arctic cold seeps in the Barents Sea region with respect to biogeography, biodiversity and a changing Arctic.
Research on the feasibility of cooperation in the Arctic affairs among China, Japan and the Republic of Korea

Jiayu Bai

Ocean University of China, China

With the melt of Arctic icecap and snow, economic, political, and military value of the Arctic has become increasingly prominent, attracting worldwide attention. Arctic affairs, as a part of global affairs, cannot be developed without the Arctic stakeholders’ participation. Arctic stakeholder is the common identity of China, Japan, and the ROK, which decides similar interest demands and similar interest influences on the formation of their Arctic policies, which also reflect their similarities. China, Japan, and the ROK’s Cooperation in Arctic affairs can improve the efficiency of the implementation of the policies, and their previous cooperation on the Arctic climate and environment, scientific expedition, resource development, and passage utilization laid the foundation of cooperation in Arctic affairs, which provide a reliable path to promote the feasibility of three parties’ cooperation in Arctic affairs.
Did the Asian monsoon influence Arctic sea ice variability in the past?: Evidences from the Mid-Pliocene analogue to future global predictions

Soma Baranwal 1, Jochen Knies 1, Giuliana Panieri 1, Kari Grøsfjeld 2

1Centre for Arctic Gas Hydrate, Environment and Climate, University of Tromsø, NO-9037 Tromsø, Norway, 2Geological Survey of Norway (NGU), 7040 Trondheim, Norway

A prediction of future disintegration of Arctic and Antarctic cryosphere will not only influence local wildlife but also remotely affect the tropical monsoon regions. The Indian Summer Monsoon (ISM), East Asian Summer Monsoon (EASM) and Australian-Indonesian monsoon (AIM) comprise distinctive components of the Asian monsoon system. The ISM-Arctic teleconnection affects the Barents, Kara, Chukchi and Beaufort Seas and is responsible for driving sea ice out of the Laptev Sea into the Fram Strait while the EASM-Arctic teleconnection influences regions of the Philippine Sea, Japan-Korean Peninsula and eastern Siberia (Grunseich and Wang, 2016). However, past AIM variability and its teleconnections are not well understood owing to the lack of high-resolution records.

The mid Pliocene Epoch (~3.3-3.0 Ma ago) is considered to be an analogue for future warming. Here we present a mid-Pliocene reconstruction of AIM from Site U1463, (NW Australian shelf). The site is located near the austral summer Inter Tropical Convergence Zone. The data are compared to our Arctic sea-ice record from Site 910, Yermak Plateau, NW Svalbard. Ice-free conditions prevailed in the early Pliocene until sea ice expanded from the central Arctic Ocean for the first time ~4 Ma ago, reaching its modern winter maximum extension ~2.6 Ma ago during the culmination of the Northern Hemisphere glaciation (Knies et al., 2014). The oxygen isotope record for Cibicidoides wuellerstorfi from Site U1463 reveals a negative excursion (ranging ~ -0.72 to -2.06 VPDB ‰) different from nearby Site 763 record (ranging ~ 2.1 to 2.7 VPDB ‰). Similar negative excursion has been reported from other tropical shallow water records of Panama (Collins et al., 2016) or Gulf of Cadiz (García-Gallardo et al., 2017). A prominent excursion is found during MIS M2 in our oxygen and carbon isotopic records. Northwest Australia underwent an abrupt transition from dry to humid climate conditions at 5.5 Ma lasting until ~3.3 Ma (Humid Interval) and became dry by the early Pleistocene at ~2.4 Ma ago (Arid Interval), well after the intensification of Northern Hemisphere glaciation (Christensen et al., 2017).

The work is funded by the Research Council of Norway: PACT project no. 248793/E10.
Making and breaking stratification in the Canadian Arctic Archipelago's Kitikmeot Sea: biological and geochemical consequences

**Bodil Bluhm** ¹, Kristina Brown ², Eddy Carmack ², Seth Danielson ³, CJ Mundy ⁴, Lina Rotermund ⁵, Bill Williams ²

¹UiT The Arctic University of Norway, Norway, ²Institute of Ocean Sciences, Canada, ³University of Alaska Fairbanks, USA, ⁴University of Manitoba, Canada, ⁵University of Victoria, Canada

As the ‘New Arctic’ opens up, new research foci, research stations and previously inaccessible geographic areas move into the focus of current Arctic research. The Kitikmeot Region Marine Science Study was initiated in 2014 to provide the newly established Canadian High Arctic Research Station a scientific basis for long-term ecological monitoring and research. The Kitikmeot Sea – which includes Coronation Gulf, Bathurst Inlet, Queen Maud Gulf and Chantrey Inlet in the Canadian Arctic Archipelago – is unique in the pan-Arctic system due to its massive freshwater input relative to the area’s size, and its shallow (<30 m) bounding sills to the north and west. Because of this, three foci guide the study: the Pacific-origin estuarine through-flow, which sets the oceanographic structure of the region; the origin and pathways of freshwater components, which influence nutrient balances and stratification; the tidally influenced biological communities whose structure and functioning differ between shallow sills / narrow constrictions and away from those. We apply a suite of oceanographic tools and year-round moorings deployed from the R/V Martin Bergmann to investigate these themes.
Epibenthos and demersal fish community structure in the Pacific Arctic inflow shelf (Chukchi Sea, Alaska) in relation to environmental variables

Katrin Iken ¹, Franz Mueter ¹, Jackie Grebmeier ², Lee Cooper ², Seth Danielson ¹, Bodil Bluhm ³

¹University of Alaska Fairbanks, USA, ²University of Maryland, USA, ³UiT The Arctic University of Norway, Norway

Arctic inflow shelves (i.e. the Chukchi Sea in the Pacific Arctic and Barents Sea in the Atlantic Arctic) experience massive changes both in terms of reduced ice cover and warming waters as well as increased human foot print. Epibenthic invertebrates and demersal fishes are both important ecosystem components of these Arctic inflow shelves with documented roles in carbon remineralization, habitat structure, and adding to food web complexity. In both areas, species range distributions of invertebrate and fish species have been recorded that contribute to community shifts. Here we investigate whether epibenthic and demersal fish species and community structure distributions in the Chukchi Sea are driven by the same shared environmental conditions and which environmental changes pose the greatest vulnerability to these ecosystem components. Based on sampling as part of the Arctic Marine Biodiversity Observing Network (AMBON) in 2015, community structures for both ecosystem elements grouped distinctly into nearshore and offshore, and southern and northern clusters. We find that many of the environmental drivers were similar for invertebrates and fishes, but the main driving forces differed: sediment grain size for epibenthic invertebrates and bottom temperature for demersal fishes. This suggests that the ability to respond relatively quickly to changing environmental conditions, such as temperature, may allow the demersal fish community to respond to change faster than the epibenthic community, which is more closely associated with slower-changing sediment characteristics.
Sea ice Biota on a pan-Arctic scale: Status and Trends - findings from the State of the Arctic Marine Biodiversity Report

Bodil Bluhm ¹, Haakon Hop ²

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

Sea ice is an important Arctic habitat that supports a high diversity of species—with over 1000 protist species alone. Multi-year sea ice is being replaced by first-year ice and open water, which will cause shifts in ice algal communities with cascading effects on the ice-associated ecosystem. Documentation of ice biota composition, abundance and natural variability is critical for evaluating responses to the decline in Arctic sea ice. The Sea-ice Biota Expert Network, therefore, aggregated and reviewed data on status and trends of ice-associated Bacteria, Archaea, microalgae, meiofauna, and under-ice macrofauna Focal Ecosystem Components (FECs) across eight Arctic Marine Areas as well as current monitoring. Sea ice biota monitoring has occurred most frequently in the central Arctic, Svalbard area, Barrow (Alaska) and the Canadian Arctic, with recent sites in northern Greenland. Many taxa in all FECs have widespread occurrence across the pan-Arctic domain. Sea ice algal community structure has possibly changed in the central Arctic between the 1980s and 2010s, and ice-amphipod abundance and biomass have declined in the Svalbard area since the 1980s. Consistent monitoring protocols, equipment and methodology should be implemented. The presentation also presents dominant drivers of observed trends, and knowledge and monitoring gaps.
**Engaging, Involving and Empowering: triple approach to stakeholders’ collaboration on the production of enhanced Arctic climate prediction**

Dragana Bojovic 1, Marta Terrado 1, Halldór Jóhannsson 2, Luisa Cristini 3, Isadora Christel 1, Gerlis Fugmann 4, Francisco Doblas-Reyes 1

1Barcelona Supercomputing Center (BSC-CNS), Spain, 2Arctic Portal, Iceland, 3Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), Germany, 4Association of Polar Early Career Scientists (APECS), Germany

The Arctic environment is changing rapidly, breaking ground for new business opportunities, while at the same time raising new challenges for the Arctic socio-ecological system. Enhanced predictions of weather and climate in the Arctic could boost development opportunities and help coping with the potential risks from the changing climate. However, only by establishing a lasting collaboration between the forecast providers and users, can new prediction capacities become an asset for all Arctic stakeholders.

The European project APPLICATE (Advanced Prediction in Polar regions and beyond: Modelling, observing system design and Linkages associated with a Changing Arctic climate) employs various user engagement techniques to share knowledge with stakeholders, going beyond basic information dissemination. The project applies a three-level approach: Engaging – Using various communication channels, such as the project website, brochure and social media, APPLICATE delivers information to the broader stakeholder community. The project shapes information around three stakeholder groups, each with different needs and capacity to handle climate data: (i) The scientific community and intergovernmental organisations, as advanced data users that can highlight gaps in scientific knowledge; (ii) Public and private sector, who can benefit from enhanced operational predictive capacity; (ii) Society at large, including the general public and Arctic communities who provide valuable local knowledge. Collaboration with relevant international projects and participation in the EU Arctic Cluster further maximises the project outreach. Involving – Interacting with stakeholders in meetings and via the Polar Prediction Matters Blog, APPLICATE extends discussion and knowledge exchange. In addition, a User Group (UG) closely follows and collaborates with the project. The UG is composed of the representatives from various stakeholder groups, such as local communities, businesses, and international NGOs. The UG represents an additional advisory mechanism to the project. Empowering – Focused relationships with representative stakeholders are achieved through their participation in the project meetings and activities. The co-development of user-relevant metrics improves our understanding of impacts and opportunities of potential changes in the Arctic and their effects on the Northern hemisphere. This active collaboration helps produce sound project results, shaping climate data into relevant products and services that support stakeholders’ decision making. Moreover, the project offers a variety of training activities, including webinars and a summer school.

User engagement activities in the APPLICATE project facilitate exchange of perspectives, ideas and opinions between stakeholders and the project scientists, producing trustworthy predictive information for decision making and improving stakeholders’ capacity to adapt to the new conditions in the Arctic.
Decentralized Energy in Northern Cities: A Comparative Analysis

Martin Boucher

University of Saskatchewan, Canada

A transition to decentralized energy is not simply an engineering or scientific endeavour. It is as much a social transformation as it will be a technological challenge. Social, economic, and environmental considerations will be critical, and a literature on “sustainability transitions” exists in which these considerations are linked to the technological challenges. The most prominent of these sustainability transition theories are transition management theory, technological innovation systems, strategic niche management, and multi-level perspective on socio-technical transitions. I will present these theories in the context of decentralized energy in the three medium sized northern cities: Saskatoon (Canada), Malmo (Sweden), and Anchorage (United States). A critical review of sustainability transition theories in the context of decentralized energy can provide insights into understanding the implications of a shift towards decentralized energy.

Decentralized energy describes a strategy that includes various generation, distribution, and conservation technologies that work in tandem. It combines the use of micro-grid and storage technologies with a portfolio of electricity generation technologies such as co-generation, biomass power, small-scale wind, photovoltaic power, geothermal, and biogas. Demand-side management technologies and provisions such as energy efficiency and conservation are also central.

Decentralized energy is an ideal socio-technical system for testing sustainability transition theories because there are noteworthy social, economic, and technical advantages of a decentralized strategy. For instance, decentralized energy can often better deal with the challenges of intermittency, scalability, cost-effectiveness, and environmental concerns. Decentralization also has the potential to create greater grid resiliency, technological flexibility, and opportunities for small business and community investment. This Ph.D. research project is currently in progress and I will be able to present preliminary work and project progress thus far.
Research for arctic outdoor workers safety and health: A Norwegian-Russian collaborative initiative.

Valerii Chashchin

Northwest Public Health Research Center, Russia

Sergei Gorbanev¹, Anje Cristina Höper², Valerii Chashchin¹, Marte Renate Thomassen³, Alexander Nikanov¹, Ludmila Talykova¹, Morten Skandfer²

¹ - Northwest Public Health Research Center, St. Petersburg; ² – Department of Community Medicine, University of Tromsø – The Arctic University of Norway; ³ - University Hospital of North Norway

As a result of long-term the Norwegian-Russian collaboration in the field of occupational health and safety there have been shown that the cold environments are capable of changing the behaviour and fate of the most of airborne contaminants as well as the human vulnerability to toxic chemicals, arm-hand vibration and ultrafine particles. There also have been selected evidence-based criteria and internal genotype-phenotype risk determinants for assessing the individual susceptibility to the acute cold exposure. In accordance with these criteria, the list of cold-related health conditions was defined. This list includes 33 classes and groups of diseases and conditions by ICD-10 codes, arising from or tightly associated with the cold exposure. According to the comorbidity principles, the novel quantitative predictive model for assessing the individual susceptibility to the acute cold exposure was developed and validated. This assessment takes into account, in addition to the meteorological risk factors, also internal risk determinants, including physical status, behavioural, pathogenic and functional disorders, as well as receiving thermoregulation-altering pharmaceuticals prescribed by recommended therapeutic doses.

Basing on research experience gained through collaboration there have been jointly specified the further research needs and related activities to better characterize and understand how occupational health and safety policies might be properly adjusted to the specific conditions occurred at arctic outdoor operations associated with high risk of hypothermia, frostbites, chilblains and cold stress. A special protection strategy has been developed to identify and control the risks associated with remote or isolated work in the cold with emphasis to cases when the work is performed alone. These measures should include the appropriate training, accommodation and communication systems, effective personal protection equipment, supervision, accessibility to first aid services and automatic warning devices that raise the alarm in an emergency and are activated by absence of activity from the worker.
The earth and near-earth space form a uniform natural system. When studying weather processes it is expedient to consider the Earth-atmosphere-ionosphere-magnetosphere system. This system is open and sensitive to impact of weak external disturbances. In such system various types of instabilities are possible. The atmosphere consists of a number of geospheres – troposphere, stratosphere, mesosphere and thermosphere. The ionosphere consists of the D, E and F regions. The D region is located at the heights of 50-90 km and is in the mesosphere and partially in the thermosphere. The processes happening in the atmosphere exert direct impact on behaviour of D region of the ionosphere. The researches of processes in the D region are studied with use model and, first of all, experimental methods. The methods use spreading of radio waves, starts of rockets, facilities of partial reflections etc. One of such facilities of partial reflections in high latitudes is located at the observatory "Tumanny" of Polar Geophysical Institute near the village "Tumanny" Murmansk region (69.0 N, 35.7 E). It is a vertical sounding radar with the frequency 2.6 MHz. The facility allows receiving a two-dimensional picture of distribution of amplitudes of the reflected ordinary and unusual waves and electron concentration at the heights of D region during all the day. It gives possibility to control the powerful atmospheric processes which happening both in the place of observation, and in the remote areas. Cyclones (anti-cyclones), jet currents, hurricanes, tornadoes, etc. are of interest. The power of such processes is considerable. These processes are followed by generation of acoustic-gravity waves which extending in horizontal and, at the same time, in the vertical direction and can reach heights of the D region and above at very distant areas. Thus, we can see a projection of these processes in behaviour of the ionosphere. From 2000 the facility of partial reflections in the observatory "Tumanny" observed acoustic-gravity waves that allowing to control emergence them from various atmospheric processes. In the report it will be presented different kinds of acoustic-gravity waves and their properties in the high-latitude lower ionosphere which followed by powerful atmospheric processes.
Advanced prediction in the Arctic and beyond: The APPLICATE project

Luisa Cristini, Thomas Jung

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

The Arctic is changing rapidly with sea ice decrease and warming ocean and atmosphere affecting the physical and biogeochemical systems in the Arctic, but also carrying the potential to influence weather and climate in mid-latitudes. It is therefore crucial to predict these changes and their impacts on the high latitudes but also on Europe, Asia, and North America. Recognizing this priority, a European consortium of scientists from different disciplines set out to advance our capability to predict the weather and climate in the Arctic and beyond in the framework of the EU-funded project APPLICATE. The project aims to improve the representation of key processes in coupled atmosphere-sea ice-ocean models, in order to deliver enhanced numerical weather forecast, seasonal to interannual climate predictions and centennial climate projections. The linkages between the Arctic and mid-latitudes is explored through a coordinated multi-model approach using coupled atmosphere-ocean models. APPLICATE will also provide guidance for the design of the future Arctic observing system to improve our capacity to reanalyse the climate system and enhance models’ predicting skills.

In addition to providing advanced climate prediction in the Arctic, a key objective of APPLICATE is to foster knowledge exchange. Public and private sector stakeholders are regularly consulted via a User Group, which will help shaping climate data into relevant information and services, and a blog, Polar Prediction Matters, to encourage the dialogue between forecasters and data users. Training activities for early career scientists, such as a Polar Prediction School 2018, will provide the next generation of scientists with valuable skills on climate prediction in the Polar regions.

The APPLICATE Consortium is also actively engaging in collaboration activities to exploit synergies with other programs working in the Arctic. On the European level, APPLICATE participates in the EU Arctic Cluster, but we also have strong links with North American partners (e.g., the Sea Ice Prediction Network, US CLIVAR, and Environment and Climate Change Canada), and several other international projects (e.g., the Polar Prediction Project, MOSAiC and GEWEX GASS). Collaboration with these initiatives is maximized on both coordination and scientific levels.

In this presentation, we will give an overview of APPLICATE activities as part of our effort to understand changes in the Arctic and their far-reaching impacts for both environment and communities.
Hybrid visuals for the communication of place-based information in transdisciplinary knowledge processes

Tracie Curry ¹, Gary Kofinas ¹, Matthew Berman ², Ellen Lopez ¹, Bill Streever ¹

¹University of Alaska Fairbanks, USA, ²University of Alaska Anchorage, USA

Iñupiat communities in North Slope Alaska are facing challenges as well as opportunities related to the current and projected impacts of climate change and industrial development. Local representatives are often called upon to share their experiences of change to outsider audiences, including representatives from industry, academia, state, and federal agencies. However, rooted in place, and tied to local values, these experiences can be difficult to convey to outsiders who have never been to the environment that is being described and who come from a different worldview with its own set of standards and values (Van Wyk et al., 2008). The implications of this disconnect can be serious when it comes to securing funding for local development projects, negotiating favourable terms for use agreements, and various other initiatives.

This project explores visual tools (maps, drawings, diagrams, digital graphics, photographs, etc.) and their ability to operate as boundary objects, aiding the development of shared understanding in transdisciplinary knowledge processes. The focus is on visual tools as opposed to other forms of communication because the visual mode can enhance the potential to express identities and values through visual artefacts (e.g. colour, perspective, typography, etc.), thus bringing an additional aesthetic and affective dimension into communication (Van Leeuwen, 2011). This research challenges the suitability of conventional scientific visuals for the communication of place-based information, which involves an added layer of complexity needing to convey a sense of the human relationship with local environmental processes. As a solution, this project proposes the introduction of hybrid images that combine the basic and abstracted style of conventional scientific visuals with naturalistic and stylized visuals more commonly encountered in everyday life. The objective is to integrate differentiated information sources into transdisciplinary knowledge processes, which currently exclude important information that is experiential or difficult to quantify such as local and indigenous knowledge. The research methodology draws from semi-structured, in-depth interviews with North Slope Iñupiat Elders from the community of Wainwright to identify major themes of social environmental change. It also incorporates input from leaders involved in North Slope environmental management to understand desirable characteristics of visual communication tools utilized in transdisciplinary knowledge processes.
Arctic Field Summer Schools: training the next generation of Arctic researchers

Anthony Doulgeris

UiT the Arctic university of Norway, Norway

The “Arctic Field Summer Schools” project is funded by the Research Council of Norway (NFR) and Norwegian Centre for International Cooperation in Education (SIU), under the grant agreement number 261786/H30. The project supports research and education collaboration among UiT-the Arctic University of Norway, University of Alaska Fairbanks (UAF), USA and University of Calgary (UC), Canada. Through a series of summer schools, the project will engage graduate students in exploring science questions related to current Arctic challenges, and bring together leading Arctic researchers from the partner institutions.

During the first Norwegian Field School held in May 2017, 15 Students and a dozen Arctic researchers participated in a remote sensing and ship-based field work in Svalbard and Tromsø. The course was divided in two tightly related events, starting with a one-week field course on board R/V Lance to the marginal ice zone (MIZ) north-west of Svalbard, where the participating students received introductory lectures and collect various in-situ and remote sensing data. The second week took place at the Centre for Integrated Remote Sensing and Forecasting for Arctic Operations (CIRFA), located within the Department of Physics and Technology at UiT-the Arctic University of Norway. This part of the course covered analysis of data collected in the field and lectures relating to current Arctic research by active researchers in the field. The participating students presented an oral proposal at the end of the school and submitted individual reports that could earn credits for the participation based on an assessment of the work. Some projects are the beginnings of scientific papers and international collaboration.

This poster will summarise the fieldwork achieved during the first field school, the research projects of the students, and introduce the next field school in Alaska 2018.
Is the northern expansion of Atlantic cod (*Gadus morhua*) impacting scavenging communities in high Arctic fjords

**Kathy Dunlop** 1, Paul Renaud 1, Jørgen Berge 2, Andrew Sweetman 3

1Akvaplan-Niva AS, Norway, 2University of Tromsø, Norway, 3Heriot Watt University, UK

Scavenging communities play a key role in the cycling of organic material in the marine environment. However, knowledge of Arctic scavenging communities is sparse and little is known about how this group may be affected by rapid changes in the Arctic. The "Anonyx" deep-sea camera lander was deployed in contrasting Svalbard fjords, and captured time-lapse imagery of scavengers consuming herring bait over 10 hours. The lander was deployed in four Atlantic Water influenced fjords; Kongsfjorden, Raudfjorden, Isfjorden, and Smeerenburg (mean water depth = 247 m, n = 4) and a single Arctic water influenced northern Svalbard fjord; Rijpfjorden (mean water depth = 249 m, n = 3) and the winter water influenced Billefjorden (water depth = 189 m, n = 1). Demersal fish species diversity, abundance and stomach contents data were also collected by benthic trawl. Scavenger-community composition was significantly different between Atlantic and Arctic influenced fjords. Arctic fjord scavenger communities were dominated by large numbers (mean maximum abundance of scavengers >500) of scavenging amphipods (*Anonyx* spp.) and ophiuroids (*Ophiopleura borealis*) that quickly reduced the bait to bones. In comparison, scavenger numbers were lower in Atlantic fjords and communities were dominated by shrimps (*Pandalus borealis*) and fish (mean maximum abundance of scavengers = 22). Bait removed rates were approximately 10 times lower in Atlantic fjords (27.7 ± 6.5 g/hr) compared to Arctic fjords (284.5 ± 0.5 g/hr). Recent warming events in western Svalbard have coincided with a northward expansion of the boreal Atlantic cod (*Gadus morhua*). The presence of Atlantic cod, and perhaps other demersal predators, in four Atlantic fjords and their absence from Rijpfjorden and Billefjorden may be responsible for the observed differences in scavenger dynamics among fjords. Northward expansion of boreal predators could have significant impacts on scavenging processes in a warming Arctic.

This study was performed by the staff and students of the UNIS 2017 Arctic Benthic Ecology course.
Effects of sea-ice and biogeochemical processes and storms on under-ice water fCO2 from winter to spring in the high Arctic Ocean: Implications for sea-air CO2 fluxes

**Agneta Fransson** ¹, Melissa Chierici ², Ingunn Skjelvan ³, Are Olsen ³, Philipp Assmy ¹, Algot K Peterson ³, Gunnar Spreen ⁴, Brian Ward ⁵

¹Norwegian Polar Institute, Norway, ²Institute of Marine Research, Norway, ³Bjerknes Centre for Climate Research, Norway, ⁴Institute of Environmental Physics, University of Bremen, Germany, ⁵School of Physics and Ryan Institute, National University of Ireland, Ireland

The ice cover in the Arctic Ocean has decreased during the last decades, manifested in particular as an extensive transition from thicker multiyear ice to thinner first-year ice. As the summer sea-ice cover is decreasing, larger areas with open water will be exposed to the atmosphere. This will have implications for the carbonate chemistry and sea-air carbon dioxide (CO2) exchange. We present measurements of CO2 fugacity (fCO2) and estimates of the effects biogeochemical processes in the surface water under Arctic sea ice, driving the sea-air CO2 fluxes. The data was obtained from January to June 2015 during the Norwegian young sea ICE (N-ICE2015) expedition, where the ship drifted with four different ice floes and covered the deep Nansen Basin, the slopes north of Svalbard, and the Yermak Plateau. This unique winter-to-spring data set includes the first winter-time under-ice water fCO2 observations in this region. The observed under-ice fCO2 ranged between 315 µatm in winter and 153 µatm in spring, hence was undersaturated relative to the atmospheric fCO2.

Although the sea ice partly prevented direct CO2 exchange between ocean and atmosphere, frequently occurring leads and breakup of the ice sheet promoted sea-air CO2 fluxes. The CO2 sink varied between 0.3 and 86 mmol C m⁻² d⁻¹, depending strongly on the open-water fractions (OW) and storm events. The maximum sea-air CO2 fluxes occurred during storm events in February and June. In winter, the main drivers of the change in under-ice water fCO2 were dissolution of CaCO3 (ikaitate) and vertical mixing. In June, in addition to these processes, primary production and sea-air CO2 fluxes were important. The cumulative loss due to CaCO3 dissolution of 0.7 mol C m⁻² in the upper 10 m played a major role in sustaining the undersaturation of fCO2 during the entire study. The relative effects of the total fCO2 change due to CaCO3 dissolution was 38%, primary production 26%, vertical mixing 16%, sea-air CO2 fluxes 16%, and temperature and salinity insignificant.
Can the harvest of Greenland's biggest export be compatible with the conservation of benthic ecosystems?

Mona Fuhrmann ¹, Chris Yesson ¹, Stephen Long ²

¹ZSL, UK, ²ZSL, UCL, UK

The over-exploitation of continental shelf fish stocks and advances in fishing technology have led to the expansion of fisheries into deeper waters, whilst climate change makes previously ice-bound areas accessible. Shrimp and halibut fisheries are of vital importance for Greenland’s national economy. The entrance of these fisheries to the Marine Stewardship Council (MSC) certification scheme, has highlighted the paucity of knowledge on the impacts of bottom-trawling on deep-sea benthic ecosystems. Trawling is likely to impact vulnerable benthic communities, such as habitat forming sponges and soft corals at depths of around 200 to 1400 m. This collaborative EU project determines the impacts of trawling on the sea bed, working closely together with partners from the industry and research institutions in Greenland. Building on previous work which started in 2011, we will develop an understanding of the structure, function and diversity of benthic communities and how they respond to exploitation in the area of Greenland shrimp and halibut fishery. This will be achieved by combining benthic photographic, video and bycatch data along environmental gradients and fishing effort data. Findings will directly support improved governance and management of these fisheries within the MSC framework, with wider applications to the sustainable management of deep-sea fisheries in the Arctic and beyond.
Review on status and changes of the Barents Sea System

Sebastian Gerland ¹, Tor Eldevik ², Marit Reigstad ³

¹Norwegian Polar Institute, Norway, ²Geophysical Institute, University of Bergen Norway, Norway, ³UiT The Arctic University of Norway, Norway

As a part of the new Norwegian research project “Nansen Legacy”, involving eight Norwegian governmental and two private research institutions (https://site.uit.no/nansenlegacy/), a scientific review about the status and changes in the Barents Sea System is developed. We will present first results from this synthesis, focusing on the physical, biological and biogeochemical systems. The review is based on recent peer-review publications about the region, with additional use of publically available long-term monitoring data, such as satellite-based sea ice extent. The Barents Sea represents both geographically and temporarily a gateway to a changing Arctic: It is connected to the Arctic Basin in the central Arctic and ocean currents, sea ice drift and ship traffic illustrate this connection. One question scientists work with is to what extent the Barents Sea can be seen as a sentinel for current changes that in a similar way could happen in the future in other Arctic regions. The Barents Sea is highly relevant as a part of the climate system, as a habitat, and within socio-economics. It is exposed to natural forcing and direct or indirect human impacts, and it is changing relatively fast, compared with other Arctic regions. We will present examples of such changes and relevant processes, including results from numerical modelling.
Arctic seasonal sea-ice variability during pre- and post-2000 periods: role of driving mechanisms

Alvarhino. J. LUIS, Burada Girija Kalyani

National Centre for Antarctic and Ocean Research, India

With a drastic decrease of the Arctic sea-ice, the Arctic has indeed undergone considerable change in the context to global warming. The Arctic ice extent in September has decreased by -13.4% per decade since 1978, followed by August (-10% per decade), while the most stable months May show a trend of -2.52% per decade, followed by April (-2.56% per decade). Therefore, it is quite evident that there is about 10% difference between the minimum and the maximum sea ice contributing months. This calls for an immense retrospection to understand the driving mechanism for the seasonal variability. The analysis of changes in sea-ice on a monthly basis during 1978 - 2017 reveals that March - August (September - February) contributed to a negative (positive) trend in the sea-ice extent. We address the spatial patterns on different time - scales, interannual and inter-decadal during pre-2000 (1978 November to 1999) and post–2000 (2000 to 2017 May). On a seasonal scale, September - October - November months are contributing to the maximum differences for post-2000 (pre-2000), compared to an overall period (1978 - 2017).

On a regional scale, the annual-seasonal statistics revealed that Kara sea sector underwent a rapid decline in the sea-ice extent in all seasons post-2000, followed by Barents sea sector with a increase in decline rate to double that of pre-2000 period in March – April - May (MAM), Sept – Oct - Nov (SON), Dec – Jan - Feb (DJF), whereas Baffin sea sector exhibited an increase in the sea-ice extent post-2000 in MAM, JJA and DJF seasons but in SON, it underwent a decline post-2000 too. Greenland sea-ice extent seems to be recover from the decline contributing in increase in trend post-2000. Annually, post-2000 results affirm that Kara and Barents sea sectors displayed extensive decline in sea-ice extent trend, while Greenland exhibited a slow recovery and Baffin sector showed an increased trend.

There are several factors influencing sea-ice like changes in ocean circulations along with the wind patterns, insolation being the utmost driving factor for the seasonal variability. We examined the relationship between the teleconnections (Arctic Oscillation and North Atlantic Oscillation and Atlantic Multi-decadal Oscillation) on a seasonal sea ice extent in Kara Sea, Barents Sea, Greenland Sea and Baffin Bay sectors. We address the teleconnections influencing the spatial-temporal variability in the Arctic sea-ice extent.
Reconciliation through education: Indigenous partnerships, university transition, and empowerment through knowledge development at Yukon College, Canada

Bronwyn Hancock, Tosh Southwick, Karen Barnes

Yukon College, Canada

There is a new opportunity in the land of the midnight sun. In Canada’s North, the landscape of education is changing. Yukon College is transitioning to Yukon University. and will be the first university north of 60 degrees in Canada. This represents a transformation grounded in a new model of reconciliation that has the potential to drastically improve the Canadian North - it is a transformation being built by the North, for the North. If knowledge is power, then this university transition represents the shift of power from the South to the North and holds some light to the goal of elevating indigenous ways of knowing and doing in postsecondary education. Yukon University has the potential to bridge chasms of opportunity that currently exist between indigenous and non-indigenous Canadians, and those in the North from those in the South. It will be a significant start to creating northern-based knowledge that can address Northern problems with northern solutions.

This presentation will explore the evolution of Yukon College and the Yukon Territory with a focus on reconciliation and partnerships with Indigenous communities. In a territory with 14 distinct First Nation governments, 11 of whom have signed Land Claims and Self-Government agreements, the Yukon is home to an evolving paradigm shift. The lessons that are being learned from 20 plus years of experience in the implementation of Modern Treaties has the potential to alter the course of other communities who are dealing with the legacy of colonization, both in Canada and abroad. Importantly, Yukon University will be home to the Indigenous Self-Determination Institute, where a research agenda built in partnership with the 14 Yukon First Nations and Yukon University’s Research Centre will be married with professional development opportunities for those who are working towards self-determination of Indigenous communities.

Through this presentation, we will use examples of Yukon University’s transition to explore empowerment through education, self-determination, and reconciliation in the North – an intersection that has the potential to address some of the deep-seated social challenges in the Arctic, and alter governance structures, the development of knowledge, and northern institutions and economies.
Reinforcement in Fucus species

William Hatchett
Nord University, Norway

The macroalgal genus *Fucus* (Phaeophyceae, Heterokonta) are ecosystem engineers that provide structure and complexity to otherwise unhospitable and barren rocky shorelines. *Fucus* populations also provide nutrients and shelter for many invertebrate and fish species and have an important ecological function in the littoral ecosystem. The genus originated in the North Pacific and after the opening of the Bering Strait (4.1–7.4 Myr BP), colonized the North Atlantic where it radiated into two distinct lineages that diverged 0.9–2.25 Myr BP: Lineage 1 including *F. distichus*, *F. serratus*; and Lineage 2 including *F. spiralis*, *F. vesiculosus*, and others. Although hybridization is not common between Lineage 1 and 2 species, hybridization within each lineage is prevalent. Lineage 1 consists of the dioecious *F. serratus* with a temperate east Atlantic distribution. The sister species *F. distichus* is a hermaphrodite and characterized by an Arctic distribution. Species form distinct patterns of zonation in the intertidal/subtidal, thereby producing a range of ecotypes to gradients in salinity, temperature, and desiccation. Furthermore, as the limited dispersal of *Fucus* gametes leads to significant genetic structure at a scale of kilometres, patterns of local adaptation can be significant; for example, evidence for strong local adaption to salinity has been demonstrated for *F. serratus* at scales.

These factors make *Fucus* an ideal group in which to study mechanisms of speciation. The evolution of species is central to evolutionary biology and speciation is increasingly viewed as a continuum. Crucial processes include local adaptation on one end of the spectrum and reproductive isolation on the other. Three hybrid zones involving *F. distichus* and *F. serratus* have been identified in the Central/East Atlantic. The zones consisted of a natural zone in Northern Norway (ca. 10,000 yrs of sympatry), and two others resulting from the introduction of either species: Iceland (*F. serratus* introduced and 100 yrs of sympatry) and the Kattegatt (*F. distichus*, introduced and 100 yrs of sympatry). A recent study of the *F. distichus* and *F. serratus* contact zones has found strong evidence for reinforcement as hybridization and introgression significantly decreased with increasing duration of sympatry and F1 hybrids were absent from the oldest contact zone. I hope to understand how reproductive isolation mechanisms evolve in the *Fucus*´ speciation continuum, from local adaptation to complete reproductive isolation, by specifically targeting both end of the speciation continuum.
Predicting range shifts in the Arctic zooplankton: On the distribution and genetic connectivity of Themisto amphipods

Charlotte Havermans\(^1\), Wilhelm Hagen\(^1\), Christoph Held\(^2\), Holger Auel\(^1\)

\(^1\)Universität Bremen, Germany, \(^2\)Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Germany

A species history is characterized by fluctuations of its geographic limits, however, climate change is currently redistributing life on Earth. Particularly in the Arctic, waters are warming at faster rates and sea ice is thinning and contracting. Amphipod crustaceans of the genus Themisto are highly abundant in Arctic waters where they play a major role as food for higher trophic levels such as seabirds, fish and seals. Throughout the Arctic region, two congeneric species co-exist: \textit{T. libellula}, a genuine Arctic species and \textit{T. abyssorum}, considered sub-Arctic boreal. Despite their overlapping distributions, the two species seem to occupy distinct ecological niches and are preyed upon by different predators. \textit{T. libellula} is bigger in size and feeds on copepods with a high lipid content. It is the main prey of some specialist feeders, such as little auks, that only feed on the largest size class, in which case \textit{T. abyssorum} would not be a proper substitute as it is much smaller. Range expansion of \textit{T. abyssorum} and retraction of \textit{T. libellula}'s range is very likely to occur considering the ongoing Atlantification of the Arctic. However, many aspects of the biology, ecology and genetic connectivity of Arctic Themisto populations are still unstudied, despite their importance for a better understanding of the consequences of their potential distributional changes on the food web and biogeochemical cycles. In this context, we investigated the abundance, geographic and bathymetric distribution as well as the genetic connectivity of the two species \textit{T. abyssorum} and \textit{T. libellula} during two cruises with R/V Polarstern to Fram Strait and East Greenland.
Beyond good intentions: Tourism as a driver of Emotion and Philanthropic Behaviour change

Christy Hehir

University of Surrey, UK

The tourism industry has been adapting to accommodate the new demand for non-consumptive forms of animal tourism. ‘Last chance tourism’ has emerged as a new and rapidly growing niche market for tourists seeking non-consumptive experiences with animals and land/seascapes that are vanishing (Lemelin et al., 2010). Climate change provides a rationale to visit areas, like polar regions, before they disappear (Dawson et al., 2011), but the act of travelling to threatened areas raises the spectre of tourists loving an already dying destination to an early death.

An understanding of how tourist experiences can help people to connect emotionally with polar environments and to drive increased levels of conservation-oriented philanthropy is currently missing from both environmental psychology and tourism research. This research responds to that gap by partnering with leading tour operators and international wildlife charities to answer the following research objectives, developed in consultation with members of the tourism industry and conservation organisations:

1. Identify and critique the key factors underpinning emotional connections to nature and wildlife within the tourist experience
2. Critique the influence of whether time dilutes tourists’ emotions towards a place, environmental action or endangered species
3. Investigate the correlation between emotional connection to nature and philanthropic behaviour
4. Determine the extent to which ‘last chance travel destinations’ and/or encounters with endangered animals in the wild, increase tourists’ long-term philanthropic behaviour

There are three phases of primary research:

Phase 1 – Emotion and anticipated experiences within Nature. Pre-trip respondents will participate in bio-sensor experimental tests and interviews to exam their existing emotional responses and connections to nature.

Phase 2 - Post-Experience emotions and actual behaviour change. Phase 2 consists of 2 sub phases; A re-run of biometric tests immediately upon return to test emotional responses to actual experiences while on holiday, and again 3 months post-trip.

Phase 3 - Tourism as a driver of philanthropic behaviour change. Conducted to position behaviour change resulting directly from tourism experiences, with philanthropic decision making in wider society. This phase adopts a quantitative comparative approach using surveys sent to recent tourists, new philanthropists and a control group.

Theoretically, it is anticipated that this study will offer a more comprehensive understanding of how people’s relationships with nature form, and what behavioural implications they may have. The study will also, potentially, provide critical insight into how to effectively meet conservation goals once completed.
Reframing education as a tool for sustainable development in the Arctic

Diane Hirshberg

University of Alaska Anchorage, USA

In its description of education as Sustainable Development Goal #4, the United Nations describes education as "the key that will allow many other Sustainable Development Goals (SDGs) to be achieved." Too often, researchers see education as a way to disseminate findings around sustainable development, rather than as a means for building the capacity of individuals and communities to respond to the social, economic, cultural and environmental changes they are facing.

In this paper I discuss how to reframe the role of education as a crucial tool for building resilience and adaptation among humans in the Arctic. I argue specifically that we need to understand the following:

- What is the role of education, both formal and informal, in expanding the capacity of Arctic residents to respond to the challenges of rapid social, economic and climate change?
- What human capital development is needed to enable Arctic residents to develop, implement and operate governance structures that move their communities toward greater self-determination?
- In what ways can education contribute to transforming the health, social services and economic systems of the North and move them toward less dependence on southern governments and economies?

I then present preliminary findings from the Arctic Youth-Sustainable Development project (a follow up to the Arctic Human Development Report) which inform these questions, and suggest next steps toward developing systems that achieve the goals of increased resilience and capacity among youth of the Circumpolar North.
Relating Regional Arctic Sea Ice and the occurrence of cold winters over Europe

Monica Ionita, Klaus Grosfeld

Alfred Wegener Institute for Polar and Marine Research, Germany

The potential increase of temperature extremes under climate change is a major threat to society, as temperature extremes have a deep impact on environment, hydrology, agriculture, society and economy. Hence, the analysis of the mechanisms underlying their occurrence, including their relationships with the large-scale atmospheric circulation and sea ice concentration, is of major importance. At the same time, the decline in Arctic sea ice cover during the last 30 years has been widely documented and it is clear that this change is having profound impacts at regional as well as planetary scale. As such, this study aims to investigate the relation between the autumn regional sea ice concentration variability and cold winters in Europe, as identified by the numbers of cold nights (TN10p), cold days (TX10p), ice days (ID) and consecutive frost days (CFD). We analyse the relationship between Arctic sea ice variation in autumn (September-October-November) averaged over eight different Arctic regions (Barents/Kara Seas, Beaufort Sea, Chukchi/Bering Seas, Central Arctic, Greenland Sea, Labrador Sea/Baffin Bay, Laptev/East Siberian Seas and Northern Hemisphere) and variations in atmospheric circulation and climate extreme indices in the following months over Europe using different statistical methods.

Based on the composite map analysis it is shown that the response of the winter extreme temperatures over Europe is highly correlated/connected to changes in Arctic sea ice variability. However, this signal is not symmetrical for the case of high and low sea ice years. Moreover, the response of temperatures extreme over Europe to sea ice variability over the different Arctic regions differs substantially. The regions which have the strongest impact on the extreme winter temperature over Europe are: Barents/Kara Seas, Beaufort Sea, Central Arctic and the Northern Hemisphere. We suggest that these results can help to improve the seasonal predictions of winter extreme events over Europe. Due to the non-linear response to high vs. low sea ice years, the skill of the predictions might depend on the sign and amplitude of the anomalies.
Contribution of deformation to sea-ice mass balance: a case study from an N-ICE2015 storm

Polona Itkin 1, Gunnar Spreen 2, Sine Munk Hvidegaard 3, Henriette Skourup 3, Jeremy Wilkinson 4, Mats Granskog 1, Sebastian Gerland 1

1Norwegian Polar Institute, Norway, 2University of Bremen, Germany, 3Danish Technical University, Denmark, 4British Antarctic Survey, UK

Sea ice growth during winter is thermodynamically driven by the temperature difference between the cold Arctic atmosphere and the ocean. By such means an equilibrium ice thickness between 1 and 2 m can be reached during one winter. The fastest and most efficient process, however, of creating thicker ice is through the mechanical redistribution of mass as a consequence of deformation. During the sea-ice growth season divergent motion produces leads where new ice grows thermodynamically, while convergent motion fractures the ice and either piles the resultant ice blocks into ridges or rafts one floe under the other. Here we present an exceptionally detailed in-situ dataset from a 9 km2 area of first and second year Arctic sea ice in the Transpolar Drift north of Svalbard that allowed us to estimate the redistribution of mass driven by a storm. To achieve this level of detail we analysed changes in sea-ice freeboard acquired from two airborne laser scanner surveys just before and right after a deformation event brought on by a passing low pressure weather system. Our analysis reveals that inside the surveyed area the deformation event caused a 4% increase in lead area whilst simultaneously delivering a similar decrease in ice area due to ice compression in distinct convergent zones. Under calm cold conditions the open water in the leads would freeze into approx. 20 cm thick ice cover over two weeks, which would increase the sea ice volume by 0.6%. The sea ice in the area is impacted by 10 to 30 storms every winter, which would result in about 12% volume increase by processes lead by sea ice dynamics. Over the survey region we calculated that 1 % of level sea-ice volume was pressed together into deformed ice. Again, at the end of the winter storms could therefore redistribute about 10 to 30 % sea-ice volume from level into deformed ice.
An analysis of the relationship between regional climate and sea ice conditions in the waters surrounding Svalbard was carried out. The waters surrounding Svalbard were divided into 6 quasi-homogeneous regions, and the sea ice conditions in these regions were analysed. The analyses included linear trends of (SAT) for different seasons and areas (Barentsburg, Pyramiden, Ny-Ålesund, Longyearbyen, Isfjord Radio, and Hornsund). In the waters surrounding Svalbard there has been a substantial decrease of sea ice over the past 35 years, both annually and for individual seasons. The total annual reduction amounts to 2600 km² calculated by linear trend analysis. Decrease of the absolute values of positive anomalies of ice cover is observed from 1979 to 1998, but from 1999 to the present time an increase in the absolute values of negative anomalies is observed. The annual and seasonal variability of ice cover is linked to the ocean circulation in the Svalbard area, and the study gives examples of differences and similarities of seasonal and long-term variability of ice cover of the waters around Svalbard. An increase of SAT by 2.9 degrees was estimated by the linear regression coefficient for the entire period of instrumental observations on Svalbard (Longyearbyen, 1900-2014). The most significant increase of SAT is observed in February, March, April and November and is 4 - 5 deg/century. The rate of increase of SAT during the "early" warming (1920-1940) was 0.17 deg/year, in the "modern" period (after 1990) is 0.11 deg/year. The analysis of the rate of SAT changes for individual months of the year showed that the most intensive growth of SAT is in February during the "early" warming (0.45 deg/year), which is 2.5 times higher than for the average annual values for this period. Higher values of the rate of change in the SAT for the period of "modern" warming compared to the "early" warming were observed only in May and August. The increase in the average annual values of SAT in the "modern" period, on average, is three times higher than similar estimates for the whole period of observations (1900-2014), which indicates an intensification of the climate warming process on Svalbard during recent decades. Preliminary estimates of continentality and anomaly of climate for the different areas of the Western Spitsbergen Island was obtained. This work was prepared within joint MET-Norway-AARI project "Isfjorden - past and present climate"
Geospatial mapping of surface facies of glaciers in Ny-Ålesund and environ, Svalbard, using WorldView-3 satellite imageries

Shridhar Jawak, Alvarinho Luis

National Centre for Antarctic and Ocean Research (NCAOR), India

The retreating glaciers, thinning polar ice caps, enhanced snowfall, and formation of more melt water lakes in the Arctic, Antarctic, Himalayas and other mountainous regions of our planet are at the very core of many environmental and climatic conditions being monitored. Especially, glacier surface facies reveal a great deal about the sensitivity and mass balance of the glacier. The present study explores the implementation of high-resolution multispectral (MS) and shortwave infrared (SWIR) imageries captured by WorldView-3 and stereo digital elevation model (DEM) data for mapping glacier surfaces in Ny-Ålesund and environ. The broad objective of this study is to understand the usage of multispectral satellite image classifications for characterization of the glacier surfaces to infer and quantify climate change in Arctic regions. We have used semiautomated object-oriented information methods by compiling four spectral band ratios for facies classification. These ratios are: (1) Normalized Difference Snow Index (NDSI) from spectral band green and SWIR, (2) Normalized Difference Glacier Index (NDGI) from traditional green and red bands, (3) Normalized Difference Snow/Ice Index (NDSII) from multispectral band red and SWIR, and (4) Near Infra-Red Ratio (NIRR) from NIR-1 and NIR-2. Seven glacier facies were identified, viz., fresh snow, wet snow glacier ice, melting ice, dirty ice, debris and shadowed ice. We also mapped the geographical directional distribution of glacier facies. Accuracies of derived glacier facies maps were evaluated using ground truth data collected during ninth Indian Arctic Expedition. Our results based on spatial directional glacier facies mapping analysis indicate that the object-oriented classification scheme yields 94.7% accuracy. Our future research would focus on spatiotemporal glacier surface change detection studies in the Arctic.
Taxonomic and functional diversity of soft-bottom benthic communities in Tysfjord: Northern Norway’s deepest fjord

Èric Jordà Molina ¹, Maeve McGovern ², Henning Reiss ¹

¹Nord University, Norway, ²Norsk Institutt for Vannforskning - NIVA, Norway

Most of the benthic ecological research efforts in Nordland have been focused on the continental shelf mainly due to management needs for the impacts of exploitation of oil reservoirs. Therefore, little has been done in coastal fjords. However, the increasing use of these areas as locations for coastal aquaculture (mainly Atlantic Salmon farming) demands increased knowledge about the ecological functioning of the fjords in order to monitor and manage impacts of these activities in the future. Fjords are generally dynamic and resilient systems subject to extreme gradients of environmental parameters. It is then of vital importance to provide an accurate description of the system if anthropogenic effects on biological communities are to be discerned from natural drivers.

Only some fjords around Bodø have been investigated. The present study will investigate the soft-bottom benthic communities of the deepest fjord of northern Norway: Tysfjorden, a multibasin subarctic fjord with depths down to 725 m. Several aquaculture farms already operate in this fjord together with other industrial facilities (quartz and concrete factories).

The main objective of the study is to identify the main patterns in community composition, taxonomic and functional diversity of soft-bottom benthic communities together with the prevailing environmental drivers along a “inner”-“outer” transect in the Tysfjord system.

In total, 36 stations were sampled in Tysfjord during May 2017. The benthic fauna was assessed together with the environmental drivers (hydrography, sediment composition, TOC, pH, Redox potential). Oceanographic models suggest a complex hydrographic setting and several rivers discharge terrestrial material into the fjord, especially close to the head of the inlet. CTD measurements showed high entrainment of Atlantic water close to the mouth and in the deepest basin of the fjord, while indications of oxygen deficiency (4 – 6 mg/L of dissolved oxygen) were found in the innermost basin. Polychaetes and molluscs dominated in all stations, but were particularly abundant in the deepest parts of the basins. Echinoderms were often found close to the sills and soft-bottom cold water corals were found in the deepest basin (700m).

Our preliminary results suggest distinct benthic communities in each of the three main basins of this fjord.
Russian and Norwegian policies on energy and climate change in the Arctic

Rabia Kalfağlu
Moscow State University, Russia

Climate change in the Arctic open a whole new ocean for human activity and knowledge, with the region’s vast energy, mineral and marine resources fuelling technological innovations. Among these economic activities, the potential for vast reserves of offshore oil and gas constitutes arguably the most attractive, yet challenging prospect in the region. By the mid to late 2000s, interest in offshore hydrocarbons had surged owing to receding sea ice making more of the region accessible, rising global energy demand, and a more politically stable investment climate relative to other global regions with large hydrocarbon resources. These factors have spurred the Arctic coastal states to support offshore oil and gas development, and the region is experiencing other growing commercial interest and activity. Russia has the greatest potential for Arctic offshore oil and gas with 52 percent of all assessed oil, natural gas, and natural gas liquids in the region. And Norway as Europe’s largest oil producer has a longer history of offshore drilling activities than most of its Arctic counterparts. The 2010 agreement between Norway and Russia on an Arctic border in the Barents Sea has unlocked significant opportunities for resource development by both countries. Moscow is seeking partners for Rosneft and Gazprom to develop offshore oil and gas, and there has been considerable interest. In the wake of a settlement of Norway’s disputed maritime boundary with Russia, Rosneft signed a $2.5 billion agreement in May 2012 with Norway’s Statoil to explore a field in the Barents Sea. Having resolved a long-standing border dispute, Russia and Norway have also worked to harmonize health, safety, and environmental standards for industrial activities in the Barents Sea through the Barents 2020 project. Norway signed a historic energy agreement with the United Kingdom in October 2011 committing to use the best available technologies to manage energy sector-related emissions and to enhance environmental protection. Russia also has attempted to alleviate environmental concerns through a series of environmental protection agreements with its Arctic joint venture partners. The agreements outline measures to protect the Arctic ecosystem during oil and gas exploration, and to minimize the impact of oil and gas activities on indigenous communities.
Does Polar Code Adequate for both Polar Regions?

Meric Karahalil 1, Burcu Ozsoy 2

1Istanbul technical university/ PolRec, Turkey, 2Istanbul technical university/Director of PolRec, Turkey

While Arctic and Antarctic regions have some similar geographic aspects, they exhibit differences such as population structure, administration and legal status conditional to their location and circumstances.

The International Maritime Organization (IMO) has adopted the Polar Code. The Polar Code amends SOLAS 74 and MARPOL 73/78 with binding regulations, which entered into force on 1 January 2017. The Polar Code adapts existing regulations on ship safety and pollution prevention to the special conditions of the Arctic and the Antarctic. The Polar Code is structured into three parts: introduction (goal, application, definition), Part 1 (Ship Safety) and Part 2 (Pollution).

Part I of the Code focuses on the safety of shipping in polar waters and addresses a wide range of safety measures including the need for ships to have a polar certificate and requirements. The hazards include operations in cold temperatures, high latitudes, lack of accurate charting, and lack of infrastructure, in particular for search and rescue operations. Part II addresses pollution discharges from ships such as oil, chemicals, and sewage while at sea and is expected to strengthen existing regulations, particularly in the Arctic. It does not provide significant additional protection for Antarctic waters because there are already regulations in place which effectively ban the discharge of oil, chemicals and various forms of garbage into Antarctic waters. The Code improves the protection afforded to Arctic waters from the discharge of these wastes, bringing the requirements for Arctic waters more in line with the existing protections in place in Antarctica. In my study, I will focus on the lack of any significant new provisions in Part II of the Polar Code that would adequately protect the environment from shipping. Ballast water discharges and hull fouling are also very important issues but Polar Code fails to introduce any new mandatory or requirements to prevent or minimise the risks of introducing invasive alien species. While some vessels will carry the necessary equipment, the Code does not clearly state what will happen in the event of an oil or chemical spill. Also, the definitions are not clear in the polar code. It is necessary to make separate definitions for each type and their physical structures. What is ice-free really?
The role of Arctic Council in regard to the protection of marine biological diversity in the high seas

Narimitsu Kato

Kobe University, Japan

Regional environmental treaty or Regional Fisheries management Organization (RFMO) are engaged in the protection of marine biological diversity in the Area Beyond National Jurisdiction (ABNJ). In Southern Ocean, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) succeeded in establishing two high sea Marine Protected Areas (MPAs) as an implementation of ecosystem approach. In North East Atlantic, North East Atlantic Fisheries Commission (NEAFC) is actively engaged in the protection biodiversity with collaboration with other international organizations such as the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention).

Even though a considerable portion of Arctic Ocean falls beyond any country’s jurisdiction, there is no clear legal framework to protect marine biological diversity in the Arctic Ocean. While some improvements seem to be appearing such as A5+5 negotiation, there is a clear legal framework, Arctic Council (AC), which is a high level forum and has mandate as regarding “environmental protection in the Arctic”. This paper evaluate whether AC have a role as to the protection of biological diversity in the high seas. This paper is composed of two parts. For the former, this paper examines whither Geographical Scope of AC’s mandate contain the high seas through the substantive practices of Working Groups such as PAME regarding to Ecosystem approach, Marine Protected Area and data collection. For the latter, The collaboration AC and other international Organization such as OSPAR Convention and International Council for the Exploration of the Sea (ICES) will examine.
Recolonization and succession of a subtidal rocky-bottom epibenthic community in Smeerenburgfjord, NW Svalbard.

Amalia Keck 1, Susanne Kortsch 1, Bodil Bluhm 1, Raul Primicerio 1, Øystein Varpe 2, Bjørn Gulliksen 1, Frank Beuchel 3

1University of Tromsø, Norway, 2University Centre in Svalbard, Norway, 3Akvaplan-Niva, Norway

Rapid changes to the physical environment of Arctic marine systems in recent years have drastic consequences for the structure and function of benthic ecosystems. Exploring the resilience of these systems to perturbations requires a solid understanding of key ecological processes and must be conducted over appropriate time scales due to the slow growth and recruitment of many Arctic benthic organisms. This study addresses the successional pattern of a hard-bottom benthic community in Smeerenburgfjord (NW Svalbard) after a perturbation, the functional traits involved in the different stages of recolonization, and how variations in community structure relate to environmental changes over a 37-year period. The time series was initiated in 1980 by clearing the substrate free of organisms on a vertical rock wall at 15 meters depth, which subsequently was photographed annually by scuba divers. The structure of the ecosystem is investigated by estimating the percentage cover and abundance of the benthic organisms along with biodiversity measures, whereas the ecological functioning of the system is examined via functional traits analysis. In the manipulated plots we observed a relatively slow return tendency to the original community structure and convergence towards the control plots. The early recolonization process and the invertebrate community reorganization following the climate driven macroalgae takeover in 2000 involved taxa with characteristic functional traits expected to influence ecosystem functioning. Our study provides insights into the succession and recolonization of Arctic benthic communities after a perturbation and their implications for ecosystem functioning, important knowledge at a time of rapid change and increasing borealization of high-latitude ecosystems.
The psychological safety of oil and gas workers of different professional groups in the Arctic

Yana Korneeva, Natalia Simonova, Tamara Tyulyubaeva

Northern (Arctic) Federal University, Russia

The study was sponsored by the RF President's grant for state support of young Russian scientists - PhD (MK-7500.2016.6). The research is concerned with the justification of a model of psychological safety of oil and gas workers in the Arctic. The safety in industrial activity in the first place depends on the employee, at the same time not only on his attitude toward observance of occupational safety and health regulations, but also on the personal attributes of the specialist, his subjective sensation and the effectiveness of his psychological self-regulation. The study was conducted at an oil and gas facility with a watch-based method of labour organization in the Arctic zone of the Russian Federation (duration of a rotation shift is 30 days).

The aim is to study the psychological safety of oil and gas workers of different professional groups in the Arctic.

The study involved 70 persons at the ages from 24 to 60 years (average age 38.7 ± 1.3). The methods are as follows: study of documentation, monitoring of work process, questionnaires, psycho-physiological and psychological testing, and statistical methods of data analysis. The study clarified the concept of psychological safety as a mental state of a subject who has control over a set of internal and external factors of the erratic system providing updating of internal resources of the individual for efficient professional activity on the psycho-physiological and psychological level. As a result, the model of psychological security of oil and gas workers in the Arctic was introduced and evidence based. It includes the following components: 1) The psycho-physiological level of functional status (reduced or optimal); 2) The psychological level of functional state (emergency or economical); 3) The image of the labour object (low undifferentiated hazard assessment or high differentiated hazard assessment); 4) The image of the subject (high undifferentiated or moderately high differentiated self-assessment); 5) The image of the subject-object and subject-subject relations (neutral, negative, or positive).

In this research, the components of psychological safety of oil and gas workers of different professional groups (operators of oil and gas, boiler operators, drivers, engineers and technical workers, maintenance specialists) in the Arctic were empirically studied and characterized. The results can be used to develop measures to control occupational hazards of oil and gas workers of different professional groups in the Arctic. The study aimed at improving the safety of oil and gas personnel.
Functional changes in sub-Arctic benthos following macroalgae expansions

Susanne Kortsch¹, Raul Primicerio¹, Frank Beuchel², Bodil Bluhm¹, Øystein Varpe³, Carl Ballantine², Amalia Keck¹, Bjørn Gulliksen¹

¹UiT the Arctic University of Norway, Norway, ²Akvaplan-niva, Norway, ³UNIS, Norway

Climate warming has triggered regime shifts in Arctic subtidal hard-bottom communities characterized by macroalgae expansions and associated changes in invertebrate community structure. It is unclear how these reorganisations change the functioning of the benthic ecosystem. Based on a 35-y photographic time series from Smeerenburgfjord (NW Svalbard), this study addresses how benthic ecosystem functions change following a macroalgal regime shift. The macroalgae takeover took place between 1998 and 2000, and co-occurred with changes in several invertebrates. Taxa living in association with macroalgae (e.g. bryozoans and epibionts) increased substantially in abundance, whereas sessile filter feeders (especially sponges, barnacles, and solitary ascidians) showed drastic declines. The increase in bryozoans and epibionts suggests that macroalgae facilitate their existence, for example, by lending structural support or protection against predators, whereas the declines in sessile filter feeders may suggest that macroalgae have negative effects on these, for example, by reducing water currents along the seafloor, by clogging the filtering apparatus or because of competition for substrate. This study shows overall increase in structural habitat complexity and an increase in functional diversity in parallel with the macroalgae takeover. The expansion of macroalgae seemingly affects invertebrate community structure via positive (e.g. food, substrate, shelter) and negative (e.g. competition) effects mediated by direct as well as indirect ecological interactions and ecosystem engineering. Climate warming in the Arctic influences growth conditions for benthic primary producers and epibenthos opening up for species with more dissimilar traits, leading to a higher functional diversity with ramifications for ecosystem functioning.
Innovation pedagogical approach to develop mental health nursing education: Service users and family members' resilience

Mari Lahti, Heikki Ellilä, Jarmo Pulli, Annaliina Vatula

Turku University of Applied Science, Finland

Background: Since 2000 the involvement of service users in mental health nursing education has been growing. Also, in the last years the scientific literature has increased its focus on this issue. It is becoming increasingly clearer that the involvement of people who have experienced mental health problems, in undergraduate nursing education has a significant potential to improve the educational and to some extent the practice experience of nursing students. However, mental health nursing is not a popular career choice and having service users involved in teaching mental health nursing has been showing promising effects also in later career choices. Moreover, service users have been empowered by being involved in teaching. This context might be suitable approach to arctic field on studying resilience and mental health problems.

Aims: Aim of this presentation is to describe service users and family members’ views of mental health nursing education and service user involvement. Especially how we can utilize service user involvement in mental health nursing education in north.

Methods: We conducted a two focus group interviews with service user association (n=7) and family members association (n=5) in Turku, Finland. We got 55 pages of transcript written text and we analysed the text using content analysis methods. This data is part of international Commune- Coproduced mental health nursing education project funded by Erasmus+ Strategic Partnership and lead by Iceland University.

Results: Mental health nursing education could be developed by utilizing the presence and involvement of service users in the teaching. According to the results financial compensation and being able to influence to nursing students, are one of the key factors that motivates service users to seek to be a part of mental health teaching. In addition, the service users felt that, seeing the results of their work and the increasing of their appreciation were encouraging factors. Relatives of the mental health service users experience education of nurse students deficient and they hope that it would be invested in the future.

Conclusion: On the basis of the results, utilizing service users in mental health nursing education is a positive phenomenon. Service users were considered as an affective addition to teaching. In the future service users will be hopefully utilized more broadly in northern parts of Europe. Using this innovative method in teaching can highlight new prosperous possibilities also among indigenous people who may suffer mental health disorders.
Intestinal bacterial community of Atlantic salmon during their early and adult life

Jep Lokesh, Jorge M.O. Fernandes, Viswanath Kiron
Nord University, Norway

Host-associated microbiome influences both host defence and metabolism significantly. A close interaction between the host and its microbiome is observed in many phylogenetically diverse animals, including fish. We are studying the intestinal microbiome of Atlantic salmon, a fish species important in aquaculture. As a first step, we examined the transition in the intestinal bacterial community of different developmental stages of the fish and the bacterial community profile of the adult fish from various sources. Such information is important for manipulating the intestinal microbial communities—a potential strategy for health management in the aquaculture industry.

Stage-specific composition and progressive transition of the intestinal bacterial communities were the features of the early life stages and the freshwater and seawater salmon. In the case of adult salmon from the wild, farms or indoor rearing facility, highly abundant bacteria varied from individual to individual, and they included *Mycoplasma* spp., *Photobacterium* spp. or *Spirochaetes*.

The overrepresented groups of the adult fish were not the abundant ones in any of the developmental stages though the bacteria were present in the intestine of the early developmental stages. These results indicate that a multitude of factors can shape the adult intestinal bacterial community profile.

Further studies are planned to delineate the contribution of host-derived factors and environment in shaping the bacterial communities of Atlantic salmon.
Observed near-inertial wave events in Kongsfjorden, an Arctic fjord in Svalbard

Subeesh M P, Divya David, Ravichandran M, Sourav Chatterjee, Nuncio Murukesh

National Centre for Antarctic and Ocean Research, India

Arctic Ocean is known for weak near inertial waves (NIW) due to the presence of sea ice, which acts as a barrier between surface wind and the ocean, restricting the momentum transfer to the ocean. The decrease in the Arctic sea ice in recent years has resulted ocean surface to become more exposed to wind energy. Since the last decade, the south-western Svalbard is sea-ice free mainly due to the warm Atlantic water intrusion, and thereby the region is increasingly vulnerable to wind action. In this study we examined the near-inertial currents in the Kongsfjorden, an Arctic fjord in Svalbard, using a year long ADCP and CTD observations (July 2014 to July 2015). The ADCP attached in the IndARC subsurface mooring was deployed at 192 m at the central fjord along with six Conductivity-Temperature sensors at different depths. The period of inertial wave, 12.2 hours, at the location was close to the M2 internal tide period (12.4 hours) and therefore difficult to separate. However, from the model and the observations, internal tides were found to be very weak inside the fjord (< 2 cm/s). Typical rms value of the near-inertial currents in the fjord was 5-9 cm/s. The wind data from Ny-Ålesund weather station and reanalysis (ECMWF) showed storm activities during the occurrence of these NIW which showed that the main forcing of NIW was atmospheric. The NIW significantly modified the vertical structure of temperature and salinity in Kongsfjorden. The vertically averaged rotary spectra showed the predominance of clockwise energy with the presence of weak counter clockwise energy at near-inertial band. NIW showed standing mode vertical structure (for instance in August 2014) and sometimes a clear downward propagating signal (for instance in June 2015). EOF analysis showed the dominance of first baroclinic mode structure, which explained 17-40% of total variance. In winter, storms were more frequent with more energy, but NIW was relatively weak. In summer, weak storm triggered relatively strong NIW. This may be attributed to the seasonal variation of stratification and the mixed layer depth. The water column was well stratified during the summer with shallow mixed layer while homogeneous in winter. NIW appears to play more and prominent role in future, if the warming in the arctic continues and may have prominent influence in the fjord dynamics.
Labyrinthula zosterae in Sub Arctic Eelgrass (Zostera marina) Beds.

Chloe Marechal, Alexander Juterbock

Nord University, Norway

The protist Labyrinthula zosterae has been identified as a causative agent of wasting disease in Zostera marina, of which the most intense outbreak led to the destruction of 90% of seagrass beds in eastern Western Europe and North America in the 1930s. In 2011, a study from Bockelmann et al showed that L. zosterae infection is common in Northern European eelgrass populations with highest abundances during the summer months. However, the northernmost place they sampled was Sandspollen, in the south of Norway. In summer 2016, we observed patchy browning leaves among the seagrass meadow in Skjerstadfjorden (Northern Norway), characteristic of the wasting disease. In this study we quantify the abundance and prevalence of the wasting disease pathogen among Z. marina populations in the sub-arctic coastal waters, using quantitative PCR with primers targeting a species specific portion of the internally transcribed spacer of L. zosterae. In view of global warming our data provide a baseline for further studies on the causes of pathogenic outbreaks of L. zosterae.
Foundations and methodology of environmental safety network-centric control of Northern sea route

Andrey Masloboev 1, Vladimir Putilov 1, Vladimir Masloboev 2

1Institute for Informatics and Mathematical Modeling of Kola Science Center RAS, Russia, 2Kola Science Center RAS, Russia

The research work is oriented to relevant scientific problem solving of environmental safety decentralized control efficiency enhancement of the critical objects and territories under condition of natural, technogenic and socio-economic emergency and crisis situations appearance. Especially important that problem is for Arctic region, because of use and exploitation stirring up of the Northern sea route and other types of economic activity in this area. The main scope of our investigation is information infrastructure of the multi-level distributed system for environmental safety organizational management of Arctic transport communications. For problem solving within our research we propose new methodology, models and software, providing efficiency enhancement of that system functioning at the expense of activities adequate information and analytical support and coordination of the organizationally heterogeneous security control actors. The workout results and developments allow decision-making operability and quality enhancement in the field of environmental safety and other regional security spheres support by the infrastructure of Northern sea route subject to different factors impact. We propose new methods and tools for formalization, integration, processing, coordination and analysis of the group expert knowledge also, which is concerned with economic and environmental security threats dynamics impact on Northern sea route transport infrastructure condition and logistic features. As a result of the research experiments and applications implementation a software simulation toolkit, which provides security actors behaviour adaptive modelling, intelligent decision-making support and coordination under group security control in conditions of emergency situations by the Northern sea route infrastructure, has been developed. For information monitoring and complex risk assessment of the environmental safety and linked to it economic security a multi-agent system, consisting of autonomous software agents with integrated simulation toolkit, has been designed and approved.
Indigenous Knowledge and Adaptation to Rapid Change in the Arctic: The case of reindeer slaughtering by Sámi in Norway and Nenets in Russia.

Svein Mathiesen 1,2

1UArctic Institute for Circumpolar Reindeer husbandry, Norway, 2UEI, Norway

The knowledge of Arctic indigenous Peoples has been at the very core of their adaptation to the Arctic environment. Today the Arctic has become a hot sport for geopolitics and economics, not just the environment. Many political, social and economic changes are underway.

Can indigenous peoples’ own knowledge assist them to cope and adapt to these current challenges? Does it only have important cultural and identity values or may it help indigenous peoples to maintain their important livelihoods while at the same time succeed economically?

This presentation investigates the role of traditional reindeer slaughtering processes and the knowledge of indigenous Sámi and Nenets for adaptation. We go back in 20th century history the development of state governance of reindeer husbandry in Norway and Russia to study the changes in knowledge and practices of reindeer slaughtering. We demonstrate the strong connection between the knowledge of slaughtering, food culture and adaptation. Finally, we analyse how the Sámi and Nenets traditional knowledge of slaughtering can indeed contribute to the adaptation in the face of the rapid change in the Arctic.
Arctic Tourist Taxation or Arctic Charity

Daria Mishina

Webster University, Austria

The purpose of the project "Arctic Tourist Taxation or Arctic Charity" is to introduce a new Arctic tourism-approach: Arctic tourist taxation. In contrast to other studies, I consider whether business (especially expensive Arctic tourism) can be connected to the direct Arctic development by governmental taxation and/or charity. Specifically, I focus on the needed changes in the understanding of the Arctic tourism in general. (Under the "Arctic tourism" I analyse Arctic territories (High-Arctic, Low-Arctic and sub-Arctic territories).

The Arctic region suffer from the lack of infrastructure, educational facilities for local habitats, territorial, social, and health development. The results of students interviews in the Russian Northern Arctic region (Yamal) have shown that teenagers (13-18 years old) show interest to the Arctic regions (77%). However, there is a lack of information about the Arctic, its value and perspectives to work and live in the Northern regions. Moreover, respondents are ready and want to get knowledge about the Arctic by outdoor seminars and conferences (62%) or have compulsory facultative lessons with invited Arctic specialists (80%).

Principles and goals of the “Arctic tourist taxation” or “Arctic Charity” are oriented on help, initiation and promotion of the needed Arctic development by combining business and pleasure. Using qualitative method of analysis, I found the evidence of possibility to manage a “Arctic tourist taxation” as a new program of the Arctic Council or “Arctic Charity” as an independent NGO. I propose to charge tour operators and tourists by 0.5% of the tour’s price for the further development of the Arctic regions. This approach will build a “checkpoint” in front of the gate to the North. The project can be implemented not only for indigenous and non-indigenous people in the Northern regions, but also for Arctic animals’ protection and for national parks in the Northern regions.

I assume that “Arctic tourist taxation” will not decrease the number of tourists and even attract more tourists, experts and scientists from many different countries, and more people around the world will know more about the Arctic regions. Every Arctic tourist is able to take part in the further Arctic development personally. The Arctic regions have a bright future, but the way it will be managed depends on our behaviour and responsibilities.
Benthic foraminiferal dissolution index for marine sediments in the Svalbard (Storfjorden)

Meryem Mojtabahid 1, Arbia Jouni 1, Hélène Howa 1, Bruno Lansard 2, Elisabeth Michel 3, Olivier Péron 4, Agnès Batlzer 5, Maria Pia Nardelli 1

1University of Angers, France, 2LSCE (UMR8212), France, 3LSCE, France, 4SUBATECH Nantes, France, 5LETG-UMR6554, France

The Storfjorden is a zone of sea-ice formation characterized by a strong production of brines (salty and acid dense waters). In order to reconstruct past dynamics of brine formation in link with past and recent climatic scenarios, we need in addition to physico-chemical proxies, reliable fossilizing marine bio-indicators. Foraminifera are very abundant protists in marine benthic environments, including in the Storfjorden. Because of their short life cycles, high biodiversity and specific ecological requirements of individual species, foraminifera react quickly to environmental disturbance, and can be successfully employed as bio-indicators of environmental changes, such as those brought by brine water formation (i.e. salinity, oxygen and pH changes). The additional advantage, especially for paleoclimatologists, is that many foraminiferal taxa secrete mineralized shells that leave an excellent fossil record. However, in such extreme environments, the fossil record may suffer from deterioration (e.g., dissolution of calcareous tests). One way to assess the resulting taphonomical loss during early stages of test fossilization is to evaluate the preservation state of the shells. In this study, four stages of dissolution were determined for the calcareous species Elphidium excavatum subsp clavata, which is dominant in the modern sediments of the Storfjorden. SEM micrographs were used to illustrate each degree of preservation and to observe the ultrastructural breakdown of the tests’ walls. Stage 1 implies transparent test, smooth surface, and no signs of dissolution. Foraminiferal tests at Stage 2 are whitish with visible pores, and usually, the last chamber is lost as well as the first layers of the chambers. At stage 3, several chambers are dissolved and the remaining ones present opaque wall tests. Finally, Stage 4 materializes the complete dissolution of the calcareous tests.
Innovation in Winter Road Maintenance

**Umair Najeeb Mughal, Geanette Polanco, Ingrid Howes**

UiT The Arctic University of Norway, Norway

Road transportation is very vulnerable to climate change, especially in the Arctic region. Even when current automobile technology has more integrated electronic sensors, they accept sensor data as precise data. However, data can be affected by a wide variety of failure modes of electronic sensors and the uncertainty level of the collected information is unknown. This situation is worse in Cold Regions where low visibility, low friction and high humidity could affect sensor functioning. The struggle to cure snow blindness is among a number of engineering problems still to be resolved. Potential of experiencing safety-critical events, such as, unnecessary emergency braking, inefficient speed control, frequent use of ABS or others increases in these regions. Norwegian Transport Agency has a 12-year traffic policy, and one of the goals is traffic safety, which is based on zero-casualties vision. Stakeholder mapping shows that Norway has a need for real-time road weather and condition systems. This research aims to understand the complexity of winter road mobility under treacherous road conditions and will suggest a support solution for viable transportation. The support system will include off-road and on-road condition monitoring sensors, with IoT at its core, to enable rational support of winter road maintenance.
The Arctic Marine Forecasting Centre of the Copernicus Marine Services

Malte Müller 1, Laurent Bertino 2, Alfatih Ali 2, Ana Carrasco 1, Arne Melsom 1, Graig Sutherland 1, Øyvind Sætra 1, Timothy Williams 2, Jiping Xie 2

1Norwegian Meteorological Institute, Norway, 2Nansen Environmental and Remote Sensing Center, Norway

The Arctic is undergoing dramatic warming and is progressively losing its sea ice cover. These changes are interesting to the offshore oil and gas industry, as well as the shipping industries and fisheries. Thus, there is an increasing demand in Arctic marine forecasting services. The goal of the Arctic – Monitoring Forecasting Centre (ARC MFC) is to provide the most accurate forecast and reanalysis products and ensure the consistency of the information on sea ice, ocean, biology, and surface waves in the whole Arctic. The system is based on a numerical ocean model assimilating in situ and satellite data. Specifically, ARC MFC provides 10-days forecasts of the ocean currents, sea ice, marine biogeochemistry and waves on a daily basis and a 25 years reanalysis of the Arctic Ocean, updated every year. The ARC MFC is powered by the Topaz configuration of the HYCOM model, coupled to the sea ice model CICE, the ecosystem model ECOSMO, and assimilating the following data with the Ensemble Kalman Filter: along-track sea level anomalies, sea surface temperatures, sea ice concentrations, sea ice drift, sea ice thickness and in situ temperature and salinity profiles. Waves are forecasted using an Arctic configuration of the WAM model. We review the main achievements of the ARC MFC during the first 3 years of the services and the plans for its future developments.
Under-ice observations of velocities, particle distribution and zooplankton diel vertical migration patterns

Anna Nikolopoulos ¹, Torsten Linders ², Elin Andrée ²

¹AquaBiota Water Research, Sweden, ²Gothenburg University, Sweden

Observational data were collected with a top anchored mooring line deployed through the ice during a twelve-day ice drift in the spring/summer transition in June 2017. The drift was undertaken over the northern Yermak Plateau at approximately 82°N/10°E, in connection to the PS106 expedition with R/V Polarstern. Equipped with three upward looking RDI Acoustic Doppler Current Profilers (ADCP) and three SBE microCAT sensors, the main purpose of the mooring was to measure the under-ice velocity and temperature/salinity characteristics in the upper 180 m of the water column. A 1200 kHz ADCP was used at 10 metres depth to measure turbulent velocities right underneath the sea ice while two 300 kHz ADCPs were deployed at 100 m and 180 m depth, respectively, to measure vertical as well as horizontal current velocities over the depth range covered by the instruments. Supplemental data of the water properties were collected twice a day with the standard shipboard CTD profiler. Additional measurements of the particle size distribution and concentration were undertaken from the ice with a Laser In-Situ Scattering and Transmissometry (LISST) particle size analyser and with an AQUAlogger turbidity sensor. These latter deployments resulted in vertical profiles down to 200 m as well as time series at fixed depths, for up to 48 hours.

Here we present results for velocities and vertical exchange processes of mass and heat within and below the mixed layer. The ADCP data are additionally presented in terms of acoustic mean echo strength and absolute backscatter to outline sound scattering layers. Such layers are constituted by various components of the zooplankton community (for the 300 kHz instruments, typically small mesozooplankton a few millimetres in size) and may be used to identify vertical migration patterns of such organisms. The results provide further knowledge about the coupling between the under-ice dynamics and the vertical positioning of organisms and adds yet some pieces of information to help decipher the effects of a changed sea-ice and water system on the ice-associated ecosystem.
Bio-geographical patterns in the low arctic tundra and their relation to the likely consequences of the climate change

Lauri Oksanen 1, Tarja Oksanen 1, Risto Virtanen 2, Juval Cohen 3, Bruce Forbes 4, Bernt Johansen 5, Jukka Käyhkö 6, Johan Olofsson 7, Jouni Pulliainen 3, Hans Tømmervik 8, Katariina Vuorinen 9

1UiT- The Arctic University of Norway, Norway, 2University of Oulu, Finland, 3Finnish Meteorological Institute, Finland, 4University of Lapland, Finland, 5Northern Research Institute, Norway, 6University of Turku, Finland, 7Umeå University, Sweden, 8The Norwegian Institute for Nature Research (NINA), Norway, 9Norwegian University of Sciences and Technology, Norway

One way to explore the likely responses of the tundra to the changing climate is to study the consequences of current spatial climate differences on this ecosystem. We analysed climate and vegetation patterns in the European sector of the low arctic zone, in its altitudinal extensions and in its counterparts on middle latitude mountains. We found that the altitudinal extensions of the low arctic tundra on heights and mountains north of the 58th parallel are more related to the arctic than to the truly alpine habitats of middle latitude mountains. Within the “inclusive low arctic” thus defined there were two main tundra types: the Scandinavian ericoid tundra, characterized by mild and snowy winters and only lightly frozen soils, and the strictly low arctic dwarf birch (Betula nana) tundra, characterized by cold and snow-poor winters, by soils, which remain frozen after the snow melt, and by at least sporadic permafrost. A likely primary reason for this dichotomy lies in the spring stress, caused by frozen topsoil, which the dwarf birch tolerates better than the ericoids. The Scandinavian ericoid tundra prevails in the altitudinal extensions of the low arctic. The strictly low arctic dwarf birch tundra is characteristic for the arctic coasts of Russia. However, the distribution of these tundra types is not just an altitude vs latitude issue but is also influenced by local altitudinal differences, generating vertical movements of air masses, and by the vicinity of permanently ice-free seas. In the northern peninsulas of Fennoscandia, the Scandinavian ericoid tundra thus extends to the sea level, whereas the strictly low arctic dwarf birch tundra prevails in the flat inland plateaus, where also permafrost is widespread. As the ectomycorrhiza of Betula spp. is functionally very different from the endomycorrhizas of ericaceous plants, the contrast between these two tundra types is likely to result to major differences in soil processes and thus in the rate of carbon sequestering. Practically all climate change models predict that winters will become milder in the arctic, which is likely to trigger a shift from the strictly low arctic dwarf birch tundra to the Scandinavian ericoid tundra. As the ericoids characteristic to the Scandinavian tundra are moderately abundant everywhere in the low arctic zone, this shift could be much more rapid than the invasion of trees and tall shrubs. This is also indicated by the recent changes in the tundra vegetation of the North Fennoscandian inland.
Blue-Action: Understanding the impact of a changing Arctic on Northern Hemisphere weather and climate.

Steffen Olsen 1, Daniela Matei 2, Johanna Baehr 3, Jens Hesselbjerg Christensen 4, Karin Larsen 5, Gerard McCarthy 6, Yongqi Gao 7, Guillaume Gastineau 8, Noel Keenlyside 9, Mark Payne 10, Kathrin Stephen 11, Raeanne Miller 12, Peter Vangsbo 13

1DMI, Denmark, 2MPI, Germany, 3Universitat Hamburg, Germany, 4NBI University of Copenhagen, Denmark, 5Faroe Marine Research Institute, Faeroe Islands, 6National Oceanography Centre, UK, 7NERSC, Norway, 8CNRS, France, 9University of Bergen, Norway, 10DTU, Denmark, 11IASS Potsdam, Germany, 12SAMS Research Services Ltd., UK, 13Climate-KIC Nordic, Denmark

Faced with a changing climate, businesses, policymakers, and local communities need to access reliable weather and climate information to safeguard human health, wellbeing, economic growth, and environmental sustainability. However, important changes in climate variability and extreme weather events are difficult to pinpoint and account for in existing modelling and forecasting tools. Moreover, many changes in the global climate are linked to the Arctic, where climate change is occurring rapidly, making weather and climate prediction a considerable challenge.

In response, the EU Horizon 2020 Blue-Action project has brought together >120 experts from over 40 organisations to evaluate the impact of Arctic warming on the Northern Hemisphere and to develop new techniques to improve forecast accuracy at sub-seasonal to decadal scales. We will:

- Develop new methods to characterise climate conditions where hazardous weather system forms across the Northern Hemisphere and establish their link to Arctic climate change.
- Deliver an improved representation of Arctic warming and its impact on atmosphere and ocean circulation.
- Enable robust and reliable forecasting to deliver better predictions at sub-seasonal to decadal scales.
- Embed scientific developments and improved model capability within international programmes through organisations including Copernicus C3S, IPCC (AR6) and WMO (YOPP & PPP).
- Co-design a series of case studies with organisations and industries that rely on accurate weather and climate forecasting, to apply new modelling techniques to cutting-edge climate services.
- Communicate new insights, results, and messages – as well as data, model improvements and storylines – to a community of stakeholders for whom understanding climate change and associated environmental trends and risks is imperative.

In doing so, Blue-Action aims to improve the safety and wellbeing of people in Arctic and across the Northern Hemisphere, to reduce the risks associated with Arctic operations and resource exploitation, and to support evidence-based decision-making by policymakers worldwide.
Arctic in Rapid Transition (ART): A Pan-Arctic interdisciplinary and international network

**Alexey K. Pavlov** ¹, Helen Findlay ², Allison Fong ³, Michael Fritz ³, Christopher Horvat ⁴, Jinyoung Jung ⁵, Sanna Majaneva ⁶, Nathalie Morata ⁷, Kathrin Keil ⁸, Allyson Tessin ⁹

¹Norwegian Polar Institute, Norway, ²Plymouth Marine Laboratory, UK, ³Alfred Wegner Institute Helmholtz Center for Polar and Marine Research, Germany, ⁴Brown University, USA, ⁵Korea Polar Research Institute, Korea, Republic of, ⁶UiT the Arctic University of Norway, Norway, ⁷Akvaplan-niva, Norway, ⁸Institute for Advanced Sustainability Studies, Germany, ⁹University of Leeds, UK

The Arctic is transforming at an unprecedented pace, with the diminishing Arctic sea-ice cover being the most alarming factor. Sea ice plays a central role in the Arctic system, its decline and thinning has a multitude of implications ranging from physics and biology to geopolitics and economics. Timely planning and mitigation activities in the Arctic are challenging, though, given the mismatch between observed and predicted patterns of change. To enable robust projections of future conditions throughout the Arctic region, a holistic pan-Arctic approach spanning across disciplines is required. Arctic in Rapid Transition (ART; www.arcticinrapidtransition.com) is an international and interdisciplinary pan-Arctic scientific network, developed and steered by early-career scientists that aims at such an approach. The main goals of ART are bridging time-scales by incorporating paleo-studies with modern observations and modelling, and applying various science disciplines to better understand the past and present response of the Arctic marine and coastal ecosystems to sea-ice transitions and climate change, thus improving our capability of predicting future scenarios. Initiated as a continuation of the International Conference on Arctic Research Planning II (ICARP II) Marine Roundtable in 2008, ART became an official International Arctic Science Committee (IASC) network in 2013. Past ART activities included the organization of science workshops, the coordination of a special issue in Polar Research, and the publication of topical priority fact sheets for the future of Arctic research from an early career scientists’ perspective, which contributed to the ICARP III process. Focusing on active Arctic data collection, ART led a TRANSSIZ (Transitions in the Arctic Seasonal Sea Ice Zone) expedition with the German research icebreaker RV “Polarstern” in 2015.
Has your labinstagrammed today? Sharing experience of Arctic science communication through social media (@OceanSeaIceNPI)

Alexey K. Pavlov ¹, Amelie Meyer ¹, Anja Rösel ¹, Lana Cohen ¹, Jennifer King ¹, Polona Itkin ¹, Jean Negrel ¹, Sebastian Gerland ¹, Stephen R. Hudson ¹, Paul A. Dodd ¹, Laura de Steur ¹, Stig Mathisen ¹, Nick Cobbing ², Mats A. Granskog ¹

¹Norwegian Polar Institute, Norway, ²National Geographic Magazine, USA

Arctic is changing faster than other regions of the planet, which has both regional and global implications and feedbacks. Therefore, communicating Arctic science is particularly important to bring the region to the attention of the public, funding agencies, policymakers, and the global scientific community. Effective science communication is essential but can be hampered by limited resources and a lack of incentives in the academic environment. Many social media platforms have recently emerged, providing free and simple science communication tools to reach the public and young people especially. While individual researchers and large institutions are present on social media, smaller research groups are under-represented. @oceanseaicenpi is a science communication initiative led by a small group of oceanographers, sea ice, and atmospheric scientists at the Norwegian Polar Institute in Norway. Here we present our experience establishing, developing, and maintaining this successful Arctic science communication initiative on Instagram, Twitter, and Facebook. The initiative is run with a relatively modest time and funding budget, and 25 researchers are contributing to the project. Over 3 years, it has built a broad audience of more than 7000 followers, half of which is associated with the team’s Instagram account. To our knowledge, @oceanseaicenpi is one of the most successful Earth sciences Instagram account managed by researchers. The initiative has boosted the alternative metric scores of our publications and helped researchers in the group to become better writers and communicators. We hope to inspire other research groups by sharing our experience on how to develop and conduct effective science communication using social media!
Arctic Security: a shifting paradigm

Pauline Pic

Université Laval, Canada

This paper tackles the role of risk analysis in security studies, in line with recent work putting forward a henceforth common research agenda. This work demonstrates that there is currently a paradigm shift in the definition of security in the Arctic region, and it analyses how this paradigm shift is being translated into policies.

Beginning with a literature review of the definition of security issues in the Arctic, outlining many tendencies in the definition of the concept, the article shows how the region was once a peripheral one, which came to be a strategic hotspot during the Cold War and is now increasingly integrated into global networks. Security thus has been considered from different perspectives, both in scientific literature and national and regional policies.

Drawing from a case study, this work then puts forward how climate change requires an in-depth shift in security policies from a threat-based definition of security to a risk-based definition of (in)security in the region. In the beginning of June 2017, the first leg of the Amundsen scientific expedition in the Arctic had to be cancelled. Some pluriannual ice was obstructing the entry of the North-West Passage around Newfound land. These ice conditions were exceptional: scientists on-board determined it was multi-year ice, not typical of the northeast coast of North America and most likely from the High Arctic. As it is an unseen – and unforeseen – phenomenon, many boats came to be stuck in the ice, and the Amundsen had to resume to its original function and engage into search and rescue activities. This raises essential questions about climate change and its consequences in terms of safety and security policies in the region, thus underlining a shifting paradigm in Arctic security.
Investigation of the Temporary Variability of the Characteristics of Atmospheric Circulation in the area of Spitsbergen

Uliana Prokhorova ¹, Pavel Svyaschennikov ², Boris Ivanov ¹

¹Arctic and Antarctic Research Institute, Russia, ²Saint-Petersburg State University, Russia

The article presents the results of a study of the temporal variability of atmospheric circulation in the Arctic region. The classification of atmospheric circulation forms according to Wangenheim — Girs for cold (November – April) and warm (March – October) periods of the year are used. We consider the repeatability of series with one form of circulation for gradations of duration and variability in time of this characteristic, as a parameter of stability of synoptic processes in the region under consideration. The West Arctic region is singled out separately: the Norwegian - Barents Sea. According to the calculated horizontal gradients of the pressure field (according to atmospheric pressure at sea level), the variability of the air advection directions is estimated.
The ambition of INTAROS Initial Requirement Mapping was to define the high-level requirements of an integrated Arctic Observing System (iAOS) based on identification of the major societal drivers of a sustained observing system in the Arctic region, driven by issues affecting the entire area and expressed through international agreements (i.e. climate, environment, biodiversity, sustaining ecosystem services, improving the livelihoods of indigenous and local communities, support to maritime safety, etc.).

It was decided to focus on the individual thematic areas - meteorology, terrestrial, cryosphere, sea ice and ocean – separately with the purpose of capturing the special requirements, phenomena and essential variables to observe within each of them. It very well known that these thematic areas are closely interconnected and have different levels of maturity in scientific understanding of the phenomena, definitions of essential variables and observing capacity. It is therefore a big challenge to INTAROS to use the collected information to design an integrated multipurpose and multiplatform observations system to optimise efforts and costs.

The detailed analysis of phenomena and observation requirements for the entire region given in this report reveals the following conclusions:

- The Arctic is a region very sensitive to environmental changes. There is a very close interrelation and delicate balance between the five thematic areas (atmosphere, terrestrial, cryosphere, sea ice and ocean). This has a great impact on physical, chemical and biological processes in the area.
- Due to the hostile environment, there is a great lack of basic observations in the Arctic that can support scientific understanding of key processes. Most of the existing data are collected via time limited research project. This lack of process knowledge is reflected in big errors in forecasting models – operational as well as climate.
- It is therefore crucial to establish a sustained Integrated Arctic Observing System that in the short timeframe can increase fundamental scientific and in a longer timeframe can secure a robust basis for decision making to the benefit of the people living in the Arctic, the environment, the broader international society, and commercial activities.
- It is foreseen that a future Arctic observation system will rely heavily on satellite observations supplemented more traditional in-situ platforms.
- In all countries around the Arctic, there are community based observing systems that represent a strong potential for further development. Existing activities shall form the natural basis for a future more intensive and integrated sustainable Arctic Observing System.
The role of Arctic snow cover in high-latitude hydrological cycle as revealed by climate model simulations

Maria Santolaria Otin, Olga Zolina

Institut des Géosciences de l'Environnement, France

Snow is a critical element of the Arctic system and is rapidly changing due to global warming with unexpected impacts on environment, society, and economy. Snow variations affect the atmosphere via changes in there reflectance of shortwave solar radiation (albedo), emissivity of longwave radiation, insulation of the atmosphere from the soil below and latent-heat and water-release in association with melting. Understanding snow processes is a crucial need. Here, we show an intercomparison of an ensemble of CMIP5 models with observations for snow-related variables over the Arctic climate system for historical runs and future projections in different RCP scenarios. In particular, we use Empirical Orthogonal Analysis (EOF) to capture the regional variability of the relationship between snow cover extent and surface temperature in the context of Arctic Amplification.
Environmental monitoring of Arctic coastal ecosystems: Sensitivity to petroleum pollution (Arctic EcoSens)

Paul Renaud ¹, Andrei Granovitch ², Liudmila Sergienko ³, Vera Petrova ⁴, Jasmine Nahrgang ⁵, Nina M. Jørgensen ⁶

¹Akvaplan-niva AS, Norway, ²St. Petersburg State University, Russia, ³Petrozavodsk State University, Russia, ⁴VNII Okeangeologia, Russia, ⁵UiT The Arctic University of Norway, Norway, ⁶Norwegian Polar Institute, Norway

Coastal ecosystems provide considerable ecosystem services for Norway and Russia, but enhanced economic activities, including petroleum exploration, potential production, and shipping, present a growing risk of both chronic and acute pollution. There has been little research to identify relevant monitoring strategies and target values in these unique high-latitude systems, however. In our recently funded project, we will use a multidisciplinary approach, combining expertise from Norwegian and Russian researchers, to inform diverse stakeholders about the sensitivity of key coastal habitats, species, and processes to petroleum pollution. The overarching objective of the project is to evaluate the sensitivity of Arctic coastal ecosystems and identify approaches for monitoring impacts of petroleum pollution. Results of our work will lead to the modernization and uniting of monitoring approaches in the Barents Sea in areas of oil extraction: the identification of new biological, ecological, and geochemical markers of pollution; the evaluation of the new monitoring techniques based on proteomic and/or metabolomics analyses, and the communication of findings to Norwegian and Russian policy makers. Habitat sensitivity modelling will identify where pollution may have the greatest impact. Salt marsh communities are key elements of coastal ecosystems, and changes in marsh vegetation may indicate sensitivity to pollution. Marsh plants contribute significant production of organic matter, and form habitats for many other organisms, provide other highly valuable ecosystem services. Thus, we will identify metrics of community structure and function for use in monitoring in a variety of nearshore habitats, including marsh vegetation, foraminiferal protozoans, and intertidal snail-parasite relationships (both in marshes and on rocky shores). Experimental studies will investigate oil impacts on early life-stages of coastal-spawning capelin. We will employ state-of-the-art tools in petroleum geochemistry to link effects with hydrocarbon sources, and investigate physiological responses using modern 'omics' technologies. Taxonomic studies will unite Russian and Norwegian knowledge to produce modern keys for local and regional faunas. We will also expand on our established collaborations to train young researchers in ecological and petroleum-relevant courses on both sides of the border. Finally, results will be communicated to end-users on regional, national, and bilateral levels to assure the most efficient transfer of new knowledge into policy and management.
Toward an ecologically, behaviourally, and socially-inclusive study of Greenland's fisheries political ecology

Hunter Snyder

Dartmouth College, Graduate Program in Ecology, Evolution, Ecosystems and Society, USA

Small-scale fisheries globally employ > 90% of the world's fishers and fish workers and catch almost half of all fish brought to market. While knowledge about the social and ecological impacts of fishing in the Arctic are known, little is known about how the small-scale sector would be part of a socially progressive and ecologically sustainable future of Arctic fishing. If governments seek to design and implement fisheries policy, management instruments, and regulation, that includes the small-scale sector then there is a need to understand drivers of subjectivities, choices and actions of small-scale fishers on individual and group levels.

This paper outlines a political ecology of fisheries that can (a) implement statistical approaches for assessing current small-scale fisher responses to fishing regulation, (b) deploy Q-methodology for understanding manifold subjectivities of regulations as small-scale fishers think and act to issues of power, control and access, and (c), how human-behavioural responses to ecosystem impacts are part of a social-ecological system.

I present conceptual, methodological and theoretical approaches in the context of Greenland’s fisheries sector. First, we propose to use catch records collected over the last five years to identify one governance challenge of small-scale fishers: fisher mobility and long-haul fishing. We test anecdotal evidence of small-scale fishers traveling long distances from home to fish in unregulated areas, with the goal of identifying the degree of prevalence of long-haul fishing.

Secondly, we propose to promote inclusivity and deepen our relationships with our research subjects by using Q-methodology to probe a series of respondent-generated attitudes for why such behaviour persists. We seek to situate our statistical findings within an ethnographic compound of respondent-ordered subjectivities of how as small-scale fishers think about and act on issues of power, control, and access.

Thirdly, we propose to synthesize our qualitative and qualitative assessments of small-scale fishing behaviour within pressing governance issues that focus on the elimination of open access fisheries, ineffective regulation, the ecological implications of concentrated fishing effort, and the neoliberal privatization of fishing. We conclude by arguing for an ecologically, behaviourally, and socially-inclusive project of political ecology. Such a project engages in core tenets of political ecology, theories from human behavioural ecology, and establishes research subjects as an essential actor in shaping the direction, design, and end-use of the research. We anticipate these contributions to political ecology will also inform a productive dialogue in Arctic social sciences between ethnographically-rich and statistically-significant research paradigms.
Growth rate and fatty acid production of a coldwater microalga in photobioreactors

Hirono Suzuki ¹, Christopher J. Hulatt ¹, Rene Wijffels ², Viswanath Kiron ¹

¹Nord University, Norway, ²Wageningen University, Netherlands

Microalgae are potential sources of novel food and feed ingredients due to their high protein contents and fatty acid composition. In this work, the polar microalga Koliella antarctica was studied in controlled bioreactor conditions, to optimize its growth and to determine its biomass and lipid productivity. Experiments in bubble-tube photobioreactors showed that growth was optimal under low salinity (2/s) on growth, light utilization efficiency and TAG production were studied. The highest growth rate measured 2.0 g/L/d and the highest light utilization efficiency measured 1.47 g/mol. The strong growth rate of K. antarctica coupled with its favourable biochemical composition may make this strain suitable for inclusion in aquafeed products. Koliella antarctica and similar coldwater microalgae, which are potentially more productive in colder climates, as in Norway, could be novel resources of omega-3 fatty acids and protein.
**Arctic Polar Regional Climate Centre Network (Arctic PRCC-Network)**

**Helge Tangen**

Norwegian Meteorological Institute, Norway

The World Meteorological Organization (WMO) has a World Climate Services Programme, under which the formation of Regional Climate Centres (RCCs) is fostered, which are also recognized to be key elements of the Global Framework for Climate Services (GFCS). In 2016 creation of an Arctic Polar RCC was initiated by the WMO Executive Council, which found support from all the member countries of the Arctic Council and now is on its way to start demonstration of operational provision of pan-Arctic climate products under the guidance of the WMO Executive Council panel of experts on Polar and High-mountain Observations, Research and Services (EC-PHORS).

The Arctic Polar RCC is established as a network with its functions distributed over 3 nodes in the WMO Regional Associations (RA) - North America (RA-IV), Nordic and Greenland (RA-VI) and Eurasia (RA-II). All WMO RCCs need to comply with a set of formal designation requirements specified by WMO. They include four Mandatory Functions and five Highly Recommended Functions. The Arctic PRCC-Network plans to start a demonstration phase in May 2018 and aim for designation by WMO to be a RCC during 2019/2020.

The Mandatory Functions are:

- Operational Activities for Long Range Forecast (LRF)
- Operational Activities for Climate Monitoring
- Operational Data Services, to support operational LRF and climate monitoring
- Training in the use of operational RCC products and services

In addition to existing air temperature and total precipitation, sea ice and sea level pressure are considered very important for the Arctic climate aspect.

The Arctic PRCC-Network and the associated user interaction will be explained.
Food web structure in the Barents Sea: insights from carbon and nitrogen stable isotope data

Mikaela Tillman 1, Bodil Bluhm 1, Kirsteen MacKenzie 2, Paul Renaud 3, Lis Lindal Jørgensen 2

1UiT The Arctic University of Norway, Norway, 2Institute of Marine Research, Norway, 3Akvaplan Niva, Norway

Food webs in the Barents Sea experience both intense fishing pressure as well as rapid environmental change mediating shifting species distributions. While the southern and northwestern Barents Sea are connected through northward-flowing warm Atlantic currents, the northwestern part is situated in a more extreme light climate, is covered by sea ice for at least some time and covers both shelf and slope areas. Differences in food web structure might, therefore, be expected compared to the southern Barents Sea shelf which is located directly in the warm water inflow and experiences less extreme seasonality in light climate. Here, we analysed tissue samples from 20 common, pelagic and benthic fish prey for their trophic position using carbon and nitrogen stable isotopes. Generally, pelagic taxa had lower isotope values than benthic taxa, and benthic predators and omnivores were more enriched in both carbon and nitrogen isotopes than filter-feeders; deposit-feeders ranged widely in isotope values. Contrary to our expectation we found an almost complete overlap in isotope niche space between the southern and northwestern Barents Sea food webs. Similarly and again contrary to our expectation, shelf and slope food webs largely overlapped in isotope niche space as well. At the species level, however, nitrogen isotope values (indicating trophic position) were negatively correlated with increasing water depth in some taxa, positively in others and not at all in a third group of taxa. We conclude that the food web of the northwestern Barents Sea largely reflects a continuum of that of the southern Barents Sea based on similar use of isotopic niche space. We recommend the study be expanded to the northeastern Barents Sea to pinpoint and monitor the location of the transition to more Arctic-characterized food webs.
Improving stakeholders' capacity for adapting effectively to changing conditions: the case of oil and gas development in the Russian Arctic

Vilena Valeeva 1, Kathrin Keil 1, Elena Nikitina 2, Johannes Gabriel 3

1IASS Potsdam, Germany, 2IMEMO, Russia, 3Foresight Intelligence, Germany

Rapid changes occurring in the Arctic affect not only the physical and biogeochemical systems and ecosystems but also have significant social and economic impacts. Future developments in the Arctic’s climate, weather, and environment are a significant variable for the pace, extent, and safety of oil and gas extraction in the region. At the same time, the Arctic petroleum industry represents, on the one hand, an economic opportunity through job creation in often underdeveloped Arctic regions but on the other hand a serious challenge through negative consequences for the local environment and through running counter to global efforts to mitigate climate change.

The present case study on “Oil and Gas Development in the Russian Arctic” is part of the international research project “Blue-Action” and is conducted by the Institute for Advanced Sustainability Studies (IASS) in Potsdam, Germany, in cooperation with the Primakov National Research Institute of World Economy and International Relations of the Russian Academy of Science (IMEMO) in Moscow, Russia, and Foresight Intelligence in Berlin, Germany. The goal of the project is to produce a series of scenarios describing possible developments of resource extraction in the Yamal-Nenets Autonomous Okrug (YNAO), Russia, and develop greater capacity among stakeholders to use climate information in their decision-making at various levels of governance and spatial scales.

Within the project, representatives of the forecast community and of different stakeholder groups (Arctic petroleum business, environmental and indigenous NGOs, media and academics) will be brought together to co-create scenarios and find alternative answers to the questions what oil and gas extraction in YNAO could look like by 2040. The scenarios will be developed and tested together with stakeholders through combining more accurate, long-term climate predictions with the forecasts of other relevant variables– i.e. economic, political and legal forecasts.

The scenarios will be constructed in a series of workshops using the method of strategic foresight, which is used worldwide by policymakers, business and analysts who want to convert uncertainties into opportunities. Stakeholders based in the Russian Arctic and elsewhere will get the opportunity to improve their capacity for adapting effectively to changing conditions and opportunities using significantly improved predictive methods and knowledge.
Translating advances in Arctic climate science to climate services across the Northern Hemisphere

Vilena Valeeva 1, Raeanne Miller 2, Mark Payne 3, Kathrin Keil 1, Erik Kolstad 4, Joan Ballester 5, Ilona Mettäinen 6, Pamela Lesser 6, Peter Vangsbo 7

1IASS Potsdam, Germany, 2SAMS Research Services Ltd., UK, 3Danmarks Tekniske Universitet, Denmark, 4UNI RESEARCH AS, Norway, 5Institut Català De Ciències del Clima, Fundacion Privada Instituto de Salud Global Barcelona, Spain, 6Arctic Centre of the University of Lapland, Finland, 7Climate-KIC, Denmark

While inducing rapid and profound changes within Arctic regions, changes in Arctic climate and weather patterns also influence Northern Hemisphere weather and climate, and potentially other climate systems worldwide. In an increasingly globalized world, decision-makers from all sectors and regions need to access improved climate and weather information across regional boundaries to address forthcoming social and economic challenges posed by a changing climate.

In response to this challenge, the H2020 funded Blue-Action project aims to deliver improved modelling, prediction, and forecasting of Arctic climate change and its impact on Northern Hemisphere climate, weather, and extreme weather events. Importantly, Blue-Action also aims to connect activities across the academic, business, policy, and public communities and align its research efforts with stakeholder needs. Creating opportunities for true co-creation of outcomes by user engagement all through the research process will enable the co-creation of climate services, which is central to Blue-Action’s approach.

To illustrate pathways for transforming complex climate model output to relevant, user-specific climate services, we highlight five case studies where climate scientists are working collaboratively with user groups to develop targeted and relevant climate services based on newly improved climate data. They include:

1. Assessing the value of improved weather and climate predictions for short-term and midterm planning of operations for ski centres in Northern Finland;
2. Developing, in collaboration with key stakeholders, a forecast scheme for temperature-related mortality for a very large ensemble of regions in Europe;
3. Forecasting wintertime cold air outbreaks from polar ice to open water, linked to dangerous weather features such as polar lows;
4. Developing and operationalizing annual and multi-annual fisheries-related prediction, and estimating their value to specific industry end-users, as well as the sector overall; and,
5. Developing and evaluating scenarios for resource extraction in the Russian Arctic to enable evidence-based decision-making at various levels of governance and across spatial scales.

Across these case studies and the Blue-Action Stakeholder Engagement Group, we are establishing a two-way dialogue around climate science, climate services, and end-user needs between Blue-Action’s project partners, European-level policymakers, businesses, NGOs, indigenous groups, and other relevant stakeholders. We must work to understand each other’s needs, as well as our limitations.
Arctic Aliens: Mapping the presence of marine alien species in west Svalbard

Martine van den Heuvel-Greve ¹, Anneke van den Brink ¹, Ainhoa Blanco Garcia ¹, Sander Glorius ¹, Jan Bovenschen ², Arjen de Groot ²

¹Wageningen Marine Research, Netherlands, ²Wageningen Environmental Research, Netherlands

Monitoring and predicting biotic changes in the Arctic ecosystem must consider both abiotic and anthropomorphic pressures. Not only do increased temperatures, ocean acidification, weather and snow changes perpetuate changes in the ecosystem, also human activities such as increased shipping traffic provide novel environmental pressures to the area. Increased shipping traffic enhances risks of introducing invasive species via hull fouling or ballast water. Monitoring the presence and distribution of marine alien species currently present in the Arctic region is essential to observe and predict the consequential ecosystem changes. We present current information on the presence and distribution of marine alien species in the Arctic and new data on observations of marine aliens species in west Svalbard using innovative metabarcoding techniques. With this information we can establish the dominant vectors for introduction of marine alien species. This is necessary to develop mitigation measures to prevent further introduction and/or range extension of established marine invasive species in Svalbard.
Results of "Arctic Floating University 2017" expedition: oceanographic conditions and plastic pollution in the Barents Sea

Anna Vesman 1, Viktor Merkulov 2, Nikita Sobolev 3, Anastasia Zagovenkova 4, Natalia Vylegzhanina 4, Valentina Volkova 4, Amelie Sechaud 5, Jocelyn Roth 5

1 Arctic and Antarctic Research Institute; 2 Nansen International Environmental and Remote Sensing Centre, Russia; 3 Arctic and Antarctic Research Institute, Russia; 4 Northern (Arctic) Federal University named after M.V. Lomonosov, Russia; 5 Lomonosov Moscow State University, Russia; 5 Ecole polytechnique fédérale de Lausanne (EPFL), Switzerland

The "Arctic Floating University" expedition on the research vessel "Professor Molchanov" was taking place from July 8 to July 28, 2017. It included an educational unit for students and scientific research unit. Oceanographic measurements in the Barents Sea and in the straits of the Franz Josef Land archipelago were carried out during the expedition. Overall 47 oceanographic stations were completed. One of the main objectives of the research was to study the distribution and transformation of the Atlantic waters (AW) in the north-eastern part of the Barents Sea.

The first oceanographic section was Russkaya Gavan Bay (Novaya Zemlya) - Flora Cape (Franz Josef Land). Approximately 120 km from the shores of Novaya Zemlya AW, which came from the south-west, occupies almost the entire water column. Another core of AW, coming from the St. Anna trough, was observed at depths 100-200m at a distance of 160-180 km from Novaya Zemlya. The second section is located between the cape Zhelaniya (Novaya Zemlya) and the Salm island (Franz Josef Land). In the southeastern part of the section, a weakened AW, coming from the south-west, was observed, but everywhere it is driven out by the Arctic waters. On the section No 2, AW coming from St. Anna trough pronounced stronger. This water mass is found at a distance of 140-220 km from the coast of the Novaya Zemlya and occupies depths of 60 to 240 meters.

In addition to oceanographic research, samples of a zooplankton were taken with a net. During the analysis, it was found that many of samples contain microplastic, mostly fibres, presumably from fishing nets. Most of these fibres were found in samples taken close to Novaya Zemlya. In addition, observation of the water surface from the ship's bridge showed that a large number of marine debris drifts along the shores of Novaya Zemlya, such as plastic canisters and lost fishing nets. In the straits of the Franz Josef Land an amount of pollution is lower, but nevertheless abandoned fishing nets were discovered there too.

Since the expedition didn’t initially planned to sample microplastic, the results are not very accurate, however, the processed samples show that large amount of marine debris accumulates along the coast of Novaya Zemlya and can pose a threat to human health.

The authors are grateful to the “Floating University» project, E. Ermolov and D. Mennikov (National Park “Russian Arctic») for their help on oceanographic sections.
Current condition and challenges of the ports infrastructure along the Northern Sea Route

Ksenia Vezhlivtseva, Ksenia Vezhlivtseva

Northern Arctic Federal University named after M.V. Lomonosov, Russia

The Arctic and its natural resources have an increasing value for commercial use in today’s world. Global warming causes melting of ice in the Arctic, opening previously ice-covered routes for commercial navigation. Currently, the Northern Sea Route is often discussed as an alternative to the Suez Canal. The Northern Sea Route can be a good source of income for Russia. Russia may benefit from Arctic and its opportunities but it requires extensive research, knowledge development and new insights. The seaports of the Russian Federation are of strategic importance for the development of the national economic complex of the Russian Federation. The increase in port capacity allows Russia not only to meet domestic needs but also to become an active participant in the process of servicing international cargo flows of transit, transshipment as well as international transport corridors. In order to achieve the trade and transport needs of the country the seaports along the Northern Sea Route must provide a competitive international port infrastructure and provide quality services in the short, medium and long term. Achieving the leading positions without complex technological modernization of all infrastructure industries including seaports is impossible. The relevance of my research is due to the fact that today the development of the Arctic ports pays great attention on the part of the Russian Federation, adopted new normative acts, strategies and new investment projects. This required a comprehensive analysis of the development of the Russian ports in the Arctic. We have analyzed the current condition of the ports as well as the main investment projects. It can be argued that sustainable growth of the Northern Sea Route is impossible without sustainable development of the ports along the NSR and its infrastructure. We have analyzed activity of the Arkhangelsk Sea Commercial Port that has a number of significant strengths and opportunities for developing the NSR what mean that the port development, becoming a key port along the NSR that will satisfy the needs of the Russian economy, foreign trade and population in transshipment of cargo and ensuring safety of navigation in seaport is possible. However, at the same time, special attention should be paid to factors and risks. Developing of ports should be based on a system of interaction between government, both national and international commercial and non-profit organizations and civil society with the use of public-private partnerships in the implementation of key investment projects.
H2020 project Nunataryuk: Permafrost thaw and the changing coast - science for socioeconomic adaptation

Leena Viitanen, Hugues Lantuit, Paul Overduin, Michael Fritz

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

Permafrost coasts in the Arctic make up 34% of the world’s coasts (Lantuit et al., 2012) and represent a key interface for human-environmental interactions. These coasts provide essential ecosystem services, exhibit high biodiversity and productivity, and support indigenous lifestyles. At the same time, this coastal zone is a dynamic and vulnerable zone of expanding infrastructure investment and growing health concerns.

Permafrost thaw, in combination with increasing sea level and changing sea-ice cover, expose the Arctic coastal and near shore areas to rapid changes (Fritz et al., 2017). The release of previously frozen organic carbon and its transformation into greenhouse gases may push the global climate warming above the 1.5 °C targeted in the COP21 Paris Agreement (Schuur et al., 2015). The pressing challenge is to quantify and project organic matter, sediment and contaminant fluxes from thawing coastal and subsea permafrost and to accurately assess the implications of permafrost thaw for the indigenous populations, the local communities and the local environment in the Arctic coastal areas.

Nunataryuk is EU Horizon 2020 funded collaborative project, with the main objective of determining the impacts of thawing inland, coastal and subsea permafrost on the global climate and on humans in the Arctic and to develop targeted and co-designed adaptation and mitigation strategies.

Nunataryuk will address its objective in three inter-related and inter-disciplinary activities (Physical Sciences, Social Sciences and Integration activities) by (1) developing a quantitative understanding of the fluxes and fate of organic matter released from thawing coastal and subsea permafrost; (2) assessing what risks posed by thawing coastal permafrost, to infrastructure, indigenous and local communities and people’s health, and from pollution; (3) using this understanding to estimate the long-term impacts of permafrost thaw on global climate and the economy.
Seasonal variability of Arctic sea ice in a 1D sea ice model

Caixin Wang 1, Keguang Wang 1, Mats Granskog 2, Sebastian Gerland 2

1Norwegian Meterological Institute, Tromsø, Norway, 2Norwegian Polar Institute, Fram Center, Tromsø, Norway

Arctic sea ice has deceased in extent and in thickness, and shifted toward a younger ice pack. Solar radiation incident on sea ice, is reflected back to the space (albedo), absorbed by snow or sea ice, and transmitted through sea ice to heat the upper ocean. The Arctic ice pack is currently dominated by thinner first-year ice (FYI), instead of thicker multi-year ice (MYI). FYI tends to have more and larger brine pocket, lower albedo, higher transmittance, and larger and shallower melt ponds in contrast to MYI. These properties changes the solar radiation partitioning and solar heating which has been attributed to the Arctic sea ice decline. However, in sea-ice models, consideration of solar radiation partitioning is still based on MYI observations. This may results in substantial underestimation of solar heating effect and the sea ice mass balance. In April 2012 and 2013, Spectral Radiation Buoys (SRB) and ice mass balance buoys (IMB) were deployed on first-year ice near the North Pole. These SRB and IMB buoys have collected two complete summer melt seasons of in-band (350-800 nm) solar radiation and sea ice mass balance data. We apply the 1D configuration of the Las Alamos CICE5.1 model to investigate the seasonal variability of sea ice in 2012 and 2013, and examine the effect of solar radiation on the sea ice mass balance during these two summer seasons. The model is initialized with the observed snow depth and sea ice thickness in April, and forced with atmospheric re-analysis data. The model simulations show that it can basically capture the seasonal variability of snow and ice mass balance. Numerical experiments were used to examine how sea ice mass balance is affected under different atmospheric forcing, surface albedo and melt ponds parameterization.
Iceland’s Fishing Industry in a New Age

James Whitacre

University of Massachusetts Boston, USA

In any fishing economy, transportation capacity and its development plays a critical role. Looking to current global events related to hacking and Iceland, a country responsible for 6% of Global Certified MSC Catch, we can see how the future of fishery exports and governance hinges on overcoming cyber disruptions to transport by sea and air. The paper concludes with options on how to make the fishing industry more cyber secure in an era of global supply chains. Co-authored with Ambassador Einar Benediktsson of Iceland.
Adaptation mechanisms of workers of extractive industries in the shift work organization in the Far North and the Arctic

Anna Yurjeva, Yana Korneeva

Northern (Arctic) Federal University, Russia

Extractive industries are located in remote areas of the Far North and the Arctic, in connection with which the shish method of organizing labour is used there. Workers of mining industries are exposed to extreme climatic-geographic factors (low temperatures, wind, lack of oxygen in the air, etc.), as well as under group isolation conditions. This makes relevant physiological, psychological and socio-psychological adaptation. Despite the large number of research in medicine and psychology devoted to these issues of human adaptation to severe climatic and geographic conditions and shift work, the systematization and classification of the mechanisms of psychological, social and psychological adaptation of workers in extractive industries is not enough.

The research purpose was to study and develop a classification of the mechanisms of psychological and socio-psychological adaptation of workers in extractive industries in the Far North and the Arctic. The study was carried out at the diamond mining site in the Arkhangelsk region of the Russian Federation, in which 70 employees took part (working schedule: 14 days of work, 14 days of rest). Methods of research are questioning, psychological and psychophysiological testing.

As a result of our research, differences in self-regulation, regulatory processes, coping strategies, psychological protections and mechanisms of socio-psychological adaptation among workers in the mining industry of various professional groups and at various stages of professional development were revealed.
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