Arctic Frontiers Science 2016

ABSTRACTS

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Editors
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About Arctic Frontiers 2016

Conference partners

Senior partners
- Troms County Council
- ConocoPhillips
- University of Tromsø the Arctic University of Norway
- Norwegian Ministry of Foreign Affairs
- The Research Council of Norway
- Arctos Research Network
- Akvaplan-niva

Partners
- Institute of Marine Research
- University of Bergen
- Barents Secretariat
- SINTEF
- University of Oslo
- The Norwegian Coastal Administration
- DNV – GL
- UNIS
- Norwegian Space Centre
- Avinor
- Innovation Norway
- Norwegian Radiation Protection Authority
- NTNU

Associated partners
- FRAM - High North Research Centre for Climate and the Environment
- NORUT - Northern Research Institute
- ICE - Centre for Ice, Climate and Ecosystems, Norwegian Polar Institute
- University of the Arctic
- AMAP
- APECS – Association of Polar Early Career Scientists
- Tromsø municipality
- University of Stavanger
- Norwegian Oil and Gas Association
- GCE | NODE
- International Centre for Northern Governance and Development
- NIVA
- GCS Subsea
- NOFIMA
- Norwegian Fishermen’s Sales Organization
- KSAT

Friends of the conference
- ArcticNet
- Russian Geographical Society
- Fridtjof Nansen Institute
- BusinessOulu
- International Centre for Reindeer Husbandry
- Korea Maritime Institute
- Blue Maritime Cluster

Steering Committee
The steering committee is composed of one representative from each of the partners. The steering committee has three formal meetings per year.

- Ole Øvretveit (Manager, Arctic Frontiers secretariat), Akvaplan-niva
- Salve Dahle (Chair of Arctic Frontiers steering committee), Director, Akvaplan-niva

Members
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Science conference organizers
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• Ole Øvretveit, Akvaplan-niva AS

Scientific committees

Part I: Environmental footprints
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• Research Professor Martin Forsius, Finnish Environment Institute (SYKE), Finland
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• Leader Arctic Environmental Technology, Hanne Greiff Johnsen, Statoil, Norway
• Head of Department, Professor Anders Goksøyr, Department of Biology, University of Bergen, Norway

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• Research Associate Dr Megan Blomfield, University of Bristol, United Kingdom
• Head of Department Dr Zafer Özgen, Department of Music and Drama, University of Tromsø (UiT) - The Arctic University of Norway, Norway
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• Secretary General Nina Jensen, WWF – Norway
• Senior Advisor Torbjørn Pedersen, Research Council of Norway
• Manager Arctic Unit Dr Toril Inga Røe Utvik, Statoil, Norway
Introduction

The 10th Arctic Frontiers conference was arranged in Tromsø, Norway from Sunday 24 January to Friday 29 January 2016. The title for the 2016 conference was Industry and Environment.

The Arctic is a global crossroad between commercial and environmental interests. The region holds substantial natural resources and many actors are investigating ways to utilise these for economic gain. Others view the Arctic as a particularly pristine and vulnerable environment and highlight the need to limit industrial development.

Arctic Frontiers 2016 discussed the balance between resource utilisation and preservation, and between industrial and environmental interests in the Arctic. Envisioning a well-planned, well-governed, and sustainable development in the Arctic, how can improved Arctic stewardship help balance environmental concerns with industrial expansion? How can the industrial footprints from future business activities be minimised? And last, but not least, what role will existing, and emerging technologies play in making industrial development profitable and environmentally friendly, securing a sustainable growth scenario for Arctic communities?

The Arctic Frontiers conference is a central arena for discussions of Arctic issues. The conference brings together representatives from science, politics, and NGOs to share perspectives on how upcoming challenges in the Arctic may be addressed to ensure sustainable development. Arctic Frontiers is composed of five sections: Arctic Frontiers Policy, Arctic Frontiers Science and Arctic Frontiers Business, Arctic Frontiers Arena and Arctic Frontiers Young.

Arctic Frontiers Science 2016 addressed three main themes:

1. Environmental footprints
2. Arctic stewardship
3. Technology needs

Part I: Environmental footprints

The Arctic is under pressure, with multiple and often interrelated stressors leading to widespread and complex environmental change. In particular, stressors such as climate change, long-range
transported pollutants, land-use change, and shifts in regional economic activity can have strong impacts on ecosystem function as well as the delivery of ecosystem services.

As the Arctic becomes an increasingly important political and economic region, it is critical to gain a comprehensive understanding of the potential environmental footprint of increased human activity. In particular, there is a need for highly interdisciplinary and integrative approaches to identify how shifts in regional activities (e.g. industry, urbanization, and aquaculture) can interact with broader global stressors (e.g. climate change) to influence the Arctic environment.

The Arctic Frontiers 2016 science session on Environmental Footprints aims to integrate these key topics by inviting abstracts on the following themes:

- Human activities in the Arctic
- Global stressors and the Arctic
- Effects of multiple stressors on ecosystems and ecosystem services

**Human activities in the Arctic**
The first theme explores current and potential future environmental impacts of human activities in the Arctic. Topics to be addressed will include:

- transport (e.g. shipping)
- oil and gas extraction
- aquaculture and fisheries
- mining (on-land and deep sea)
- urbanisation

**Global stressors and the Arctic**
The second theme explores current and potential future impacts of global stressors on the Arctic environment. Topics to be addressed could include:

- climate change (higher temperatures, altered precipitation and hydrology, changing ice regimes, permafrost thaw, altered biogeochemical cycles)
- ocean acidification
- long-range transported pollution (contaminants, particulate matter, acid compounds)
- change in biodiversity (species declining, changing biomass, invasive species)

**Effects of multiple stressors on ecosystems and ecosystem services**
The third and final theme focuses on assessing how multiple environmental stressors (both regional and global) can interact to affect Arctic ecosystems and the services they provide. Here, we particularly encourage abstracts that take interdisciplinary approaches to assess environmental impacts in the context of not only ecosystem health, but also the balance between environmental considerations and the needs that different end users have for the services these ecosystems provide.

**Part II: Arctic Stewardship**
Stewardship is an essential element of long-term viable people-environment relationships, reflecting the fact that humans and the rest of nature are mutually interdependent. Stewardship thus addresses two interconnected goals: ecosystem resilience and human wellbeing. These goals are shaped by broadly held societal norms and values. A stewardship approach can direct us towards a more sustainable future by emphasising human responsibilities with respect to the environment, by
focusing on solutions rather than problems, by creating opportunities for public dialogue and social learning, and by promoting integrated governance.

The Arctic region is emerging as a global crossroads between public interest and private and commercial gain. The region is also warming twice as fast as the rest of the planet, with significant knock-on effects for the global environment. When the Ottawa Declaration of 1996 formally established the Arctic Council as a high-level inter-governmental forum, its purpose was to provide an international platform for promoting cooperation, coordination and interaction among the Arctic States, with the full involvement of the Permanent Participants. By integrating human development and environmental protection in the Arctic, stewardship provides a framework to understand how diverse human beings and organisations can influence the achievement of these goals and successfully respond to navigate in a rapidly multi-dimensional Arctic. Arctic stewardship may thereby facilitate more sustainable outcomes for societies in the Arctic and beyond.

This part of the Science session explores, via four themes, the multiple ways that Arctic stewardship is articulated, developed, conducted, nurtured, supervised, and governed through the arts, cultural expression, institutional and organizational performance and other participatory processes. Particular emphasis is given to learning and co-producing knowledge in formal and informal mechanisms that govern the interface between people and nature.

To address issues related to arctic stewardship we invite abstracts on the following suggested topics:

- Arctic narratives
- Arctic public stewardship
- Arctic civil stewardship
- The Arctic globalised

Arctic narratives
The first theme intends to set the stage. Throughout human history, and today, ideas and notions about lived life and prosperous ventures in the Arctic have been presented and perceived in art, literature, historiography, science, journalism and other media. These perceptions have been reflected in various aspects of human organization and activity – in law and politics, in civil and corporate society. This theme will allow for investigation of Arctic Stories told and Arctic Future imagined.

Arctic public stewardship
The second theme aims to investigate how public stewardship is practiced in the Arctic, at different levels and by different public and private actors and drivers. Actors considered may include the Arctic Council or other international and intergovernmental institutions, as well as individual Arctic states. Different types of interaction between government and industry may be addressed, e.g. how private actors such as international standardization organizations or quality assurance companies act on behalf of on public authorities or private-public partnerships.

Arctic civil stewardship
The third theme aims to investigate how civil society and private/corporate businesses should be involved in the stewardship of the Arctic. The natural resources of the Arctic have long been utilised by communities of indigenous peoples and the non-indigenous population. More recently, Arctic resources have attracted international corporate interest. Given the link between Arctic resource exploitation, global climate change and other environmental risks, the region has also become a focal point for regional, national and international non-profit civil actors who claim a say in the future development of the Arctic.
The Arctic globalised
The fourth theme concerns the Arctic as part of the global environment. It may include investigation of how other regional and global regimes and drivers affect stewardship of the Arctic. Discussions of the appropriate involvement of non-Arctic states are encouraged. This may include assessment of why perceptions tend to the negative when absent their involvement, global issues affecting the Arctic cannot be addressed effectively. Submissions could also explore how Arctic issues are communicated and considered in global regimes (e.g. climate change, biodiversity, shipping and trade), for example via studies of intergovernmental organizations and multilateral treaty bodies. Relevant drivers may include the influence of regional policies and geopolitics on cooperation in the Arctic.

Part III: Technology needs
The activity level in the arctic regions is increasing. Fisheries has for centuries been a fundamental economic activity with participation from several nations whilst now the aquaculture industry is rapidly developing. United States Geological Survey (USGS) estimates that 30% of the world’s undiscovered gas resources and 13% of the undiscovered oil resources are to be found in the Arctic. Offshore oil and gas resources are now in development with a potential for increased activity in the future. Further, the use of the northern seaways as transport channel are growing, and new industries such as ocean mining and renewable energy production seems prosperous.

Driving forces are on the one hand of a global character as need for food, transportation services and energy. Parallel with these economic motives we see global warming with ice retraction making the vast areas in the north more available.

Operations in the Arctic are however challenging towards the extreme with ice, rapidly developing low pressures and storms, long distances, darkness and so on. Northern operations will further take place in a vulnerable environment making the tolerance levels versus failures, subsequent oil spills etc. close to zero. Improved knowledge and technology is needed to make sure that operations are within safe and sustainable limits. To address issues related to technology needs we invite abstracts on the following suggested topics:

- Offshore oil and gas under arctic conditions
- Fishing and aquaculture under harsh and exposed conditions
- Shipping in the North
- Ocean mining in the Arctic

Offshore oil and gas under arctic conditions:
The first theme explores current and potential future technological challenges and needs with respect to oil and gas installations and operations in the Arctic. Topics to be addressed will include:

- Sub-sea installations
- Logistics under harsh conditions in waste areas
- Safety systems
- Positioning and demobilisation in ice
- Ice management
- Remote operations

Fishing and aquaculture under harsh and exposed conditions
The second theme explores current and potential future technological challenges and needs with respect fishing and aquaculture activities in the Arctic. Topics to be addressed will include:
- Navigation systems
- Rescue operations
- Aquaculture in exposed areas
- Logistics support
- Ecosystem interaction (technology for environmental friendly exploitation of marine resources)

Shipping in the North

The third theme explores current and potential future technological challenges and needs with respect to shipping activities in the Arctic. Topics to be addressed will include:

- Route and convoy planning
- Shipping and ice interaction
- Manoeuvring and automation
- Emergency preparedness

Ocean mining in the Arctic

The fourth theme explores current and potential future technological challenges and needs with respect to possible ocean mining operations in the Arctic. Topics to be addressed will include:

- Sub-sea operations
- Logistics support
- Exploitation strategies
- Environmental concerns
Oral abstracts

Keynote presentations

Man and The Last Great Wilderness: Human Impact On Deep-sea Ecosystems

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The deep sea, the largest ecosystem on Earth and one of the least studied, harbours high biodiversity and provides a wealth of resources. Although humans have used the oceans for millennia, technological developments now allow exploitation of biological resources, hydrocarbons and, potentially, minerals below 2000 m depth. The remoteness of the deep seafloor has promoted the disposal of residues and litter. Ocean acidification and climate change bring a new dimension of global effects. Thus the challenges faced by deep-sea ecosystems are large and accelerating. This demands new efforts from the science community, industry and national and international organizations to work together to develop successful ecosystem-based management measures and conservation options for deep-sea ecosystems and the services they provide. In recent decades, the most significant anthropogenic activities that have affected the deep sea have evolved from mainly waste disposal (past) to resource exploitation (present). We predict that from now and into the future, increases in atmospheric CO₂ and facets and consequences of climate change will increasingly impact deep-sea habitats and their fauna and may develop significant synergies with other stressors. This is particularly important in the Arctic, where the reduction of permanent ice cover may open new areas and attract new industries such as shipping, fishing or deep-sea mining.

Because of the limited knowledge of deep-sea ecosystems and rapid increase of industrial activities in deep waters, it is imperative to move from a frontier mentality of exploitation and single-sector management to a precautionary system that balances use of living marine resources, energy and minerals from the deep ocean with maintenance of a productive and healthy marine environment, while improving knowledge and collaboration. The Deep-Ocean Stewardship Initiative (DOSI) was created in 2014 with the aim to serve as a platform for all stakeholders to share information and move forward in the stewardship of our oceans, both in areas within and beyond national jurisdiction.
Stewardship in The Global Arctic: Between Private Rights and Public Goods

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Although a broad range of narratives have been deployed by actors within and beyond the Arctic to classify the region, these can be divided into two scalar categories. On the one hand, some narratives conceive the Arctic as a fundamentally global space: a frontier for meeting global resource needs, a geostrategic flashpoint for world rivals, a last repository of globally significant nature, an indicator and amplifier of climate change, a venue for world-spanning shipping lanes, a laboratory for global science. On the other hand, other narratives conceive the region as a space of concern to specific ‘Arctic’ actors: a site for investment and development, an indigenous homeland, a heartland of national identity, an environment of local livelihoods, a repository of situated knowledge. In this keynote address, I suggest that the concept of stewardship is uniquely suited for fusing these two concepts of the Arctic. The goal of stewardship is to join recognition of a greater, universal good with an acknowledgment that some actors are in a privileged position for safeguarding or realizing that good. Acknowledgment of stewardship leaves many details unanswered, including precisely what aspects of the Arctic require safeguarding and precisely which actors should be entrusted with safeguarding that value in the public interest. However, the concept establishes a basic framework for establishing the region as one of both global significance and local privilege.
Arctic Civil Stewardship: The Distinct and Primary Role of Indigenous Peoples

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As the original stewards of the Arctic, Indigenous peoples throughout the circumpolar region should play a primary role in the management and utilization of its natural resources. Furthermore, their basic individual and collective human rights to self-determination and self-government as well as lands, territories and resources are central to any dialogue concerning corporate interests, resource exploitation, mitigation and adaptation to climate change and other environmental risks that have the potential to dramatically change the balance of sustainable development in the Arctic. The voice and role of Arctic Indigenous peoples must be fully recognized, respected and accommodated at the regional, national and international level and their corresponding right to participate in matters that impact them must be assured in the future development of the Arctic.
Technology Challenges Related to Year-round Operations at 74N in the Norwegian Part of the Barents Sea

Gunnar Lille

OG21 - Norway’s oil and gas technology strategy for the 21st century, Norway

Several oil companies are looking at opportunities close to 74°N on the Norwegian Continental Shelf, recently demonstrated by the great interest in the 23rd Licensing Round. Exploration drilling, which can be carried out at suitable times of the year, has been going on for many years. The next step, given successful exploration, would be year-round operations. Year-round operations will face challenges, particularly climatic and logistical, that are different to what has previously been experienced on the NCS.

In 2015, OG21 in collaboration with DNV GL, carried out a study to identify and prioritize technology challenges related to year-round operations on the NCS. Three generic development cases at two different 74°N locations were used to describe climatic conditions and identify technology challenges. Results from other recent studies of Arctic challenges were also collected and used as part of the basis for the study.

The study suggests that some technologies should be considered essential for year-round operations. Such enabling technologies are typically related to safety and environmental risk reduction. In addition, there is a need for technologies that increase the value and strengthen the business case of field developments, such as drilling and reservoir performance technologies and certain subsea technologies. Although some climatic conditions in the area are more challenging than further South on the NCS, relevant operating experience exists internationally from areas with comparable challenges. The study concluded that all technologies identified are relatively mature, and should be ready for implementation after optimization to local conditions and final testing.
Part I: Environmental footprints

Anthropogenic Footprints: Litter and Microplastic Pollution in the Fram Strait

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The global change induced decline of sea ice has led to increasing anthropogenic presence in the Arctic Ocean. The Fram Strait is likely to become an important shipping lane as indicated by increasing numbers of fishing vessels and cruise liners in this area. One footprint of anthropogenic activities in the oceans is litter pollution, especially long-lived plastic, which is recognised as a global problem of growing concern given annual global production rates of 299 million t. Litter affects 580 marine species primarily by entanglement and ingestion, through which it can also enter food webs. Although recent reports indicate that anthropogenic waste has made it to the remotest parts of our oceans, there is still only limited information about temporal trends and its distribution, especially in polar and deep seas. Still less information is available about the contamination with microplastics, a degradation product of larger fragmented litter items. Mean litter densities from the water surface recorded during ship- and helicopter-based surveys in the Fram Strait (2012) were 0.0062 items km\(^{-1}\), which is comparable with observations from Antarctica. Despite the notion that plastic floats at the water surface, 50% of municipal waste exceeds the density of seawater and sinks. Repeated camera transects from the seafloor of two stations of the HAUSGARTEN observatory (2500 m depth) showed that litter densities increased from 3,523 in 2002 to 6,566 items km\(^{-2}\) in 2014, comparable to densely populated European seas. There was also an increase in smaller-sized items, indicating fragmentation. Differences in litter type and size between the two stations may suggest different pathways of litter to the deep seafloor. For example, the northern station experienced longer periods of sea ice cover, which may explain the higher densities of small plastics, released from sea ice upon melting. Microplastic concentrations in two sea ice cores from the FRAM Strait were analysed by FT-IR Imaging technology and exceeded those from previous reports in the Arctic by four orders of magnitude. The upper sections of the core contained far more microplastics compared to those in direct contact with the underlying seawater corroborating the assumption that sea ice is a source for microplastic in the Fram Strait. Considering the ever increasing production rates of plastic (~4% p.a.) and the failure of solid waste management practice, our footprints are likely to become larger unless serious mitigating actions are taken to reduce the amounts of litter entering the oceans.
To Eat or Not to Eat: The Role of Taste in Microplastic Ingestion by Zooplankton

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Plastic waste has become ubiquitous in the marine environment. Due to its high buoyancy and durability, it can be transported over long distances by ocean currents and end up in pristine areas, including the Arctic. Microplastics <5 mm in size are relatively understudied, having only recently become a topic of scientific interest. These small particles can pose threats to aquatic organisms. In this study we focus on zooplankton, an important ecosystem component, which targets prey in a size range similar to that of microplastics. Ingestion of microplastics by zooplankton has been confirmed both in vitro and in situ and was observed to negatively affect feeding rates, survival and fecundity in copepods. Using fluorescence microscopy, we studied ingestion of 15 and 30 µm polystyrene beads by Arctic zooplankton taxa *Acartia longiremis*, *Calanus finmarchicus*, *Pseudocalanus* sp. and decapod larvae. After 24 hours of incubation at 0.333 mg plastic l⁻¹, 15 µm beads were ingested more frequently than 30 µm beads by all species, except *Pseudocalanus*, which did not ingest particles of either size. Plastics in the marine environment are quickly colonized by microbes (biofouling), hence we investigated whether ingestion by zooplankton was influenced by the presence of a biofilm. ‘Fouled’ microplastics were created by soaking 15 µm polystyrene beads in sea water for three weeks. *C. finmarchicus* copepodites V (4 hours incubation; 100 particles ml⁻¹) and *A. longiremis* females (24 hours incubation; 200 particles ml⁻¹) more frequently ingested fouled microbeads compared to clean beads. This can be attributed to chemical exudates secreted by biofilm microbes, aiding chemodetection by copepods. To test whether the presence of an algal food source would influence plastic ingestion, we exposed *C. finmarchicus* females to 15 µm beads (4 hours incubation; 50 particles ml⁻¹), in the presence or absence of algae at bloom concentrations (2.8 µg C l⁻¹). Microplastic ingestion stayed similar when algae were present. After ingestion, microbeads passed through the gut and egestion in faecal pellets was observed within 1-3 hours. In a longer-term 11-day exposure, microbeads (15 µm; 50 and 500 particles ml⁻¹) did not affect survival of *C. finmarchicus* females. Our findings indicate that biofouling plays an important role in microplastic ingestion and should be taken into account in further studies. Investigation of sublethal effects and the potential for trophic transfer is required to gain a more complete understanding of microplastic fate in marine ecosystems.
Is Dilution the Solution? Impact of Urbanization on Chemical Emissions to Arctic Environments

Nicholas Warner¹, Ingjerd Krogesth¹, Guttorm Christensen², Mick Whelan³, Line Christoffersen¹

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Contaminant exposure in Arctic regions is known to occur through long-range transport from urbanized areas further south. However, as human activities within the Arctic increase (e.g., resource exploration, transport/shipping and research), greater contaminant exposure will also occur from local sources. In particular, if infrastructure for wastewater treatment remains unchanged where limited or no treatment currently exist, per capita emissions of chemicals will be higher from Arctic settlements compared to larger cities with higher-tiered wastewater treatment. To highlight the impact of urbanization on chemical exposure to Arctic aquatic environments, concentrations of cyclic volatile methylsiloxanes (cVMS) were investigated in 1) the marine environment of Tromsø, Norway and 2) Lake Storvatn in Hammerfest, Norway. cVMS are common ingredients in personal care products and enter the aquatic environment via wastewater effluents. However, they are currently under heavy regulatory scrutiny within Europe regarding their environmental persistence and bioaccumulation potential, making them ideal candidates for this investigation. Concentrations of cVMS in wastewater effluent from Tromsø (after primary treatment) and Hammerfest municipality (no treatment) ranged between 0.8 – 21 µg/L and 0.02 – 1.4 µg/L, respectively. Higher concentrations in Tromsø can be attributed to its higher population (72 000 vs. 10 000 inhabitants) and potential higher use of cVMS containing products. Sediment concentrations of cVMS ranged between 86 ng/g – 3.9 µg/g organic carbon (OC) and 166 ng/g – 4.2 µg/g OC within Tromsøysund and Storvatn, respectively. Average concentrations of cVMS were higher in Storvatn despite higher emissions of cVMS from Tromsø. Similar results were also found in biota with higher average concentrations of cVMS in fish from Storvatn compared to Tromsøysund. This is likely attributed to differences in environmental characteristics between the two locations (e.g., dilution in receiving waters, water residence times, ice cover) which can influence environmental persistence of these chemicals. Concentrations for cVMS in wastewater and sediment from Tromsø and Storvatn were comparable to or higher than concentrations measured near larger cities in Norway and more widely in Europe. Biota concentrations were also comparable between Arctic sites and more urbanized areas, although comparisons between different fish populations is confounded by individual fish characteristics. These findings highlight that considerable emissions of cVMS occur from Arctic settlements due to limited wastewater treatment. Slow degradation under Arctic conditions combined with high emissions causes greater exposure to cVMS and other down-the-drain chemicals in the surrounding environment.
Industrial Contaminants in Local Food Items from the Finnish -- Norwegian - Russian Border Area

Anita Evenset 1, Eldbjørg Heimstad 2, Guttorm Christensen 1, Alexey Dudarev 3, Arja Rautio 4, Päivi Myllynen 4, Eugenia Dushkina 3, Milena Horvat 5, Sauli Laaksonen 6, Martine Hansen 7, Torkjel Sandanger 7

1Akvaplan-niva, Norway; 2Norwegian Institute for Air Research, Norway; 3Northwest Public Health Research Center, Russia; 4University of Oulu, Finland; 5Jozef Stefan Institute, Slovenia; 6Natural Resources Institute Finland, Finland; 7UIT - The Arctic University of Norway, Norway

Contaminant exposures in many Arctic communities are complex, with both long-range transport and local sources acting as inputs for contaminants. This is also the case in the Finnish - Norwegian - Russian border area. The main local source for contaminants in this region are the industrial facilities at Zapolyarny and Nikel in Russia. These are located 30 km apart, approximately 15 and 5 km from the Norwegian border, respectively. The emissions from these industrial complexes has raised concerns from the local population regarding food safety and potential risks to health through consumption of food from this region. Traditionally this border area has been home to the Saami people and reindeer herders. Fishing and farming activities are still important in the area, but in the major settlements of the region (Kirkenes, Pechenga, Nikel and Zapoljarny) most people are employed by the mining or metallurgic industry. Local food in therefore of varying importance, but mushrooms, berries, freshwater fish, game (ptarmigan (Lagopus muta), moose (Alces alces), and reindeer (Rangifer tarandus) constitute parts of the diet for a considerable fraction of the population.

In this project we have analysed samples of these food items collected close to the border area in Finland, Norway and Russia for a selection of metals (cobalt (Co), nickel (Ni), copper (Cu), arsenic (As), cadmium (Cd), lead (Pb) and mercury (Hg)). In addition, a sub-set of the samples (mainly fish and reindeer) were analyzed for persistent organic pollutants (polychlorinated biphenyls, chlorinated pesticides, and dioxins/furans). The results show that the levels of metals in all samples are low to moderate, but that there are elevated levels of most metals in mushrooms and berries collected close to the border area. In fish, metal levels are generally low, but in some lakes Hg-levels in pike (Esox Lucius) and perch (Perca fluviatilis) exceed the European limits for allowable levels of mercury in fish (0.5 mg/kg). In game and reindeer, low metal levels have been measured. Levels of POPs are generally low in all analyzed samples (fish, reindeer), but elevated dioxin-levels have been measured in reindeer from the Pasvik area. As part of the project, dietary questionnaires have been obtained from the inhabitants living in the border area (in all three nations), so knowledge about consumption of the local food items is also available. In the conference, results from analyses of food samples will be presented and implications for human consumption discussed.
Is The Atmospheric Footprint of the South Decreasing or Increasing? -- Monitoring of Long-range Transported Legacy and Emerging Organic Contaminants at 79 Degrees N

Pernilla Bohlin-Nizzetto, Ingjerd Sunde Krogseth, Nicholas Warner, Knut Breivik

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One of the many stressors the Arctic is experiencing is long-range transport of persistent organic pollutants (POPs) mainly from more populated areas in the South, which potentially enter and bioaccumulate in Arctic ecosystems. The Zeppelin Observatory in Ny Ålesund has monitored the atmospheric POP footprint of the South for decades. Its remote location means that any detection of chemicals here is a sheer proof of long-range transport potential, and hence the observatory is of vital importance to monitor the chemical pressure that the Arctic is exposed to. In addition, the monitoring data and trend analyses are essential for effective evaluation of international agreements (e.g. CLRTAP and Stockholm Convention) and to support relevant programmes (e.g. AMAP). Due to the successful implementation of national and international control strategies, decreasing concentration trends have been seen for some legacy POPs, including polychlorinated biphenyls (PCBs), hexachlorocyclohexanes (HCHs), chlordanes and DDTs. This illustrates the importance of international measures to protect the Arctic from chemical stressors. However, concentrations decrease only slowly due to the high environmental persistence of these compounds as well as their release from secondary and remaining primary sources. For example, concentrations of hexachlorobenzene (HCB) in Arctic air have increased during the last decade, and current levels are higher than in Southern Norway. Yet, the cause of this observed increase remains poorly understood. In today’s society, humans are highly dependent on a multitude of chemicals, many which may possess long-range transport potential to Arctic regions, but their occurrence in Arctic air remains unknown. In the context of identifying new Arctic contaminants, monitoring at remote sites such as the Zeppelin Observatory is of vital importance. Starting in 2013, two new groups of chemicals have been incorporated in the Norwegian air monitoring programme of long-range transported air pollutants at Zeppelin; i) cyclic volatile methyl siloxanes (cVMS), common ingredients in personal care products, and ii) short- and medium chained chlorinated paraffins (S/MCCPs), widely used as plasticizers and flame-retardants. Both of these groups of compounds are found in air at Zeppelin with 100-1000 times higher concentrations than the legacy POPs. This highlights the importance of (i) continued monitoring of both legacy POPs and emerging/novel compounds to follow their emission trends, and (ii) increased research and monitoring towards emerging contaminants at Zeppelin to identify their potential presence in Arctic air.
Temporal Trends in Hg Contamination and Food Web Transfer on a Remote Arctic Island (Bear Island, Svalbard)

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The global release of Hg to the environment has increased greatly as a result of human activities. Since Hg is subject to long-range atmospheric transport, its continued global use and emission poses risks to humans and ecosystems both at the point of use and in remote locations. Bjørnøya, a remote Norwegian island in the Barents Sea, is an ideal location for research on Hg transport to the Arctic, given the presence of lakes supporting Arctic charr populations that can act as reference sites where inputs are limited to long-range atmospheric transport (e.g. Laksvatn and Øyangen), as well as sites with a high abundance of seabirds (e.g. Ellasjøen), which may act as a biological vector of transport and inputs of Hg.

This work had two key aims: 1) to gain a detailed understanding of current Hg concentrations, uptake and biomagnification in aquatic food webs on two lakes on Bjørnøya (Laksvatn, and Ellasjøen); and 2) to combine contemporary data with existing data and analysis of archival samples in order to assess long-term changes in Hg contamination at Bjørnøya.

Briefly, to address the first of these key aims, MeHg analysis was carried out for a comprehensive set of water and food web samples collected in 2014/2015 from Laksvatn and Ellasjøen. Hg data were paired with characterization of food web structure and trophic interactions based on stable isotope analysis in order to describe Hg trophodynamics and food web transfer at two contrasting sites (one with substantial seabird inputs and one without). In order to address the second of our key aims, we carried out MeHg and stable isotope analysis on archival frozen muscle tissue samples from Arctic charr collected from Ellasjøen over the past nearly two decades. By pairing these results with data from the 2014/2015 sampling campaign and existing data from 2001 (Hg in several abiotic and biotic matrices for Ellasjøen and Øyangen; mostly unpublished data), we present an incredibly unique time-series of Hg concentrations in Arctic charr from a remote Arctic island, and assess long-term trends in Hg contamination at this site.
Potential Effects of Persistent Organic Pollutants on Telomere Length in an Arctic Seabird

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Owing to their high volatility and persistence in time, organic pollutants reach remote areas such as the Arctic. Once deposited in aquatic ecosystems, organic pollutants are assimilated by living organisms via food intake, bioaccumulate in individuals and biomagnify along food webs from lower to higher trophic levels. Seabirds are long-lived apex predators; consequently, they are particularly exposed to persistent organic pollutants (POPs). It is now well established that such compounds represent a threat for wildlife, as they can decrease reproduction and survival, disrupt the hormonal system, immune defences and even damage DNA. Telomeres are DNA-protein complexes located at the end of chromosomes which play an important role in maintaining the genomic integrity. Telomere shortening, which is accelerated by oxidative stress, is related to cellular senescence and decreased survival. However, the effects of POPs on telomere length are poorly known for wildlife. In this study, we investigated the relationships between some legacy organic pollutants (organochlorine pesticides and PCBs) and telomere length in an Arctic seabird, the black-legged kittiwake *Rissa tridactyla*, an abundant seabird in Svalbard. Our study, conducted in the Kongsfjord, Svalbard, revealed a negative relationship between telomere length and oxychlordane, the metabolite of an insecticide banned since the 80s and listed in the 2004 Stockholm convention. This suggests that some organochlorine pesticides could be associated with birds aging, thus, possibly explaining the previously reported lower survival rate of the most oxychlordane contaminated kittiwakes.
Relationships Between Contaminants and Stress Hormones in Arctic Seabirds

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Environmental pollutants, such as polychlorinated biphenyls (PCBs), have received an increasing attention during the last 30 years. Because of bioaccumulation into organisms and bio-magnification along the food chain, marine apex predators such as seabirds are particularly vulnerable. Some PCBs are able to act as endocrine disruptors and thus, to alter the functioning of hormones. Stress hormones, such as corticosterone (CORT), a glucocorticoid released by the hypothalamo-pituitary-adrenal (HPA) axis, are known to affect reproductive behaviours and to mediate major reproductive decisions in vertebrates. However, the relationships between PCBs and CORT have been poorly investigated in seabirds. Some studies have suggested that environmental exposure to PCBs and altered CORT secretion might be associated in Arctic breeding seabirds. First, we investigated the relationships between blood PCB concentrations and circulating CORT levels in black-legged kittiwakes Rissa tridactyla according to sex and breeding stage. We found positive relationships between ∑PCBs and CORT secretion in pre-laying females and incubating males. However, it is difficult to attribute these relationships to a dysfunction of the HPA axis or to other confounding factors. In order to explore the relationships between the HPA axis activity and PCBs, we tested whether different aspects of the HPA axis of incubating male kittiwakes would be related to blood PCB concentrations. Incubating male kittiwakes were subjected to different stress series: 1) a capture-restraint stress protocol, 2) an injection of dexamethasone (DEX) that enabled to test the efficacy of the HPA negative feedback and 3) an injection of adrenocorticotropic hormone (ACTH) that informed on the adrenal responsiveness. We observed a positive relationship between ∑PCBs and CORT concentrations after the ACTH injection. It is suggested that PCBs may increase the number of ACTH-receptors on the adrenals depending on the level of PCB exposure. Second we explored whether the PCB-CORT relationship depended on the level of PCB exposure. To do so we investigated these relationships in six other free-ranging Arctic and Antarctic seabird species occupying different trophic positions (common eider, glaucous gull, wandering albatross, snow petrel, cape petrel and south polar skua), and hence covering a wide range of PCB exposure. Blood ∑7PCB concentrations were positively associated to baseline or stress-induced CORT levels in three species and negatively associated to stress-induced CORT levels in one species. This result suggests that the nature of the PCB-CORT relationships may also depend on the level of PCB exposure.
Polar Bear Ecotoxicology - Establishing Understanding Through Toxicogenomic and Ex-situ Approaches

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Ecotoxicology involves studying the behaviour of contaminants in the environment but also organismal and ecosystem responses to such compounds. Organisms at the top of the food chain are especially susceptible to the effects of lipophilic, persistent organic pollutants (POPs) and other emerging contaminants. In the Arctic, many species, e.g. the polar bear (*Ursus maritimus*), are vulnerable to such effects, accumulating high levels of POPs through their diet, mainly being seal blubber. Polar bears are not amenable to experimental studies, and only tissue or blood samples are available for laboratory analyses. These provide a basis for correlation analyses between contaminants and specific gene responses, but mechanistic understanding is more difficult to obtain. We have developed a strategy where we clone the genes of representative target receptors found in the defensome of the polar bear, e.g. the pregnane X (or promiscuous xenobiotic) receptor, PXR, and the peroxisome proliferator activated receptors (PPARs), and study their ligand binding ability in a cell-based luciferase reporter assay. These studies indicate which compounds that are able to activate these receptor pathways in the polar bear, and may be performed in direct comparison with human and other species’ receptors. An additional approach for studying cellular responses of the adipogenic pathway in the polar bear has also been established. By culturing mesenchymal stem cells from polar bear fat biopsies, adipocyte differentiation can be studied in the laboratory. A number of emerging contaminants have been shown to be able to interfere with adipogenesis in murine and human systems. With these approaches, we can investigate whether contaminants found in Arctic biota and polar bear tissue can affect toxicological pathways in the polar bear.

The study was supported by the Norwegian Research Council (181888/Miljø 2015) and the Fram Centre Hazardous Substance Program.
The Size-based and Depth-mediated Trophic Structure of Beaufort Sea Fish Communities: An Indicator of Community Change

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Fish food webs are often strongly size-structured such that larger individuals occupy higher positions in the food web regardless of species identity. As a result, relationships between biomass abundance and body size, known as size spectra relationships, can be employed to track changes in community structure incurred from anthropogenic stress (e.g., the loss of large-bodied individuals from overfishing). However, processes that contribute to natural variation in size-spectra relationships must be understood before the relationships are used as a monitoring tool. One of the most important variables that establishes variation in demersal marine environments is depth. Depth can play a key role in the trophic structure of demersal marine ecosystems by imposing constraints on the quality and quantity of food reaching the seafloor. It remains unclear how biomass size-spectra relationships in demersal Arctic fish communities are affected by depth-mediated changes in the relative availability of pelagic versus benthic resources. Here, we used demersal fish collected from four habitat depths in the Canadian Beaufort Sea, spanning 18 to 1000 m, to investigate depth-related changes in the slopes of biomass size-spectra relationships, and whether depth-mediated changes are related to benthic resource use. Significant positive relationships between biomass-weighted trophic level (estimated from δ15N) and log2 body mass classes demonstrated strongly size-structured fish communities at all habitat depths, with larger individuals occupying higher trophic levels. Total fish community biomass peaked between 350 and 500 m. The decline in biomass production beyond 500 m was greater for smaller size classes, resulting in significantly shallower normalized size-spectra slopes with increasing depth that indicated lower energy constraints for large individuals in deep habitats. Large size classes at deep habitats were dominated by species known to obtain pelagic subsidies. Lower isotopic distinction between benthic and benthopelagic fish species in deeper habitats, based on estimates of 13C isotopic enrichment relative to a pelagic baseline, suggested lower dietary differentiation between feeding guilds with increasing depth. We suggest that pelagic subsidies allow the maintenance of high relative biomass in larger size classes of fish in deeper habitats, while decreasing benthic resources limit biomass production in smaller size classes. The size spectra of demersal fish communities may thus provide an important indicator of change in both pelagic and benthic Arctic environments, and the size-spectra relationships quantified in this work may serve as the first pre-development baseline relationships for Beaufort Sea fish communities.
Risk Perceptions Related to Hazardous Substances in the Norwegian-Finnish-Russian Border Area

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In the communities in the Norwegian-Finnish-Russian border area there is pollution to various degrees and types. Data on the populations’ risk perceptions related to pollution in the area is presented, highlighting differences and similarities between the municipalities in the three countries, and also investigating how the risk perceptions associate with the populations’ consumption of locally produced food, their outdoor activities, and wish for their children to grow up in the area. The data are from a survey performed in the region in 2013-14. The populations’ risk perceptions are also evaluated against expert opinion on the pollution situation and health risks associated to it.
Net Environmental Benefit Analysis Support Tool to Assess Oil Spill Response Technologies and The Environmental Effects of Arctic Oil Spills

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There are remaining uncertainties on the impact of oil spill and response technologies in the Arctic and the resilience of species to recover. To develop a net environmental benefit analysis (NEBA) system we need to understand the dynamics of these Arctic ecosystems (seasonal migration of organisms, ecology of the marginal Ice Zone during the productive spring and summer as well, ecosystem function during the Polar night and also potential impacts of a spill and response actions). This project seeks to increase the existing knowledge base and deliver a tool for identifying the most appropriate response technology based on environmental conditions and knowledge about initial impacts and recovery. NEBA is a recognised methodology for comparing and ranking the net environmental benefits associated with multiple management alternatives, such as oil spill response options. Net environmental benefits are the gains in value of environmental services or other ecological properties attained by the action(s) minus the value of adverse environmental effects caused by the action(s). The overarching goal is to balance the risks, benefits and trade-offs between competing management alternatives. The International Association of Oil and Gas Producers (IOGP), in support of the Arctic Response Technologies Joint Industry Program (JIP) has enlisted an international team to develop a NEBA tool for response decision-making and environmental impact assessments related to Arctic spills. The objectives are: 1. to assess the potential encounter rates of Arctic ecosystems with oil and spill response through data gathering, workshops, and modelling exercises. 2. to enhance the "science base" on the impact of oil spill and the consequences of oil spill response (OSR) on unique Arctic ecosystems using in situ mesocosms. 3. to enhance the "science base" on oil weathering and microbial community in sea ice ecosystem to understand biodegradation processes and exposure. 4. Compare population level impacts for two Arctic species with (i) acute effects and (ii) acute and chronic effects of accidental oil spills using population models. 5. Develop information tables called Arctic Response Consequence Analysis Tables that reflect the "science base" for Arctic ecosystems, effects of OSR technology residuals using a scoring system that compares effects and resilience of population and compartments to decrease the time for recovery from a spill. The team will deliver a NEBA decision-making support tool as a product. Last year, we have presented our approaches and methodology, this year we will present the results and deliverables of the project.
Ongoing Research on Herding Agents for In Situ Burning in Arctic Waters

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Herders are surfactants that cause an oil slick to thicken when they are sprayed on the water around the slick perimeter. Herders were studied in the 1970s as a technique to enhance mechanical recovery. In this application herders were limited to relatively calm conditions because the herder itself dissipated and re-spread in tens of minutes, which likely isn’t enough time to skim, and slicks were still mobile requiring challenging repositioning of equipment. In situ burning of slicks at sea requires only minutes to implement. Further, the complete process of herding and burning can potentially be implemented from either manned or remote-controlled helicopters. Responding rapidly by helicopter to very dynamic oil slicks at sea is a significant advantage compared to ship-based response.

Researching the use of herding agents to contain and thicken oil slicks for in situ burning in Arctic waters continues under the auspices of the International Association of Oil and Gas Producers’ Arctic Response Technology JIP. In 2014/2015 studies were conducted on: fate and effects of herders; defining windows-of-opportunity for herder use; and, operational testing of herder application and slick ignition using helicopters.

The presentation will describe research undertaken to develop the herder technology. Positive small-scale tests led to a field test where over 90% of a slick was successfully herded and burned. One of the herders was found to be readily biodegradable and have low toxicity. The positive results of these studies have led to commercialization of the herders and development of a helicopter-based delivery system. Full-scale testing of both manned and remote-controlled helicopter delivery systems occurred in April 2015. Herders have the potential to turn a rarely used oil spill response option (at-sea in situ burning) into a readily available response option because it is aircraft deployable.
The Arctic Council Guide to Oil Spill Response in Snow and Ice Conditions in the Arctic

Edward Owens¹, David Dickins²

¹Owens Coastal Consultants; ²DF Dickins and Associates

The objective of the new (2015) Arctic Council-EPPR Guide¹ is to identify and describe those aspects of planning and operations that are directly associated with a response to an oil spill in ice and snow conditions. The Guide consolidates many of the recent research projects and preparedness and planning initiatives of the IMO, IPIECA, the Arctic Council and the Arctic Oil Spill Response Technology Joint Industry Programme (JIP) and others conducted over the past decade. The Guide focuses on strategic concepts and is intended to complement existing field manuals that provide more technical step-by-step advice for managers and responders at the operations and tactics levels (Alaska Clean Seas, 2013; EPPR, 1998).

The many different forms of arctic ice and coastal environments present a wide range of possible operational scenarios that must be understood for planning, preparing and implementing an effective oil spill response with ice and snow present. One key element to mounting an effective offshore marine response is to provide responders with access to the full suite of appropriate countermeasures without a protracted approvals process. Timing is everything in this regard: the ability to mechanically recover while the oil is still relatively unweathered, to disperse while the oil is still dispersible, or to burn while the oil is still ignitable, can significantly alter the outcome of a spill in ice (or open water) anywhere in the world.

For remote arctic regions, there is a strong need to have a rigorous, scientifically defensible, streamlined process in place to rapidly assess the environmental trade-offs and to process the necessary approvals related to the use of dispersants and in situ burning. The goal is to maximise all the available options in an emergency, including mechanical recovery, where they are appropriate and effective. Giving responders the flexibility to rapidly select and apply the most effective and environmentally beneficial strategy is crucial to ensuring success of any spill response; linked with the need for thorough contingency planning and drills in advance.

¹ https://oaarchive.arctic-council.org/handle/11374/403
Risk Perceptions Related to Hazardous Substances in the Norwegian-Finnish-Russian Border Area

_Eirik Mikkelsen_ ¹, Sindre Myhr ¹, Anne Katrine Normann ¹, Päivi Myllynen ², Arja Rautio ², Erik Anda ³, Alexey Dudarev ⁴, Eldbjørg Heimstad ⁵, Torkjel Sandanger ⁶

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In the communities in the Norwegian-Finnish-Russian border area there is pollution to various degrees and types. Data on the populations’ risk perceptions related to pollution in the area is presented, highlighting differences and similarities between the municipalities in the three countries, and also investigating how the risk perceptions associate with the populations’ consumption of locally produced food, their outdoor activities, and wish for their children to grow up in the area. The data are from a survey performed in the region in 2013-14. The populations’ risk perceptions are also evaluated against expert opinion on the pollution situation and health risks associated to it.
Oil Spill Response Challenges in Greenland Waters

Odd Willy Brude, Camilla Spansvoll, Anne Wenke, Anders Rudberg

DNV GL, Norway

In a recent study, DNV GL has performed a marine environmental risk assessment where the probability for oil spills from ship accidents has been calculated for the Greenland waters. The risk has been mapped by looking at the oil spill potential based on high resolution AIS data on ship movements, combined with the seasonal environmental sensitivity. In a second Greenland study, DNV GL did quantify the possibilities and environmental limitations for different oil spill response techniques in open water, and mapped this out in an extensive oil spill response GAP analysis.

By combining the results from these two studies, we were also able to calculate a response challenge index (RCI). An area with high RCI is identified as the combination of high environmental risk and dominating ineffective response conditions – in short: vulnerable areas where oil spill response measures do not work as of today. The RCI maps are presented monthly with an aim to give decision support regarding future oil spill response options and possible technology development.
Environmental Footprints of Drill Cuttings Deposition in the South-western Barents Sea -- Local to Ecosystem Perspectives. Introduction to the "BARCUT" Project.

Sabine Cochrane 1, Stian Røberg 2, Noortje Dijkstra 2, Juho Junttila 2, Bjarne Landfald 2, Steffen Aagaard Sørensen 2, Øyvind Leikvin 1, Nora Hveding Bergseth 3, Liv Nielsen 3, John Eirik Paulsen 3

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Exploratory drilling on the Norwegian continental shelf is moving into both increasingly northern and deeper marine environments. Many of these areas are considered as being potentially sensitive due to either the sea-floor habitat types, such as deep-sea sponge grounds, or proximity to the ice edge and/or valuable marine resources such as fishing grounds, and sea-bird colonies at Bear Island. Both the industry and environmental authorities face numerous challenges in the regulation of activities in such areas, and the greatest of them all is the lack of specific knowledge of the environmental impacts of exploratory drilling on the sea floor, in both space and time.

The Eni Norge Barents Sea Drill Cuttings initiative (BARCUT) project was established to address exactly this need. Our questions are as follows: 1) Where are drill cuttings deposited after drilling events in the south-western Barents Sea, in relation to oceanic currents? 2) What is the spatial footprint of drill cuttings deposition? And 3) What are the temporal scale of impacts, i.e. patterns of recovery over time? The ultimate aim of addressing these questions is to promote knowledge-based decision-making on the net most beneficial environmental strategy for drilling waste management.

We conducted three field sampling campaigns, and in total visited eight drilling sites, ranging in age from recently drilled (in 2015; within months of our sampling campaign) to nearly 30 years since being abandoned. In addition to optical surveying around the drill sites, we sampled benthic macrofaunal communities, which are a standard indicator of sediment health and disturbance status, microfaunal (bacterial and benthic foraminiferal) communities, sediment properties as well as sediment oxygenation and other relevant parameters (for example heavy metals). In addition, we have measured current directions (and thus sediment dispersal patterns) throughout the water column, from the bottom to the surface, over two periods of over two months each, using an Acoustic Doppler Current Profiler (ADCP), supplemented with a stationary current measurer.

We show a pattern of a relatively local disturbance from drilling, depending on deposition strategies employed, and put into an ecosystem perspective, where many wells are drilled within a localised area. We show a consistent trend of recovery over decadal scales, depending on the type of drilling fluids used. We contribute our findings into an overall assessment into the optimal waste deposition strategy – from deposition at sea-bed, from sea-surface or transport to land.
Tendencies of Black Carbon Transport and Deposition to the Arctic in Winter Due to Past Atmospheric Transport Trends

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The understanding of the processes driving the transport and deposition of black carbon aerosols to the Arctic is of great importance due to its strong effects on the radiative balance, directly through absorption of short-wave radiation and indirectly through decreasing the albedo and favoring melting of snow and ice. In this study we investigate the statistical relationships between the large scale atmospheric circulation patterns and the transport and deposition of black carbon from the mid-latitudes, where most of the anthropogenic and biomass burning emissions are located. The Independent Component Analysis method is applied to estimate large scale meteorological patterns related to the trend of near-surface temperature. By using the Bayesian approach, the most likelihood distribution of concentration and deposition of atmospheric pollutants is then associated to each meteorological pattern. Winter anomalies of meteorological fields from the global reanalysis are processed together with black carbon surface concentrations and deposition simulated by a general circulation model coupled with atmospheric chemistry (ECHAM5-HAMMOZ) and physics driven by the ECMWF reanalysis meteorology. We investigated two distinct black carbon simulations, with varying anthropogenic and biomass burning emissions for the period 1980-2005 and with fixed anthropogenic emissions of year 2000 for all the 26 years. The statistical analysis of meteorological fields isolates three large scale patterns significantly related to the temperature change in the Northern Hemisphere: North Atlantic Oscillation (NAO), Scandinavian Blocking (SB) and El Nino-Southern Oscillation (ENSO). We found that negative anomalies of the NAO oscillations likely favor the transport of black carbon from North America to the Canadian Archipelago and Greenland, but with a small deposition over the Arctic sea-ice. A positive anomaly of the Scandinavian pattern apparently increases the transport directly from Western Europe towards the Barents Sea, with increasing deposition over the sea-ice. ENSO shows a weaker impact at the high latitudes, but may sustain the transport of pollution from Asia toward the Arctic. The novel statistical method developed in this study may provide additional information on past and future trends of black carbon in the Arctic, on source regions in the mid-latitudes and on the performance of coupled climate-chemistry global models.
Terrestrial DOM in Thaw Lakes of Yamal Peninsula: Connection to Catchment Properties, Lake Parameters, Permafrost Thaw and Climate Change

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1Earth Cryosphere Institute, Russia; 2Alfred Wegener Institute; 3Zentralanstalt für Meteorologie und Geodynamik

Climate warming in the Arctic might lead to increase of organic matter inflow to lakes by accelerating permafrost thaw and vegetation dynamics. Coloured fraction of dissolved organic matter (CDOM) is a significant component of the aquatic ecosystems including thaw lakes in the high Arctic. The work presents results of a study of coloured dissolved organic matter (CDOM) in thaw lakes of Yamal peninsula (Western Siberia, Russia). In this study used is a complex approach including field studies, high resolution optical and synthetic aperture radar (SAR) remote sensing and geographical information system (GIS) data analysis. CDOM absorption and spectral slope (S) values, suspended matter concentrations (SPM) in several thaw lakes were obtained during 2011 – 2014 field campaigns. Lake characteristics were compared with different catchment properties (cryogenic processes, geomorphology, productivity of vegetation, snow accumulation), hydrology (drainage regimes, seasonal water level changes, volume of lake water) as well as with climatic controls (air temperature, precipitation). The climatic fluctuations and thermal denudation in the shore line seem to be responsible for the additional portion of terrestrial organic input into the thaw lakes. Measured CDOM concentration is at least twice higher in lakes affected by thermal denudation (and accompanied by declined S values) than in not affected lakes. The increase of CDOM concentration in 2012 compared to that in 2011 is probably due to higher summer air temperature and amount of precipitation which increases the organic transport from active layer and from the tundra surface. Decrease of S values explains the increase of mobilized organic matter recently stored in permafrost in past years. Generally, variation of CDOM in studied lakes is very high due to different conditions in which the lakes are located. The catchment properties (especially vegetation) may explain the differences in CDOM concentrations between Yamal lakes. The presence of high productive shrubs and sedges in this particular area makes the CDOM concentration parameter comparable with more southern regions like taiga within the tree line.
Impact of Arctic Coastal Erosion on Arctic Ecosystems Due to Sediment Release

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Erosion of permafrost coasts is one of the fastest in the world, despite the fact that it is limited to 3 – 4 months of sea ice-free season. Especially vulnerable are ice rich and unconsolidated coasts. Yearly coastal erosion rates up to 20 m were recorded at such places. Coastal erosion can endanger Arctic communities in two ways. (1) Coastal retreat cause land loss and subsidence which can threaten human infrastructure. While active settlements have to undertake protective actions, the loss of historical sites in the Beaufort Sea has been reported. (2) Sediment released by coastal erosion contains an abundance of organic matter and nutrients, which are stored in permafrost environments and have a potential to alter near shore ecosystems. Many Arctic communities that depend on these ecosystems might be affected under the warming climate and possible coastal erosion increase. Studies of coastal erosion in permafrost environments are often limited to coastline retreat rates inferred from air photos and satellite imagery (planimetric erosion). Timespans between different datasets are often several years or decades and therefore these studies are unable to catch short term coastal erosion characteristics. In our study we use high resolution digital elevation models (DEMs) to observe short term coastal erosion and compare it to the studies based on long term coastline movements. Our results show high complexity and short term variability of coastal erosion, which can undergo a series of erosion and accumulation events. Simple coastal retreat can be modified in high bluff coast by mass movements, especially retrogressive thaw slumping. Comparison of planimetric and volumetric erosion showed different patterns. Consequently, the sediment loss calculated from planimetric erosion combined with cliff heights and sediment loss calculated from DEM are significantly different. We attribute this difference to mass movements that can cause sedimentation and coastline progradation, while sediment is being constantly released. Thus studies that estimate sediment loss by coastal planimetric erosion and cliff height, should take into account the effect of mass movements in order to better estimate carbon and other nutrient release, which can, in turn, impact Arctic coastal ecosystems.
Effects of Temperature on Arctic Methane-Oxidizing Bacteria: Resilience and Response to Climate Change

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The Arctic releases an estimated 32-112 million metric tons of methane (CH4) per year, and warming temperatures are causing the rate of CH4 emission to increase. Methane-oxidizing bacteria (MOB) are key ecosystem players that consume an estimated 60% of biogenic CH4 produced, constituting the largest biological CH4 sink. In High Arctic regions, the genus Methylobacter and in particular the species M. tundripaludum has been repeatedly identified as the dominant active MOB. We originally isolated M. tundripaludum from Arctic peat soil in Ny-Ålesund, Svalbard. It is currently the only published High Arctic MOB in pure culture, underpinning its importance as a model organism and CH4 filter.

We will present data from our studies of M. tundripaludum CH4 oxidation capacity as a function of temperature and CH4 concentration. We complement these studies with transcriptomics to understand at a genetic level how M. tundripaludum responds to temperature stress. Our results show that changes in growth and oxidation rates of M. tundripaludum at different temperatures coincide with massive shifts in the gene expression for its central metabolism. The majority of shifts are simple adjustments of the transcripts to accommodate the altered rates of biochemical reactions. However, multiple gene copies encode some key cellular functions. M. tundripaludum switches between these different gene-copies when the temperature changes, suggesting that the genes are adapted to specific temperature-windows. This remarkable flexibility enables M. tundripaludum to grow efficiently at low temperatures while having a high temperature growth optimum.

By combining transcriptomics with CH4 experimental oxidation data, we seek to link M. tundripaludum genes to their function in the context of Arctic ecosystem health. Understanding how M. tundripaludum responds to environmental stressors also informs predictions for the Arctic CH4 budget. Our findings indicate that warming temperatures affects the capacity of M. tundripaludum to serve as a CH4 filter, which has consequences not only for the health of circumpolar ecosystems, but also for inhabitants and industry in the Arctic.

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3 Reeburgh et al., 2007, *Chem. Rev*
4 Wartiainen et al., 2006, *IJSEM*. 
Winter Sea Ice Deformation in the Sea Ice North of Svalbard During the N-ICE2015 Cruise

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The recent decrease in Arctic sea ice extent is most pronounced during the summer months. While during winter sea ice grows back almost to its normal historical extent, it still remains thinner and younger than in the winters a couple of decades ago. Old, multiyear ice has practically disappeared from the marginal seas of the Arctic Ocean and has been replaced by the first year ice that can be not only thinner, but also less deformed, more saline and covered by thinner layer of snow. Such Arctic sea ice is easier to move by winds and ocean currents, which causes a clear increase in sea ice drift speed. What does this new sea ice regime mean for sea ice dynamics and its mechanical properties? The answer to this question is not only important for the understanding of the climate system, but also for planning of potential permanently installed infrastructure in the Arctic Ocean.

During the Norwegian Young sea ICE cruise (N-ICE2015) we deployed over 40 buoys north of Svalbard as part of the N-ICE2015 campaign. The buoys were brought out in nested arrays at distances of 5 to 100 km apart from each other in 2 deployments in January/February and in April/May 2015, respectively. The buoys were deployed by ship, snow mobiles and skiers during the dark winter time and by helicopter during spring. Our preliminary results show that the deformation rates and sea ice drift speed detected by the buoy array are higher than those measured by previous similar experiments on older ice in other parts of the Arctic. The deformation events are strongly connected to the atmospheric forcing. While it is known that the relationship between the deformation rate and the spatial scale over which it is measured can be represented by a power law, we find that the relationship depends also on the drift speed associated with high wind speeds and looser ice cover.

The buoy array is complemented with ship radar data which provides local ice dynamics information on a high temporal and spatial scale. The data indicates that pack ice is a mosaic of composite units which include undeformed first and second year ice, pressure ridges, cracks, and refrozen leads. Each unit moves like a solid body, but the differences in velocity of each individual unit (that may depend on their mass and drag) are leading to the sea ice to deformation.
Impacts of Sea-ice Dynamics and Snow Cover on Arctic Algal Biomass and Production During the N-ICE2015 Drift Expedition.

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Algae are the basis of every marine ecosystem since the amount of carbon they fix using sunlight determines how much energy is available for upper trophic levels. In the high Arctic, fish stocks, seals and polar bears ultimately depend both on phytoplankton and sea-ice algal production. Due to anthropogenic global warming, the Arctic’s sea-ice cover is decreasing fast, the ice margin retrieves further north every summer, and the ice is thinner and younger every year. Thinner ice will allow more light to penetrate through the ice potentially increasing phytoplankton production. However, increased cloudiness and snow precipitations will probably dampen this increase. In addition, the amount of nutrients available for algal growth might decrease as the ice margin retrieves further north away from the shelves where upwelling events are more common than in the deep central basins. To assess the effects of changing sea-ice and snow conditions on the seasonality of phytoplankton and sea-ice algae at the marginal ice zone, in 2015 the RV Lance was frozen into the pack ice north of Svalbard and was allowed to drift with the ice for 6 months. This expedition (N-ICE2015) has provided us with a unique seasonal data set during the winter-spring-summer transition in the high Arctic pack-ice ecosystem. Algal productivity started in April but due to the thick snow cover (20-30 cm) almost no biomass accumulated until late May. In the water below the ice we followed the evolution of an under ice bloom mainly composed by Phaeocystis sp. Although the initial biomass was probably advected from the ice margin, the bloom continued growing below the ice, consuming nutrients, until it started sinking in late June. Sea-ice algal productivity was generally low and most of it occurred in refrozen leads and in first year ice ridges. Interestingly, distinct sea-ice algae species populated different parts of the ridge ledges. In addition, we discovered significant algal biomass accumulations below the snow in seawater flooded areas. These snow infiltration communities were mainly formed by water column species such as Phaeocystis sp. and Thalassiosira sp. These rarely studied sea-ice microenvironments seem to provide appropriate light and nutrient conditions for algal growth and they might become increasingly important in the future Arctic controlled by not only sea-ice but also snow dynamics.
Risk Governance in the Changing Arctic

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The Arctic region is experiencing a rapid environmental and socio-economic transformation. Climate change impacts, direct and indirect, are already visible. These impacts are increasing the vulnerability of Arctic ecosystems and affecting dependent local communities. Growing economic interest in natural resource exploitation is predicted to result in further damaging land use changes which increase the risk of pollution and potential conflicts, for instance, between the mining industry and reindeer pastoralism. Sustainable future development and transition pathways for the Arctic need a holistic approach and collaboration between multiple actors on how to equally govern the risks, share responsibilities, and adapt to inevitable changes. In this research project, we will examine the current status and future trends of Arctic risk governance through the lens of Ostrom’s Socio-Ecological Systems Framework of the commons. By using a risk governance framework, we will take a systematic approach to study how climate related risks are perceived by critical Arctic stakeholders, based on a case study of reindeer pastoralism, a vulnerable socio-ecological system in Finland. The project will engage stakeholders across multiple levels of governance in a participatory dialogue, provide guidance for decision-making, and inform development of future scenarios of the Arctic, developed in connection with the Shared Socio-Economic Pathways (SSPs).
Metals and POPs in Fish and Shrimps from the Barents Sea -- Results from Ten Years of Monitoring

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In 2006, the Norwegian government adopted a management plan for the Barents Sea. As stated in the management plan, a range of "indicators" have since then been monitored. NIFES has annually been monitoring a range of undesirable substances including metals, POPs and pesticides in Atlantic cod (Gadus morhua), capelin (Mallotus villosus), polar cod (Bodeogadus saida) and deepwater shrimps (Pandalus borealis). The results show that most of the analysed substances are present in biota of the Barents Sea, but that concentrations of most of the substances are well below established maximum levels for food safety. However, cod liver contains concentrations of dioxins and dioxin-like PCBs are near the EU and Norway’s maximum level of 20 ng TE/kg ww which applies to fish liver, although levels are lower than in cod from the North Sea and Norwegian coastal areas. And capelin and polar cod contain levels of some pesticides (HCB, dieldrin) which are close to or over the maximum levels applying to fish feed. However, this would only be an issue if capelin or polar cod were to be used as fish feed or feed ingredients directly without any processing. Mercury concentrations in cod from the Barents Sea are very low and much lower than what has been found in the North Sea and along the Norwegian coast. The mercury levels have been very stable since the monitoring started, in contrast to the increase that appear to be taking place in the south of Norway and in freshwater fish. Cadmium levels in shrimps from the Barents Sea are higher than in shrimps from the Norwegian Sea and the North Sea. Concentrations in polar cod of polybrominated diphenyl ethers, PBDEs, appear to have decreased since the monitoring started.
A Circumpolar Comparison of Visible Land Use Associated with Socio-economic Conditions in Six Arctic Regions

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Land use changes are among the most important causes of decline in biological diversity and ecosystem services globally. In the Arctic, research on land use has mostly revolved around oil, gas and mineral exploitation, but few studies have focused on how socioeconomic development changes spatial land use by Arctic residents themselves. Here we investigate how the spatial use of land around Arctic and sub-arctic villages differs under contrasting socio-economic conditions in six different regions in Russia, Canada and Alaska. We use very high resolution satellite pictures from 28 villages representing six regions (Russia: Murmanskaya Obl., Yamalo-Nenestki AO and Taimyr; Canada: Labrador and Nunavut; USA: Alaska) to map all visible traces of human use. Medium sized settlements (200 – 5000 residents) have been chosen according to a design of nested spatial contrasts: Regions were selected to have contrasting governance systems, and within each region, we chose villages with contrasting sources of income. To analyze extent of spatial use we used one image covering the village itself (intense use area) and one image taken 30 km from the village in a random selected location (extensive use area). Overall, the largest proportion of area with visible traces of land use was recorded in Yamalo-Nenetski AO. Most of this consisted of tracks of off-road vehicles. In Canada, on the contrary, land use consisted mostly of permanent infrastructure such as roads or airstrips. These differences could be explained by land use at present and during the recent past, but the results need to be interpreted carefully as the main substrate may be more or less vulnerable to off-road traffic. When controlling for regional context, we found that socioeconomic development (i.e. industry, regional service hubs) results in more visible land use traces independently of the size or the age of the village. This was true both for the intensive and for the extensive use area indicating that the spatial extent of the land use also increases. Relationships of local land use to remoteness of the settlements, predominant natural resource use and the presence of extractive industry are also discussed.
Arctic Frontiers of What? Competition, Exchange and Global Collective Action

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You can perceive the exact geographical boundaries of the Arctic on a map. Its social frontiers, however, stretches way beyond this physical space. In the race for the Pole, the ice was a border that men like Nansen tried to push beyond, to advance science and the greatness of nations. What is however, the symbolic meaning of today’s famous image of the polar bear on a shrinking ice floe? I suggest it is the necessity for global collective action.

The aim of this paper is to develop a conceptual framework to study the interaction between nature and society with reference to the Arctic. The model draws on several sources as Tvedt’s model of dynamic water systems, Luhmann’s theory of social systems and Searle’s distinction between action as bodily movement and social action that regulates bodily movements. The organizing principle for the theoretical discussion is the distinction between collective and individual rationality appropriated from game theory. This fusion of different theoretical sources enables a new perspective on the three basic social relationships of competition, exchange and cooperation.

I will demonstrate the fruitfulness of the conceptual framework with examples from the Arctic: Rivalry between nation states and competition between private corporations for natural resources, but also exchange for mutual benefit. The paper puts most effort in the development of the concept of cooperation, as the rational aspects of collective action is the least understood by the social sciences. Rational collective action is the most basic of social relations. Exchange take place only on the background of mutual recognized and cooperatively established institutions, and even rivalry – at least as competition, needs collective recognition. Today the Arctic is a frontier for solving problems of global collective action. The drowning bear is ourselves, and symbolizes the need for the global society to attain capacity for collective action, just at the nation state once did.
Effects of Multiple Stressors on the Benthic Ecosystem in the Barents Sea

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Arctic marine environments are experiencing many human-induced and natural pressures, including climate change, harvest, introduced species, pollution from ship traffic, fossil fuel exploitation, etc. The size and complexity of the Arctic benthos poses many challenges to predict how these potential cumulative pressures affect benthic species and to detect biodiversity changes. The Barents Sea, one of the shelf oceans in the Arctic, represents a transition from warm Atlantic to cold Arctic waters and consequently an area for climate change studies. Since 2007, the Norwegian-Russian annual ground fish surveys in the Barents Sea, were added benthic taxonomists and a still developing standardised monitoring of invertebrates from the fish trawls. This has resulted in a time and cost efficient method with simple and transparent analysis tools, easily adopted by other national ground fish surveys. The database, including 3073 stations, 23 Phyla, 49 taxon groups, 590 species, abundance and biomass, are continuously developing and improving. A baseline map has been developed (Jørgensen et al 2014⁵) and areas vulnerable toward trawling identified (Jørgensen et al 2015⁶). Coding species vulnerability toward trawling, temperature affinity, and preference to invasive top-predators can indicate geographical areas of particular concern where these impacts operates solely, and where they operate simultaneously as multiple impact factors. We will present the first results indicating ways to find the balance between environmental considerations and the needs that the commercial fishing fleet have for the services the Barents Sea ecosystem. This is particularly challenging in the areas where multiple impact factors operate due to the complexity that anthropogenic footprints posed on a dynamic natural fluctuating Barents Sea environment.

Growth and Condition Data Suggest Suboptimal Resource Availability for Redlisted Greenland Sea Hooded Seals

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The Greenland Sea hooded seal population has declined by 85% since the late 1940s and was estimated at 80000 in 2012. In spite of this, reproductive rates have remained low since the late 1950s by comparison with maximum levels for the species observed in Northwest Atlantic hooded seals. This suggests that resource availability has been reduced concurrently with the population decline thus preventing density dependent increases in reproductive rates of Greenland Sea hooded seals. If the low reproductive rates are due to suboptimal resource availability scenarios, Greenland Sea hooded seals would be expected also to show lower body growth rates and condition than the NWA hooded seals during their time of high reproductive rates in the period 1956-1978. We compare data on body size and condition in 1045 female Greenland Sea hooded seals sampled from 1958 to 2008-10 with similar data from 1464 female NWA hooded seals sampled over the period 1956-1974. Richards growth curves for moulting NWA hooded seals were homogeneous over the periods 1958-64, 1970-72 and 1974-76 and showed significantly higher asymptotic length than for moulting Greenland Sea hooded seals sampled in 2008-10 (197.2 vs 190.5, p<0.01). Nonlinear modelling also shows significantly lower length-at-age in breeding Greenland Sea hooded seals sampled in 1958-64, 1972-80 and 1999 compared to reference data from the Northwest Atlantic for 1967-72. GAM modelling further suggests reduced body condition in Greenland Sea hooded seals throughout the study period compared to reference data from the Northwest Atlantic. Hooded seals are known to feed upon several commercial fish species and based on morphometric data and reproductive data from both sides of the Atlantic, we suggest that massive increases in commercial fisheries after world war 2 may have contributed to reduced resource availability for hooded seals.
Circumpolar Arctic Marine Synthesis: Identifying Important Marine Areas and Conservation Gaps

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Climate change remains the greatest threat to the circumpolar Arctic marine ecosystem and continues to threaten the persistence of iconic species, encourage poleward species shifts, fragment and reduce critical ice habitats, and alter essential food web structures. The resurgence of a geopolitical “race for ocean space” in the Arctic has been met with increased levels of shipping traffic and oil and gas exploration that also presents serious risk to some of the most important and productive marine ecosystems in the world. We conducted a synthesis of important marine areas across the circumpolar Arctic and examined the level of protection received from existing marine protected areas to identify gaps in spatial conservation. We evaluated the methods and results of past efforts used for identifying important marine areas in the Arctic to identify trends and make comparisons. We also analysed existing marine protected areas in the Arctic in relation to previously identified important marine areas, and used the IUCN protected areas classification system to ascertain the level of protection these areas have received. Our synthesis further helps illustrate conservation priorities and gaps at the pan-Arctic scale, and we anticipate the results will help with future conservation and marine protected area planning exercises.
The Politics of Environmental Stewardship: Defining The Regional in a Globally Interconnected World

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What role can regional international governance play when global environmental negotiations move very slowly and when local action is not sufficient for ensuring sustainable development? Can regional fora build bridges across strong political interests and play a key role for environmental stewardship? At one level, these questions can be empirically investigated analysing entities such as the Arctic Council. However, they also raise fundamental issues related with how different actors use discursive power, including rhetorical tools, in attempting to shape notions of appropriate scale for various governance concerns. We argue that understanding the role of regions for environmental stewardship requires unpacking the notion of scale. This presentation puts forth an approach that focuses on three key dimensions in the construction of governance scale: the problematic notion of “fit”, “regions” as arenas and tension fields for transnational politics, and the increasing role of media as a global meta-process that shapes and reshapes political discourses.

The notion of fit has been highlighted as a key issue for success in environmental governance, where fit refers to governance arrangement matching the scale and scope of the problem in focus. However, in a globalized interconnected world, there are many ideal scales and scopes, depending on what perspective is taken as starting point. Rather than being absolute, fit becomes the result of social negotiations where discursive power plays a central role. This calls for a focus on how issues are framed and reframed in political messaging and how these messages travel and become dominant narratives in a global media landscape. One such narrative is that economic development in the Arctic is driven by climate change. Another is that climate change mitigation is a global responsibility while adaptation is a local concern. Global interconnectedness also affects the politics of stewardship as questions of stewardship ‘of what’ and ‘for whom’ transcend both spatial and temporal scales. Regions form a meso-level between the global scale at one end and the national and local at the other. Yet regions often lack strong governance mechanisms, the Arctic being a case in point, making them likely to be particularly prone to scalar politics. Taking discursive power as one major thrust, we argue for further focus on how ‘how’ and ‘what’ messages travel in a world where media play a central role and shape our understanding of both regions and stewardship. In the presentation, the arguments will be unpacked using examples from the Arctic.
International Arctic Petroleum Cooperation: Barents Sea Scenarios.

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The Arctic region contains large amounts of natural resources considered necessary to sustain global economic growth, so it is unsurprising that it is increasingly susceptible to political, economic, and environmental conflicts. This presentation builds on a recent book that discuss in details the preconditions and outlook for international cooperation on the development of Arctic petroleum resources, focusing on Norwegian–Russian cooperation in the Barents Sea towards 2025. The framework of the study builds on a cross-disciplinary approach including geopolitical, institutional, technological, corporate and environmental perspectives to analyse the underlying factors that shape the future development of the region. Three future scenarios are developed, exploring various levels of cooperation and development influenced by and resulting from potential political, commercial and environmental circumstances. Through these scenarios it is developed an understanding of the challenges and opportunities for Arctic petroleum resource development and the possible outcomes of future cooperation.
With the dependence of polar bear populations on Arctic sea ice for feeding, breeding, and migratory movement, the forecasted decline of sea ice coverage as a result of climate change poses a serious threat to polar bear populations. This concern is amplified in large part due to the importance of polar bear populations to the security of Arctic peoples who rely on them for cultural identity, income and as a vital part of the subsistence economy. As such, a decline in polar bear populations will likely be paralleled by a decline in environmental security—that is, a negative impact on the economic, cultural and political facets of Arctic societies and on those Arctic states invested in the security of these communities and the continued viability of polar bear populations. Given this, conservation and management efforts in the species’ Arctic range have been supported by two research methods—western science and Traditional Knowledge (TK). While both methods have been widely acknowledged for their contributions to the conservation and management of Arctic environments and populations, attempts to incorporate both methods into the research and conservation have been strained. This is in part the result of conflicting data brought forward by both research communities—rooted in different epistemologies and historical relationships and interactions—and the effects of this data on hunting quotas and conservation methods. Further, previous calls for collaboration between the two groups have been made, largely, in the spirit of inclusion and rooted in cultural sensitivity, not necessity. As such, investigations into the accuracy, scope, and comprehensiveness of both methods have been scarce and inadequate. While both research methods provide valuable insight, data, and information, incomplete data recorded through observation, scientific method, first-hand experience, and computer modelling have led to conflicting conclusions as to the status of particular subpopulations. Neither method adequately addresses the threat that polar bear population decline places on environmental security in the Arctic. As such, a collaborative, cooperative and integrated approach to research, observation, and data collection is recommended. This approach will necessitate, expanded methodologies, the inclusion of information from both sources, and the co-management of conflicting data and subsequent investigations.
Cooperation in Greenland Between Public Sector, Private Sector and Civil Society in Order to Protect the Environment

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Greenland Oil Spill Response, Greenland

In 2012 the Government of Greenland decided that the time had come to form a nationally owned oil spill response company in order to accommodate the need to have a sufficient oil spill response set-up for the oil and gas exploration taking place at the time. With equipment donations from the oil gas industry; Greenland Oil Spill Response was formed.

Developing and maintaining an oil spill response organization, regardless of how small it may be, when a country is still in an exploration phase is not an easy thing to do for several reasons. However, cooperation between the authorities and the oil and gas industry has been good and has resulted in Greenland Oil Spill Response being financed by the industry entirely. The dialogue has been open and both the industry’s and the public’s needs have been taken into consideration when developing the company e.g. location of equipment and involvement of local stakeholders.

Protecting the Arctic environment now and in the future requires close cooperation between all stakeholders, including, but not limited to, authorities, private companies and local population. Greenland Oil Spill Response has taken this approach to heart, especially the involvement of local stakeholders. It has been of the utmost importance to involve the local population and Greenland Oil Spill Response started training volunteer oil spill responders in the two towns of Nuuk and Aasiaat in Greenland in 2015. The plan was to involve local communities that might be affected by oil and gas exploration and recruit up to 20 responders in the two chosen towns. Recruitment was not as easy expected, however the involvement from the recruited volunteers has been outstanding and Greenland Oil Spill Response is now halfway through the extensive training programme of the volunteer responders and considers the project and this approach a success to build on in the future protection of the Arctic environment.
Engagement of Extra-Regional Actors in the Arctic Stewardship: Identity-shaping and Appropriate Approaches

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The impacts of climate change and the extending navigability of the Arctic sea routes have brought about global consequences, as well as opportunities and challenges to a number of actors beyond the Arctic, especially those situated in mid-latitude of the Northern Hemisphere. The Arctic states, with distinct roles in the Arctic stewardship, tend to ensure their dominance in the Arctic issues through setting threshold of admission (i.e. observer status in the Arctic Council mechanism, formation of the Arctic 5 bloc, etc.) or excluding the extra-regional actors in the policy-making process with regards to fisheries management in the Arctic High Sea, search and rescue, as well as prevention and response to marine oil pollution, which are the domains more or less of interests to the extra-regional actors. In response, a few Arctic extra-regional states have attempted to redefine and reconstruct their Arctic identity by means of establishing the geographical, environmental, socio-economic or legal connections to the Arctic and proposing such identity-related notions as “near-Arctic state”, “Arctic stakeholder” and “Arctic nearest neighbour”, in order to justify their proper presence and engagement in the Arctic issues.

This presentation seeks to illustrate how Arctic extra-regional states attempt to shape their Arctic-related identity and to explore what approaches or tactics could be appropriate for a better engagement in the Arctic stewardship, by taking China as an instance, who is a signatory of UNCLOS and Spitsbergen Treaty, as well as an observer to the Arctic Council. On the global scale, as emerging power with global responsibilities, China could contribute to the response to the Arctic climate changes under the UN framework; on the regional scale, China could play a constructive role in the functional domains of Arctic stewardship in shipping, economic and resource development, as well as fisheries management and marine environment protection on the Arctic high seas in the Arctic (sub)regional arrangements; furthermore, humanities concerns and indigenous rights are to be taken into consideration in coping with bilateral relations with Arctic states. In general, for Arctic extra-regional actors participating in the Arctic stewardship, it may require properly coordinating between the expectations of the regional governance mechanisms and the objectives of their own domestic policies, seeking the common ground of interests, reducing the conflicts of interests and creating new interests to be shared, in order to prove their engagement mutually reciprocal.
Russian-Norwegian Cooperation in the Field of Oil and Gas: Can The Fisheries Management Model Be Copied?

Irina Zhilina

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Since the 1970s, Russia and Norway have been cooperating on marine resources management in the Barents Sea. The joint management of fish stocks and fisheries developed despite Cold War, and it has survived under shifting geopolitical constellations. Today, the Russian-Norwegian cooperation is an internationally acclaimed example of good fisheries management. Unlike in most other ocean areas of the world, fishing is sustainable and the marine ecosystem in the Barents Sea is in good health.

Over the last few decades, offshore oil and gas development has emerged as a new industrial activity in the Barents Sea Region. Arctic hydrocarbon development is characterized by many uncertainties. Nevertheless, it is expected that petroleum operations will intensify in the long term. So far, economic sanctions and low oil prices have only had limited effect on Arctic exploitation activities. As the activities are stepped up on both sides of the Russian-Norwegian border, oil and gas represent another potential field of close cooperation between the two countries.

Based on the experiences from the joint marine resource management, this paper asks if a similar regime can be expected in the field of oil and gas. This article will analyse the governance of the offshore activities through the lens of international relations and regime formation theory and examine business operations within different institutional contexts. This allows to research the conditions under which the two countries will be willing either to engage in collaborative management or act independently.

The article investigates similarities and differences in the collaboration efforts among Russian and Norwegian stakeholders in the two sectors. The comparison is carried out at three levels. Firstly, the paper investigates the institutional level, shaped by national and regional authorities across the border. Secondly, it explores industrial or B2B interconnections in the same manner. Lastly, the paper addresses collaboration in the field of education and research. The comparative analysis aims to detect possible disparities between different stakeholders across the Russian-Norwegian border and to discuss the possibility of transferring the fisheries cooperation regime to the petroleum domain. The obtained results will contribute to the analysis of the emerging petroleum province in the Barents Region from the perspective of good governance and ocean stewardship.
Strategic Planning as a Method for Regional Climate Adaptation Stewardship

Ilona Mettiäinen

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The concept of stewardship can take many different forms from community-based resource management solutions to national environmental policies and international agreements. In climate change adaptation and mitigation work, a tool or method that has during the past few years gained increasing interest is strategic planning.

In regional climate strategies, regions can identify ways of reducing greenhouse gas emissions for mitigating climate change as well as produce knowledge about the regional impacts of climate change to socio-economic and cultural aspects, and on health, well-being and businesses. This knowledge can help the region to adapt to climate change – both by reducing vulnerability to certain risks and by finding ways to utilize the potential benefits opening from climate change for instance to the region’s economic development. If climate adaptation and mitigation viewpoints are considered as functional parts of regional development and future visions, new growth and community development is in some cases hoped to emerge.

For my doctoral research on knowledge practices in climate change related strategic planning in the Arctic, I observed the collaborative planning process of Lapland’s regional climate strategy in 2010-2012. Within the process, climate projections were elaborated by practitioners and other experts in order to produce regionalized knowledge about the socio-economical and cultural impacts of climate change in Lapland. In the regional climate strategy, the impacts of climate change identified within the collaborative planning process dealt largely with hydrospheric and cryospheric changes. In addition to the expected 20 - 30 % decrease in snow cover days, the increase of precipitation throughout the year and, consequently, the likelihood of severe spring floods was actively discussed. Rovaniemi, the capital of Lapland, is already now a nationally recognized flood risk site.

When interpreted from relational viewpoint, several new facts were created within the collaborative strategy-making process about climate change as a risk or an opportunity for the region. From the viewpoint of strategic planning, the line between a threat and an opportunity can be elusive.
Fisheries in the Arctic: Lessons to be Learned

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The development of fisheries governance worldwide is now fairly well documented. When global marine catches had hit the roof at around 85 million tons per year in the late 80’s the management failures had become evident. Fishing technology had fast surpassed the mainstream approaches for limiting catches. Internationally there were many responses to the 'fishery crisis', most notably UNCLOS and the FAO Code of Conduct for Responsible Fisheries. Yet, even if the FAO Code has reached a highly elevated status as a document describing how we should conduct capture fisheries and aquaculture it misses an important point: The importance of securing tenure in fisheries.

Yet, this is changing and the importance of creating the right incentives for the sector to do the right things is being recognized as well as full involvement of industry in the management process.

Over time the scientific foundations of sustainable harvesting of marine resources have been strengthened and the Ecosystem Approach to fisheries management is being developed. Environmental objectives and risk approaches are being acted upon.

Thus, when new areas of the Arctic open up for making use of the marine resources found there we have wealth of tools and experience to build upon to ensure balanced harvesting and effective management: To avoid the mistakes made in the past.

In that respect we need to ensure that harvesting policies are Science based rather than having policy based science.
Place-Specific Arctic Urbanism

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The Arctic is urbanising. Little attention is paid, however, to the contemporary urbanism of the region. The planning of Arctic cities largely still happens within a modernist master-planning framework. This tendency has paradoxically persevered, as anti-urban identity discourses relating to indigenous populations have left little room for re-evaluating city design. Twentieth century planning of Arctic cities has revolved around concepts of harsh climate, Arctic survival, and the robustness of infrastructure. Prevailing concepts of the Arctic city is still largely concerned with the urban “hardware”: roads, airports, pipes, functional buildings, and so on. This fundamentally modernist approach is founded on a deterministic relationship between the physical environment and people. However, looking outside the Arctic, one finds contemporary forms of urbanism that increasingly acknowledges the complexities of this relationship as the basis for the design and planning of cities.

The theory and practice of urbanism have been revised significantly after the modernistic urban planning regime. To narrate this shift, Provoost and Vanstiphout coined three categories: ‘hardware’, ‘software’ and ‘orgware’. ‘Software’ refers to the ideas, images, memories, opinions, and plans of residents, visitors and professionals while ‘orgware’ (organisation-ware) describes the organisational complex of institutions, enterprises and civic society in a contextual, post-modern urbanism. This framework allows them to analyse and engage with a complex and contextual urbanism that deals not only with the climatic function of buildings or the efficiency of infrastructure, but also with people’s perceptions. This enables a meaningful co-creation of place rather than reductive modernist fabrication of space, while acknowledging the socio-economic framing conditions of the (re-)design of cities.

Based on fieldwork in Canada, Greenland, Iceland, Norway, Russia, this paper will employ Provoost and Vanstiphout’s categories in a reading of cities and the planning behind them. It will suggest ways to move beyond the meta-narratives of e.g. industry versus environment or modernity versus aboriginality, in order to reveal the complexity of urban life in the Arctic cities. This includes identifying tensions between narrations of urban life as constructed from the outside and ones based on walking through the everyday environment of the city. Concluding, the paper will discuss wider implications of these perspectives on Arctic Urbanism – as a base for future planning beyond the current modernist logic.
A Millennium of Changing Environments in the Godthåbsfjord, -bridging Cultures of Knowledge

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This PhD project is an interdisciplinary study drawing on both natural and social sciences to improve our understanding of long-term climate variability in Greenland. The environment is under threat from so many directions that it is vital to look in an interdisciplinary way. It is important to look at the whole spectra of interrelated fields, some obvious and some surprising with their relevance, when trying to understand environmental variations both in relation to pollution, climate change or just environments in general. The project explores the links between variations in past and present sea ice, climate conditions, changing environments and human societies. The Godthåbsfjord region has been the most densely populated part of Greenland, both in the past and present. Climatic and environmental variations in this area are significant, resulting in different patterns of human habitation and settlement (past and present Inuit cultures, or medieval Norse farmers). In the past, links between variations in sea ice, climate, and changing environments had significance for the dynamics of human societies. Each of these cultures were dependent on the natural setting in their own specific way, leaving their footprints of these interactions with the environmental variations in the landscapes. This project aims to understand the environments in change through the eyes of the cultural landscapes, traditional knowledge, archives and together with marine geological history depositions and data, reconstruct these lived environments with changing ice patterns, resources and changing human-environment relations in the Godthåbsfjord.

The paper bridges cultures of knowledge through the stories told by local hunters, archives and the proxies of natural science. It demonstrates the importance of how these different approaches and perspectives supplement each other in the understanding of environments in change. It amplifies the relevance for understanding climate and environments in change within the context of social and cultural change, changing settlement patterns and mobility, transformations in resource use, and local concerns over the development of large-scale industries. The paper provides a detailed description of the inner fjord region, pre historic, historic and environmental, supplemented by local knowledge from old hunters, discovering and preserving the diminishing history together with cultural heritage of this area. A knowledge and history that is unique and indispensable for natural scientists to understand the complexity of environments in change, prolong times series and better monitoring in arctic fjord systems.
The Prospects of Russian Bioeconomy as Envisioned in the National and Regional Level

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This paper examines how the national and international strategies discuss innovative technologies utilizing biomass products in energy industry, especially as an answer to broader Arctic stressors such as climate change and sustainable development. Based on the ideas of institutionalism and institutions as both restricting and enabling factors, the study focuses on why the adaptation of innovative practices is slow in the energy industry of the Russian permafrost region, even though the state mandate might be high. The bioenergy industry has received at least moral support from the state and municipalities, since it has the potential to answer to the needs of several global trends in the region, but in order to ensure the social legitimacy of a plan implementation process, it has to steady itself on several pillars in addition of official national strategies. This study examines especially the importance of infrastructure and norms related to the concept of energy security as helpful tools in the legitimizing process.

The data studied consists of both Russian national strategies regarding the economic development of the Russian Arctic and Russian bioenergy and other strategies produced by the EU or some fellow Arctic states. The values to which they refer to when envisioning the Arctic future are analysed, linking policy making with the broader global stressors mentioned above. This dataset is completed by interviews of relevant Russian experts in the field in order to grasp a more rounded perspective. The interviews study the realities affecting the objectives mentioned in the strategies, namely the non-human factors (such as weather conditions, infrastructure, town planning and oil and gas industry) that must be taken into consideration in the policy-making level and what possibilities does the region have to control them, especially in regard of its energy infrastructure. The relationship between energy security and biomass products is discussed in the strategies to some extent, so it is useful to find out how it features in the everyday reality of a Northern region.

At this point, intermediary findings indicate that depending on circumstances, several of these factors may act either as a restraining or an enabling element. This contradiction defines greatly the plan implementation environment in the Russian North, but how is it present in the stewardship? Could it help to explain why in the Russian conditions, even a strong political incentive is not always enough when modernising the energy industry?
Information as Legitimacy Broker in Zoning Efforts in the Numto Natural Park in the Russian Arctic: Planning for Sustainability Versus Vested Interests

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Creation of protected areas in the Arctic has been an important element of protection of valuable ecological systems. It is particularly important when nature conservation priorities match the efforts for preservation of indigenous people lifestyles. Combination of both is problematic when industrial activities, such as oil extraction, arrive to such areas. This paper presents the case of the Numto natural park in the oil-rich Russian Khanty-Mansi Autonomous Okrug situated in the subarctic climate. The park was created in the late 1990s to preserve the unique region with high ecological, historical and ethnographic value, as well as to protect the habitat and reindeer herding activities of indigenous Nenets peoples. Shortly after the creation of the park different claims were put on various use of nature area. Original zoning of the park has been challenged by the ongoing operations of the oil company, Surgutneftegas, that has undertaken attempts to rezone the park areas in order to accommodate expanding oil actives. The most recent zoning attempt endorsed by the oil company in 2014-2015 has involved researchers from different Russian regions that introduced “wise use” principle pioneered by the Ramsar Convention. Next to valuation and mapping of ecologically valuable areas by natural scientists, social scientists were involved for charting socio-economic and cultural properties of the lands used by the indigenous population. The case employs informational governance framework to analyse how and to what extent zoning, as an informational tool, accommodates different priorities and claims. Through the literature analysis, interviews with the stakeholders and surveys, this study concludes that zoning is used to legitimize practices driven by the vested interests. It does not necessarily lead to more sustainability, but rather serves as an additional leverage for powerful actors to exercise authority over other engaged stakeholders. However, inclusion of wide variety of parties and application of the best internationally accepted standards and practices can counterbalance the dominant players vis-à-vis less-powerful actors on the way to finding the middle ground.
Where Do We Begin? The Socio-Legal Aspect of Environmental Risk Governance of the Energy Sector in the Arctic Region.

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“Risk,” “risk analysis,” and “risk-based regulation” have become popular terms in the discourse surrounding hydrocarbon development in the Arctic region. Risk and its derivatives are considered an integral part of prudent decision-making practices in both government offices and corporate boardrooms. The conventional view puts risk at the core of operational procedures associated with oil and gas development and designates technical standards, regulations, and rules as appropriate instruments for assessing, managing, and communicating risks. However, the conventional view ignores the systemic nature of risks associated with hydrocarbon development in the Arctic region, including their complexity, ambiguity, uncertainty, and potential for ripple effects. It also ignores the multitude of actors involved in dealing with and bearing the risks, as well as the complex power relations among the actors.

While recognizing the importance of technical risk analysis at the operational level, this study highlights the necessity for expansion of the policy, legal, and regulatory instruments and mechanisms to accommodate a more inclusive and holistic approach to handling risk – risk governance. It aims to develop an analytical framework for understanding power relations in environmental risk governance of the oil and gas activities in the Arctic under the Russian and Norwegian policy, legal, and regulatory regimes. The study focuses the environmental dimension of systemic risks that are capable permeating into socio-economic and geo-political realms such as implications of large oil spills and greenhouse gas emissions associated with exploration, production, transportation, and use of hydrocarbons.

This study is premised on the analysis of the following pools of data: (1) texts of relevant policies, laws, and regulations and their legislative history; (2) observations obtained during fieldwork conducted in Norway and Russia, including data from semi-structured interviews; (3) transcripts of official presidential and parliamentary meetings; (4) results of various public polls; and (5) contents of online discussions in response to relevant articles published in the leading online news media outlets.

This is a qualitative interdisciplinary study employing literature and methodology from several fields of social science including law, human geography, philosophy, anthropology, sociology, and economics. It utilizes the Grounded Theory to reach theoretical and conceptual findings. It employs content (legal) analysis of the applicable laws and regulations, as well as discourse analysis of official meetings in corroborative fashion. This analysis is complimented by the discourse analysis of the fieldwork data, public polls results, and contents of online discussions.

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Love, murder and isolated existence in the cold climate beyond the Arctic circle are at the centre of two very different yet similar films, one Norwegian, another Russian. The first – an adaptation of Peter Tutein’s Larsen (1925) – describes the conflict between an experienced fir trapper and a new recruit to his hunting station in East Greenland (the actual filming took place in Svalbard): the newcomer believes in true love and that his girlfriend will wait for him to come back, while his boss, who was cheated on by his woman once (with disastrous consequences), believes only in lust and constantly teases his subordinate about his naivety, thinking that he needs a lesson in life. The men are stuck with each other for the winter with no escape route. The rookie gets fed up with his boss, shoots him and subsequently returns to the mainland to find out that his girlfriend did indeed remain faithful. However, he cannot enjoy their reunion because he is deadened by the brutalising experience he has gone through. The other film depicts a tempestuous relationship between a weather station manager and his temporary summer-time assistant sharing living quarters on a fictional island in the Arctic Ocean. Instead of following the commandment of “loving thy neighbour as thyself”, they are at each other’s throat – not because they represent two opposite philosophies of life, as in the Norwegian film, but because of a banal ego clash that grows out of proportion. After several attempts on each other’s life, the assistant poisons his boss with radioactive food, before returning to the mainland. It appears that, independently and by different means, both films set out to prove the same points: that, in the early XX as well as XXI century, men of different cultures and backgrounds repeatedly fail the test of nature demanding cooperation, not confrontation; that they can kill each other not only for resource control and survival but also for a higher principle, such as true love; that love is incompatible with murder (treated as the ultimate manifestation of environmental irresponsibility); and that the position of authority implies cruelty and is questionable not only at an individual level but as a society’s governing principle. So much for arctic stewardship.
The Great Walrus Hunt -- A Forgotten Arctic Narrative?

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The role of walrus hunting, and the importance of walrus products for North Atlantic maritime technology during the Late Iron Age and Early Medieval, is the subject of a recent book by Birgisson (2013). Walrus products were in high demand; not only walrus ivory, but also walrus hides for strong ship ropes. Furthermore, oil from Walrus and other sea mammals were important and expensive products. So called slab-lined pits are archaeological evidence of the oil production. These pits are numerous along the coast of northern Norway. They appear as rectangular shallow depressions in the ground. Most of them are dated to the first millennium AD, and the peak of production probably took place between AD 600-800 (Hansen Olsen 2004; Myrvoll 2011) Birgisson draws up a picture of a large scale walrus enterprise in Iceland, operated from approximately 860, until the collapse of the walrus population in Iceland 50 years later. Ottar’s description of the north of Norway from the same period (ca 890), also indicates large scale harvesting of walrus; the tax payments from the Sami were the basis for the fortune of the northern chiefs, the tax was paid in hides, feathers, whale bone (walrus ivory) and ship ropes made from whale hides (walrus hides) and seal hides. As walrus retreated from the coast of Norway and Iceland, between year 900 and 1000, an alternative source of these products was found in Greenland. New interpretations of archaeological evidence from the Norse settlements in Greenland by McGovern (1994) and Dugmore et al (2007) draw a picture of a walrus hunting station, rather than a typical Norse agricultural settlement. A reconstructed walrus narrative, about large scale commercial harvesting (and depletion) of marine mammals more than a thousand years ago, points to the role of Arctic resources and Arctic peoples for European economy in the middle ages – a role mostly forgotten.
Diverse Local Futures in Common Global Worlds

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There is an abundance of narratives about Arctic futures, where actors portray their ideas about development or discuss climate change as a driver that will change the region as we know it. But the Arctic is a diverse region and the future looks different depending on where you are, who you are, and what your interests are. While local futures will be linked to global developments, the local outcomes also depend on the social and environmental specifics of each context. This paper presents narratives from three workshops in the Barents region in which local and regional actors discussed possible futures linked to a set of global scenarios in a time perspective of 30-50 years. The workshops were held in Pajala, Sweden, in Kirovsk, Russia, focusing on the Murmansk region, and in Bodø, Norway focusing on Nordland. The results will inform the chapter Future Narratives of the Barents report for Adaptation Actions for a Changing Arctic.

The method for producing local futures narratives is an attempt to link bottom-up and top-down approaches to scenarios, where the global contexts are provided by Shared Socioeconomic Pathways (SSPs) that have been developed by the climate scenario community in response to a request by IPCC. The purpose of these global storylines is to highlight the uncertainty space of adaptation and mitigation challenges and to provide a framework for regional, local and sectoral analysis of impacts and response strategies. The bottom-up input is generated in interactive workshops where participants identify locally relevant drivers of change and discuss how they might play out in different future worlds as provided by the SSPs. The results show that engaging with local actors brings out dimension and issues that are usually not highlighted in scenarios that focus on larger scales. They include issues of power over decision-making, sense of place, and social features that affect the capacity to shape the future and to adapt, such as entrepreneurship. In addition to climate change and its impacts, the local narratives generated from the workshops highlight the central role of demography, including migration, for understanding future challenges from a local perspective. Global markets are seen to play a central role for local development, and one in which different global futures are likely to have major local implication. The workshop results show that participatory methods for co-producing future narratives are a powerful way to add nuance to discussions about Arctic futures.
Sustainable Development in the Arctic Area - From Soft Law Responsibility to Hard Law Liability - Impact Benefit Agreements (IBAs) as a legal tool for Arctic stewardship?

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International law increasingly calls upon corporations to address broader environmental, social and governance issues and to act in a social responsible way, i.e. to demonstrate corporate social responsibility (CSR). The increasing body of soft law instruments demonstrate the growing desire among governments to frame corporate behaviour as legal responsibilities. Such instruments include for example the UN Guiding Principles on Business and Human Rights and the OECD Guidelines for Multinational Enterprises. Yet, these soft law instruments give rise to major difficulties. First and foremost, the content of the corporate responsibility is typically vaguely formulated, which makes it difficult for corporations to implement the duties enshrined. Moreover, the absence of judicial enforcement mechanisms establishes social responsibility but 'with the lack of teeth.'

For Greenland, climate change in the Arctic is opening up new opportunities in terms of extraction of natural resources. At the same time mining projects may have significant social, cultural and environmental impact on the local community. In an attempt to minimize the negative effects and enhance the positive implications 'impact benefit agreements' (IBAs) have been negotiated between the mining company, the Greenlandic government and the local municipality. These contractual agreements contain legally binding obligations on social, cultural and environmental aspects thereby 'giving teeth' to the social responsibility of corporations.

The Greenlandic IBA practice illustrates how international soft law norms may crystalize into legally binding obligations in the public-private relation. IBAs may thus potentially serve as a legal tool for Arctic stewardship in managing the social and environmental impact of a mining project. Yet, there is a need to address central pitfalls. When it comes to implementation and enforcement of CSR, the Greenland IBA practice reveals a governance gap. Drawing on theoretical considerations on soft and hard law regulations and the formation of norms in international law it is argued that the governance gap may even serve as an engine for further international regulation to enforce corporate social responsibility in the Arctic area.

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CSR and Sustainability in a 'non-boom' Arctic: Reflections from Post-Shtokman Fieldwork

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Since the early 2000s, there has been increasing international scrutiny, and at times great enthusiasm, about the possibility of a surge in large-scale oil and gas development in the Arctic. The shale gas revolution in the United States and the dramatic drop in oil prices since late 2014 have resulted in some high-cost Arctic oil and gas prospects being shelved. This presentation aims to bring such Arctic ‘non-boom’ sustainability dynamics into focus by presenting and analysing Russian Arctic residents’ expectations and experiences of petroleum companies in an ‘oil and gas bonanza that wasn’t’ around the Shtokman field in the Barents Sea. The analysis is grounded in the findings of an interview-based study of Murmansk, during which a wide range of questions relating to expectations of oil and gas companies and the notion of ‘corporate social responsibility’ (CSR) were posed. Two themes were prominent in the interview results: 1) a diverse set of expectations placed on companies as providers of social services and environmental safeguards based in both Soviet/Russian and international experiences and 2) competing definitions/expectations about which actors should and could play a role in holding companies to account. The regionally distinct understandings of key concepts – like CSR and sustainable development – suggest that Arctic policymakers, corporate practitioners and academics must remain attuned to the contested reach of concepts that seem so widely accepted and understood in international Arctic settings. Arctic regionalism has long relied on the assumption or hopeful injunction that not only is a regional environment shared, but also that some shared policy approaches can be developed. As Arctic cooperation continues to expand – most recently to economic issues via the newly established Arctic Economic Council – caution about the limits of shared ideas and practices and attention to the importance of local context remain essential. Furthermore, in thinking about the role of private companies in Arctic stewardship, the findings suggest that oil and gas companies engaged in or working to win a place in an uncertain and high-cost Arctic offshore prospect need to strike a delicate balance. While demonstrating their capacity to engage in quality societal engagement, these companies should also play a cautionary role given the fundamentally uncertain nature of oil and gas development. This would serve to dampen hype-driven inflation and decision-making and ensure that Arctic communities cultivate their capacity to robustly meet multiple possible futures.
The Evolution of the Arctic Council in the Context of International Law

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In 1996, a non-legally binding declaration established the Arctic Council as a high-level intergovernmental forum for cooperation on Arctic issues, in particular sustainable development and environmental protection. Climate change, as well as the Russian Federation’s planting of its flag on the geographical North Pole’s sea-bed in 2007, resulted in concerns on the adequacy of the existing international regime for the governance and regulation of the (marine) Arctic, including the Arctic Council. Following intensive high-level cooperation between the five Arctic Ocean coastal States during 2008-2010, the Arctic Council eventually emerged as the principal intergovernmental body for pan-Arctic cooperation. The various steps towards strengthening the Arctic Council, in particular through the establishment of the permanent Arctic Council Secretariat, reflect the Members and Permanent Participants’ strong commitment to the so-called ‘primacy’ of the Arctic Council.

This past evolution does not seem to have changed the Members’ view on the status of the Council under international law: it still falls short of an intergovernmental organization. However, at least one of its Members - Finland - calls for changing the Council’s status by re-establishing the Council under a treaty. A significant institutional development has nevertheless been the negotiation of legally binding instruments under Council’s auspices, thereby giving rise to the so-called ‘Arctic Council System’ (ACS). Two of these treaties - on search and rescue, and on marine oil pollution preparedness and response - have already been adopted, and a treaty on scientific cooperation is scheduled for adoption in 2017. The Arctic Coast Guard Forum, which was established in October 2015 by a Memorandum of Cooperation to further the implementation of these treaties, is arguably at least linked to the ACS. Conversely, other domains of Arctic-specific cooperation - for instance on polar bear conservation, marine capture fisheries and hydrography - have no formal or practical linkages with the Arctic Council or the ACS.

The presentation will examine the substantive mandates of these instruments and their bodies in light of the various domains of regional cooperation recognized by the international law of the sea. Attention will also be devoted to ongoing developments such as the Arctic Council’s Task Force on Arctic Marine Cooperation - which will “assess future needs for a regional seas program or other mechanism, as appropriate, for increased cooperation in Arctic marine areas” - and the recently commenced ‘broader process’ on the regulation of high seas fishing in the central Arctic Ocean.
Social and Environmental Responsibility of Oil and Gas Companies in the Arctic Region: The Creation of Societal Value Through Internalization of Externalities

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CSR can be defined as the way through which a company achieves a balance of economic, environmental and social imperatives (“Triple-Bottom-Line Approach”), while at the same time addressing the expectations of shareholders and stakeholders.

CSR practices elaborated and implemented with the help of best practices of stakeholder engagement can help companies create real societal value by internalizing companies’ externalities. Externalities may be positive or negative. Internalization of externalities is a process through which a company is more fully rewarded for the societal benefits it creates and/or pays for more of the costs it inflicts on society. And only through the internalization of externalities, realization of CSR practices companies can create societal value – economic, social and environmental value created for society in the course of doing business.

The issue of this research concerns CSR activities of Russian oil and gas companies that operate in the Arctic region. Key research question is how Russian oil and gas companies that operate in the Arctic create societal value. Do they minimize negative social and environmental externalities and increase positive ones by understanding urgent problems and needs of their stakeholders and engaging them into discussion processes, by making positive externalities exceed negative ones.

The analysis of Annual Reports 2014 of six Russian oil and gas companies (Gazprom Neft, Lukoil, Rosneft, Zarubezhneft, Surgutneftegas, and Novatek) has shown the following results:

- CSR practices are mostly perceived by the six companies as essential activities of environmental and social responsibilities such as emission reduction or charity projects;

- however, social and reputational risks are rarely included into the list of the most significant risks of the Russian oil and gas companies;

- there are several scopes for development for Russian companies that operate in the Arctic: to identify and evaluate main environmental and social risks and create a risk map, to identify main stakeholders and establish more profound relationships with them in order to indicate the main needs and problems in order to help solve them.

So, Russian oil and gas companies that operate in the Arctic region do create real societal value and there are several aspects that should be developed in order to create more value for the long-term perspective and achieve sustainable development in the Arctic region.
Perceptions of Corporate Social Responsibility for Arctic Petroleum in Russia and Norway

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Many players involved in or opposing petroleum exploration and extraction propose and critique corporate social responsibility (CSR). A common understanding of CSR’s theoretical and practical meanings rarely exists—and perhaps could and should not exist. Using Arctic petroleum in Norway and Russia, our research aims to identify and analyse similarities and differences in CSR views.

We conducted semi-structured interviews in four locations: Hammerfest, Murmansk, Komi Republic, and Nenets Autonomous Okrug (NAO). Interviewees included the local population, regional and local authorities, NGOs, and petroleum company representatives. The main overall pattern from the field research is that those gaining directly from the petroleum were more inclined to be positive about it. Hammerfest sports the world's first commercial Arctic offshore petroleum development which has revitalised the town and area. CSR was equated with the economic boom from petroleum revenues. Very few have been left out of the affluence, so interviewees hesitated to be negative. Murmansk had the prospect of significant petroleum development, but the companies have withdrawn for the moment. Petroleum-related CSR received generally negative comments because little had amounted from the promises of petroleum development. Conversely, CSR from Soviet-era resource enterprises such as mining was viewed positively.

Both Komi Republic and NAO are earning significantly from petroleum, but with split community views. In NAO, those receiving CSR-related benefits, such as taxes and new buildings, tended to appreciate the petroleum companies. Some interviewees chose not to work in the sector because they disapproved of petroleum extraction, describing pollution and interference with traditional livelihoods. In Komi’s Usinsk District, the city dwellers gain significantly from the petroleum industry and were most content with CSR benefits. In the villages, people wished that CSR would involve reducing spills and better sharing of information. They often expressed opposition to the industry, even while working in it.

The consequent community model developed from our analysis is "insider-outsider". Rather than splitting along for-profit/NGO or indigenous/non-indigenous lines, at the community and individual levels, those inside the sector tended to be more positive about petroleum-related CSR than those outside the sector. At times, being an "insider" meant being closer to the centre of wealth and farther from the industrial sites, rather than necessarily working for the sector. Policy recommendations highlight benefit-sharing approaches, but care is needed regarding how much companies should take responsibility for community welfare.
Efforts Under the Arctic Council to Protect Sensitive Sea Areas from the Impact of Shipping.

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The objective of this presentation is to review the Arctic Council’s effort on identifying areas of ecological significance and their potential for the regulation of merchant shipping. The background for this study is the initiative from the Artic Council to look at effective measures for the regulation of shipping in the Arctic. This work resulted in a report completed in December 2009 on The Arctic Marine Shipping Assessment. The outcome of this assessment was a list of recommendations which were developed to provide a guide for future actions by the Arctic Council and the Arctic States.

In this presentation I will look at two specific recommendation- namely recommendation C and D under category II, regarding the need for internationally designated areas for the purpose of environmental protection in regions of the Arctic Ocean.

At PAME’s request, Det Norske Veritas (DNV), submitted a report on specially designated Arctic high seas marine areas to PAME in 2014. The report explores the need for protection of the high seas area and describes the traffic volume and vulnerability of the area. The report also reviews potentially available IMO measures suited to protect the vulnerable areas. Based on the Report, PAME decided to explore whether, and if so how, international protection for the high seas areas of the Central Arctic Ocean might be pursued by Arctic States at IMO.

The presentation will assess the findings of the work under PAME and identify and analyse possible available mechanisms for protection of marine areas. The concept of PSSA and the criteria for designating an area as a PSSA will be presented. The potential challenges with establishing a PSSA in the Arctic high seas will be identified and discussed, e.g. the possibility to designate a PSSA which is in its entirety situated in the high seas and also possible procedural challenges. Specific regulation in PSSAs requires the adoption of one or more associated protective measures (APMs). The possibility to adopt flexible associated protective measures in the arctic high seas due to the moving of the pack ice and ice edge, was among the questions raised in the DNV report and will be discussed in the presentation. Finally, the added value of designating an area as a PSSA will also be debated and possible alternatives will be presented by identifying relevant protection measures.
The Effectiveness of the Regulatory Regime for Black Carbon Mitigation in the Arctic

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Black Carbon (BC), the second biggest cause of the Arctic warming, has been on the agenda of climate activists and international organisations for a few years. But it is only in 2015 that the Arctic Council has adopted a framework attempting to achieve reduction in emissions of this particulate matter. As the Arctic is warming twice faster than the rest of the world, approaching the tipping point in a not so distant future, the necessity of taking steps in lowering the warming is striking. While the efforts to reduce BC cannot replace long-term mitigation of CO₂, immediate reductions in BC emissions could lower the rate of Arctic warming over the next few decades.

The problem of BC pollution is being tackled at the international regulatory level by the Arctic Council and the Convention on Long-Range Transboundary Air Pollution. The Arctic Council recognises the challenges presented by the climate change and is working on its mitigation through joint research and non-binding legislation. The norm-creating powers of the Council have often been questioned. However, the voluntary BC and Methane Framework adopted by the Council shows a positive compliance dynamic in comparison with its earlier norm-creating attempts.

The effectiveness of international environmental norms has been a subject of debates within legal and political science scholarship. The present paper argues that the nature of the norm (binding or non-binding) is not the decisive factor in its effective implementation in the present-day Arctic. It attempts to demonstrate that the current efforts of BC mitigation by the means of the non-binding Arctic Council Black Carbon and Methane Framework demonstrate an improvement of the Council’s normative function and would have more effect on the behaviour of the Arctic States than the relevant obligations under the legally binding Gothenburg Protocol to the CLRTAP. To support this statement, the first section presents an overview of the Arctic Council as an actor in the Arctic policy-making. It further provides the assessment of the current efforts to combat BC taken by the Arctic Council and the CLRTAP.
Russian Proposals to the IMO’s Process on the Polar Code: Contributing to the Common Good or Furthering State Interests?

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The International Maritime Organization, during its Maritime Safety Committee’s 94th session in November 2014 and its Marine Environment Protection Committee’s 68th session in May 2015, adopted the mandatory International Code for Ships Operating in Polar Waters. The Polar Code, which has been negotiated since 2009, aims to provide additional regulations for safe ship operations and pollution prevention in polar waters. The present paper examines the role the Russian Federation played in the decision-making process of the Polar Code, through the proposals it submitted to and the statements and interventions it made at the (Sub-)Committees of the IMO. The documents analysed are those publicly available in the IMO’s online database.

The paper investigates what purpose these proposals, statements and interventions served with respect to the goals of the IMO – and thus the common good of the international community – on the one hand, and to the interests of the Russian Federation on the other. The analysis identifies major issue areas represented in the Russian proposals, including regulation of icebreaker assistance, role of national regulations, the geographical scope of the Polar Code, regulations related to the discharge of oil and oily mixtures, and POLARIS, a system for operational limitations. Despite Russia’s great experience in polar shipping, the paper finds that the majority of the issue areas taken up by Russia did not serve to contribute to and further the safety and environment protection goals of the IMO.

Regarding those issue areas and proposals that, thus, seem to serve a purpose other than furthering the common good of the international community, the paper asks how Russia’s (coastal) State interests could be promoted in the context of the IMO, keeping in mind that the IMO, first and foremost, regulates the flag State and industry side of shipping. More precisely, what kind of reasoning did Russia use to further its interests?

The research finds that Russia used technical arguments in a textual surroundings where these served to support interests which often do get mentioned in the proposals. These interests have to do with Russia’s coastal State jurisdiction and control over shipping in its Arctic waters, as well as the costs and negative effects of implementing the Code’s provisions on Russia’s activities, such as fishing in the Bering Sea and the operation of icebreakers.

The paper generates knowledge on the role of the biggest Arctic State in the development of uniform international standards for polar shipping.
Hybrid Governance in the Arctic: Carving Out a Political Space for Coastal Indigenous Communities in Arctic Emergency Preparedness and Response

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As the Arctic’s ice recedes maritime and coastal traffic is increasing. Arctic climate change is also affecting indigenous coastal communities’ abilities to hunt and travel on ice with the same predictability as traditionally existed. These factors become more complex in that extreme and unexpected Arctic weather happens at all times of the year and there will be a continued presence of seasonal and other forms of ice into the future. In a region where little, if any, infrastructure exists a well-coordinated regional regime focusing on Arctic Emergency Preparedness and Response (AEPR) and SAR is a necessity. To address these challenges, the Arctic Council (AC) states’ have passed two binding declarations. The AC has additionally - through its PAME and EPPR working groups’ - set out to address these growing Arctic maritime challenges. At the international level, the IMO is further working to help construct ways to mitigate environmental and human maritime disasters (largely through its Polar Code).

Yet, there remains room to better account for the fact that emergency responses will begin from a number of indigenous communities along the Arctic’s shores; communities which own or have rights (through domestic and international law) to the land, waters, and resources where they live, maintain invaluable traditional knowledge, and rely on the Arctic environment for sustenance, culture, and overall community well-being. This issue is further exacerbated by the need for governance mechanisms which can effectively coordinate local community governance, national governance, regional governance (e.g. AC) and international institutions (e.g. IMO). The question that our presentation will addresses is how, and in what ways, can and should coastal indigenous communities play a role in AEPR policy and governance; how can indigenous peoples can find their political space in a legal landscape that is filled with government overlap at the domestic levels and governance gaps at the subnational, regional, international, and transnational levels. Further, what can indigenous coastal communities in the North American Arctic learn from existing AEPR and SAR programs in Iceland and northern Norway?
Making Risk Acceptable: Oil Spill Preparedness and Response in the Arctic

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The Arctic is a global crossroad between commercial and environmental interests. While oil companies strive for greater access to this region, environmental interests emphasize the Arctic’s vulnerability and the lack of well-functioning oil spill preparedness and response systems in case an accident would occur. One of the requirements for increased offshore petroleum activity is thus that improvements are made in oil spill contingency plans and response systems. Without a trustworthy infrastructure for protecting the environment, the companies will not obtain a license to operate.

The oil spill preparedness and response systems, however, have paradoxical characteristics. Large investments are made in material and personnel resources that hopefully will never be used for major accidents. It is hard to tell when the systems have a capacity and standard that provide an acceptable level of risk. Since the systems serve as entrance tickets to the Arctic, it may be more important to show that a system is in place than how it actually works.

This paper analyses how the requirements for oil spill preparedness and response are established and defined in the Norwegian part of the Barents Sea. Furthermore, it describes the actions that public and private actors undertake towards improvements. How are the standards for a well-functioning system set? Which actors are involved in setting these standards and in specifying and testing the necessary resources? How do public and private actors cooperate to bring about technological and organizational innovations? The paper shows that improvements in the oil spill response infrastructure fosters environmental stewardship in the Arctic, but it also demonstrates the contested nature of the very concept of stewardship.
Natural Resources and Social Visions for Greenland's Future

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The Arctic is often perceived as the new resource frontier in a resource hungry world. Many actors both inside and outside the region are eager to know what opportunities lie under the ice, and many claim a say in the future development of the Arctic. In Greenland, the possibility of discovering oil and gas reserves is seen as an opportunity to become financially independent from Denmark: A national economy based on natural resources will lessen the dependence on the former colonial power, and is by many considered an important step towards real independence and statehood for Greenland. While oil and gas exploitation could be crucial for the future development in Greenland, and give jobs to its’ population, others warn against oil and gas drilling, raising environmental concerns about for example oil spills, pointing to climate change due to the emissions from burning fossil fuels and its effects in the Arctic, but also questioning the indigenous ambition of joining the market economy. This paper looks at representations of natural resources in the Arctic region, the so-called resource frontier, and in particular the case of Greenland: How do certain representations of natural resources impose constraints on social visions for Greenland’s future? Inspired by Carol Lee Bacchi’s (1999) What’s the problem approach, I look at the representation of natural resource exploration and exploitation from the view of the Greenlandic Government, the Inuit Circumpolar Council and Greenpeace International. These are chosen as three voices, representing national government, a regional, multinational organisation, and an international non-profit civil actor, who all have opinions about the Arctic’s future development. While a need for development is recognised by the three, there are different perspectives on what this entails, what type of ‘development’ is needed and what role different types of natural resources should have in this. For example, if climate change opens up new natural resource opportunities in Greenland, such as uranium mining, oil drilling or farming, should this not be developed further due to environmental concerns? Or should these types of developments be resisted due to more ideological standpoints? The concluding discussions focus on the constraints on social visions and how representations of certain natural resources as ‘the’ development path inhibit other imagined Arctic futures.
Marine Stewardship and Complexity -- How to Enhance a Better Process of Risk Governance in the Norwegian Area of the Arctic Ocean

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In 2006, the Norwegian government published a white paper that presented an integrated oceans management plan for the Barents Sea and Lofoten areas (St.meld. nr. 8 (2005-2006). The plan was based on environmental principles such as sustainable development, the ecosystem approach and the precautionary approach (ibid). The plan came about mainly as an incentive to open new oil- and gas fields, and map consequences with respect to the environment and the other sectors using the ocean space (Knol 2010). The overall idea is to create a foundation for joint, cross-sector decision-making for those actors that use the area. The Barents Sea houses many commercially important fish species such as cod, haddock and saithe (Olsen et al 2009). These species provide the basis for a large industry that generates large export values. Increased activity in the Arctic enhances the risks of unwanted effects on the fish stocks, and consequently the fisheries depending upon them. Potential severe risks include acute pollution from petroleum activities and shipping in addition to radiation from accidents due to more nuclear- powered vessels (Meld.st.10 2006: 127). Interests in the Barents Sea include oil and gas, shipping, fisheries, tourism and bioprospecting amongst others. Opening the management from single species to ecosystems, as well as spanning across sector boundaries, highlights interdependencies, trade-offs, knowledge gaps and joint risks. The Barents Sea Plan established three working groups to implement the plan. These were the “scientific forum”, the surveillance group and the risk group. To govern risks of a high level of complexity, uncertainty and ambiguity Renn, calls for an inclusive risk governance and a discourse with many different stakeholders (Renn 2008). In areas of great complexity, the risk escalator model can be a way to sort different obstacles to suitable levels and increase the understanding of the different scientific research discipline needed for these fields. The risk model gives a total overview and can be a tool to process many types of information. Theories from collaborative planning underlines the need for a procedure to reach consensus (Innes and Booher, 2010). How can a planning process including a great variety of stakeholders aim for consensus? Using this theory can be a way to map what is working or not in the process. To make improvements experts in the field of consensus building could be included in the new process with the new Barents Sea White paper that will apply from 2020 to 2040.
Sami People in Decision-making Processes - Analysing Sami People's Possibilities to Participate and Influence on Decision-making Processes

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The Sámi people are the only officially recognized indigenous people's group living in the region of the European Union. They live in Norway, Sweden, Finland and Russia, and their culture and traditional livelihoods have always been strongly connected to the nature. They have a long history in exploiting natural resources; and with traditional knowledge they have managed to regulate that in a sustainable manner. In the 17th century the impact of other cultures started to increase rapidly in Sápmi region and since that many new actors have settled in to the region.

The states have nowadays naturally a lot of power in the Sámi people's homeland region, and the interests of the states and the Sámi people are not always coherent with each other. In the world of increasing economic and political competition states have to think also their competitiveness and economic growth. "Soft values" might stay in the shade of "harder values" especially in the Arctic region, and the possible revealing of natural resources has recently increased the gamut of national and international actors and competition. In many occasions minority groups' voices concerning these issues are not heard. For example, in Finland conversation over indigenous people's possibilities to take part in to decision-making processes has burst radically lately. However, despite many protest voices among the Sámi people the situation has not visibly improved and this can be seen for example in the public conversations and media.

This paper will introduce shortly how the Sámi people are engaged to the decision-making processes when building resilience at the state - and regional level in Sápmi. I will also discuss about the possible advantages and disadvantages of taking small indigenous people group's view into consideration when strengthening the vitality of the region at every stages. Especially environmental and political aspects are highlighted in this paper, since the environment is seen as one of the most crucial element of the Sámi culture. It is also one of the most vulnerable resources which the Sámi people still have managed to preserve relatively clean in this region.
Quantifying Resources and the Discovery of Deep Sea Hydrothermal Systems of the Arctic Mid-Ocean Ridge

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Decades have passed since the first discovery of an active seafloor hydrothermal system, but nevertheless the scientific community is just starting to grasp the complex nature of these systems that form mineral deposits and host unique life communities. Some seafloor mineral deposits are of sufficient size and metal content to be considered for mining. Along the Arctic Mid-Ocean Ridge there are several known seafloor hydrothermal systems and many more may be found in the upcoming years of Arctic exploration. Oceans, their ecosystems, geodynamics and economy impact all of us. The putative need to exploit the deep-sea mineral resources has to be balanced with the environmental impact unknowns. For that to be attained, a combined effort between the scientific community and governments is required to collect comprehensive knowledge on the nature of these systems. Solid scientific data will serve as foundation for establishing management and monitoring guidelines for future exploitation.
VDES - A First Step Improving Arctic's Telecommunications in the Future

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First, this presentation at Arctic Frontiers will give an overview of the current situation and the resulting gaps in telecommunications (terrestrial and satellite) infrastructure in the Arctic. There is a large increase of activities in the Arctic (shipping, mining, eco-tourism, etc.) and, therefore, a larger demand on communications - also for safety reason. Currently, the existing infrastructure cannot meet this demand. During the last years, this is slowly noticed by different organizations and committees. Activities speed up towards this topic. For example, these days, the Arctic Council starts a Task Force on Telecommunications Infrastructure in the Arctic.

One identified key element for future Arctic communications is a new communications system, namely VHF Data Exchange System (VDES), mainly in respect of shipping activities. Now, this system is in the standardization phase and is envisioned as one pillar supporting the maritime e-navigation concept by United Nations' International Maritime Organization (IMO). The system contains a terrestrial and also a satellite component and, thus, it has a global coverage including the Arctic. We will give an insight of VDES in terms of its specifications and requirements. Also what are challenges for the system design for the Arctic shipping and other users?

Finally, we would like to aim at providing answers to the fundamental questions:

- Are there any other innovative solutions out there which can provide communications with higher data rates in the Arctic, e.g., during oil and gas installations?
- Could these solutions be shortly available?
- Are there technical solutions which are compatible with existing or other future techniques?
Biogas Production from Shrimp By-products in Sisimiut, Greenland

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The fishing industry is the main industry in many Arctic locations. In most places with local fish processing facilities, such as the otherwise state-of-the-art shrimp and crab production facility in Sisimiut, by-products are disposed of at sea. Shrimp production by-products constitute a potential resource for shrimp flour, chitin or biogas production. The biogas potential arises from the relatively large organic fraction left in the material, which for the same reason cause oxygen depletion and thus severely impacts the waters in which they are disposed. The objective of this study was to determine the biogas potential of shrimp and crab waste from the processing facility in Sisimiut, Greenland. Co-digestion of the shrimp by-products with waste water sludge (from experimental primary treatment by coagulation and filtration of local wastewater from Sisimiut) and common brown algae (Saccharina latissimi) found along the coastline in the Sisimiut area was also investigated. Batch reactors with different concentrations and mixtures of substrates were incubated at mesophilic conditions, and the methane production was monitored over a 32-day period by gas chromatograph. Of the unmixed samples, shrimp and crab by-product had the highest biogas potential (300 STP ml CH₄/g VS), wastewater sludge had a potential of 220 STP ml CH₄/g VS, and the brown algae 260 STP ml CH₄/g VS. The combined shrimp and algae digestion showed synergistic effects with a biogas potential of 320 STP ml CH₄/g VS. The biogas potential of the Greenlandic products is thus comparable to commonly utilized agricultural by-products such as cattle slurry, straw and pig slurry. Recalculated to potential energy output, the shrimp processing facility in Sisimiut would be able to gain between 50 and 100% its energy consumption from gasification of the by-products. Development of an appropriate technological solution is however necessary before biogas production becomes feasible in small remote Arctic communities. Advanced thermophilic plants optimized for maximum energy production are sensitive towards changes in operating conditions; require highly specialized labour, high capital investments and would require energy for heating. Low tech biogas plants as implemented on a single household/farm basis in third world countries on the other hand cannot run during winter periods. An intermediate solution designed for the remote Arctic and run at mesophilic conditions for higher process stability may be feasible.
Exposed Aquaculture in Norway - Technologies for Robust Operations in Rough Conditions

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Significant parts of the Norwegian coast are unavailable for industrial fish farming due to geographical remoteness from onshore infrastructure and exposure to harsh wind, waves and current conditions. While farming of salmon and trout started in more sheltered coastal environments, fewer such areas are today available for salmon farming, both due to competition with other coast-based industries such as tourism and fisheries, and due to the radical growth the salmon industry has seen during the last decades. This has led to a gradual move towards also using more exposed coastal areas for salmon farming. Exposed farming locations could be ideal for production and simultaneously reduce key environmental effects. There is a large industrial interest in enabling safe and sustainable seafood production in exposed coastal and ocean areas. Except for a few proposed concept solutions, no concrete plans to move production into the open ocean environment have been published. Rather, the industry has focused on utilizing the limited shelter and bathymetry of outer coastal areas.

Fish farmers who have started utilizing exposed areas report considerable difficulties in maintaining reliable production. Farming in exposed areas poses unique challenges to operations, structures and equipment due to severe and irregular wind, wave and current conditions, and sheer remoteness. Furthermore, many of the operational challenges seen at present sheltered sites are likely to be amplified when moving production to more exposed locations. There are sites that have been abandoned because of difficulties to perform key operations effectively and when necessary, which is a fundamental requirement for profitable and sustainable farming.

While aquaculture production has moved towards more exposed locations, few significant technological and operational changes have accompanied this transition. Exposed farming requires novel technical solutions combined with operational concepts to maintain safety and ensure reliability. Norwegian maritime industrial clusters and research institutions are at the forefront of innovation and competence focused on demanding maritime operations and can play a significant role in this task.

This paper will focus on the technological challenges of salmon and trout farming at the most exposed locations currently in use in Norway and future farming at more offshore sites. A new research centre for Exposed Aquaculture Operations is presented, where these technological challenges will be addressed. Research needs for realization of exposed aquaculture are discussed and planned activities at the centre together with expected impact of results are presented. This will also be relevant for exposed aquaculture internationally.
Environmental Challenges Related to Seabed Mining in the Arctic

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Seabed mining has many environmental challenges and when preparing a project all the environmental aspects and impacts should be included. Seabed mining in the arctic will in many ways be extra challenging, due to the low temperatures, the long distance to service functions and the limited knowledge of the environmental impacts on the seabed fauna.

To be able to handle the different challenges the project as a whole has to be analysed and the hazards of the project have to be identified. When the hazards have been identified, they need to be classified with respect to probability and consequence. By combining the probability and consequence the risk for each hazard is obtained. If there are risks that are critical for the environment they have to be mitigated by suitable measures. Significant risks for the environment shall be monitored and further risk-reducing actions have to be considered. When risk-reducing actions have been suggested a new risk assessment is done to check that the hazards now are acceptable.

Examples of environmental hazards for seabed mining in the arctic that should be included in an environmental risk assessment are:

- Direct destruction of seabed habitat
- Sediment disturbance and plume discharges
- Surface operations; use of chemical, waste, emissions to air and water
- Thermal and light pollution
- Noise and vibrations
- Equipment not working in Arctic conditions

Examples of risk-reducing actions are:

- Only allowing mining equipment that causes a minimum of sediment disturbance and plume discharges
- Exclude certain environmentally vulnerable areas from the mining project
- Require that the return water is filtered on board the mining vessel before it is discharged to the sea
- Define weather conditions where seabed mining is acceptable
- Use of special equipment suitable for Arctic conditions
- The presentation will use a fictive seabed mining project in the Arctic to illustrate the environmental challenges.
Underwater Vehicle for Autonomous Net Inspection in Salmon Aquaculture

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In modern aquaculture using gravity net cages, holes in the net and other types of net failures constitute a challenge with respect to fish escapes. To minimize escapees caused by net failures, periodic net inspections are required to detect holes as early as possible. We will in this work present technology and methods developed for an Autonomous Underwater Vehicle (AUV) with hovering capabilities, to be used as a platform for autonomous net inspection. The AUV must operate in a demanding seawater environment with current, waves, dense biomass, relative to flexible structures (net cage and mooring) with unpredictable variations in position and geometry. The time varying shape of the net cage leads to special requirements for the guidance, navigation and motion control (GNC) system. Machine vision will be applied for inspection and net failure detection. Using an optical camera as sensor is challenging due to the varying degree of net biofouling, water turbidity and lighting conditions. Given these special aquaculture conditions, research has been conducted within three main areas: 1) Navigation and motion control system, 2) Machine vision for net failure detection and 3) Design and development of the autonomous system. The conference contribution will give an overview of the results from these research areas:

1. Experiments have been conducted on full scale aquaculture farms to determine the suitability of certain navigation sensors to contribute to an AUV navigation system for use within aquaculture net cages. Vision based methods, and state-of-the-art hydro acoustic sensor systems has been tested and validated. In addition, a motion control system, consisting of algorithms for multi-sensor fusion and net relative tracking, has been tested and validated.

2. Machine vision technology has been facilitated for net failure detection using collected image material. Local adaptive methods have been utilized in order to extract the net from the background. Non-linear operations strengthen the structural representation of the net. A time-dependent analysis is used to detect regions of interest (potential net damage) and labels potential failures.

3. Design, development and validation of the autonomous system have been conducted using the SEATONOMY methodology. This ensures that important abilities within mission and path planning, error handling, decision making and human interaction are treated systematically, which is paramount for safe and efficient net inspection. The autonomous system has been tested and validated in a simulation environment.
NORSAR’s Contribution to the Riddle of the Arctic -- How to Use Established Knowledge in Innovative Ways

Anne Strømen Lycke

NORSAR, Norway

NORSAR is an independent research institute within the fields of seismology and geophysics. We are the National Data Center and advisor to the Ministry of Foreign Affairs under the Comprehensive Nuclear-Test-Ban Treaty (CTBT). In this context we operate seismic, radionuclide and infrasound monitoring stations in the European Arctic (Svalbard since 1992, Finnmark since 1987, Jan Mayen since 2001).

On Svalbard, we have a long lasting and close cooperation with partners in Russia and Poland. Among other activities NORSAR supported the building of seismic stations in Hornsund and Barentsburg and the Apatity seismic array in the Kola Peninsula.

This has given a basis for excellence in technologies now seen useful for civil purposes. NORSAR subsequently ventured into services and software within:

- earthquake hazard and risk assessments,
- seismic modelling for optimizing seismic data acquisition and imaging,
- microseismic monitoring for better understanding of induced earth movements due to fracking, underground storage, geothermal energy, ...

Bringing these technologies to extended use, NORSAR can add values and new perspectives to important challenges like climate change processes and the subsequent quest for a safer society.

NORSAR is currently involved in the CO2-Lab project close to Longyearbyen, where the potential for safe CO2-underground storage was investigated. NORSAR’s work focused on geophysical methods to evaluate how a network of sensors will be able to identify and locate small deformations in the subsurface caused by stress changes related to fluid injections in the storage reservoir. As such, an extensive network was installed, fluid-injection tests were conducted and data analysed that are now used towards best practice monitoring requirements, in particular under Arctic permafrost conditions.

Other examples:

- infrasound waves reach atmospheric layers, which cannot be observed from satellites or weather balloons and thus add new data for better understanding of movements in the weather system and of climate change
- the radionuclide station in Svalbard observed the Fukushima accident and can be used to map the extent of future radioactive releases to the atmosphere
- seismology is useful for mapping and understanding movements in the cryosphere and their temporal behaviour of these movements can be correlated with changes in the Arctic
- seismology contributes to a safer society by a better understanding of possible ground shaking, which is essential for engineering of large infrastructures (platforms, bridges, water dams, tunnels, ...); by monitoring of sites for potential rock slides; and by providing risk assessment software to decision makers
Research Centre for Arctic Petroleum Exploration (ARCEx) - Collaboration Between Academia and Industry

Alfred Hanssen

University of Tromsø, Norway

ARCEx (Research Centre for Arctic Petroleum Exploration) is a long-term research collaboration between academia and industry. The centre aims at improving our understanding of the petroleum resources in the Arctic, with a special focus on eco-friendly exploration technologies and risk management. In this presentation, we will discuss some of the interesting ongoing research projects within the centre, and we will describe some of the results we have achieved so far and how they might affect future Arctic petroleum projects.
Arctic Transportation Challenges and Emergency Preparedness. Svalbard Region

Nataly Marchenko

The University Centre in Svalbard, Norway

Locating in the centre of Arctic, Svalbard region has uniquely large for such high latitude (72-80 N) transport activity, with clear tendency for increasing. The high level of ship traffic can be explained by warmer climate and easier ice conditions due to North-Atlantic Current. So Svalbard can be considered as model/example for the future development of the whole Arctic in the case of Global/local warming. Meanwhile, all features of harsh weather conditions, difficulties for navigation, vulnerable environment are obviously seen here. That’s why, Svalbard experience of navigation and emergency preparedness is very valuable. The main town, Longyearbyen plays key role in search and rescue operations for the whole Western Sector of Arctic.

Vessels of 4 main groups (tourist, cargo, research and fishing) navigate in Svalbard area. Naturally the first prevails by people on the board, and the last dominates by numbers. Ship traffic has great seasonal variation, with the increasing in 4-6 times in summer.

The main challenges for navigation are logistics and large distances; sea ice and inadequate charts.

Fortunately, there were not so many ship accidents in the area, 2-3 per year in average. Fishing vessels account for 64% of events. Groundings prevailing. Capsizing by ice is specific for Svalbard. Trawlers, going far north, following fish/shrimps are caught by ice and need icebreaker assistance almost each second year. There were also several large accidents (cruise liners Maxim Gorky, 1989 and Heanseatic,1997) rather instructive for safety in the Arctic.

The main challenges for SAR are very limited human resources, large distances and harsh weather conditions. Longyearbyen (governor office, Red Cross and other) has very good emergency preparedness. The good examples of fast mobilization and effective rescue operation are rescue of tourists of “Maxim Gorky”, with evacuation of more than 700 people from sinking vessel (100 km from the town) during the day. The most recent event is Svalbard rescue exercises (November 2014) conducted by Ministry of the health. When 80 persons, playing the role of victims had been “saved” and delivered to Longyearbyen hospital from accidents place (50 km distance) during 5 hours.

The risk assessment matrixes for environment and human beings have been created on the base of an evaluation of the probability of accidents and the possible consequences of the negative events. Analysis of ship traffic pattern, previous accidents and SAR features; the efficiency of preparedness system and adequate means for improvement will be discussed.
Ocean Mining Potential in Norway

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In 2012 the Norwegian University of Science and Technology (NTNU) and Nordic Ocean Resources AS, with support from Statoil ASA, established a project to assess the ocean mining potential in Norway.

A special focus area has been to increase the knowledge of possible massive sulphide mineralization along the Mid-Atlantic Ridge. This Ridge is a subsea mountain range which separates the Eurasian and the North American continental plates. In this area, seafloor massive sulphides (SMS) are formed from the volcanic and hydrothermal activities along the Ridge. A large part of the North-Atlantic Mid-Atlantic Ridge between Jan Mayen and Spitsbergen is located on the Norwegian shelf.

Analysis and interpretations of multibeam data have been carried out by NTNU in cooperation with the Russian Institute for Geology and Mineral Resources of the Oceans in order to identify relevant areas for the formation of SMS deposits. This analysis has located several promising areas.

Based on these data, a probabilistic mineral resource evaluation (play analysis) has been performed using similar methods used for oil and gas resource evaluations in Norway. These calculations result in a gross value estimate for the SMS deposits on the Norwegian part of the Ridge of NOK 430 billion (USD 75 billion).

To further evaluate this assessment, the Norwegian Research Council has recently awarded 25 million NOK to NTNU and 12 Norwegian companies. The ‘Marmine project’ will collect seafloor samples from deposits on the Ridge in the summer of 2016 to further evaluate the ocean mining potential in Norway.
Which Telemedicine Services Work in Arctic Environments - A Systematic Literature Review from 1984-2015

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Objective

Since the early years of modern technology, the application of telemedicine in healthcare has always been apparent, and sometimes a driving factor for development - especially in rural areas or communities. The purpose of this review is to assess and report findings that are published between 1984 up to 2015, focusing on two questions; "which telemedicine concepts are fitted for an arctic environment?" (1) and "what is the focus of telemedicine projects in the arctic?" (2).

Methods

For this review, we have conducted literature searches in peer reviewed journals and articles in the various databases including Google Scholar, (Springer), IEEE Xplore and ACM Digital Library. The work was conducted following best practices for structured literature review.

Results

The technology behind Telemedicine is ultimately tools used by people, which promotes accessibility and quality of service. In this review we see a tendency that the users are inclined to favour simple technological adaptations of these tools, and that complicated solutions generate factors that are potential problems. For our results we found that few papers are addressing our research questions; where the initial search gave some 3000 papers based on title. This was narrowed down to 266 papers based on abstracts, and finally down to 35 papers by content. These were then defined into 7 non-exclusive categories: Development, education/training, human factors, mental healthcare, rescue, self-monitoring, and video transmissions.

Conclusion

Connectivity and distance in the arctic regions is a recurring issue, and while there is a multitude of papers on this topic among other rural areas, publications in context to an arctic environment remains largely poor. More scientific and realistic evaluations are called for, preferably starting with simple systems already in use.
Assessment of the Northern Sea Route Throughput by Simulation

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The interest for the transportation via the Northern Sea Route (NSR) increased significantly in the last decade. It can be primarily explained by the effects of global warming that affected the Arctic and thereby new economic possibilities have appeared. Marine routes between Europe and China are approximately 40% shorter compared to the ones via the Suez Canal. This makes the transit through the NSR more attractive in terms of time and cost savings. In the current research factors affecting the transit of vessels via the Northern Sea Route were analysed and a simulation tool modelling the transit process accounting for ice conditions, icebreaker support requirements and convoy formation was developed. The model allows for the assessment of the route throughput measured as the fraction of transit orders satisfied during the navigation period, and the average order delay time, affected by the total number of transit orders and the number of available icebreakers. The information on order processing, the procedure of convoy formation and customer’s logic behind order cancellation for the transit via the route is presented and the needs for further investigation are highlighted. The developed approach is valuable to shippers and transport providers as a means for evaluation of the expected average delay time from the requested transit order start date.
The Norwegian Oil and Gas Industry Response to The Arctic and Cold Climate Challenges

Håkon Skretting

INTSOK, the Norwegian Oil and Gas Partners, Norway

The project's main goal is to contribute towards Norwegian petroleum industry becoming world class within arctic and cold climate technology.

The aim of this project is to facilitate Norwegian industry, delivering world class technology/solutions for arctic and cold climate capital development projects. Both offshore technology and onshore coastal facilities as LNG plants and terminals in Arctic waters are included, as well as related maritime offshore activities.

Further, the aim is to promote Norwegian petroleum industry and Norway’s position as a responsible actor in the North. The project will contribute towards Norwegian petroleum industry being leaders of arctic and cold climate competence, cost-effective technologies and solutions and be in the forefront of responsible sustainable management of the environment and oil gas resources in the markets Norway, Greenland, The United States (Alaska), Canada, Russia and Kazakhstan (The Caspian Sea).

Through mapping future oil and gas related activities in areas with arctic and cold climate conditions, as well as related technology needs within each capital development project and related infrastructure, this project will prepare Norwegian petroleum industry for upcoming challenges and enable them to be in the forefront of this market, increase their competitiveness and to commercialise cost-effective and environmentally friendly technology and solutions in cooperation with operators.

It is expected to provide great value to operators with activity in the arctic and cold climate areas. INTSOK, through this project, could be an effective tool for both operators and the industry to promote the right innovation and technology development and strengthen the Norwegian petroleum cluster to become world class within arctic/cold climate technology. Emphasis will be placed on cooperation with e.g. OG21 and Demo2000 to ensure coordinated focus on cost-effective solutions in the industry. The project is industry focused and its execution aimed to help all companies, project participants and sponsors, to ensure all participants benefit from their participation in the project and the running of its activities.

The project has three main elements: Part 1: Norwegian arctic technology and solutions Part 2: Which markets, projects and tasks? Part 3: Commercialisation of Norwegian arctic and cold climate technology
Assessment of Hazards in The Professional Activity of Personnel in Oil and Gas Companies in the Arctic

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The human work in the Far North and the Arctic, particularly when using shift (fly-in-fly-out) forms of work, characterized by a high professional load significantly exceeds the standard for normal conditions. The combination of adverse environmental, social and occupational factors impedes adaptation of workers to the conditions of the Arctic, which may lead to an increase in morbidity and reduction of disability rights. Security employee behaviour and success of professional activity in extreme conditions depends on the features of the person of the expert, subjective feelings of self-regulation, and protection from danger. The research purpose is to study the subjective assessment of the hazards in the professional activity of workers of oil and gas companies in the Arctic. The study involved 55 employees of oil and gas companies in the Nenets Autonomous Okrug (the length of the shift-in 30 days) between the ages of 24 to 60 years (mean age 38,7 +/- 9,7) from March to April 2015 Work experience in shifts surveyed ranging from 0.5 years to 31 years (9,53 +/- 7,6). Methods are questioning, testing, psycho-physiological tests, descriptive statistics, t-Student test for independent samples, multivariate analysis of variance MANOVA. Treatment was carried out using the software package SPSS 22.00. The study revealed that greater risk for the workers of oil and gas companies in the Arctic are the following features: transportation to the workplace from shift-town, climatic factors (wind and low temperatures), increased compliance with safety regulations and corporate standards, difficulties with transport and communication danger to the health of the work, the inability to help the family and loved ones in the event of their problems. The study recommendations were developed that enhance the feeling of safety among workers of oil and gas companies in the Arctic.
Chemical Herder Effectiveness as an Oil Spill Response Tool in Ice-infested Water

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The effectiveness of the chemical herding of crude oil, an enhancement for oil spill response methods, was studied in ice-infested waters to evaluate the applicability to oil spills in Arctic waters. The average slick thickness, surface coverage distribution of the slicks, as well as the burning efficiency of a North Sea crude oil were studied after herding to determine the herder effectiveness as a function of the ice coverage, amount of herder, wind speed and use of free floating or fixed ice. Experiments were performed in a small scale laboratory setup, featuring a 1.0x1.0x0.5 m³ water basin (1 m² surface area), and in an outdoor test basin of 4.0x4.0x0.05 m³ (16 m² surface area) in Sisimiut, Greenland. The chemical herder, which is a surfactant that spreads out to form a monolayer, was distributed equally (150 μl/m² oil) among the edges of the water surface after the crude oil had spread out, to compact and thicken the oil slick. Objects on the water surface were shown to have a negative effect on this process, distributing up to 25% of the total oil among additional small oil slicks as compared to the formation of a single oil slick on open water. The average slick thickness of the herder oil reached up to approximately 6 mm and the oil slicks could easily be ignited. However, the formation of additional slicks reduced the burning efficiency by at least 8%, as some of the smaller slicks did not participate in the burning. Burning times were also increased significantly as separate slicks needed to be ignited one at a time. The results showed that while the herding process is effective because it thickens the oil slick to an ignitable thickness, its effectiveness was reduced with increasing ice concentrations on the water surface. Current herding and in-situ burning logistics would need to adapt to the formation and burning of multiple oil slicks in ice-infested waters common in the Arctic environment in order to achieve maximum efficiency.
Data Collection of Iceberg Shape, Drift and Forcing Through Field-tested Novel Survey Techniques

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The presence of drifting icebergs in areas of hydrocarbon exploration and development represents a potential threat to offshore installations. From the perspective of platform design, the most important iceberg characteristics are frequency, size, and speed. Operational iceberg drift forecasting is also required in order to determine which icebergs need to be physically managed or when shutdown and disconnection of a facility needs to be initiated. In order to improve the basis for design and establish a data set for advancement of iceberg drift models, a study program was performed as a part of an 18-day research expedition with the Canadian Coast Guard research icebreaker Amundsen offshore Newfoundland and Labrador in April/May 2015. Statoil Canada, ArcticNet, the Research Development Corporation of Newfoundland and Labrador and Husky Energy partnered on the program, which brought together expertise from both industry and academia in an effort to collect scientific data and execute full-scale field testing of novel techniques to survey the three-dimensional shape of icebergs and monitor the essential drift forcing mechanisms. In total, 14 position beacons were deployed on five different floating icebergs and one temporarily grounded ice island fragment to monitor drift trajectories. The iceberg shapes were surveyed above water using a combination of repeated laser scanning and photogrammetry, while the iceberg keels were mapped with sonar. The influence of internal waves was studied through performing a series of CTD casts, while Lagrangian drifters were deployed in order to provide an estimate of the surface current. In a unique experiment, an autonomous, wave-powered vehicle (Wave Glider) was deployed to monitor waves, current profile, wind speed and surface hydrography, utilizing the iceberg position beacon to guide the vehicle. The study aimed to collect a complete and accurate data set of iceberg drift, iceberg characteristics, and the state of the ocean in which it is drifting. This paper will focus on the survey design, results and conclusions of the iceberg studies and provide an overview of the complete technical scope achieved through this collaborative research expedition.
Icebreakers -- A Key to Development of Shipping in the Russian Arctic

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Developments on the Northern Sea Route are contradictory. Until 2014 traffic increased at a pace few predicted only a few years ago – although still very limited in absolute terms – one of the explanations being a longer sailing season because of reduced ice cover. Nevertheless, icebreaking will be necessary for extended use of the sea route, but renewal of the Russian nuclear icebreaker fleet has been much slower than announced in various state programs over the last decade and more, whereas the official Russian expectation is still that traffic will increase considerably in the coming years. The realism in Russian forecasts can be questioned, but even if more modest projections are applied it seems possible that an icebreaker capacity problem will arise. There are uncertainties in the implementation of the adopted construction program for new nuclear icebreakers and also about the possibility to prolong the service life of existing icebreakers, as well as the capacity of diesel-electric icebreakers and the role they could play. Development of the Northern Sea Route - in connection with offshore and coastal development projects and for international transit, as well as for internal deliveries - enjoys high priority in Russian policy papers and declarations. But the question is if financial pressures will force through a rethinking of how the NSR is managed. In this connection analysis of the interest and power of actors who can influence development of the NSR is very relevant. This paper will explain and analyse the organization of the NSR with a special focus on icebreaking, and also discuss whether the use of icebreakers could be optimized to meet needs at a lower cost.
Shortcomings in Present EER Solutions for Maritime Operations in Ice-covered Arctic Waters

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There are some major differences in Norwegian and Russian maritime SAR services. The main tool in Norway is SAR helicopters (present Sea Kings will be replaced by new Augusta Westland AW101 SAR helicopters where the first two helicopters will be delivered in first half of 2017), while ships are the most important tools in Russian EER at sea. This difference reflects the distinctions between the Norwegian and Russian Arctic waters in terms of distances, infrastructure and conditions. Norway has approximately 20% ice cover while most of Russia’s Arctic waters are covered by ice in winter. This paper will present status and development prospects for Arctic SAR systems in Norway and Russia, and focus on how successful outcomes of maritime SAR operations in Arctic waters depend on a number of factors such as distance to available SAR resources, early information/detection of accidents, metocean and ice conditions. Some of the challenges that will be discussed are:

- Transit speed for seaborne rescue vehicles
- Sailing of enclosed life boats in ice with more than 60% coverage
- Pick-up of enclosed life boat using a stern ramp system
- Improve system for transfer of personnel from lifeboat/life rafts to helicopter or rescue vessel - reduction of transfer time
- Cross borderer operations between Norway and Russia (operations, accidents, prevention and EER).
Detection of Oil in Water with HLIF LiDAR

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Real-time reliable detection of oil spill in water remains a challenging task for offshore and maritime industry, first responders and environmental authorities. The task becomes even more complicated for operations in the vulnerable Arctic environment due to extreme weather conditions, icy water and very scattered and limited infrastructure. Effective oil detection in this respect means locating and characterizing the oil pollution before it becomes a major spill, thus addressing not only response but also prevention and recovery actions. The type, volume, status and dynamics of oil in water are the key parameters for planning and implementing the adequate clean-up measures. The LiDAR (Light Detection and Ranging) based on Light Induced Fluorescence (LIF) is the only tool of direct detection of oil molecules in water. The Hyperspectral LIF (HLIF) LiDAR acquires comprehensive LIF spectra and analyses them by spectral pattern recognition technique to detect and classify the type of oil in water without false alarms.

Combined use of HLIF LiDARs with Real-Time Data Management System provides the economically effective solution for the task. The HLIF LiDAR is equally effective in icy water and at varied wind, visibility and ambient light conditions. It is capable of detection of thin oil films on water surface, emulsified oil in water column, and submerged oil under the water surface. Its ability to quantify and characterize the oil can be used for managing the clean-up activity efficiently, and the high sensitivity (ppm level) allows it to be used for post-cleaning control. Multiple LiDARs installed on board of moving operational ships and stationary platforms in the area constitute the dynamic sensor network for continuous local surveillance. The cloud-based RTDMS serves to handle and visualize the geo-referenced findings of HLIF LiDAR and integrate the information from other cooperative sensors on the multilayer map with back-tracking capability. Shared access to the real-time and historical data allows information delivery to different clients according to their existing control and information systems.

Ocean Visuals AS has developed Oil in Water Locator (OWL) based on HLIF LiDAR technique. This is a novel technical solution for oil in water detection providing unattended continuous 24/7 operations without false alarms. OWL™ has been extensively tested on board of various vessels in Norway and Finland and has proved its capability to operate in harsh environment including the Arctic. The presentation describes the HLIF technology features, and the results of operational use in 2014-2015.
New Technologies for Arctic Waters: Under-ice Monitoring, and an Observatory for Real Time Ice/ocean Data and Freeze-up Forecasts

Jim Hamilton

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Effective ocean monitoring in the Arctic requires innovative tools and strategies to overcome unique challenges of the harsh environment and limited accessibility. Yet to enable responsible development and to identify and access climate change impacts, year-round long time series measurements are crucial for building an understanding of Arctic ocean ecosystems. For operational planning of Arctic marine and industrial activities, having key ice and ocean data available in real time is also desirable. A monitoring program conducted by Fisheries and Oceans Canada in the Canadian Arctic Archipelago has led to the development of several innovative technologies. The need for critical near-surface data to quantify freshwater transports was addressed with the development of a moored profiler called Icycler. This device consists of a float moored at a depth below the high-risk ice zone which houses a winch that pays out and reels in a sensor float once a day. This device has provided detailed information of the freshwater content of the upper water column, and yearlong records of fluorescence, revealing the timing and intensity of phytoplankton blooms. With different sensor payloads, Icycler has potential for under-ice monitoring of a variety of environmental parameters or contaminants. The development of a zooplankton biomass index using moored acoustic Doppler current profiler backscatter data has provided a means of monitoring the timing and productivity of the Arctic zooplankton growing season. The development of this proxy and its application to our decade-long time series, have allowed us to establish a tight link between zooplankton populations and water temperature on inter-annual time scales. Most recently, we have developed and installed an ocean observatory in the eastern end of Canada’s “Northwest Passage”. The observatory system uses acoustic modems to pass ice and ocean data from moored instruments to the end of an 8 km long underwater cable that transfers the data ashore for transmission via 2-way satellite link. Real time data from the observatory, combined with knowledge gained from the previous long-term monitoring in the area, has allowed us to provide accurate freeze-up forecasts with lead times of 2 to 4 weeks. These ice forecasts, combined with the bi-hourly year round ice and ocean data, point to the value of real time observatories for marine and resource development activities in remote Arctic locations.
Technological Challenges for Arctic Shipping

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Shipping and offshore activities in Arctic waters are increasing. In addition to shipping companies with experience from Arctic operations a number of inexperienced operators are looking for commercial opportunities for their vessels. There is need for investigation of challenges for shipping in these waters. This presentation highlights selected aspects of the A-LEX project, an interdisciplinary research of challenges related to shipping in the Arctic exemplified by the European Arctic. The main objective of the project is to establish a common integrated knowledge base of the political, legal, environmental and technological challenges related to shipping in the Arctic. The work on technological challenges focuses on investigating the kinds of systems and technologies that need to be developed to maintain safety and environmental sustainability of maritime operations in the European Arctic. The focus on technological challenges at this point would be limited to the areas of communication, navigation, and search and rescue (SAR). We study the availability of communication services ranging from shore based radio systems to satellite systems. The existing infrastructure of emergency support resources is of vital importance in the Arctic, an overview for the Norwegian and Russian sides are presented. The interdisciplinary of this work is supported by the investigation of acting rules and guidelines relating to vessel design, communication and navigation requirements for vessels operating in the European Arctic. Some preliminary results on the availability of navigational charts and hydrographic information is presented. A particular focus is placed on the status and new regulations regarding shipping along the Northern Sea Route.
Passive Turn of Turret Moored Vessel in Drift Ice: Mathematical Model and Numerical Simulations

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Turret moored vessel (TMV) is considered as potential design conception for the development of hydrocarbon deposits in deep waters infested by drift ice. In particular, this conception was discussed for Shtokman region. In conditions of relatively thick and compact ice the Azipod propulsion could be not sufficient for active turn of TMV on the spot to the position when the ice drifts against the TMV bow. Therefore, characteristics of passive turn of TMV on the spot are of interest. A model of passive turn of TMV in conditions of drift ice is formulated using the method of limit ice stresses. It is assumed that ice loads on TMV hull are varying in the time randomly in a range from zero to limit value. Limit values of ice loads for different types of ice failure are taken from ISO 19906 and other papers on ice-structure interaction. Model equations consist of kinematic equations describing 2D movements of TMV as anchored rigid body and equations of static equilibrium written for the forces and angular momentum relatively vertical axis acting on TMV by drift ice. Mooring system is modelled by single point mooring (SPM) with prescribed linear elastic characteristic. It is shown that movements of TMV before it will take final position parallel to the ice drift can consist of translational displacement together with drift ice, translation displacement with axial displacement, rotation without axial displacement and rotation with axial displacement relatively drift ice. On the last stage of the turn TMV rotates as a whole together with SPM around the gravity centre of the mooring system. SPM tension reaches maximum on this stage. Typical times and spatial orientation of the vessel relatively drift ice during passive turn are discussed in the paper.
Subjective Assessment of Risk Professional Situation of Shift Workers for Different Professional Groups in Arctic Conditions

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Activities in the oil and gas industry specialists carried out in shifts, which lead to a number of hazardous situations. These situations differently valued employees: to some of them adapted workers know how to behave and act, and therefore reduced their subjective assessment of the hazards, and the other part is still cause some difficulties and demands greater attention from the management of the enterprises. The study of these situations are addressed in this study. The aim of the research is to study the subjective assessment of hazards in the production employees in shifts of different professional groups in the Arctic. The study involved 55 employees of the oil industry in the Nenets Autonomous Okrug (the length of the shift-in period 30 days) between the ages of 24 to 60 years (mean age 38.7 +/- 9.7). Experience of work varies from 0.5 years to 31 years (9.53 +/- 7.6). With the help of survey was found a subjective assessment of hazardous situations that may arise during shifts on its hazards to the workers of the oil industry. Situations were identified based on the results of previous field research and analysis of documentation on labour protection of oil and gas companies. The assessment was made on a 7-point scale, where 1 is a minimal risk to the employee, and 7 a maximum. Statistical methods were also used. The most hazards for workers in shifts are the following situations: when family members' problems at home, and you can't help them; when you have to perform hazards for the health of the work. Due to the fact that under the terms of the labour professions in demand in the oil and gas industry, have significant differences, we assumed that assess the hazards situations of professional workers are different. Therefore, we conducted an analysis of all professions specialists who participated in the study and divided them into 5 groups: operators of oil and gas, other operators, drivers, engineers and technical workers and service technicians. The results of our study have shown that shift workers of different professional groups, there are differences in the risk assessment of professional situations: the situation changes in the weather, so that there is no exit; situation when you are ill and need to consult a doctor; have a chronic illness, but you forgot the necessary medicines, the deprivation of means of communication and injury.
New Satellite Sensors for Improved Sea Ice Monitoring

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The use of satellites for monitoring sea ice during field operations in the Arctic has grown exponentially in the past years. Governments, companies and research institutes have been using satellite imagery to analyse sea ice during their expeditions. National ice services have been using satellite imagery for years to create daily sea ice charts. This increased interest has led the satellite industry to focus their innovation towards the Arctic, launching more satellites than ever, and building sensors that can provide novel information on sea ice. The satellite sensor most often used in the Arctic is Synthetic Aperture Radar (SAR), because of its ability to see through clouds and to work even in darkness. During the last 15 years, the number of SAR satellites orbiting around the poles has increased from 2 satellites to 10, with at least 6 more planned for launch in the coming years. This multitude of satellites improves the monitoring of the Arctic by increased re-visit frequency and improved spatial coverage. Thus, providing near real time data, which is crucial for route planning, safeguarding operations, improving information and forecasting in the fast changing Arctic environment. Until now, multimillion dollar satellites have been built by national space agencies like ESA or NASA, or big companies. Recently, new private companies have found ways around this by building small satellites at the cost of only a few 100 000 dollars. They are also looking into building SAR sensors, which we believe can be expected in the next few years. The duty cycle of the radar instrument primarily depends on the spacecraft’s power constraint. The energy consumption of a SAR sensor is very high. As small satellites are not able to generate as much power as the bigger ones, low-cost satellites are limited by a poorer duty cycle. In comparison with larger satellites the small satellites fall short regarding resolution, swath width, and spectral frequency. Most SAR satellites are limited by a dawn/dusk orbit cycle. Hence, the largest coverage will occur in the early mornings and the late afternoon. High latitude increases the number of acquisition per day.

The increased amount of satellites in orbit is not the only thing changing the information available to operations in the Arctic. A new imaging mode, i.e., hybrid polarization, available on board RISAT-1 and on the pending RADARSAT Constellation Mission, will provide sea ice information that is not yet available with the traditional SAR sensors.
Ship Route Planning in Arctic Ice Infested Waters Using Near-Real-Time Satellite Image Products

Hans Eilif Larsen, Mari-Ann Moen

Kongsberg Satellite Services (KSAT), Norway

Ships operating in or near ice are exposed to various risks, dependent of ship ice class. The ice situation is continuously changing due to ice drift, causing both ice pressure areas and other areas of open waters within the ice or polynyas which are more ease to navigate within compared to through solid ice. Finding these leads requires continuously and timely deliveries of fresh data describing the ice situation. Various ice products and forecasts are delivered from met-institutes and ice service providers, however, higher resolution and better real-time-deliverables has been requested from the users optimizing their route planning.

The satellite sensor most often used in the Arctic is Synthetic Aperture Radar (SAR), because of its ability to see through clouds and to work even in darkness. Numbers of SAR satellites orbiting around the poles has increased significantly last years; hence the previous issue about coverage and frequency of potential updates is now limited in the areas around the poles. This multitude of satellites allows for increased total coverage and monitoring frequency, which is crucial for safeguarding operations in the Arctic.

Data download for ships at high latitudes in Arctic is still an issue, both the limited communication bandwidth and the lack of reliability in the data links. Cost for transfer of large data volumes is another factor the users are concerned about. Handling these issues, intelligent selection of what data should be transferred to the ship at what time would then optimize the use of the scarce bandwidth resource. A solution using ship position at the satellite image acquisition, has been demonstrated as useful to optimize the file size of the assembled satellite product provided to the ship in "Near-Real-Time". Hence, enabling route planning both finding the best way through ice or avoiding ice to reduce risk.
The Researches and Developments for Enhanced Protection of a Human Being Under Conditions of Arctic Offshore Oil and Gas Industry

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The work at offshore oil and gas industry platforms on the shelf of the Arctic seas belongs to the most hard and dangerous kinds of labour since it must be carried out in extreme natural and climatic environments (frost, strong wind and mist, see ice, icebergs, icing, constant darkness/daylight) and hazardous production environment (danger of explosion-like eruptions and fire, work area pollution with chemicals and gases, general and local vibrations) which may account for increased frequency of accidents and severity of their consequences. We have conducted experimental works, which allow for an assessment of a decrease of thermal protection properties of special clothing due to strong wind and the saturation of fabric with the sea salt at low temperatures and high humidity. A microscopic analysis of fabrics saturated with sea salt demonstrated the alteration of their structural properties entailing decreased wear resistance due to abrasiveness of the salt crystals, decreased strength due to crystals stuck into the fibres and destroying their integrity, degrading of pigments and protective impregnations, a change of anti-static properties. For protection of human beings under the previously mentioned conditions, we have developed special garments with enhanced ergonomic and thermal protection properties. The advantage of the designed special clothes is an increase in the estimate value of the total thermal resistance of 18%. According to the results of this research and development, three patents for the inventions in Russian Federation were received.
Optimising Situational Awareness in the Arctic Through Integrated Space Technologies - Arcticsat

Kay Fjørtoft 1, Fritz Bakkadal 2, Hans Eilif Larsen 3

1MARINTEK, Norway; 2Gersemia, Norway; 3Kongsberg Satellite Services AS (KSAT), Norway

The investigations performed by the Arcticsat feasibility study within the ESA’s Integrated Applications Programme has revealed the following gaps regarding appropriate situational awareness in the Arctic; a) Poor e-com infrastructure (coverage and bandwidth constraints, especially above approx. 75 degrees N), b) Poor integration of services, mainly due to limited interoperability, c) Lack of vital custom-made Arctic-specific information distribution and services (e.g. ice forecasting) - and advised means to leverage medium to longer term improvements, particularly regarding infrastructure and definition of pertinent standards.

The project’s method of approach has been to involve users and perform stakeholder analysis founded on user requirements. Concurrently a review of state-of-the-art technologies and methodologies was conducted. Together these issues resulted in a specification of an integrated solution and a system concept, followed by a proof of concept exercise. Finally, a roadmap for the way ahead was undertaken, which addressed "commercial and non-commercial" viability of the various concepts that were under consideration during the work.

Two use-cases were examined to identify service needs and opportunities; the e-Navigation and the oil spill system concepts. Some typical e-Navigation applications includes: Tactical Route Exchange, Route Suggestion, Mariners’ Notification Service, No Go Area Service, Vessel Operations Coordination Tool, Dynamic Predictor, Route Topology Model, Augmented Reality Head Up Display, Multi-Source Positioning Service (Resilient PNT), Virtual Aids to Navigation. The oil spill case focused both methods for early detection of pollution and means of deterring potential polluters, emphasizing guidelines and standards being defined by the Oil and Gas Producers Association - the global industrial body for oil companies.

The use of broadband satellite communication services in the Arctic differs from user group to user group and region, the typical usage being determined by the type of operation they are running. Ships operating in the Arctic require reliable two-way voice and data communications with the shore for exchanging information relating to the needs of the ship, its crew and its passengers. For some users, such as Cruise Ships, the Polar Code specifically requires suitable means of communication to enable telemedical assistance in polar areas, and to contact emergency response providers for salvage, SAR, spill response, etc., to be provided. Cruise ships are likely to need data rates of 25 Mbps, and oil and gas exploration vessels up to 100-300 Mbps, which is currently unavailable in the High North. The Arcticsat project has provided advices and recommendations regarding the crucial issues for awareness in Arctic.
3D Numerical Study on the Optimum Porosity Distributions of Porous Fences

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Porosity is one of the artificial devices constructed to have optical porosity greater than zero. Porous fence systems are widely applied in offshore infrastructures in the form of windbreaks to enable the control of natural climate. It was found that porosity has the most significant influence on the distribution of wind velocity and turbulence intensity, and has been recognized as the most important structural feature in the optimal fence designs. Investigations of the optimum porosity generally focus on the ratio between the open area of the fence and its total area. However, identification of the optimum porosity should further include porosity distribution, size and shape of pores, as they are the parameters that constitute the porosity as a whole. Researches on the optimum porosity are not well documented and the issue remains debatable so far. In this paper, under the same overall porosity ratio of 0.30 and the same shape of circle pores, four different 3D numerical fence models are created as: 1) uniformly spaced; 2) porosity distribution decreased with the fence height in proportion to the logarithmic nature of wind velocity profile; 3) porosity ratio of 0.40 near the fence top and 0.15 near the fence bottom; and 4) porosity ratio of 0.15 near the fence top and 0.40 near the fence bottom. For each case; size of the fence, simulation domain, inlet velocity profile and boundary conditions were kept the same. The realizable k-Epsilon turbulence model with Non-Equilibrium Wall Function was employed in all of the CFD simulations. These procedures ensure consistent comparison criteria among the different cases. Numerical models are validated through the analyses of the structures of wind velocity, turbulence and reattachment lengths, and by comparing with published experimental observations. It is concluded that 3D numerical simulations provide useful information in the research of the optimum porosity distribution with advantages of flexibility and cost efficiency.
Pre-impacted Baselines and Bio-monitoring of the Marine Environment Using Benthic Foraminiferal Assemblages -- Examples from the SW Barents Sea

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The SW Barents Sea contains significant oil and gas resources. Exploration activities were initiated during the 1980s, gas production started at the Snøhvit Field in 2007 and oil production will begin at the Goliat Field in the near future. Petroleum exploration in the region is projected to expand significantly in the coming years, increasing the potential for releases of waste associated to drilling activities into the marine environment. With these prospects, the region is a valuable natural laboratory to monitor and assess the impact of increasing petroleum industry related activities on the environment. Macrofauna is traditionally used to demonstrate the impact of petroleum industry related activities on the Norwegian continental shelf. However, benthic foraminifera are also sensitive indicators of environmental conditions, due to their specific environmental preferences and fast reproductive cycles. Additionally, benthic foraminiferal tests remain in the fossil record, enabling the reconstruction of past environments and therefore pre-impact conditions and re-establishment at already impacted sites. The use of fauna as a monitoring tool is however often complicated due to natural variability in both the ecosystem and the physical environment. As a result, site-specific impact studies are needed in a variety of habitat types in order to develop an accurate bio-monitoring tool using benthic foraminifera.

Results from the Barents Sea drill cuttings research initiative (BARCUT) –project will be presented. The main objective of the study is to identify the distribution and accumulation of pollutants in bottom sediments related to drill cuttings and their effect on benthic foraminiferal assemblages. Benthic foraminiferal assemblages, in addition to heavy metal concentrations and grain size properties are being studied close to drilling sites in the Ingøydjupet trough to capture potential environmental impacts of previous exploration activities. Additionally, the same parameters are being studied in more distal locations of the SW Barents Sea, to capture the natural variability of the area. This enables to distinguish between natural environmental change and anthropogenic induced environmental change in the future. The outcome of this study will contribute to the development of a bio-monitoring tool based on benthic foraminifera for the SW Barents Sea.
Effects of Oil and Dispersants on Microbial Community in Arctic Sea Surface Layer

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The sea surface layer is an environmental compartment heavily impacted by oil spills and oil spill response actions. While oil weathering on the sea surface has been extensively studied in various environments, effects of hydrocarbons and dispersants on the microbial communities in Arctic sea surface layers are largely unknown. As part of the Arctic Response Technology Joint Industry Program (JIP) initiated by the International Association of Oil and Gas Producers (IOGP), we tested the effect of oil spill and oil spill response to microbial communities in the Van Mijenfjord in Svalbard (78 °N). To this end, square basins were dug into the sea ice in May 2015 during a time an ice algae bloom was observed. Four treatment were tested: oil, oil and dispersant, burnt oil residue, and dispersant only. Sea surface samples were collected during a five-day incubation using glass plates, and seawater samples were collected at 1 m depth. Microbial abundance (bacteria, pico- and nanophytoplankton) was quantified using flow cytometry, and bacterial communities were characterized by 16S rRNA gene sequencing. Concentrations and weathering of hydrocarbons were analysed using gas chromatography. We will discuss the results of these experiments and will highlight the influence of dispersants or burnt oil residues, differences between surface layer vs seawater samples, and extent of oil weathering. Overall, the results of this study shed light on the effects of various oil spill response options on the microbial community and on weathering of oil at the sea surface layer in Arctic environments.
Mathematical Modelling of Stress-strain State of Encased in Concrete Subsea Pipelines

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Subsea pipelines for the transport of oil and gas are complex engineering structures, source of potential danger for the environment, therefore they should meet increased safety requirements. Under arctic conditions in particular, they must maintain a stable position and integrity under the influence of currents, storms, winds and ice movements as well as resist collisions with anchors and trawl nets. The most common cause of pipeline accidents is displacement of the pipe from the designed position, consequently this could lead to increase of stresses in the wall of the pipe and possible accidents. Earlier studies, however, have not taken into account the impact of the equivalent longitudinal force on the strength and stability of the pipeline encased in concrete. The present study, therefore aimed at investigating the effect of these longitudinal forces on concrete coated underwater beam crossing and free span section of the pipeline lying on the seabed, using a mathematical model. Briefly, the mathematical model of the pipeline was considered as a hollow elastic rod with tubular cross-section deformed under its own weight with the product, operating loads and the buoyant force of the water. Different scenarios of rigidly fixed and free bearing endings of the pipeline section were considered. The results show that neglecting equivalent longitudinal forces can lead to underestimates of the calculated deflection, bending stress and other characteristics of stress-strain state of the pipeline. Moreover, it is also illustrated, that the largest contribution to the formation of this force has an operating pressure of the pipeline. The present findings highlight the importance of equivalent longitudinal force and its necessary consideration in pipeline system engineering.
"We Were the Incubator Kids": Narratives About State Intrusion in Education and Family Matters Among Sámi People in the Soviet Union

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People living in the Arctic have had decisions made for them far away in Southern capital cities, be it in Russia, Norway or any other Northern country. The ORHELIA research project, within which I have been working on my PhD thesis, takes a bottom-up approach to the writing and reading of the histories of several indigenous peoples of the North, and how their lives developed in the 20th century. The acronym ORHELIA translates as “Oral History of Empires by Elders in the Arctic” with the subtitle “A comparative history of the relations between states / Empires and their subjects in their northernmost peripheries”. The project aims to looking at these relations in the eyes of Arctic indigenous elders, by using the method of life history analysis and oral history fieldwork combined with anthropological participant observation.

One of the common threads of all field sites of the ORHELIA project are stories about boarding schools for indigenous children. In my poster, I will focus on the implementation of a paternalistic family and education policy by the Soviet state towards indigenous people, on the example of Sámi families on the Kola Peninsula. This rigorous policy was blaming and punishing parents and children for social ills like joblessness and alcoholism for example by forcibly taking children to boarding schools, even if the parents were living in the same settlement. The comparison between oral history testimonies and documents from the archives reveals details about the dynamics of a social life inside the boarding schools, which often were not intended by the planners in the higher authorities. However, one can speak of a general strategy of shifting responsibility from the state to individuals for failures in societal changes which had been ordered by the authorities.

The data from my historical research about boarding schools on the Kola Peninsula shows in an exemplary way that significant state intrusion in the lives of Sámi people in the Soviet Union and Russia led to a very ambivalent relation of the people to the state which lasts until today. While the state and its officials are often blamed for all evil, people are used to a heavy handed state, which often results in passive, expectant attitudes.
The end of the Cold War has triggered a new process for the Arctic region. It became less militarized opening space for entrepreneurship and economic development stimulated by political support on industrialization based on the abundance and prices of local commodities. These factors increased interest in industrial and maritime activities in the region representing an incipient and unregulated reality for the local context. Industrial and maritime activities are synonymous of risk and pollution, despite the additional risk imposed by climate change. Environmental and social risks have been severely materialized by the presence of environmental contaminants as a result of intentional use or unintentional release which dispersion, accumulation and persistence gave rise to monitoring programs of Persistent Organic Pollutants (POPs), Heavy metals, Hydrocarbon pollution, methane emissions, wastes pollution and radioactivity proved to be common factors affecting Arctic ecosystems and human health. Transboundary pollution produced by natural resources exploitation and the effects of Climate Change have both global and local impacts on ecosystems and human communities. In particular, the Arctic ecosystems are intrinsically vulnerable, dynamic and highly productive providing essential ecological services for other interdependent ecosystems and human communities. Marine and terrestrial ecosystems are also interdependent and have been stressed by locally- and globally-produced pollution from different geographical and sectoral sources since the start of the industrial revolution. According to AMAP Arctic Pollution Issues 2015, the most serious environmental stressors in the Arctic have been the Persistent Organic Pollutants (POPs), Brominated flame retardants (BFRs), poly-fluoroalkyl substances (PFASs), chemicals used in pesticides, Heavy metals and Radioactivity. They have been transported long distances and deposited far from their sources of release as configuring a classic case of transboundary pollution. They tend to accumulate in the fatty tissues, milk and blood of living organisms compromising the local food chain and affecting other dependent ecosystems and human health in the Arctic local communities. It has also been observed that climate change has been affecting pathways and mobility of contaminants in Arctic snow and ice creating an important political arena for decision-making oriented to reduce emissions of contaminants, to provide sufficient and accessible information on contaminants lifecycle, to design a wider mechanism of human biomonitoring and prioritise clear food consumption guidelines and risk communication. These and other measures will need to be incorporated into a large-scale development planning to build strategies regarding future population growth, sources of energy and more resilient resources exploitation.
The Arctic Marine Biodiversity Observing Network (AMBON) in the Chukchi Sea

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The goal of the Arctic Marine Biodiversity Observing Network (AMBON) project is to build an operational and sustainable marine biodiversity observing network for the US Arctic Chukchi Sea continental shelf. This effort is critical, because the study area is undergoing both rapid climate change and increasing human activity such as oil and gas exploration. The AMBON has four main goals: 1. To close current gaps in taxonomic coverage in biodiversity observations from microbes to whales, 2. To integrate with past and ongoing research programs on the US Arctic shelf into a biodiversity observation network, 3. To demonstrate at a regional level how an observing network could be developed through an efficient set of observations, and 4. To link with programs on the pan-Arctic to global scale just as the Circumpolar Biodiversity Monitoring Program under the Arctic Council. The AMBON provides taxonomic (from microbes to mammals), functional (food web structure), spatial and temporal (continuing time series) data, includes new technologies such as state-of-the-art genomic tools, and links biodiversity and environmental observations through central data management. AMBON is a 5-year partnership between university and federal researchers, funded through a consortium of government agencies and industry. AMBON will allow us to better coordinate, sustain, and synthesize biodiversity research efforts, and make data available to a broad audience of users, stakeholders, and resource managers. The project’s first field season was successfully completed in early September.
Global warming, recorded in recent decades in the North West Siberia, leads to a change in soils temperature regime, gradual degradation of permafrost and changing landscape as a whole. We investigated the variability of active layer thickness of CALM R1 grid for last 18-years period and parameters of soil biological activity for last 3-years period. The research CALM SITE R1 (Nadym Grid) (N65°20, E72°55') is located on north of West Siberia (Russia) within the zone of sporadic permafrost of north taiga. It is 1-ha (100m*100m) grid consists of a square array of permanent stakes separated by 10 m (121 data points per grid for all measurements). Permafrost is closely associated with frozen peatlands, bog and frost mounds. The typical soils are Turbic Cryosol of frozen peatland and Histosols of bog. For last 18-years period of CALM R1 measurements was determined active layer thickness increased from 119±6 to 166±8 cm. It varies widely from 45 to 185 cm (1997) and from 55 to 200 cm and more (2015) (variation coefficient is 27,0-40,0 %). Area with small active layer thickness (50 cm) decreased from 14% to 0% in this period. Areas with deepest thaw (more than 200 cm) increased from 16 to 56%. The climatic record (weather station “Nadym”) indicates a progressive warming of annual air temperatures of ~2°C over the last 18 years (an average of -6°C to -4°C), due to increase in both summer and winter temperatures. The contribution of winter warming is ~2 times greater that of summer warming. Soil carbon dioxide emission is low and does not differ from year to year (156±21 – 2013; 132±17 – 2014; 170±30 – 2015) mgCO2m-2h-1. Average content of TOC in the upper 15 cm of soil is high (34,24±1,92%). Soil of peatland is characterized with high spatial variation of labile organic carbon (WEOC) and the microbial carbon (MC) in organic layers: average WEOC=1400±300 mgC*kg-1 soil (ranging from 100 to 3920 mgC*kg soil-1); average MC=4260±880 mgC *kg-1 soil (ranging from 100 to 9840 mgC*kg-1soil). The values of microbial biomass are high, but permafrost and hydrothermal conditions inhibit all soil biological processes. So the main factor, which determine the soil carbon efflux is the depth of permafrost table; it determines the type of ecosystem in such transitional landscapes and organic matter transformation processes.
The Impact of Climate Change on the Human Health in the Arctic Regions of Russia

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The territory of the Russian Federation in the Arctic region includes the northern and related areas of over 10 million sq. km, which comprises 64% of the total RF area. The process of the global climate changing affects the living conditions of as people so as bacterial and viral strains of northern ecosystems [11, 12, 13]. The reasons for this phenomenon are varied: the displacement of forest boundaries more to the north caused the range displacement of pathogens and infectious disease transmitters; warm air and water in the northern rivers evoked an increased contamination of the local population with infectious and parasitic diseases due to increased cases of marine mammals, birds, fish and shellfish (botulism, pneumoencephalitis, plague, seabirds' flu, herpes like virus with oysters). In future the period of a stable snow cover is expected to shorten, rainfall and runoff are likely to increase, and the temperature of water in the reservoirs will raise. Precipitation changes, drinking water quality and its availability variations are affecting the number of infectious diseases associated with water. An increased level of infectious and parasitic diseases is registered on a considerable part of the Russian Arctic as compared to the national average level of morbidity: the Nenets, Taimyr and Chukotka Autonomous Okrugs, Arkhangelsk region. An access to safe water still remains a crucial issue to ensure the health of the population as there are infectious agents revealed in the water in a number of localities [10]. The impact of climate change on human health in these regions is regarded as one of the leading negative factors that are most clearly expressed and can lead to unfavourable consequences for ecosystems in these regions, public health and traditional indigenous way of life. Infectious morbidity in these areas directly depends on the geographical location of the region and the impact of complex adverse climatic factors.
Impact of Crude Oil and Oil Spill Response Technologies on Arctic Microbial Populations

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With the oil and gas industry intensifying exploration in the far North, the impact of a potential oil spill on Arctic communities and the fate of the oil in the environment need to be better understood and response technologies need to be assessed. The International Association of Oil and Gas Producers (OGP), in support of the Arctic Response Technologies Joint Industry Program (JIP), has enlisted an international team to develop a Net Environmental Benefit Analysis support (NEBA) tool for supporting decision-making and environmental impact assessments related to Arctic spills. The project presented here is part of this undertaking, and focuses on sea ice microbial communities, with emphasis on better understanding the biodegradation process and microbial responses to petroleum and on assessing the efficiency of different response technologies, through in situ-exposure experiments in Svalbard. Total and active microbial populations in the different layers of the sea ice were characterized and specific species and genes were quantified in order to (1) evaluate the microbial response to oil spills and (2) identify the best course of action to minimize negative impact on the environment. The impact of spills and of different treatment scenarios (dispersant addition and in-situ burning) through the ice layers down to the water column were studied to better understand the inherent ability of indigenous microorganisms to degrade petroleum compounds and to increase knowledge on the fate of the oil in Arctic sea ice. Our data pointed to relatively high total bacterial numbers in clean and oil polluted sea ice. Addition of oil in all experimental cases (oil and burned oil, oil and dispersant) in the mesocosm study induced shifts in community structure (total and metabolically active fraction) indicating a fast positive response from oil degrading organisms despite the low temperatures. Q–PCR analysis targeted on Oleispira antarctica, a psychrophilic alkane degrader, showed much higher contribution of this genus in oil contaminated ice-cores compared to the controls. The contribution of Oleispira antarctica in oil and dispersant treatment reached 12 % 1 month after spill event whereas the contribution of this genus was less than 0.1 % in the control.
Microbial Populations in Greenland Seawater and Sea-ice and Their Response to Crude Oil Exposure

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Arctic seawater microbial communities and their immediate response to crude oil exposure have been investigated through the analysis of pristine and crude-oil exposed sea-ice and seawater samples. Pristine samples were collected in Scoresbysund in Amdrup Havn, Greenland at different geographical locations over the iced period (April to June), while seawater crude oil exposed samples were acquired from on-site mesocosms placed outdoors on the sea ice. Samples were collected at regular intervals over a 3-week time period to assess changes in microbial abundance, composition, with emphasis on a number of selected hydrocarbon degrading bacteria. These experiments were performed both during the Arctic winter at temperatures below -10 °C and in early spring during the start of the sea-ice melting. An increase in the total number of microorganisms over time was measured by qPCR in both mesocosm setups. Shifts in the bacterial community compositions, within days for both exposure temperatures were also observed. The ratio of *Colwellia*’s SSU rRNA gene copy to total number of bacterial SSU rRNA gene copy indicated an enrichment in these bacterial community within 1-2 days in both experimental set-ups. Enrichment of bacteria affiliated to genus *Oleispira* following crude oil exposure were also observed in both experiments, but with a much faster response from these organisms at the higher temperatures. Interestingly, the obligate oil-degrading bacteria (OHCB) Alcanivorax and Cycloclasticus often found to be abundant in oil polluted seawater sites were not significantly stimulated following these experimental exposures. Analysis of contribution of 16S RNA gene sequences in overall pool confirmed qPCR data, indicating a rapid enrichment of Gammaproteobacteria affiliated to *Oleispira, Colwellia, Glaciecola, Marinomonas* and *Marinobacter*. Sequences assigned to *Polaribacter* were found to be abundant in both polluted and non-polluted samples.
Environmental Impact Assessment: It's in the DNA

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As the sea ice retreats northward and various industries expand into the Arctic, marine organisms are potentially going to be impacted by human activity. Calculating biodiversity is integral to environmental impact assessments and requires accurate species identifications. 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 so-called DNA barcodes. We can potentially determine the species composition of complex communities, such as that of small, bottom-dwelling marine organisms, from reading the barcodes of the total DNA content of a sediment sample. However, current genetic methods introduce certain biases to the data. Our work aims to develop new techniques to eliminate the two most important biases in DNA based diversity estimates, so that they could be applied in industry. First, the DNA that we extract from environmental samples might not be representative of the live community of organisms because of so-called zombie DNA (extracellular DNA). This DNA is released from dead or broken cells and can be preserved in marine sediments. Zombie DNA creates false positives in our data. We tested chemical, physical and enzymatic treatments aimed at zombie DNA removal from mock (engineered) samples. Secondly, significant bias to the barcode read-out is introduced by the DNA amplification step, which is a necessary procedure in current methods. For our experiments, we generated mock environmental samples containing DNA free soil and known species from marine sediments. We use high throughput sequencing without DNA amplification followed by digital capture of barcode sequences. We present findings that are relevant to the application of genetic techniques for marine diversity assessment. Such methods will most certainly be essential for environmental impact assessments in the future, as industry edges its way into the Arctic.
Mining On Svalbard, Past and Present

Peter Brugmans

Directorate of Mining with Commissioner of Mines at Svalbard

About the Directorate: The Directorate of mining with Commissioner of mines at Svalbard (DMF) is the government’s technical department for administrating the extraction of mineral resources. The Directorate is a department within the Ministry of Trade and Fishery. The Commissioner of Mines at Svalbard administrates the Mining Code for Svalbard.

Legislation: DMF administrates the Mining Code for Svalbard ordered by Royal Decree on August 7th 1925. The Mining Code regulates acquisition of mining rights. Other legislation that apply to mining is the environmental act for Svalbard that is administered by the governor (Sysselmann) at Svalbard. In addition, there are legislation with regard to labour protection etc.

Mining and Petroleum activities on Svalbard: Coal mining has been the main mineral activity on Svalbard. In the period from 1920 to the early 1960ies coal was mined from 6-8 mine-camps. In addition, there has been prospecting activity. In the period from 1960 to 1990 petroleum companies and others made a considerable effort in prospecting on the island. During the last two decades the prospecting activities have declined and mainly been concentrated on coal.

Footprints of mineral activities: There have been mining operations in about 8 – 10 mining camps. Most of the mines have been small. They have however left physical remains that today comprise buildings and structures that are regarded as cultural heritage if older than before 1946. In addition, some newer remains from mining is also regarded as cultural heritage. Some measures have to be observed with regard to old and abandoned mines and technical structures even if cultural heritage. Open mineshafts and adits can represent danger and have to be closed. Acid drainage/seepage from mines has to be taken care of. Constructions that represent danger must be removed or repaired etc.

Final remarks: During the period 1907-2015 about 80 million tons of coal has been shipped from the different mine-sites at Svalbard. About 35-40 % of these coals have been extracted and shipped during the last 15 years. At present there are three mines operating at Svalbard (two Norwegian and one Russian). The annual output of coal from these mines amounts to 1,5-2 million tonnes shipped.
Using a Composite Indicator to Robustly Assess Social-ecological Systems: The Ocean Health Index in the Arctic

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Composite indicators or indices are an aggregation of individual indicators which are compiled into a single index, usually capturing multi-dimensional concepts such as sustainability, health, performance, etc. Composite indicators are used for decision making in a range of sectors such as economics, business statistics, health and academic performance and increasingly so for the environment i.e. Environmental Performance Index, Sustainable Society Index, Climate Change Vulnerability Index. Their ability to summarise and interpret complex issues, garner attention with the press and public, and reduce the need for multiple indicators has made them a popular choice among some scientists. However, composite indicators are subject to criticisms over their relevance, accuracy, construction methods, and because often the constructors are not clear about the uncertainties present, nor take sufficient consideration of the political environment they might operate in.

The Ocean Health Index (OHI) is unique in that it measures and tracks ocean health through human interactions with the ecosystem, and not merely just the state of the natural ecosystem. A healthy ocean is therefore defined as one that sustainably delivers a range of benefits to people now and in the future. The OHI assesses the ocean based on 10 widely-held public goals for a healthy ocean and each goal expresses a broad, long-term purpose; optimizing a sustainable flow of benefits to people. The index recognizes the linkages between people and the oceans and that people are inherently part of coastal and ocean systems. This means that the index emphasises values such as conservation and sustainability of extractive use.

This work will discuss the background and construction of the OHI as well as its application to the Arctic Ocean, including data, indicators and challenges. I will also discuss lessons learnt from an assessment of uncertainty in composite indicators and potential methods to reduce uncertainty within the OHI in the Arctic Ocean.
Effects of Seasonality and Spatial Heterogeneity on Polar Cod (Boreogadus saida) Diet and Distribution in Svalbard Waters.

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Changes in the seasonal light regime of high latitude environments may be of particular importance for some fish species believed to be visual predators. Endemic arctic organisms, such as the polar cod (Boreogadus saida) may be adapted to these drastic light variations whereas encroaching species may be confronted to a new set of environmental variables that could limit their northward expansion in the context of a warming arctic climate. In order to estimate fish distribution, expansion of boreal species in the future, and their impact on endemic arctic species it remains important to understand their feeding strategies and the way seasonal variation in light regime affects their ability to forage north of the Arctic Circle. This study offers a first understanding on the seasonal diet of a true arctic gadoid fish in Svalbard fjords, the polar cod. We attempted to identify whether adult polar cod feed actively during the polar night and if yes, whether their diet differs from that of the spring, summer, and fall seasons. Additionally, we investigated whether seasonal variation in oceanographic characteristics (changes in water masses) and biological factors (presence of competitors or predators) have an impact on the distribution and ultimately on the diet of polar cod across Svalbard fjords.

For this study, polar cod were harvested using bottom and pelagic trawls at different seasons and under different light regime throughout the years of 2014 and 2015, and January 2016. Polar cod were collected in both fjords influenced by Arctic water masses and fjords influenced by Atlantic water masses. The organisms’ stomach content was extracted and analysed and prey species were identified to the lowest taxonomic level possible. Additionally, we assessed fish community composition for every trawl by identifying, counting, and weighing members of species collected in the trawls. We expect that seasonal light regime and oceanographic physical components will have a strong influence on B. saida’s foraging habits. Furthermore, we expect that seasonal variation in water masses and biological factors such as the presence of large Atlantic cod (Gadus morhua) will affect the seasonal distribution of B. saida around Svalbard fjords.
Effects of Crude Oil, Chemical Dispersed Oil, and In-situ Burning on Arctic Zooplankton Reproduction.

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The copepod Calanus glacialis is a key species in the Arctic ecosystem. Increased shipping and oil and gas activities in the Arctic, potentially increases the risk of an oil spill. It is therefore important to study the potential consequences of an oil spill on this key species in the Arctic marine ecosystems. As a part of a large joint industry initiative (www.arcticresponsetechnology.org) a first of its kind mesocosm experiment was executed in an Arctic fjord of the Island of Svalbard. The aim of this study is to improve the knowledge base for conducting Arctic Net Environmental Benefit Analysis (NEBA). Mesocosms placed in a sea ice covered fjord were dosed with crude oil, crude oil mixed with chemical dispersant and residue from burnt crude oil (two replicates). In addition, the set-up included a control treatment (two replicates). The mesocosms were placed in Van Mijenfjorden (Svalbard) in February. In May water samples were collected from the mesocosm and Calanus glacialis females were incubated in this water (45 females per treatment). During a period of 14 days, egg production where measured every day, and eggs were regularly incubated to determine the egg hatching success. Preliminary results show slightly higher cumulative egg production for females exposed to chemically dispersed oil, but for the egg hatching success all treatments showed similar moderate hatching rates (45-60%). Some of the nauplii were deformed. This was especially the case in the dispersant treatment where 11% of the nauplii had deformations compared to 2-3% in the other treatments and zero in the control. Of the four treatments, 24% of the hatched nauplii in the dispersant treatment compared to ~40% in the other treatments were able to develop to the NII. Our findings support the fact that dispersants use might locally increase exposure and effects in the water column. The next challenge is to evaluate the potential consequence of locally reduced offspring of Calanus for the Arctic ecosystem in the light of effects to other Arctic resources in case dispersants would not be used (e.g. birds, marine mammals or coastal resources).
Effects of Human Activity and Global Warming on the Vegetation Productivity Around 28 Arctic Cities Detected from Satellites over 2000-2014

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Arctic vegetation in the vicinity of the urban settlements experiences significant stress from both the human activity and global warming. This study presents statistical analysis of changes in vegetation productivity within 40-km buffer zones around 28 cities in Northern West Siberia. The productivity was approximated with the seasonal maximum NDVI derived from the satellite data sets over the period 2000-2014. The analysis revealed that Arctic urbanization has a statistically significant impact on the NDVI as well as on its long-term trends. Despite the fact that Arctic cities disturb the vegetation cover, the vegetation in vicinity of the cities is generally more productive. The results demonstrate that the background regional trend in response to global warming is amplified in very close proximity to the city and shows stronger positive (or weaker negative) trends.
Effect of Glacial Drainage Water on the CO₂ System and Ocean Acidification State in an Arctic Tidewater-glacier Fjord During Two Contrasting Years

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In order to investigate the effect of glacial water on the carbonate (CO₂) system in the fjord, we studied the variability of the total alkalinity (AT), total dissolved inorganic carbon (CT), dissolved inorganic nutrients, oxygen isotopic ratio (δ¹⁸O) and freshwater fractions from the glacier front to the outer part of Tempelfjorden, Spitsbergen, in winter 2012 (January, March and April) and 2013 (April) and summer/fall 2013 (September). The two contrasting years clearly showed that the influence of freshwater, mixing and haline convection affected the chemical and physical characteristics of the fjord. The seasonal variability showed the lowest calcium carbonate saturation state (Ω) and pH values in March 2012 coinciding with the highest freshwater fractions. The highest Ω and pH were found in September 2013, mostly due to CO₂ consumption during primary production. Overall, we found that increased freshwater supply decreased Ω, pH and AT. On the other hand, we observed higher AT relative to salinity in the freshwater end-member in the mild and rainy winter of 2012 (1142 µmol kg⁻¹) compared to AT in 2013 (526 µmol kg⁻¹). Observations of calcite and dolomite crystals in the glacial ice suggested supply of carbonate-rich glacial drainage water to the fjord. This implies that winters with a large amount of glacial drainage water partly mitigate further ocean acidification, and will also affect the air-sea CO₂ exchange.
Long-term Resilience in Polar Cod Exposed to Dispersed Oil and Burned Oil Residue

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Scientifically sound information on the efficiency of oil spill response (OSR) actions to reduce environmental impacts is essential for net environmental benefit analysis. The use of chemical dispersants as an OSR is debated, as dispersants are known to significantly increase the oil concentration in the water column for a restricted time. In situ burning of spilled oil may be an alternative OSR to dispersant. However, after successful in situ burning of spilled oil, approximately 10% of the oil slick will remain in the environment as burned oil residue. The main aim of the present study was to assess potential long-term effects on polar cod (Boreogadus saida) after an acute exposure to dispersed crude oil or in situ burned oil residue. Wild caught polar cod (N=240) were individually tagged prior to being exposed for 48 hours to clean seawater (control), an environmentally realistic concentration of either mechanically dispersed oil, chemically dispersed oil or burned oil residue (N=60 per treatment). At the end of the exposure period all fish were transferred to a common rearing tank in order to study potential long-term effects on survival, growth (specific growth rate, condition factor) and reproductive investment (gonadosomatic index, gonadal histology) throughout a six months’ resilience period. The experiment is still in progress.
Coastal salt marshes are highly-productive vegetated areas at the upper intertidal that develop in wave-sheltered estuaries, deltas, and semi-enclosed bays. They sequester and store organic carbon and provide food, shelter and breeding sites for multiple invertebrates, fish, waterfowl and mammals. Due to their location salt marshes are vulnerable to anthropogenic impact associated with oil and gas exploration and transportation, which puts them at risk, as the petroleum industry develops in the Arctic region. The present levels of chemical contamination in the subarctic White Sea still allow to establish reference sites in pristine environments that can be further used in environmental monitoring studies.

Foraminiferans are meiofaunal protists common in salt marshes and well suited for environmental monitoring due to their diversity, abundance, reproduction rate, and presence of stress-tolerant taxa. The salt-marsh foraminiferal assemblages at the White Sea have never been surveyed yet.

Here, we related the species compositions of the foraminiferans and vascular plants from the two undisturbed salt marshes in the White Sea. We identified 9 foraminiferal species: *Jadammina macrescens*, *Balticammina pseudomacrescens*, *Trochammina inflata*, *Miliammina fusca*, *Ovammina opaca*, *Elphidium williamsoni*, *Elphidium albiumbilicatum*, *Ammotium salsum*, *Ammobaculites exigus*, which grouped into two distinct assemblages (‘high marsh’ and ‘low marsh’) each confined to certain vascular vegetation belts. Foraminiferans *J. macrescens*, *B. pseudomacrescens*, *T. inflata* resided at high marsh and were associated with reed foxtail *Alopecurus arundinaceus*, black-grass *Juncus gerardii* and sea plantain *Plantago maritima*, whereas *M. fusca* and *E. williamsoni* dwelled at low marsh and were associated with annual glasswort *Salicornia pojarkovae* and seashore alkali grass *Puccinellia maritima*. The foraminiferal species diversity of the studied subarctic salt marshes is lower than in temperate regions (approximately 10-30 species) but remains unexpectedly high (9 species). The White Sea salt-marsh foraminiferal fauna is highly abundant (up to 3000 living specimens per 10cm³). Expected disturbance thus can be traced using foraminiferal abundance and species diversity. We acknowledge the RFBR grant 14-04-93083 and OSL-14-11 grant.
This paper aims at unravelling the discourses on the Arctic future entailed in Russian media, in particular the dynamics related to the ongoing Ukrainian crisis and subsequent decline of economic and political cooperation between Russia, the EU and the US. During the past decade, a large number of reports, books, and articles seeking to anticipate, predict and evaluate Russia’s role in Arctic futures were published across social science disciplines. This interest is justified, as Russia is one of the key Arctic players in many respects (significant portions of oil and gas assets fall under Russian jurisdiction, Russia has a functioning icebreaking fleet (incl. nuclear icebreakers) to enable Arctic exploration, the amount of people living behind the Polar Circle is largest in Russia). However, research mainly focused on Russia’s external Arctic policy and analysed Arctic strategies, official speeches and interviews with political leaders thus following the agendas, strategies and discourses of the federal political elite, whereas local voices were seldom taken into account. Also, only a few recent publications accounted for the repercussions of the Ukrainian conflict. In order to redress this research gap, this paper offers a comprehensive study of Russia media and pursues a systematic consideration of the effects of an external crisis upon framing of the Arctic futures at two different levels (federal and regional). Methodologically, computational data mining approach is used to conduct analysis across large number of publications appeared in three federal and three regional newspapers over the period from 2012 (begin of Putin’s third presidential term) until today (N=100s). Topic modelling, a technique that allows finding and defining latent thematic structure (groups of tightly co-occurring words) in a document corpus, allows mapping networks of topics around Arctic development at different levels (federal and regional) and different periods (before the escalation of political situation in Ukraine in December 2013 and thereafter). Comparing the topic models and investigating the dynamics in media discourse relying on large and diverse data sample constitute originality of this research. Theoretically, this investigation contributes to two strains in contemporary Arctic research. First, it adds to the discussion on the Arctic exploration as a national identity-building project, investigating how Arctic futures are ‘served’ for ‘domestic consumption’ in Russia. Second, it delivers new empirical evidence on the interaction between the Arctic and the global environment, showing how a conflict in a remote area can influence expectations of the future in the Arctic region.
Outdoor Recreation in Norilsk: A Compromise Between Mining, Well-Being and Remoteness

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In XX century, several northern territories of Krasnoyarsk region, areas of traditional land use in the past, started to be managed as new industrial areas. One of the largest mining plants in Soviet Union, built above 69°N, caused emergence of Norilsk – one of the most populated cities above the Polar Circle. In XXI century, Norilsk has approx. 176,500 inhabitants and is estimated as one of the most polluted cities in the world. The city is de facto managed by Norilsk Nickel mining company, one of the world-leading non-ferrous metal producers.

Limited transport availability and remoteness of the newly built area in combination with hazardous climate and industry triggered creation and development of local recreation practice. Since 1940s, dozens of camps and outdoor recreational centres were built in the neighbourhoods of Norilsk and on the lakes of Western Putorana Plateau, a unique basalt landscape, UNESCO natural world heritage object hundred kilometre east of Norilsk industrial area.

The research has showed that transport connection of Norilsk with southern regions of Russia remains travel limiting factor due to insufficient capacity and expensiveness, even partly subsidized. It was consequently revealed that local tourism and outdoor recreation are in high demand, although the quality of environment, both natural and built, degrades with proximity of the certain recreational area or facility to Norilsk Nickel plants. The fieldwork, done in 2013, identified different forms of outdoor recreational activities and facilities in the region, with same-time capacity of more than 8,500 visitors of built recreational environment, mainly owned by Norilsk Nickel. Putorana Plateau, being the least polluted, most beautiful and short-seasoned recreational destination in Norilsk region, is visited mostly by incoming tourists due to its cost that majority of Norilsk citizens cannot afford.

The study has found that local tourism and outdoor recreation is an essential part of everyday living and determinant of well-being of area inhabitants, not only due to its necessity for healthcare in polluted conditions but also because of lack and underdevelopment of other services, including public transportation (both interregional and local), and ways of free time spending. The further discussion of the topic is aimed to the possible ways of sustainable development of Norilsk in terms of recreational resources: how to balance quality of healthcare and free time of locals, regional economic development (including tourism) and quality of natural and built environment in the region.
Microplastics in the Arctic - The Missing Link?

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Marine litter in the oceans and especially small plastic debris < 5 mm in size, termed microplastic, has emerged as a major environmental concern world-wide and has been recognized as a threat to marine ecosystems. The yearly production rates of plastics are enormous, and have been increasing from the onset of plastic mass production (1950: 1.7 million tons) until today (2012: 288 million tons). It is estimated that by 2010 5-13 million tons of plastic ended up in the oceans. How much of this plastic litter is distributed across the Nordic seas is at present unknown, but monitoring efforts are emerging throughout Europe and beyond. When considering this problem in the high North, not only activities within the Arctic are of importance, but inputs from more densely populated areas further south contribute to the local distribution of plastic litter. Plastic sources are varied and manifold, e.g. industrial fishing, tourism and recreation, as well as inputs coming from land with wastewater and/or wear and tear of everyday items and products that enter the sea through water runoff or wind transport. A number of collaborative activities have been researching the state, fate and effects of meso- and microplastics in the framework of the FRAM Centre flagship ‘Hazardous Substances’. Investigations encompass collection and characterization of marine plastic litter in water and sediments, as well as ecotoxicological investigations, spanning the arctic food web from minute plankton to top predators in Svalbard and northern Norway. For example, the effects of plastic ingested by plankton are studied experimentally (APN), while the occurrence of microplastics is examined in field samples of sediments and bottom feeders (IMR and NILU). Plastic ingestion has also been investigated in Northern Fulmars (NILU and NPI). Knowledge gaps for socio-economic assessments of microplastics pollution in the Arctic are also performed (NORUT). In addition to basic research, outreach to the general public and different stakeholders are important goals of the program.
Influence of Glaciation On Mechanisms of Mineral Weathering in Two High Arctic Catchments

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It is increasingly recognised that microbially mediated processes have a significant impact on chemical fluxes from glaciated catchments. One important reaction is the oxidation of pyrite since the production of sulphuric acid facilitates the dissolution of minerals without the need for acidity generated by dissolved atmospheric CO₂. Thus weathering processes can continue even when isolated from the atmosphere, as is thought to occur under large ice masses. However, as a glacier melts, it is expected that the microbial community will change with knock-on effects on the stream water chemistry. Understanding the difference in solute generation processes between glaciated and unglaciated terrain is key to understanding how glacial-interglacial cycles affect atmospheric CO₂ consumption by chemical weathering.

In order to investigate the effect of local environmental conditions on pyrite weathering we collected stream water samples from two small catchments in Svalbard. One catchment is glaciated and the other catchment is unglaciated but is affected by permafrost and a seasonal snow-pack. The two catchments are situated next to each other with identical bedrock (shale with minor siltstone and sandstone). The proximity of the catchments to each other ensures that meteorological variables such as temperature and precipitation are very similar.

Despite the nominally identical lithology and meteorological conditions, there were significant differences in the stream water chemistry and bacterial composition between the two catchments. Sulphate was the dominant anion in the unglaciated catchment whereas bicarbonate was dominant in the glaciated catchment. The solute chemistry of the glaciated catchment was consistent with carbonate and silicate weathering by both carbonic and sulphuric acids. In contrast, the unglaciated catchment was dominated by sulphide oxidation coupled to silicate dissolution. Stable isotope measurements of sulphate together with microbial sequencing of river sediment samples revealed that the pyrite oxidation reaction occurred under oxic conditions in the unglaciated catchment and under anoxic conditions in the glaciated catchment.

This study indicates that sulphuric acid generated from pyrite weathering is a significant weathering agent in both catchment types (unglaciated/permafrost and glaciated) and could therefore be a widespread phenomenon throughout the permafrost zone where shale exists (approximately 46% of the land draining into the Arctic ocean). Furthermore, the combination of glaciation and bacteria adapted to living in those environments fundamentally alters weathering processes and the resultant stream water chemistry, with potential downstream impacts on seawater chemistry.

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In Oulu region there has been systematic work done in defining arctic trends, technological needs and potential. A large amount of expert knowledge and insight have been collected and analysed to provide guidelines to utilizing and directing arctic expertise in the future. Strong emphasis on the expert views during analysis can be regarded as a somewhat new approach. The Finnish Funding Agency for Innovation's (Tekes) strategic opening SMARCTIC Roadmap to a smart Arctic specialization and Council of Oulu region funded project Arctic business and RDI-activity in the Northern Ostrobothnia are the background for this abstract.

To make the arctic a more accessible concept, it can be interpreted as special conditions (e.g. light, ice, natural resources, culture), operations and know-how related to them. On the other hand, arctic can be interpreted as a location of various economic activities related to arctic resources. From the latter perspective, the Barents region is often regarded as a highly potential location for Finnish companies.

In the SMARCTIC project some technological cases were modelled and analysed. For instance, in the thematic area of natural resources and economics, three separate cases were investigated highlighting business potential and research and technological needs in zero-waste integrates of metallurgical industry and bioeconomy, closed nutrient cycles and in smart energy networks.

Considering the business potential, Arctic business context can be defined in several ways. One grouping can be that (1) the core of arctic business is related to arctic resources. This core business is supported by (2) specific products and services that are based on the arctic know-how. Furthermore, as the arctic core business and necessary support activities evolve, (3) generic business emerges to respond to various needs of the core businesses. The importance of arctic expertise can be regarded as minimal with these kind of businesses last mentioned.

Some conclusions have been made in the process. Focusing means understanding the strategic significance of arctic for the companies and the clarification of RDI-actors’ position in the arctic context. Networking means e.g. creating business-orientated clusters in which the public and RDI-actors have a supporting role for the demand. Visibility means that a solution for bringing out and marketing arctic expertise is needed.

Prioritizing identified future scenarios turned out to be extremely difficult. Research process itself has helped to divide arctic context into categories according to technological needs, which should be narrowed down within co-operation with the customers when operationalizing various Arctic concepts.
From Science and Policy to People and Back: Processes of Risk Communication

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The following paper will examine the production, understanding and communication of knowledge regarding the links between pollution, local industries and inhabitants’ everyday practices in relation to health and well-being through risk communication. The paper will investigate processes and translations of official risk communication related to hazardous substances from the evidence generated by health sciences research, to the authorities’ efforts to give advice and regulation of hazardous substances. This will draw upon the knowledge that local authorities/politicians have stated as their sources of information about environmental and health risks, and it will further examine what the general population understands about health risks associated with hazardous substances and their perceptions and reactions. Thus, the content of official and industrial risk communication will be compared to the perceptions, attitudes and actions/priorities of local inhabitants, politicians and bureaucrats about hazardous substances. The analysis will draw upon surveys and interviews conducted in Russia and Norway.
Acute and Chronic Effects of Oil Spills on the Population Dynamics of *Calanus hyperboreus*

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As the oil and gas industries are moving North, there are remaining uncertainties on the impact of oil spill and response technologies in the Arctic and the resilience of species to recover from these potential impacts. The International Association of Oil and Gas Producers (OGP), in support of the Arctic Response Technologies Joint Industry Program (JIP) has enlisted an international team to develop a Net Environmental Benefit Analysis tool for response decision-making and environmental impact assessments related to Arctic spills, see Camus et al. (this conference). Part of this program is to compare population level impacts for two Arctic species with (i) acute effects and (ii) acute and chronic effects of accidental oil spills using population models. For this aim, age structured matrix models were developed for the Arctic herbivorous copepod species *Calanus hyperboreus* and the polar cod *Boreogadus saida*. These are two important species for the transfer of lipids in the Arctic food web. Information was collected on their habitat, distribution, life stages, vital rates and toxicity effects of these two species from literature and experts within the project. Vital rates selected from this information were used in the matrix models for these species. Matrix models were constructed based on four classes and based on “typical” Arctic conditions. Here we will concentrate on the copepod *C. hyperboreus* which showed a large plasticity in its life strategy and vital rates for the various life stages are site and time specific. Selecting suitable values from the broad range in the duration of life stages and vital rates is thus more limiting than actual gaps in knowledge. Toxicity information to compare acute versus chronic effects is sparse. Reported endpoints, such as biomarkers do often not reflect the information needed in population models, such as mortality and reproduction rate. Therefore, extrapolation techniques were applied to derive a function of how exposure time affects the impact at the population level.
Mineral Extraction in the High North -- Radiological Risks, Impacts and Mitigation (MINEXRIM)

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Mineral extraction is predicted to be a growing industry in Northern Norway and it is important that the development occurs in an environmentally responsible manner, taking into account the interests of other sectors. One of the main concerns with the mining industry is the large volumes of potentially contaminated tailings that are generated and the placement of these in the environment.

Mine tailings may contain metals, naturally occurring radioactive materials (NORM) and process chemicals, which due to relocation in the extraction process are made available for uptake in the ecosystem. The main focus of environmental impact assessments in former and existing Norwegian mining sites has been on metals and process chemicals, with little knowledge on NORM or the combined assessment of multiple stressors. Internationally, NORM are recognised as a matter of concern to human health and the environment in relation to mining and processing of a number of different ore types, and a better overview is needed for Norwegian sites.

In the Minexrim project, financed by the Fram Centre, we have reviewed current knowledge on NORM and other contaminants concentrations near former and present mining sites in Northern Norway. Based on this information, a field campaign was conducted around selected mining sites and known deposits in Finnmark, Troms and Nordland counties in 2015 to assess environmental concentrations of selected metals and radionuclides, and their transfer to important environmental indicator species.

Impact assessment of multiple stressors has been highlighted as one of the major challenges by national and international research and regulatory communities. Samples from the Minexrim field campaign are now being analysed, and exposure information will be used in combination with existing effect data to predict the cumulative risk these stressors represent. This effort will combine the cumulative risk assessment of chemical mixtures and radionuclides to assess the total risk of these multiple stressors for subsequent identification of the main risk drivers and the most sensitive species, and indicate areas where mitigation processes might be of most benefit. Future work within this project will be to conduct initial experimental studies on the uptake and effects of NORM and metal contaminants on various environmental indicators both alone and in the presence of other contaminants.
Decreasing Vulnerability of Mining Activities to Climate Change Impacts by Modelling Areal Water Balance

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Mining activity in the Arctic is intensifying in response to growing global demand. However, mining has vast environmental and social impacts, which might be amplified by the climate change. Therefore, it is also important to utilize modelling in assessing the possible climate change impacts on mining.

Areal water balance modelling is a powerful tool for the management of the water balance in a mine and surrounding area, especially in changing climate conditions. Areal water balance of the Kittilä mine was simulated using SYKE’s operational Watershed Simulation and Forecasting System (WSFS). The model is based on precipitation – runoff and river routing models and includes several areal hydrological variables, such as, for example, precipitation, evapotranspiration, lake evaporation, snow, soil moisture, and surface and groundwater flow and storages. Areal water balance can produce daily values, historical data series and short and long term forecasts.

The impacts of climate change on mining in the Arctic are not only negative but may also create new opportunities for mining business. According to the results of the modelling, mines will need to be prepared for possible seasonal changes in groundwater level. Elevated groundwater levels may cause undesirable development (groundwater pollution, change in biodiversity) as a result of connections of groundwater with surface water. On the other hand, lower groundwater levels could provide an economical benefit to mines, diminishing the need for dewatering and purifying contaminated waters.

The overall change in hydrology (precipitation, evaporation, snow conditions, groundwater), sea ice melting and biodiversity are expected to cause challenging situations for the mines in the Arctic. Increase in precipitation as well as extreme weather events and heavy rains require mines to adapt to these changes by improving the management of the water balance of the operations and the dam safety.

The hydrological data and knowledge in the Kittilä mine is delivered with automated data transfers utilizing online services. In this way the hydrological situation of the past, present and future in the mine area is known all the time, which significantly strengthens the decision making and risk management in the mine.
In the land areas southwest of Repparfjorden, Finnmark, several ores enriched in copper are present close to the surface. Folldal Verk mined these formations between 1972 and 1978, and during this period 1 000 000 tons of mine tailings were deposited to the inner part of Repparfjorden. The Environmental Waste Management (EWMA) project is studying industrial waste and pollution in Arctic areas. One of the objectives of the project is to use sediment cores to investigate how the deposited mine tailings in Repparfjorden spread and how it influences the fjord biota. This is particularly important if the fjord seafloor is being used as a waste deposit site for mine tailings in the future. During cruises in 2013 and 2015, several multicore cores were retrieved from sites covering large parts of Repparfjorden. These cores will be dated and are used to study the spreading of fine particles from mine tailings and distribution of heavy metals in the fjord, both temporally and spatially. In addition, faunas of benthic foraminifera will be studied. These will be coupled with the sedimentological and geochemical data, to see how variations in those records impact the fauna of benthic foraminifera, as they are known to be highly sensitive to environmental changes.
We use a multi-trophic model of socio-ecological systems (Kaiser and Roumasset, 2014) to investigate how early trade with non-Inuit communities affected long run opportunities for Inuit. At the base are living natural resources, in the middle are their human harvesters, and at the top are any managers of communities who may not directly harvest resources but can organize activities that increase the resource base and/or its harvestability. These increases create returns from physical and human capital. The effects of trade include both direct changes, e.g. in the population and in the resource base, and indirect changes through institutional gaps. A change in the terms of trade within the existing socio-ecological systems accompanied new, desirable goods like tea and tobacco. What held value came to change over time with its ability to be monetized or traded for non-Inuit goods. Examples include Arctic fox and Bowhead whales. Early trading seemed relatively innocuous -- unlikely to affect Inuit communities’ ability to thrive within their limited but balanced socio-ecological system exchanges. Both Inuit and outside traders saw trades as mutually beneficial. Further, trade introduced new technologies (e.g. guns) that increased resource pressures, and diseases that reduced human populations, sometimes rapidly. These introduced technologies and diseases and the changes in the relative value of marketable goods shifted communities away from a set of equilibrium conditions under which Inuit communities had been generally capable of sustained operations at or near carrying capacity for the environment and technology available. These transformations changed the potential role of the top layer of the socio-ecological system. The increased availability of physical capital and the increased pressure on the resource base and population led quickly to new economic challenges that needed changes in stewardship and institutions. In particular, institutional solutions needed to address dynamic impacts from overharvesting of common resources and to assure that trade not only increased present day well-being but also increased intertemporal well-being in order to restore equilibrium to the dynamics of the communities. Such stewardship evolved too slowly. Better understanding of the underpinnings of these failures should improve understanding future economic development’s opportunities without losing the benefits derived from the long-successful Inuit socio-ecological systems, which include, inter alia, superb technologies derived from full integration in the socio-ecological system.

Sustainable Mining and Climate Change - Challenges and Opportunities

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The vulnerability of the mining sector on impacts of climate change indicates that adaptation actions may be needed in the future. Mining industry has potential in the Barents area, but the future growth must rely on sustainable and environmentally sound technological solutions and long term planning.

Climate change causes challenges but it also offers opportunities for the mining industry in the north. Our case study of Kittilä gold mine in Finland, as part of the Adaptation Actions for a Changing Climate –project, indicated that some changes may be expected in terms of areal water balance of the mine. These changes may call for adaptation measures in water management and increased flexibility for both water storage capacity and water purification processes. Temperature is expected to rise especially during winter time, which will cause reduction of snow and ice cover. The snow melting period which increases water volume in the mine area may occur in different times of the year and in different intervals during the spring. Intense precipitation may be expected as well as increased number of storms, and this poses a need to develop water management in mines. It has been estimated that consequence of increased temperatures may cause need for new cooling systems for operational equipment, which might even be an advantage/opportunity for the mining in the north.

The first steps towards sustainable mining have already been taken. In general, sustainable mining industry should go beyond the regulatory requirements with long term planning of the operations. Planning should cover the whole life cycle of a mine, from the exploration to the planning phase and construction, and further on through the operational phase, and finally closure and aftercare. Mining is water and energy intensive and has overall long global supply chains. All disruptions that climate change may have on these also affect the mining sector.

The uncertainties related to impacts of climate change call for new approaches. Global demand is a driver that affects the price of raw materials, but economically profitable mine should also be concerned about what kind of technological solutions are chosen and what are the environmental and social impacts of their actions. The future sustainable solutions should be resilient, adaptive and flexible and should be continuously updated in changing climate conditions.
Emerging contaminants are widely used in the society (electronics, textiles, building materials, surfactants), but little knowledge still exists on their sources and fate in Northern environment. Tailor-made risk management needs up-to-date exposure assessment based on accurate and regionally covered research and monitoring. It will not be possible to create exposure scenarios without these, nor proof that there is no risk.

Arctic Monitoring and Assessment Programme (AMAP) produces integrated assessment reports on the pollution and trends of the conditions of Arctic ecosystems, detect emerging problems, their possible causes and the potential risk to Arctic ecosystems and residents. To this end, Finnish governmental research institutes will gather present information on both legacy and emerging contaminants in selected compartments of Northern Finland (atmospheric, terrestrial and freshwater environments and human populations). The data to be assessed includes atmospheric trends and source analysis, fish, reindeer, bank vole, osprey eggs and human breast milk. Contaminants in focus are selected persistent organic pollutants (chlorinated, brominated and perfluorinated POP substances) as well as mercury.

Time trends of contaminants (mainly legacy POPs) will be analysed using general linear regression (GLR) and source analysis with positive matrix factorization (PMF) method combined to wind and trajectory analysis. Aquatic effects of both legacy and emerging contaminants will be assessed e.g. comparing concentration data against recent environmental quality standards developed under European Water Framework Directive. Human health risk assessment will be based on concentration and exposure data and specific toxicological characteristics of the substances. Finally, the project will suggest a road-map to revised monitoring, risk assessment, management and risk communication of emerging and legacy contaminants.
Benthic Foraminifera in the Polar Winter Darkness: Starvation, Dormancy, or Algal Food Available?

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Benthic foraminifera from tropical seas often harbour intracellular photosymbionts (dinoflagellates, diatoms, haptophytes, red algae), and the cytoplasm of the host is coloured. Foraminifera at mid and high latitudes never harbour photosymbionts, but many species also have brightly coloured cytoplasm (green, brown, red, pink, yellow). This coloration is an indication of feeding activity and has two principal sources. One is the photopigments of digested microalgal food (diatoms and others). The other is sequestered chloroplasts, so-called kleptoplasts, derived from the prey diatoms. Since many proteins of the sequestered chloroplasts are coded by the prey’s nuclear genome, which is already devoured, the kleptoplasts in the foraminiferal cytoplasm cannot last longer than 2-3 months.

It is not known how high-latitude foraminifera cope with the scarcity of food during winter and whether they feed at all during lean times. In January 2015, during the Marine Night cruise with RV Helmer Hanssen, we collected live specimens in the Kongfjorden area, Svalbard. All major species (*Nonion labradoricum, Islandiella helenae, Cassidulina reniforme, Elphidium excavatum, Elphidium bartletti*) had brightly colored cytoplasm. The coloration was species-specific. Transmission electron microscopy revealed chloroplasts within foraminiferal cytoplasm. These results strongly indicate that high Arctic benthic foraminifera are not dormant during the polar night, and they access algal diet. The source of this food is yet to be detected: (1) benthic diatoms, (2) ice diatom flux, or (3) microalgal cysts.

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Environmental Effects of Arctic Oil Spills: Oil Biodegradation and Persistence

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When spilled at sea, crude oil is subjected to weathering processes such as evaporation, emulsification, dispersion, and photo-oxidation. These processes occur under natural conditions due to sea surface agitation by wind, waves, currents, seawater temperature and exposure of the oil to solar light. The chemical composition and physical properties of the oil are constantly changing according to its weathering stage. Understanding these changes is a key element in evaluating the potential impacts, optimizing the response options, and implementing the emergency response plan to an oil spill.

This project investigates the oil biodegradation and persistence in the Arctic environment. When faced with an oil spill, the measures taken to minimize environmental impact are based on a net benefit analysis (NEBA). This project aims to provide robust information for NEBA related to Arctic spills, and will address both the acute and long-term effects of oil spills as well as the impacts of various response options. It focuses on the assessment in natural conditions of the persistence and biodegradation of oil following different treatment scenarios, according to regular response options used at sea, such as natural attenuation, in situ burning (on water and on ice) and dispersion, as well as natural attenuation on different types of shoreline (rock and sediment). The first part of the project consisted in field Arctic petroleum exposures designed to monitor the long-term fate, behaviour, persistence, biodegradation of the oil and impact on the microbial communities, following different response scenarios. Oil exposures were conducted in large semi-contained mesocosms specifically designed for Arctic conditions that were placed in Svalbard. Analyses of the chemical composition of the oil within the water column, through the ice layer, water under the ice, on sediment and rock surfaces, over a six-month period will improve our knowledge on response options in case of oil spills in the Arctic environment.
Ice Sheet Velocity Estimation from Sentinel-1 Data

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In Greenland, rises in air temperature have led to an increase in ice sheet surface melting, and ice flow has fluctuated in response to changing ocean and atmospheric conditions. The mass loss from 1992 to 2011 was approximately 2700±930 Gt of ice in Greenland and 1350±1010 Gt of ice in the Antarctic continent. The average contribution of the two continents to the sea level rise from 1993 to 2010 was around 0.60 mm yr⁻¹. Thus, monitoring their changes is essential to assess their on-going impact upon society. The high cost and the difficulty of field campaigns has led to alternative methods of analysis, and specifically those which utilise satellite data. Aiming to improve the understanding of the main instability processes occurring in the polar ice sheets, interferometric techniques using synthetic aperture radar (SAR) images have being developed since 1990s to detect displacements in the glaciers surface. These methods have enabled comprehensive maps of ice sheet flow to be developed and also the tracking of changes in the position of glaciers' grounding lines. This study will aim to estimate glacier surface velocities, at a selected glacier on the Greenland ice sheet, derived from images through an algorithm based on Sentinel-1 Interferometric Wide swath (IW) mode images. The main objective is to develop observations from intensity tracking to investigate and evaluate ice velocity fields in the 12-day repeat period and resolution of the Sentinel-1 data.
After 1000 Years of Absence - The Worlds Northernmost Blue Mussels Population is Once Again Thriving During the Time of a Rapidly Changing Arctic

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The Arctic is currently facing drastic changes with regard to climate, oceanography, sea ice extent, species distribution and human activities leading towards a warmer in many areas summer ice free and therefore more accessible ocean. More favourable conditions in the North will be used especially by species with high proliferation potential and short generation times to push the edge of their distribution further. Previous periods of warming climate during the Holocene inherit drastic changes in the benthic assemblages and are found all over the Arctic.

This work focuses on the current and past distribution of the blue mussel *Mytilus edulis*, in and around the Svalbard archipelago. Blue mussels are commonly known to be a reliable climate indicator, thriving during periods of warmer ocean temperatures. By looking at the borders of their presence, the patterns in which they occur and linking this to the physical- and environmental conditions at times, we will help to better understand the driving forces behind the species distribution and changes to it over time. Furthermore, we will give an insight into the growth of the world’s northernmost known blue mussel population and provide first observations regarding reproductive output, larvae settlement and recruitment of the species along the West coast of Spitsbergen.
Indigenous Dreams About the Future -- Two Different Visions of the Arctic

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For many years the Arctic has been an object of various representation practices performed by people from outside the region as well as by the indigenous peoples themselves. In consequence, a number of different narratives appeared, projecting not only the past and present, but also the futures of the given arctic regions. Among them the native narratives seem to be of special interest, since their voices have often been neglected or even silenced in debates about the arctic futures. In our talk we turn our gaze upon two different indigenous narratives produced in two different time periods as well as by two different peoples and, what is more, with the help of different aesthetic means. The objects of our inquiry is the very first novel written by a Greenlandic author, A Greenlander’s Dream of Mathias Storch from 1914, and theatre performance The Frost Haired and the Dream Seer from 2013 based on a play written by the contemporary Sami author Nils Aslak Valkeapää and directed by Haukur J. Gunnarsson. Both narratives are indigenous projections of the futures of respectively Greenland and Sápmi. Having appeared as a reaction to different political and social situations, they both offer a unique remedy for the current problems prevailing in those politically dependent territories. Our goal is to focus on those two different indigenous visions of the future of the Arctic in order to throw light on the fact, that the indigenous inhabitants in the Arctic were active agents in the process of the discursive “mapping” of the arctic territories.
Proteomic Studies: A Prospective Tool for Estimation of Environmental Stressor Impact and Ecosystem Biodiversity

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Intertidal communities are an integral part of the complex marine ecosystem. Intertidal species can be important indicators of ecosystem health, especially in areas subject to environmental threats from municipal and industrial pollution. Periwinkles (Gastropoda, Littorina) are common inhabitants of intertidal zones in the North Atlantic region. Six species have been recorded for Barents Sea - L. saxatilis, L. arcana, L. compressa, L. obtusata, L. fabalis, L. littorea. Periwinkles are widely involved in biotic community interactions as consumers of microbial biofilms and littoral macrophytes, and as prey for crustaceans and birds. They also harbor a spectrum of parasitic worms, which are ultimately transmitted to sea bird and fish hosts. Because of their abundance and importance in communities, periwinkles could be used as model organisms for monitoring possible stress-induced shifts in community state. Littorina species populations are partially sympatric, and exhibit species-specific distributions across an intertidal zone. The species differ in their tolerance to stress factors.

Therefore, there may be differential impacts of contamination on the species populations and physiology.

Proteomics is a powerful tool in quantifying physiological changes in any organism. We characterized typical proteomic patterns of all six littorinid species and their plasticity at the proteomic level. We showed that there is significant intraspecific macrgeographic variability of proteomic patterns. British populations of L. arcana, L. saxatilis and L. compressa differ prominently from the populations of White, Barents and Norwegian North Seas. This can reflect both phylogeographic history of closely related species and ecological difference of the specific shores. We revealed that these three closely genetically related species significantly differ at the proteomic level, even while inhabiting the same shore. This demonstrates the importance of epigenetic mechanisms for emergence of species individuality. Robust proteomic differences found between two other closely related species - L. obtusata and L. fabalis - are consistent with differences in ecological preferences, indicating that their speciation was driven by ecological factors.

These results characterize littorinids as an informative model with elaborated methodology for estimation of their response at population and physiological levels to diverse ecological shifts, including those driven by contamination from various human activities. The comparison of such ecological parameters as composition of littorinid species, their vertical distribution, parasite load, and physiological state as measured by proteomics could be effective tools for estimating the effect of pollution on intertidal communities in the Barents region.
Safe maritime operations in the High North depend on the risk assessment, preparations and preparedness of the companies involved as well as the government. Activities in the Arctic are challenged by limited infrastructure, long distances and harsh weather conditions. In this paper we emphasize the importance of adequate capabilities within the emergency preparedness system based on an understanding of the probable risk factors and risk assessments. Activity and probability of accidents differs in various parts of the Arctic. In this study, we look into different risk factors in different sea regions. We focus in particular on Norwegian areas around Svalbard, along the coast of mainland Norway and on West-Russian Arctic in the Barents Sea up to Novaya Zemlya. We estimated maritime activity in these regions and provide risk assessments in the form of risk matrix (for 3 groups of the ships and 5 main types of accidents), regarding human life and environment.

We analyse existing level of preparedness, available resources for each region and possibility of collaboration and teamwork in emergency situation; the perspective of improvement, consequence of IMO Polar Code implementation after adaptation in May 2015 and SOLAS, MARPOL and specific requirements for regions under consideration.

Implications for the preparedness system both related to government and companies are discussed.
Development of new fields of oil and gas by Gazprom, Rosneft as well as extracting natural resources companies are facing transport problems. The decision will be implemented in conditions of scarcity of finances due to the global crisis, as well as time constraints. Most of the technological equipment, construction materials and other cargo for the Arctic coastal and offshore fields are transporting by sea transport, improving the efficiency of the fleet is a priority. In the Arctic there is lack of ports. Very often the transhipment is carried out in open raid ports by ships with lifting equipment (cranes and derricks). There is lack of ships of unlimited navigation area, overloads are carried out on vessels of small tonnage. During the 93rd session of the Committee on safety at sea, International Maritime organization (IMO) approved the new Chapter XIV of the International Convention of the safety of life at sea, mandating compliance with the provisions of Part I of the Polar Code for vessels that are certified according to the requirements of the Convention. The introduction of the Polar Code is expected before January 1, 2017. Existing ships will need to confirm compliance with the provisions of the Code no later than the first intermediate or renewing certification after January 1, 2018. The paper reviews the existing fleet within the jurisdiction of the Russian Federation and promising projects tramp vessels for coastal shipping. Attempted analysis of the system response and international cooperation in case of emergencies in remote areas of the Arctic.
Environmental Implications Associated with Permafrost Thawing in the Communities of Eastern Chukotka

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Eastern Chukotka is the region which is mostly populated by indigenous people - Chukchee and Eskimos. All the settlements of the region are confined to the sea coasts. This fact is generally associated with the traditional way of life of local population: sea hunting and fishing. Modern engineering facilities in the communities have been weakly adapted for exploitation on permafrost and have been having negative, but non-critical impact on frozen grounds. Since 1990s the socio-economic situation has dramatically changed, and consumer service of engineering systems has declined. In addition, climate changes have complicated the situation. This had led to building deformations, geotechnical risk increasing and acceleration of negative cryogenic processes. The research methods include geophysics, thermal modelling, field geodetic surveys, use of archival topographic maps, data of permafrost engineering surveys, satellite high-resolution imagery, etc. The majority of living houses in Eastern Chukotka was built before 1990 and has deformations, following with numerous cracks in walls and floors. Frequent fresh water leakages form swampy areas, which often leads to thermoerosional ravines formation. Study revealed existence of technogenic taliks (thawed areas) under old living houses. Built-up areas of studied settlements have changed permafrost conditions that can be dangerous for further exploitation and development. As the general population depends on the hunting on marine mammals, the communities of Chukchi Peninsula are experiencing sea impact to a different degree (mostly negative), because they confined to the shores of the Bering and Chukchi seas. The information about most of the settlements in the region is known since XVI-XVIII centuries, which allows indirectly judge about relative stability of coast sections where they are located. However, the comprehensive analysis has revealed the fact of retreat of coastal sections located within some communities in the recent years. Some engineering facilities situated near the sea either has been destroyed or are under the threat of destruction. Mentioned problem may have more disastrous trend in the future. Thus, forecast of cryogenic processes development and key recommendations for mitigation and adaptation to changing permafrost conditions has been developed. The work was financially supported by U.S. National Science Foundation OPP-0352957 grant and UK PF PPY RUS 338 «The human impact on carbon emissions in tundra environment: estimation and reduction (case study) ».
The Calculation of Maximal Depth of Unexplored Lakes of Karelia

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In this work we have created a formula for calculation maximal depth of unexplored lakes of Karelia. Information about a maximal depth of a lake is very important for understanding anthropogenic influence. The method allows to get information about a maximal deep of a lake quickly, without spending a lot of time and money.
Local Populations’ Perceptions of Risk Related to Pollution. Cases from North Norway and Russia

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Industrialisation in North Norway and Russia has led to various degrees of local pollution. Some communities are also exposed to long-transported pollution. This can constitute human health risks through air, food or water, and can also impact local ecosystems. We present data on risk perceptions related to this for populations in communities in North Norway, Murmansk oblast, Arkhangelsk oblast and Komi Republic. We show differences and similarities between the communities, and also analyse associations between the populations’ risk perception and consumption of locally produced food, their outdoor activities, and wish for their children to grow up in the area. We also compare the risk perceptions with expert knowledge. The data are from a 2013-14 survey.
The Russian Mining Industry's Role for Use and Development of the Northern Sea Route

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There has been considerable attention to transit shipping between the Atlantic and Pacific seas through the Northern Sea Route. The possible contribution of destination shipping of minerals and metals to the shipping in the Arctic, and particularly along the Northern Sea Route has been less described. We present three elements for a better understanding of the potential the mining industry in Russia constitutes for Arctic shipping: 1) A mapping and analysis of transport alternatives, policies, reserves and plans of the mineral sector in the different regions of the Russian North; 2) a system for data and analysis of world prices for minerals relevant for the Russian Arctic, export and shipping statistics, and; 3) an analysis of the links between them.
Sources of Polyaromatic Hydrocarbons in the Bottom Sediments of the Northern and North-Western Parts of the Barents Sea

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Detailed organic geochemical study of the immersed bottom sediments of the Northern and North-Western parts of the Barents Sea region indicated the significant difference in the group and molecular composition of the dispersed organic matter (DOM). Hydrocarbons (HCs) distribution anomalies were identified in the western part of the Svalbard Island shelf, the area around the Shtokman gas condensate field and the Kola-Kanin Monocline shelf zone. The studied sediments (9 cores, up to 2 m length) were collected during scientific research cruises of “VNIIOkeangeology named after I.S. Gramberg” (Saint-Petersburg, Russia) to the Barents Sea between 1992-2006. Analytical procedure included the determination of elementary (TOC, Ccarb), group and molecular composition of DOM soluble part using preparative liquid chromatography and GC-MS analysis with the Agilent Technologies 6850/5973 GC System. The studied samples are generally represented by low carbonate homogeneous pelites and aleuropelites (Ccarb≤0.8% in sed.). The total organic carbon slightly varies through the sediment section and regularly decreases with depth, not exceeding 2% in the upper layer of sediments for the region. The maximum of chloroform bitumoid “a” was detected in the Svalbard shelf area (up to 0.04% in sed.). The molecular composition and ratio of PAHs in the Svalbard samples points to the high level of OM transformation (MPI1≥0.6), that along with the lack of biogenic structures (perylene, cadalene, rethene) and increased concentrations of naphthidogenic PAHs (phenanthrene, alkyl-phenanthrenes), indicates the genetic association with the shore coal deposits. The Shtokman and Kola-Kanin Monocline sediments revealed other general trends in PAHs distribution. They are distinguished by a lower maturity level (MPI1<0.5), halving of naphthidogenic components and the great increase of biogenic structures (mainly perylene) relatively the Svalbard shelf zone. In the case of the Shtokman gas-condensate field area this could be due to the process of endogenous migration resulting in strong reducing conditions of sedimentation and new PAH formation. Speaking about the special DOM distribution near the Kola-Kanin Monocline the significant influence of the Atlantic flow, as well as an increased level of sediments contamination (high content of pyrogenic PAHs) should be considered. Thus, the character of the group composition and hydrocarbons molecular structure of this three studied Barents Sea sites allow to conclude the prevailing importance of the provenances and endogenous processes for the formation of OM background in the region.
Industrial Metal Pollution - New Methodologies for Identification of Source and Biological Threshold Levels in Terrestrial Ecosystems - Isotope Fingerprinting and Bacterial Community Responses (ISOFIN)

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Industrial activities in northern areas are important for socio-economic development. Mining and metal smelting processes do, however, often result in widespread contamination of the surrounding environments with e.g. metals and metalloids. Metals at high concentrations are a reason for serious concern, especially for humans and other mammals, due to its accumulation in food chains. Increasing temperatures from climate change may increase the abundance of available metals in the nature. Most practices used so far in order to monitor pollution from metallurgical industries focus on concentration data alone, which results in difficulties in evaluation of pollution sources and their relative contribution.

ISOFIN is a long-term EEA-Norway Grants project 2014-2018. Researchers from the Czech University of Life Sciences in Prague will develop and test new powerful pollution evaluation methodologies based on stable isotope fingerprinting. The method has previously been used for tracing Pb pollution sources and the ISOFIN project extends this approach to other metals such as Cu, Ni and Cd. Along pollution gradients various "immediate" environmental samples (snow, lichen, mosses, soil) will be analysed and peat cores and other "archives" will be analysed to trace historical pollution and its sources. Manuals for sample preparation, pre-treatment and analyses using TIMS will be developed.

In the ISOFIN project, the Norwegian Institute of Bioeconomy Research (NIBIO) will in addition develop new methods using microbial communities (N-fixing cyanobacteria) responses as indicators of thresholds for metal pollution effects in terrestrial ecosystems. Metal and organic pollutant levels in humus soils has been monitored in Eastern Finnmark by The Geological Survey of Norway (NGU) from 1995 and this will continue within ISOFIN. The importance of such monitoring is shown from recent observed elevated Cu and Ni abundance in North-East Norway.

The ISOFIN project focuses on polluted areas with metal processing industries in North-East Norway (Pasvik) and in North-East Czech Republic (Ostrava). The approach using stable metal isotopes enables for the first time identifying and quantifying separate pollution and natural sources. When coupled to concentration and mineralogical data, and biological threshold indicators, it has good prospects to become a powerful tool for environmental analysis, monitoring, risk assessment and subsequently for environmental managements decision-making. Preliminary results from the project will be presented.
A Local Level View on how Potential Harms of Local Industrial and Long-range Transported Pollutants are Discussed and Communicated in the Barents Region.

Anne Katrine Normann ¹, Natalia Kukarenko ², Eirik Mikkelsen ¹

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As part of a larger Russian-Norwegian collaborative research project, we study the role of local bureaucrats and politicians in balancing industrial and environmental issues. Their interaction with local industry actors, as well as the information exchange with each other, and with the local community, about environmental pollution, are part of their role as local level decision makers. The presentation is based on cases from Norway and Russia. We seek to understand the role of local authorities and local politicians in regulating polluting industries, and their different direct and indirect approaches to regulation. Of importance is to get an understanding of how they acquire scientific and other knowledge of hazardous substances, and how they monitor the status of environmental pollution in their community. This determines their deliberation and their approach to pollution related tasks. In presenting results from the study, we will emphasize local bureaucrats’ and local politicians’ own view on their role, options and choices regarding local level pollution regulations. This is analysed in relation to legislation at national and international level. To some extent, local level bureaucrats and politicians are tied by national and international agreements and obligations. We seek to reveal how they act within such external frames, and how they negotiate and manoeuvre within their local level action space of decision making, where economic, demographic, social and environmental realities are to be taken into consideration.
NEES and NEES2 -- Natural Energy Efficiency and Sustainability in Design and Construction in the Northern and Arctic Periphery of Europe.

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Architecture and building must take on board the need for increased energy efficiency and sustainability that the world’s scientific community now demands to combat climate change and associated environmental challenges. There are a variety of approaches and strategies that have been advanced towards this aim, some stressing the need for more advanced technological solutions, others advocating a shift or return to lower-impact intermediate technologies and materials. A Circular Economy approach, based on the reuse of materials previously considered waste, has been promoted. The NEES Project, developed from 2010 to 2014 by the Cork Centre for Architectural Education (UCC and CIT) explored a range of approaches to this problem, starting with a review of the producers and service providers that were active in Northern Periphery and Arctic region of Europe, identifying best practices on the basis of a holistic NEES Criteria for sustainability, assessing and grading available resources and setting up a small number of Pilot projects to demonstrate and evaluate the viability of these approaches. The paper will address the specific challenges of the Northern and Arctic Periphery of Europe, aiming to define both the rural and arctic nature of design and construction required in the region, and suggest how renewable and recycled building materials available and nature-based processes can be appropriate for the region. The paper will look at the central importance of the life-cycle impact of products and services used, and explore the potential of nature-based processes, such as constructed wetlands and bio-climatic design in providing more sustainable building in the region. The paper will also look at appropriate case studies at a product specific and whole-house level and neighbourhood level, which illustrate these approaches. The paper will try to establish the ideal profile for sustainable design and construction for this region, in preparation of the development of a NEES 2 Project.
Modelling of Metals Transformation in the Seawater Originated from Produced Water

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Drilling activity results in appearance of produced water (PW) and drill cutting that are the major sources of contaminants entering the sea from offshore oil and gas regular operation. Metals in PW discharges on the Norwegian Continental Shelf are significantly above Norwegian coastal water background level (Ba, Fe, and Hg – a factor 1000). Ba and Fe are redox sensitive and may precipitate upon discharge that also influence the behaviour of other metals (by coprecipitation). The toxicity of PW may be influenced by chemical portioning and kinetics following discharge. The large overall discharge volumes, the complex content of partially hazardous chemicals, and the lack of knowledge on possible long term ecological impact has made PW discharges the strongest target for research in recent years. The goal of this study is to evaluate the effect of PW on oxygen depletion, nutrient regime and transport and transformation of metals in the benthic layer. We use a biogeochemical model BROM (Bottom RedOx Model) that considers transport of matter in the water column, the Bottom Boundary Layer, and in the upper sediment together. This model includes descriptions of organic matter formation, decay, and reduction, oxidation and transformation of N, C, S, Mn, Fe and P and Si species. In this study, we plan to parameterize transformation of the chemical elements injected with PW to the seawater in highest concentrations, i.e. Ba, Fe, Mn, Hg and Ni. Modelled results of seasonal variability of distribution of dissolved oxygen, hydrogen sulphide, and species of nitrogen, iron and manganese both in water column and in the sediment upper layer are in good agreement with data of observation for regions subjected to seasonal anoxia. Seasonal dynamic of dissolved barium is characterized by its accumulation in the surface layer during the formation of summer thermocline that leads to the possibility of a further spread of this toxic forms of barium and its bioavailability in a larger area of the sea from the drilling well. It should be noted that dissolved barium presents in free form in seawater for a long time after PW discharge, despite the supersaturation with respect to BaSO₄. This shows the importance of considering both the deposited and dissolved forms of barium in the interpretation of its effect on the ecosystem at PW discharge. This research is funded by VISTA – a basic research program and collaborative partnership between the Norwegian Academy of Science and Letters and Statoil.
In High-North mining, oil and gas, offshore and metal industries face large challenges in wear, corrosion, fatigue and excessive energy consumption. To address these needs, novel cost-efficient and environmentally friendly surfacing and additive manufacturing technologies based on cold-arc and laser hybrid metal deposition techniques are developed. Development, adoption and commercialisation of high productivity deposition techniques enable:

- Fabrication of low diluted and fusion bonded coatings with enhanced wear and corrosion properties with low friction and anti-icing properties.
- Fabrication of large near net-shape 3D metal objects with 30-40% more weight efficient structures compared with conventional manufacturing.
Examination of an Arctic Search and Rescue Communication Architecture

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Over the next ten years, $100 billion or more could be invested in support of Arctic natural resources, shipping, and tourism. In the near term, traffic due to fishing, exploration, tourism and both destination and through shipping will increase. Drilling for oil and gas along with undersea mining will further increase traffic and increase the risk of an environmental mishap. Even though areas of responsibility are well defined, a coordinated search and rescue response is hampered by a lack of infrastructure that includes out-of-date hydrographic surveys, insufficient aids to navigation, and poor communication capability. The United States lacks a strategy and investment plan that makes the best use of limited resources in a region that needs infrastructure improvements in many areas. Almost all stakeholders agree there is an immediate need for improved communication capability and in particular, a need for broadband communication infrastructure above 65 degrees north.

Related to communication, there is a need for a multi-national command and control strategy that operates within the limited bandwidth currently available. There is also a need for improved situational awareness and forecasting with respect to environmental, weather, and ice conditions. Existing systems have been deployed over time without a consistent view of the needs or capabilities of an internationally coordinated search and rescue mission. A systems engineering approach was used to document current and potential future capabilities as an integrated technical architecture. A mission decomposition was used to identify stakeholders, stakeholder needs, and primary search and rescue scenarios. These were then used to derive a functional architecture that included navigation, domain awareness, and communication. The architectural tradespace for communications was analysed using quality function deployment as a way to examine the impact of potential investments in filling capability gaps. This was used to create a tradespace analysis tool that evaluates various technical solutions based on prioritization of capabilities versus cost. This analysis provides a baseline for a toolset supporting an incremental development plan that increases capability with increases in maritime traffic. The presentation will summarize the primary motivations, the primary findings, and future study. Conference Suggested Topic, Part III: Technology needs, 3. Shipping in the North, Emergency preparedness
Spheroidal Carbonaceous Particles (SCPs): Indicator of Atmospherically Deposited Pollutants in Kongsfjorden, Ny--Ålesund, Arctic

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Spheroidal carbonaceous particles (SCPs) are produced during the incomplete high temperature combustion of fossil fuels. Since these particles have no other known natural source, their presence in the snow and soil in such pristine areas as the Polar Regions can serve as proxy indicators for anthropogenic pollution. In this study we have carried out a morphological and chemical characterization of the SCPs extracted from the surface sediments of Kongsfjorden in Ny--Ålesund, the Arctic. The characterization was carried out by scanning electron microscopy coupled with X--ray spectrometer (SEM-EDX). The prevalent particle types in all the samples studied were granular-spherical, hollow-spherical and irregular shaped carbonaceous particles. Analysis of the elemental composition showed that the particles are mainly composed of C, O, Na, Si, Al, K, Cl, and Ti. Some particles contained heavy metals Fe, Al, Cu, Cr, Zn, Pb and Ni which indicate that the SCPs could have acted as the dominant carriers of the heavy metals deposited in the surface sediments.
Areas of strong tidal currents have previously been described as important habitat for small cetaceans such as harbour porpoises (Phocoena phocoena). These areas are often also of interest for marine renewable energy developments, due to the high energy production potential from such currents. This study investigates the presence and habitat use of porpoises in the tidal current Rystraumen (69.55°N 18.73°E) in Northern Norway. It discusses the findings in light of the ecological importance of the tidal channel as a feeding and transit area for porpoises, and the various human uses such as shipping and future plans for the development of tidal turbines. Two methods were applied to monitor the use of the site by porpoises; passive acoustic monitoring and visual land-based observations. Five C-PODS that record echolocation clicks from toothed whales, were deployed along with 3 SoundTraps. They were placed in and around the Rystraumen strait, between the islands of Kvaløya and Ryøya. Visual observations were carried out at Hella, a vantage point overlooking the width of the strait. Using a camera/reticular binocular system and a number of geographic reference points on shore, harbour porpoise movements could be tracked with high precision by triangulation. The acoustic activity was analysed using a classification algorithm that distinguishes harbour porpoise click trains from other acoustic signals. The occurrence of these click trains was then linked to environmental variations such as time of day and state of the tidal cycle. Data collection was done from late August to the end of September 2015. The results from both methods show that porpoises use the area regularly. Both non-directional (most likely foraging or milling) and directional behaviour was observed and the small scale spatial movements were analysed in respect to the occurrence of tidal flow. Porpoises were observed frequently using (and remaining in) areas adjacent to the areas of highest tidal current flows, while movements in high tidal flows were generally directed and rapid. Rystraumen is a potential site for future development of tidal energy plants, but it is also designated as a potential future marine reserve. The findings of this research therefore provide important baseline data that will provide important input, both into risk and environmental impacts assessments of potential future site developments, but also for habitat classification and designation as a potentially important marine reserve.
Sensitivity of Arctic Zooplankton to Chlorine as Ballast Water Treatment

Andrea Sneekes 1, Klaas Kaag 1, Martine van den Heuvel-Greve 1

IMARES Wageningen UR

Climate change has caused the retreat of sea ice in the Arctic region, opening up the northern sea route for shipping. This route has great economically advantages, but also allows unwanted alien species to enter and pass the Arctic region. To stop the spread via ship’s ballast water, a treatment to sterilise the ballast water will be used. Chemicals related to ballast water treatment may enter the ecosystem posing new and unknown risks for this specific region. During the Dutch expedition SEES.nl in August 2015, the sensitivity of Arctic zooplankton to chlorine as ballast water treatment chemical was investigated for the first time. Locally collected zooplankton species were exposed to a range of electrochemically produced chlorine concentrations and the mortality was monitored. The tested species, test set-up and results will be presented.
The Northern Sea Route Development: Economic and Political Implications

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Intensifying world economy now faces resource and transit challenges which make officials of different states and international companies pay more and more attention on the melting Arctic. In this context the Northern Sea Route (NSR) is considered to play a key role since its development will open up new transport opportunities and foster the extraction of Arctic resources in the decades to come.

Nevertheless, alongside with ambitious plans of various states (both Arctic and Asian ones) to exercise their strategic plans in the Arctic, there exist the range of potential obstacles able to hinder the NSR development in the short-term perspective. First, Russia faces huge infrastructure problems (in terms of constructing ports, icebreakers, and intellectual infrastructure) aggravated by the recent economic instability and the decline in the relationships with Western countries. Both the decrease in oil prices and the slowdown of oil gas activity in Russian Arctic bring no benefits for the further development of the NSR. Second, the transformation of Asian socio-economic development model (primarily Chinese) change patterns of the world trade, making countries be less exposed to interregional trade. The growth of Euro-Asian trade is gradually decelerating in recent years.

What is more, it is hard to neglect the fact that the short-term development of the NSR is highly dependent on its commercial viability and cost efficiency as compared to the Suez Canal route (the most common route bridging Europe and Asia). Together with depicting long-term factors impeding and fostering the NSR route development this paper focuses on current economic feasibility of the NSR which is defined by the level of transportation costs in comparison to alternative transport routes. The NSR is commercially viable only for transportation of specific type of cargo – bulk cargo in warmer months from Northern East Europe to Eastern Europe. The paper provides evidence on cost components establishing the level of total transhipment costs for a vessel, attaching importance to ambiguity of fuel costs which can play both positive and negative roles in terms of the NSR competitiveness.
Whaling Regulations and Greenland: The Case of Qeqertarsuaq

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At the Environment Council on 2008, the European Union stated its common position in support of maintaining the moratorium on whaling. The ‘Protection of whales’ is part of acquis communautaire which new signatories are obliged to adopt. This law prohibits the slaughter and transportation of whales within European community waters. In essence, while it clearly presented the standard of protection of whales as the common position held by all member states. In general, the controversy over whaling is mostly generated from organizations within the protection of whales’ block, whose members believe that whales should not be exploited by humankind. This can be traced back to the protectionist activities of countries such as the United States, which created an influential whale-protectionist majority, especially after the 1970’s. Moreover, the actions and ideas of the whale-protectionist block were synchronous with the broader animal rights movement and the Green Movement which emerged after the 1970’s. This led to the recommendation of a ten-year moratorium on commercial whaling at the United Nations Conference in 1972. The adoption in 1973 of the Washington Convention aimed at regulating the trans-border commerce of certain species. In addition, commercial whaling was temporarily banned in 1982 by the International Whaling Commission. The establishment of whale protection as a standard EU position is in line with the trends of the broader global community and the IWC. The Environment Commissioner of the EU said: “With this decision, the EU can now take a strong role at the IWC and use all its political, moral, and economic weight to ensure a more effective protection of whales worldwide”. The fact that the EU established whale protection as a common position held by all 28 countries clearly shows it acted in collaboration with the IWC, and that all the individual actors aligned themselves with the whale protection discourse promoted by the IWC. The main objective of this presentation is to examine the actual influence of EU decisions on the areas that conduct whaling and on the people who live there. Greenland enjoys the right to whale under the framework for aboriginal subsistence whaling officially regulated and managed by the IWC. We shall conduct a survey in Qeqertarsuaq, Greenland and, based on that, offer an analysis of the current whaling situation, which is influenced by international politics and the movement for the protection of the environment.
More Oxygen in Water - More Cod on the Table

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Oxygen is present in water molecules. Oxygen saturation of sea water is calculated as a percentage of the equilibrium saturation at specific temperature and salinity. The biochemical oxygen demand (BOD5) indicates the volume of oxygen consumed for oxidation of organic matters and marine pollution. Dissolved oxygen is an important determinant for stability of waters and survival of water organisms. The generally accepted minimum amount of dissolved oxygen that will support a large population of various fishes is from 4 to 5 mg/l. Most pristine waters may have BOD5 value below 2 mg/l. Oxygen saturation of bottom waters in the Barents Sea is most frequently measured along the Kola Section. More than 330 cases of measurement were made in 1957 – 2015. Since 2010 PINRO has observed BOD5 (biochemical oxygen demand) in the bottom layer. Arctic seas have in general well-oxygenated water that is due to a strong convective mixing and relatively low biochemical oxygen demand. In open areas of the Barents Sea, oxygen content in water rarely falls below 8 mg/l (80% saturation). The BOD5 value ranged from 0.3-2.2 mg/l in 2010-2015. According to these indicators the Barents Sea is quite comfortable habitat for marine organisms. Moreover, oxygen saturation of sea water is most statistically reliable natural indicator of abundance of Northeast Arctic cod year classes. Abundant generations of cod appear under increasing water aeration of bottom waters, so the relationship has a complex mathematical character. It is proved that aeration of bottom layers is related to intensity of Atlantic water advection from the western Barents Sea and intensity of convective mixing of the water column. It is now also studied the relationship between BOD5 and oxygen content in water. Thus, changes in water chemistry and biomass of large commercial fish populations of the Arctic seas show processes that were previously known for lakes and enclosed seas such as the Baltic Sea. In contrast to the previously known laws, changes in the oxygen saturation of the Barents Sea waters occur in the range that has no direct effect on the survival of young fish. The existence of such laws is a prerequisite for the expansion of research into the impact of changes in the aeration of water in the Arctic seas. So, we can safely say that for the Barents Sea just saying that more oxygen in water means more cod on the table.
The copepod *Calanus glacialis* is a key species in the Arctic ecosystem. Increased shipping and oil and gas activities in the Arctic increase the risk of an oil spill. It is therefore important to study the potential consequences of an oil spill on this key species in the Arctic marine ecosystems. As a part of a large joint industry initiative (www.arcticresponsetechnology.org) a first of its kind mesocosm experiment was executed in an Arctic fjord of the Island of Svalbard. Effects of natural attenuation of the oil, *in-situ* burning and chemical dispersion were studied on grazing, egg production and hatching of the Arctic copepod *Calanus glacialis*. Eight mesocosms with open top and bottom were deployed in the sea ice in Van Mijenfjorden, Svalbard, in February 2015. Two replicates were used for all treatments. After application, surface ice was allowed to re-establish. Water was collected from the top 2 cm water column in March and just before sea ice break up in May, and was used in two 14-day incubation experiments with *C. glacialis* collected in Isfjorden. Copepods were fed during the experiment and eggs and pellets were quantified daily. Egg hatching was determined in the beginning and end of the experiment. There was no significant effect of the oil spill treatments on average cumulated specific pellet production or egg hatching success. However, in May, the average cumulated specific egg production was significantly higher in the dispersed oil treatment compared to the control from day 2 (+ 169 %) until the end of the experiment (+ 41 %).
Light Penetration, Nutrients and Ice-algal Growth in Experimental Mesocosms Exposed to Oil and Dispersants.

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The production of microalgae in bottom sea-ice contributes to support benthic and pelagic food webs in the Arctic Ocean. The presence of oil and dispersants in the ice can potentially affect ice-algal productivity directly through toxicity or indirectly by modifying their growth environment. Indirect effects may occur through alterations of light and nutrient availability, which regulate the timing, quantity and quality of primary production. Impurities in the sea ice can attenuate light penetration during winter, but eventually augment it in the spring by reducing albedo and fostering the formation of melt ponds. The accumulation of biomass by ice algae and the consumers that rely on this biomass is contingent on the supply of essential nutrients at the ice-water interface and within brine channels. Upward nutrient supply can either be diffusive, turbulent or advective, depending on the physical properties of the brine, which is possibly affected by the presence of oil and dispersants. Within the framework of the Arctic Response Technology Joint Industry Program (JIP), the International Association of Oil and Gas Producers (IOGP) supported a field study of the impact of oil and dispersants in sea ice within mesocosms installed near Svea (Svalbard). The 3 experimental treatments included the addition of oil alone, combined oil and dispersant, or burnt oil alone at the surface of the mesocosms. In each of the 8 mesocosms (3 treatments + 1 control, all in duplicate), we measured nutrient concentrations, light penetration, the concentration of chlorophyll-a, the elemental composition of organic matter, and rates of primary production and nitrogen assimilation in bottom ice cores (3-5 cm) during late March, mid-April and early May. The preliminary results are presented here, along with a discussion of possible impacts and methodological challenges.
Reshaping Arctic Discourse(s) and the Emergence of an Arctic Transnational Field: Change as a Precondition for Change

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In this presentation I discuss the emergence of ‘Arctic change’ as a discourse, and the implications of this on Arctic politics. Changing Arctic has been a hot topic in recent public and academic considerations. Environmental change through climatic shifts and the subsequent awakening of economic interests have inspired novel conceptions of a more open and globalized north. Simultaneously an increasing number of actors have expressed their interests in relation to the Arctic forwarding interpretations of potential for conflict and cooperation. A fundamental issue often escaping the analytical gaze of Arctic (geo)political research is how ‘the Arctic’ is being (re)constructed by the actors to realize their emerging interests. This can be revealed through studying Arctic discourse(s) the actors engage in and produce. To achieve this, strategic policy documents and/or declarations addressing Arctic issues were analysed. The material included documents produced by state and sub-national actors, the EU and NGOs, which opened up a possibility for a comparative approach. Critical discourse analysis was applied, through which the socially shaped and shaping aspects of the interests were interpreted. Key argument drawn from the analysis is that while the actors justify the expression of their goals by addressing the Arctic as a ‘changing region’, they simultaneously (re)construct the change and ‘the Arctic’ discursively by attaching new meanings to them. These meanings revolve around possibilities and threats connected to change that require specific action. The intermingling of physical change and the discourse built on it attracts and enables new actors to state their ‘Arctic’ interests. As the Arctic has been constructed into a geographically and politically exclusive region through institution-led regimes (especially the Arctic Council) since the 1990’s, the growing attention Arctic issues are receiving suggest, and forward the emergence of a topological space transcending established institutional settings. Rather than merely reading this as internationalization of the Arctic, this emerging space can be theorized as an Arctic transnational field, where the Arctic, its discursive constitution and especially the terms of political inclusions/exclusions are becoming increasingly contested. This contestation, is based on actors’ possession of specific forms of legitimate capital, on which a status as an Arctic ‘stakeholder’ is built. Forms of capital deemed legitimate and applied in the Arctic context are transforming alongside the discursive (re)production of Arctic change. Especially the production and utilization of knowledge in facilitating sustainable development and environmental stewardship are competing with territorial narratives as key forms of legitimate capital.
How Does Temperature Affect the Acute Toxicity of Oil at Sea?

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With the Arctic as upcoming economic region, environmental risks increase. One of these risks are oil spills at sea. Although current literature shows little difference in sensitivity to oil between Arctic and temperate species when tested at their optimal conditions, temperature may affect both the viscosity and solubility of oil as well as the physiology of marine organisms. To facilitate proper risk assessment and development of effective mitigation measures for oil spilled at sea in the Arctic, it is important to understand these temperature effects. We conducted laboratory tests with temperate species to assess the acute toxicity of oil at three temperatures (4°C, 12°C, 18°C). Copper was used as positive reference toxicant. EC50 values for five species and consequent Species Sensitivity Distribution curves will be compared for these 3 temperatures. This provides insight into the differences in oil behaviour and toxicity at temperate and Arctic regions.
Experimental Research of Urban Heat Island Effect for the Biggest Arctic Cities

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Nowadays more than half of the Earth’s population live in the cities. Therefore, the researches about urban climate and its impacts on citizen’s life is actual and important part of modern climate science. Urban climate features and well-known effect of the Urban Heat Island (UHI) are studied in details for moderate and tropical climate zones. In general, UHI is considered as a negative phenomenon because of its negative effect on people health and energy consumption rates during summer heat waves, but for Arctic cities positive effect from UHI could be expected because of the long winter, when UHI could mitigate severe weather conditions within urban areas and provide fuel economy for house heating. However, until nowadays knowledge about UHI of Arctic cities was very poor, the only existing researches considered small towns in Alaska, while UHIs of the biggest Arctic cities, which are located in Russia, remained undiscovered. Investigation of the UHIs of these cities according the data of standard meteorological is impossible: only one meteorological station exists in each of these cities and their surroundings, while for UHI research at least two stations are needed. In this study, we consider the results of the experimental UHI research for four among five biggest cities, located to the north from the Arctic circle: Murmansk (303 000 inhabitants), Norilsk (180 000), Vorkuta (60 000) and Apatity (57 000). Source data for research was obtained in several experiential measurement campaigns, supported by Russian Geographic Society, during the 2013-2014 and 2014-2015 winter seasons. Measurements in these cities included installation of several automatic weather stations and the net of small temperature sensors in the city and surrounding landscape and car-based temperature sounding. Out measurements showed that Arctic cities in spite of their relatively small sizes and very weak solar heating, which is important for UHI appearance, could have significant UHIs during the winter, with the difference between city centre and surrounding landscape up to 10 °C and its mean value about 1-2°C. In case of very low or absent solar radiation the only possible explanation of such temperature anomalies is the release of the anthropogenic heat from buildings, cars and industrial plants to the atmosphere. Economic effect of the UHI of during the Arctic winter, related to the fuel consumption for house heating, was roughly estimated by the first million EUR per year per city.
Indigenous peoples’ responses to industrial interferences in their lands, economies, and cultures can often be contradictory, even within one community. Many scholars focus on conflicts between industrial development and indigenous lifestyle; at the same time, the fact that some indigenous groups have been traditionally involved in resource extraction in the past receives less scholarly attention. Addressing this bias means viewing each concrete situation beyond the dichotomies of “traditional”- “industrial” or “sustainable” - “unsustainable”.

This paper focuses on the case study of Vepses, an indigenous minority residing in the North-West of Russia. Already in 18-19 centuries the Vepses were involved in mineral extraction, and this involvement was preserved throughout the Soviet period. Two extremely rare minerals – raspberry quartzite and gabbro-diabase – were extracted at their territory. In different periods of time stone played an important role in the life of Vepsian villages. The aim of the paper is to track the variety of meanings stone had in Vepsian communities and to study the symbolism of mineral extraction.

The research is based on the analysis of archival documents as well as the materials published in the local newspapers Kommunist Prionezhja (later Prionezhje) and Krasnoe Sheltozero during Soviet and post-Soviet periods. I will also use the data obtained during ethnographic fieldwork and a series of interviews with the residents of Shoksha, Rybreka and Kvartsitny villages in summer 2015.

This case study shows that indigenous lifestyle, industrial development and nature may be perceived as coexisting and interconnected things. For Vepses mining development at their territory was a result of its natural richness and the uniqueness of their stone. Thus, stone working may be considered an essential continuation of nature. Vepsian collective identity was also in many aspects formed because of mining development, but nevertheless their bonds with nature remained strong. As a result, the residents of Vepsian villages see the possibility of coexistence for nature and mining industry.
Are the Models of Biodiversity Around the North Sea Offshore Oil Platforms Suitable for the Barents Sea Data?

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Gradients of environmental conditions form around the offshore oil platforms. Among other factors, the drill cuttings, various liquid effluents from the platforms, and fouling communities that develop on the submerged parts of the installations affect the composition of the surrounding benthic assemblages. The radius of the impacted areas may span from hundreds of meters to a few kilometres. Spatio-temporal variation of such gradients had been previously studied around a few platforms at a time. It’s still uncertain, whether the spatio-temporal patterns observed around individual platforms in the North Sea are consistent among different platforms, and whether the models are potentially scalable to other regions of North Atlantic such as the Barents Sea. To answer this question, we modelled trends in environmental and diversity gradients around the offshore oil platforms in different regions of the North Sea using the data from the Norwegian Environmental Monitoring Database (MOD). We also assessed performance of those models on the data from the Barents Sea. We found a well expressed gradient of hydrocarbon concentration in the sediment around the installations; the strength of the gradient changed in time. Hydrocarbon concentration also depended on sediment properties and lead content. Shannon-Wiener diversity in the samples depended mainly on hydrocarbon concentration. It decreased rapidly with increasing hydrocarbons, irrespective of distance from the platform, depended on sediment properties, and fluctuated with production duration. The models of hydrocarbon distribution and Shannon-Wiener diversity, that had been initially developed for the North Sea, also performed reasonably well on the data from the Barents Sea. Finally, we have found a set of species significantly affected by change of hydrocarbon concentration using the data from the North Sea, and checked the consistency of spatial patterns and dynamics of abundance of those species on the Barents Sea data.
According to predictions, up to 30% of the world’s undiscovered gas reserves and 13% of the world’s undiscovered oil resources are located in the areas north of the Arctic Circle, mainly offshore in relatively shallow waters. However, major parts of these areas are covered by sea ice, permanently or during particular periods of the year, which raise new issues related to potential accidental oil spills. Due to the reduction of sea ice in recent years, the presence of ships in Arctic is expected to rise, not only as a consequence of increased oil exploration, but also because such ice loss in the Arctic facilitate increased shipping in these areas. If northern areas are to be explored, the construction of a proper Net Environmental Benefit Analysis (NEBA) framework is necessary. NEBA is a process that can be applied by the response community in order to minimize the impact of an oil spill on the environment. For a NEBA to become an effective tool, it requires the input of reliable information about the distribution of species in the area of interest. However, for a variety of reasons such information is fragmentary for northern ice covered regions. We summarize the most recent information about physical and ecological processes in Arctic waters, with a particular focus on shelf areas. We provide information on ecology, life history and distribution of the key species in these areas, to assess their vulnerability to potential oil spills. Based on this information we carry out a gap analysis identifying further needs in terms of ecosystem information prior to the construction of an effective NEBA. The vulnerability of a species to oil spills depends on its potential for being exposed to oil, which in turn depends on the spatio-temporal distribution of both the species and the drifting oil. Therefore, focusing on the Barents Sea, we conduct oil spill modelling in order to simulate the various species’ potential risks of being exposed to oil in the case of an oil spill. Leveraging historical data from atmospheric and ice-coupled oceanographic circulation models, we realistically simulate hundreds of possible oil spill trajectories from a hypothetical spill site in the Barents Sea. Results of this “stochastic” simulation process provide insight into the likelihood and timing of oiling impacts in the Barents Sea region from a major spill event, which in combination with information on ecology will inform the NEBA.
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