Table of Contents

Arctic Frontiers 2015................................................................. 2
Conference Partners................................................................ 2
Steering Committee................................................................. 2
Advisory Board..................................................................... 3
Science conference organizers ................................................. 3
Scientific committees............................................................... 4
Convenors............................................................................. 5
Introduction............................................................................ 5
Arctic climate change – global implications.............................. 7
Ecological winners and losers in future Arctic marine ecosystems........ 8
The Arctic's role in global energy supply and energy security........ 8

Abstracts, orals

Keynotes.................................................................................. 10
Part I: Arctic climate change – global implications ....................... 14
Part II: Ecological winners and losers in future Arctic marine ecosystems ...... 45
Part III: The Arctic's role in the global energy supply and security......... 78

Abstracts, posters

Part I: Arctic climate change – global implications ....................... 107
Part II: Ecological winners and losers in future Arctic marine ecosystem ...... 133
Part III: The Arctic's role in the global energy supply and security........ 176

Index of presenters.................................................................. 196
Arctic Frontiers 2015

Conference Partners

- Troms County
- ConocoPhillips
- Akvaplan-niva
- The Research Council of Norway
- The Norwegian Barents Secretariat
- The University of Tromsø
- Institute of Marine Research
- SpareBank 1 Nord-Norge
- SINTEF
- ICE - Centre for Ice, Climate and Ecosystems, Norwegian Polar Institute
- NORUT - Northern Research Institute
- University of the Arctic
- FRAM - High North Research Centre for Climate and the Environment
- ARCTOS - The Arctic Marine Ecosystem Research Network
- Arctic Net
- APECS – Association of Polar Early Career Scientists
- Tromsø municipality
- Norwegian Ministry of Foreign Affairs
- UNIS
- University of Bergen
- The Norwegian Coastal Administration
- DNV – GL
- University of Stavanger
- Norwegian Oil and Gas Association
- Norwegian Space Centre
- Avinor
- Innovation Norway
- AMAP
- GCE | NODE
- Russian Geographical Society
- Fridtjof Nansen Institute
- BusinessOulu
- International Centre for Reindeer Husbandry
- Korea Maritime Institute
- World Petroleum Council

Steering Committee

- Salve Dahle (Chair), Director, Akvaplan-niva;
- Secretary: Ole Øvretveit, Akvaplan-niva;
- Anne Husebekk, Rector, University of Tromsø;
• Ivan C. Burkow, Director, Northern Research Institute;
• Ole Lindefjeld, Research Director, ConocoPhillips;
• Kirsten Broch-Mathiesen, Department leader, Research Council of Norway;
• Rune Raafaelsen, Director, Barents Secretariat;
• Lars Otto Reiersen, Secretary, Arctic Assessment and Monitoring Programme;
• Alf Håkon Hoel, Institute of Marine Research;
• Jørgen Berge, Leader, ARCTOS;
• Tor Arne Morskogen, Troms County
• Jan Gunnar Winther, Director, Norwegian Polar Institute;
• Marina Kalinina, Deputy Vice-Rector of International Cooperation, Northern Arctic Federal University (NArFU) and Steering Committee member representing the University of the Arctic (UArctic);
• Are Johnsen, CEO Framsenteret;
• Stig-Arne Engen, Director Communication SpareBank 1 Nord-Norge
• Gunnar Sand, Project Director, SINTEF.
• Ole Arve Midsund, Director, UNIS
• Nils Arne Masvie, Vice President, DNV
• Gerlis Fugman, Director, APECS
• Pål Brekke, Senior Advisor, Norwegian Space Centre
• Stein Gunnar Loftås, Tromsø Municipality
• Kirsti Slotsvik, The Norwegian Coastal Administration
• Peter M. Haugan, University of Bergen
• Øystein Lund Bø, University of Stavanger
• GCE | NODE, Anne-Grete Ellingsen,
• Geir Seljeseth, Norsk Olje og Gass
• Stein-Gunnar Bondevik, Innovasjon Norge Troms

Advisory Board

• Hans Corell, Ambassador (ret.), Former Under-Secretary-General for Legal Affairs and the Legal Counsel of the United Nations, Sweden
• Martin Fortier, Executive Director, ArcticNet Canada
• Priscilla Wohl, The Northerners Forum Alaska, USA
• Bente Aasjord , Norwegian Union of Municipal and General Employees, Norway
• Arild Moe, Director, Fridtjof Nansen Institute, Norway
• Jukka Olli, Business Oulo, Finland
• Svein Disch Mathiesen, International Centre for Reindeer Husbandry
• Justin(Jong-Deog) Kim, Director General of Strategy Research Division, Korea Maritime Institute

Science conference organizers

Matias Langgaard Madsen, Akvaplan-niva AS

Ole Øvretveit, Akvaplan-niva AS
**Scientific committees**

**Arctic climate change – global implications**

**Leader:** Professor Tor Eldevik (Leader), Geophysical Institute, University of Bergen and Bjerknes Centre for Climate Research, Norway

- Research Director Nalan Koc, Norwegian Polar Institute, Norway
- Director Jenny Baeseman, Cryosphere and Climate Project, Norway
- Dean Kjell Magne Mælen, UiT - The Arctic University of Norway, Norway
- Senior advisor Einar–Arne Herland, Norwegian Space Centre, Norway
- Associate Professor Janike Kampevold Larsen, Oslo School of Architecture and Design, Norway
- Inga May, APECS & Alfred-Wegener-Institut Helmholtz-Zentrum für Polar und Meeresforschung, Germany
- Special advisor Torill Engen Skaugen, The Research Council of Norway, Norway
- Head of Conservation Martin Sommerkorn, WWF, Norway

**Ecological winners and losers in future Arctic marine ecosystems**

**Leader:** Associate Professor Janne E. Søreide (Leader), The University Centre in Svalbard (UNIS), Norway

- Professor Paul Wassmann, UiT, The Arctic University of Norway, Norway
- Professor Rolf Gradinger, Leader of the Barents Sea Ecosystem Programme, Institute of Marine Research, Norway / University of Alaska Fairbanks, USA
- Special Adviser Dr. Christian Wexels Riser, The Research Council of Norway, Norway
- Professor Jean Eric Tremblay, ArcticNet, Québec-Océan & Takuvik / Laval University, Canada
- Mar Fernández Méndez, APECS / Alfred-Wegener-Institut Helmholtz-Zentrum für Polar und Meeresforschung, Germany

**The Arctic's role in the global energy supply and security**

**Leader:** Research Director Dag Eirik Nordgård, SINTEF Energy Research, Norway

- Professor Peter Haugan, University of Bergen, Norway
- Professor Bjorn Helge Hjertager, University of Stavanger, Norway
- Director Leiv Lunde, Fridtjof Nansen Institute, Norway
- Consultant Coco Smits, APECS / Royal HaskonigDHV, The Netherlands
- Special advisor Ingrid Anne Munz, The Research Council of Norway, Norway
**Convenors**

Arctic climate change – global implications,
- Professor Tor Eldevik Geophysical Institute, University of Bergen and Bjerknes Centre for Climate Research, Norway

Ecological winners and losers in future Arctic marine ecosystems
- Associate Professor Dr. Janne Søreide, The University Centre in Svalbard, Norway

The Arctic's role in the global energy supply and security.
- Research Director Dag Eirik Nordgård, SINTEF Energy Research, Norway

**Introduction**

The 9th Arctic Frontiers conference, Climate and Energy,

will address three main themes: I) Arctic climate change – global implications, II) Ecological winners and losers in future Arctic marine ecosystems and III) The Arctic's role in the global energy supply and security.

The earth is in the midst of major climate changes. The Arctic is experiencing the impact of these changes more and faster than other parts of the globe. Processes starting in the Arctic may have deep and profound impacts on other parts of the globe. At the same time the Earth's population is rising and with it the global energy demand. New and greener energy sources are gaining market shares, but still the energy mix of the foreseeable future will have a substantial fossil component. The Arctic is expected to hold major oil and gas resources, while the regions green energy potentials are less explored. How will the Arctic's energy resources contribute to the global energy mix in the decades to come? How will the climate changes impact the Arctic environment and societies? And where will we find a balance between the planet’s energy demand and the necessity to reduce CO₂ emissions?

**Structure of conference**

To discuss these major questions there is a need for solid scientific evidence and documentation. This is why the policy section and the scientific section of the Arctic
Frontiers Conference are organised back to back. The scientific presentations will serve as a knowledge base for the discussions during the policy section. To elucidate major opportunities and challenges for future development within the Arctic region, four research themes have been chosen. These themes will be presented during three parallel parts of the science conference:

- Arctic climate change – global implications
- Ecological winners and losers in future Arctic marine ecosystems
- The Arctic’s role in the global energy supply and security

To further bridge between the first two days of politics and the following three days of science, and also to link between the three different research parts, Arctic Frontiers has invited four key note speaker to give a popularised presentation. These presentations will be given in a plenary session on Wednesday January 21st and will be moderated by the science section conveners, Tor Eldevik, Janne Søreide and Dag Eirik Nordgård.

**Plenary keynote presentations**

- Julienne Stroeve - Arctic Sea Ice and Impacts of its Disappearance.
- Antje Boetius - Observing Arctic Ocean ecosystem change: lessons learned from open-ocean field studies.
- Fridtjof Fossum Unander - Energy perspectives of the Arctic and Northern Areas: Outlook and research challenges
- David Molden - Arctic Himalayan Connections
Three parallel sessions

Arctic climate change – global implications

Climate and Energy is the very appropriate title for Arctic Frontiers 2015. Climatic conditions largely define societies’ need for energy, and the means by which the energy is provided directly influence climate. The duality is particularly manifested in the Arctic, where present climate change both makes access to Arctic oil and gas resources more readily available, and underlines the global need for more sustainable energy sources.

Our session focuses on the climate change aspect of the above. The signature of global climate change is arguably most pronounced in the Arctic. Associated with ongoing Arctic change are an amplified warming, retreating sea ice cover, melting ice sheets and glaciers, changing weather and ocean circulation patterns, ocean acidification, and thawing permafrost. The changes influence and may have severe consequences for life and societies in the Arctic – from ecosystems via landscapes to people. Change in Arctic climate can also have remote implications, including an influence on mid-latitude climate extremes, interactions with the global freshwater cycle and oceanic heat transport, as well as creating opportunities and demands for new societal or commercial development in the Arctic region.

The aim of our session is to contribute to the robust assessment of Arctic cause-and-effect and the interplay between drivers and impacts. We will in particular address the mechanisms driving Arctic climate change, their observed physical or societal manifestations, as well as their interaction with climate and societies beyond the Arctic, including the geopolitical dimension. A most pertinent discussion point will be the predictability of Arctic climate change, and how a predictable climate may resonate with identifiable human responses to negotiate or remediate changes in the physical environment.

The programming of the session Arctic climate change – global implications is broadly as follows. Wednesday afternoon is dedicated to Social manifestations and adaptation. Presentations on Thursday cover Arctic-Atlantic climate change: from past to future, Changing ground properties; and Sea ice: processes and implications. We end our session Friday morning with Glaciers, sea level and mobility, Greenhouse gas emissions in the Arctic; and a summary on behalf of the scientific committee. Last, but not least, there is the poster session after lunch on Thursday (and before the afternoon’s oral presentations) that covers most of the above and provide a lively arena for debating the various topics at hand.

We look forward to your participation and your contribution to enthusiastic discussions in our session Arctic climate change – global implications.
Ecological winners and losers in future Arctic marine ecosystems

This session explores negative and positive impacts of climate change on Arctic marine ecosystems. A warmer climate with a less extensive ice cover will most likely increase phytoplankton primary production which has the potential to increase the overall secondary production. However, altered climate conditions will also affect timing, quantity and quality of ice algal and phytoplankton food sources with potentially reduced food quality which may have extensive implications for grazers and their predators. Depending on these organisms' ability to adapt to the new living conditions, some will be favoured more than others, resulting in ecological winners and losers.

In this session we focus on how species, through phenotypic plasticity, may adapt to rapid changes in their physical and biological environment with a special look at metabolic rates, behaviour, diet and energy allocation, including reproductive strategies and migrations. Species' long-term evolutionary response is also addressed through various modelling studies. The Arctic Ocean is tightly connected to the northern Pacific and Atlantic oceans, and a change towards a more boreal species composition at all trophic levels in the Arctic is predicted. Due to the complexity of multiple species and their interactions, all trophic levels must be considered simultaneously. This highlights the importance of long-term observational programs and ecosystem-based management of Arctic marine living resources.

The Arctic's role in global energy supply and energy security

The scientific committee of Part III The Arctic's role in global energy supply and energy security is proud to present its session consisting of high level scientific presentations covering a wide range of topics related to energy and the Arctic.

The Arctic is rich in energy resources, and holds the potential to play a significant role in the global energy supply in the foreseeable future. A key challenge is how the energy potential of the Arctic can be utilized in a sustainable and safe manner both locally and as a global resource.

Arctic petroleum production started fifty years ago in Alaska, and today Arctic Norway and Russia are exporting oil and gas to the world markets. Further west, Iceland and Greenland are actively pursuing oil and gas exploration in their Arctic waters.

Yet the very climate change development that is currently opening up the Arctic for business through ice melting is also by many seen as a fundamental challenge to Arctic oil and gas production. The official position of Arctic coastal states is that the world needs more energy and that the Arctic is a low-conflict region that can provide energy supplies to the world. Most environmentalists, on the other hand, hold that both local and global environmental and security concerns, implies that Arctic oil and gas should be left in the ground. It has also been argued that Arctic energy needs should preferably be served by locally harvested renewable energy, thereby contributing to the global energy transition.
The current turbulence and changes on the geopolitical scene may also affect the role of the Arctic as an energy supplier to the world, emphasizing the importance of Arctic peace and stability as a condition to further develop the region’s rich natural resources.

Part III of the Arctic frontiers conference 2015 seeks to offer an arena for researchers, industry representatives, authorities and other experts, to discuss the Arctic’s role in the global energy supply, and to address both technological and societal challenges and opportunities of Arctic energy.

The abstracts of Part III are divided into four blocks:

- Renewable energy of the Arctic
- Societal aspects of Arctic Energy activities
- Oil and gas exploration in the Arctic, and
- Arctic energy and the global energy supply

Renewable energy of the Arctic addresses challenges and possibilities related to different types of renewable energy sources in the Arctic.

The block Societal aspects of Arctic Energy activities will highlight the impact energy activities in the Arctic have on the local societies – providing examples both from Northern Europe, U.S. and Canada.

Oil and gas exploration in the Arctic is a highly relevant and interesting research topic from many perspectives, including potential environmental impact, technical challenges and solutions, and operational challenges of operating in the harsh arctic climate.

The last block - Arctic energy and the global energy supply - deals with different aspects related to the role the Arctic can and will play in the global energy supply, including the perspectives of states which have a clear ambition to strengthen their position in Arctic energy.
Keynote presentations

Science conference opening by

Rector Dag Rune Olsen
University of Bergen, Norway

Moderators

Professor Tor Eldevik
Geophysical Institute, University of Bergen
and Bjerknes Centre for Climate Research, Norway

Associate Professor Dr. Janne Søreide
The University Centre in Svalbard, Norway

Research Director Dag Eirik Nordgård
SINTEF Energy Research, Norway
Observing Arctic Ocean ecosystem change: lessons learned from open-ocean field studies

Antje Boetius, and the FRAM team

Alfred Wegener Institute Helmholtz Center for Polar and Marine Research, Bremerhaven, Germany

The ice-covered open ocean of the Arctic is among the least explored areas of Earth. Very basic questions still have to be answered as to their ecology, including the identity, distribution and life cycle of key species, their energy, carbon and nutrient budgets, as well as the role of the ice-cover in the functioning of the Arctic ecosystems from surface to bottom. However, no other region on Earth faces a similarly rapid change with regard to warming and its ecological consequences. Recent field studies indicate that the sea ice retreat is already changing the distribution of key species, their productivity and habitats quickly, with consequences for regional biogeochemical processes. But it remains difficult to measure and predict the consequences of such changes without baselines, which are urgently needed. Key uncertainties are as to the role of sea-ice algae in total Arctic productivity and carbon flux to the ocean interior, and the influence of sea-ice thinning and retreat on the primary producers and their grazers. This presentation discusses recent scientific and technological advances and further needs in accelerating observation of Arctic Ocean ecosystems change from surface to bottom, with a focus on the link between sea ice-cover and the deep-sea floor via the biological pump. It addresses recent results from long term ecological time series of the Arctic seafloor, and how to establish indicators for Arctic ecosystem change.
Arctic Sea Ice and Impacts of its Disappearance

Julienne Stroeve

University of Colorado, Boulder, CO, USA

The Arctic is a complex system that has experienced some of the most extreme environmental changes, including large declines in the sea ice cover, mass loss from glaciers and the Greenland ice sheet, reductions in snow cover, a warmer climate and ecosystem shifts. All these changes in turn influence the global surface energy and moisture budget, atmospheric and oceanic circulation and feedbacks. Limited observational data together with large variability and sensitivity of Arctic climate to global change make attribution of these changes difficult, though simulations from climate models suggest rising concentrations of atmospheric greenhouse gases play a large role. This plenary talk focuses on changes in the sea ice cover, factors behind ice loss, future projections and climate impacts of a diminished sea ice cover.
Arctic Himalayan connections

David Molden

International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal

The Himalayas, Hindu Kush, Karakorum mountains and the Tibetan Plateau make up the Hindu Kush-Himalayan (HKH) region, an area that has more snow and ice resources than any other region outside of the Polar regions. Similarities between the HKH and Polar regions do not stop there. The HKH region, like the Arctic, provides a range of ecosystem services that are important both for local communities and for people living in the surrounding regions and across the world, yet both regions are highly vulnerable to global change.

The HKH region is diverse in many dimensions, including numerous indigenous communities, high biodiversity and agro-diversity, and diversity in climatic regimes. Water, energy and food security in Asia is highly dependent on mountain water supplies. About 200 million people in Asia live in the HKH Mountains, while 1.3 billion people indirectly depend on mountain resources for growing food and obtaining energy. However, mountain communities, who are the custodians of these resources, are typically both economically and politically marginalized compared to people on the plains. Like the Arctic, the HKH region faces severe pressure from changes taking place across the world, such as climate change, air pollution, globalization and outmigration, all of which have put mountain people’s adaptive capacity to the test. Like the Arctic, resources are shared between many countries, and cooperation is critical for sustainable management of resources. The HKH countries include: Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. There are many opportunities, including sustainable use of resources, and sharing of benefits of resource use between mountain and downstream communities. While there is a limited science base compared to the Arctic, there is a growing amount of scientific research and knowledge sharing that will help to realize these benefits.

The numerous similarities between Arctic and the Himalayan regions indicate that there is scope to enhance the linkage between the two regions and promote cross learning. Lessons learnt in the Arctic could help strengthen scientific cooperation and build capacity in the HKH taking examples from relevant institutions like the Arctic Monitoring and Assessment Program, the University of the Arctic, and the Arctic Council. Strong scientific cooperation between regions can contribute to better understanding of physical and social processes, help in developing improved regional policies, and help to bring issues of these critical regions to the global stage.
Arctic climate change – global implications

Scientific committee

Leader:
Professor Tor Eldevik (Leader), Geophysical Institute, University of Bergen and Bjerknes Centre for Climate Research, Norway
Research Director Nalan Koç, Norwegian Polar Institute, Norway
Director Jenny Baeseman, Cryosphere and Climate Project, Norway
Dean Kjell Magne Mælen, UiT - The Arctic University of Norway, Norway
Senior advisor Einar-Arne Herland, Norwegian Space Centre, Norway
Associate Professor Janike Kampevold Larsen, Oslo School of Architecture and Design, Norway
Inga May, APECS & Alfred-Wegener-Institut Helmholtz-Zentrum für Polar und Meeresforschung, Germany
Special advisor Torill Engen Skaugen, The Research Council of Norway, Norway
Head of Conservation Martin Sommerkorn, WWF, Norway
Changing climates in local communities on the Barents coast

Peter Hemmersam, Janike Kampevold Larsen
Oslo School of Architecture and Design, Oslo, Norway

Along the Barents Coast, we find a number of towns and local communities that have been put ‘on hold’; in different ways they are waiting for a future resolution to contemporary problems. Prospective solutions seem to be tightly knit to the expansive extractions industries and new transportations routes opening due to climate change.

This paper looks at a number of communities that in various ways and with different immediate results have been affected by the expanding industries in the north. Teriberka in Northwest Russia for a few years featured as the designated land hub for the Shtokman gas field in the Barents Sea. The Norwegian town of Vardø has experienced depopulation due to changing industrial climates, and Hammerfest west of the northern tip of Norway is home to a major LNG production site. These communities’ expectations for the future demonstrate the close connection between expected climate change, industrial possibilities and social development.
A brief history of climate — the northern seas from the Last Glacial Maximum to global warming

Bjørg Risebrobakken\textsuperscript{3,2}, Tor Eldevik\textsuperscript{1,2}, Anne Bjune\textsuperscript{3,2}

\textsuperscript{1}University of Bergen, Bergen, Norway; \textsuperscript{2}Bjerknes Centre for Climate Research, Bergen, Norway; \textsuperscript{3}Uni Climate Research, Bergen, Norway

The understanding of climate and climate change is fundamentally concerned with two things: a well-defined and sufficiently complete climate record to be explained, for example of observed temperature, and a relevant mechanistic framework for making closed and consistent inferences concerning cause-and-effect. This is the case for understanding observed climate, as it is the case for historical climate as reconstructed from proxy data and future climate as projected by models. The present study offers a holistic description of northern maritime climate — from the Last Glacial Maximum through to the projected global warming of the 21st century — in this context. It includes the compilation of the most complete temperature record for Norway and the Norwegian Sea to date based on the synthesis of available terrestrial and marine paleoclimate reconstructions into continuous times series, and their continuation into modern and future climate with the instrumental record and a model projection. The role of the Norwegian Atlantic Current — the Gulf Stream's extension towards the Arctic — is assessed in particular. This includes the introduction of an explicit and relatively simple diagnostic relation to quantify the change in ocean circulation consistent with reconstructed ocean temperatures. It is found that maritime climate and the strength of the Norwegian Atlantic Current are closely related throughout the record. The nature of the relation is however qualitatively different as one progresses from the past, through the present, and into the future.
Can we produce realistic seasonal forecasts in the new Arctic paradigm?

Julienne Stroeve

University of Colorado, Boulder, CO, USA

The accelerating decline of the Arctic ice cover has lead to an increase in socio-economic activities in the Arctic leading to a growing interest in developing reliable methods to predict the summer minimum sea ice extent a few months in advance. While potential predictability studies have estimated that monthly pan-Arctic sea ice extent could be significantly predictable for 2 years after initialization, when these models are used to predict the observed sea ice conditions, they show a significant degradation of skill and offer skillful forecasts for only 2 to 5 months during summer. Disappointing results may originate from several limitations of the forecast systems, such as insufficient or poor quality initial conditions for data assimilation, insufficient or inadequate model physics, and climate model drift, while it is ultimately possible that inherent predictability in nature may be lower than that in dynamical models.

However, inspection of the observational record reveals several notable aspects of the September trend that bear upon seasonal forecasting. First, the trend has steepened over time as the ice cover has shifted from thick multiyear ice to thinner first-year ice. Second large departures from the trend seldom persist for more than a few years, pointing to a strong negative autumn and winter feedbacks in the sea ice system associated with ocean heat loss. Thus, in the absence of strong summer atmospheric forcing, one may expect the summer ice cover to follow the linear trend line. Indeed, contributions to the Sea Ice Outlook show that forecasts for the September extent do not perform as well during years when there are large departures in extent from one year to the next. Thus, while studies show that better initialization of initial conditions can lead to more skillful forecasts, there remains an inherent limit to seasonal predictability due to the chaotic nature of atmospheric variability.
Glaciers between Little Ice Age and Anthropocene – causes of the global meltdown

Ben Marzeion¹, J. Graham Cogley², Kristin Richter¹, David Parkes¹, Alexander H. Jarosch³

¹University of Innsbruck, Innsbruck, Austria; ²Trent University, Peterborough, Canada; ³University of Iceland, Reykjavík, Iceland

By changing the seasonality of runoff, glaciers are important regulators of water availability in many regions of the world. Retreating glaciers lead to increased geohazards, e.g. from destabilized slopes and lakes dammed behind unstable, ice-cored moraines. Finally, even though the ice mass stored in glaciers seems negligible compared to the Greenland and Antarctic ice sheets, glaciers have contributed significantly to sea level rise in the past, and probably have been the biggest single source of observed sea level rise since 1900.

Glaciers respond to changes in the climate with a lag of decades to centuries, and thereby allow people to directly perceive changes of the climate system that otherwise would be overwhelmed in human perception by short-term weather fluctuations. Because of this property, and since glaciers form prominent features of many arctic and high mountain regions, shrinking glaciers have become an icon of climate change.

At the same time, the lagged response of glaciers to climate change complicates the attribution of the observed changes to any particular cause, because glacier mass change at any time is in part an ongoing adjustment of the glacier to previous climate change. Nevertheless, there is strong evidence that most of the glacier mass loss of the recent past is caused by human activities, implying that also current sea-level rise is largely anthropogenic.

In this talk, we will review the recent advances in our understanding of how natural and anthropogenic factors shape global glacier change, with a particular focus on the Arctic. We will also discuss the implications for the future of glaciers, and for projections of sea-level rise.
Public Perceptions in the Arctic: Maritime vs. Oil and Gas Activities

Sandra Hogenboom, Børre Johan Paaske

DNV GL, Høvik, Norway

Declining sea ice in the Arctic is creating new possibilities for development of industrial activities, such as expanded maritime activities and oil and gas developments. However, the area is vast and many different resources, conditions and challenges are creating a complex risk picture. In order for these activities to be able to take place they need a license to operate. Nowadays, with increased scrutiny from both regular and social media, public perceptions play an even more important role in granting a license to operate. The current study has taken a temperature check amongst a sample of the Norwegian (N=779) and the Alaskan (N=521) population with a survey concerning perceived risks and benefits related to increased maritime and oil and gas activities in the Arctic. The study presents the findings of the survey and compares it to the risk picture of these activities. The main findings were that people perceive more concerns for oil and gas activities than maritime activities, and the main worry from the Norwegian and the Alaskan population is related to environmental consequences of these activities. Moreover, even though the public perception indicated that oil and gas activities are viewed as more risky than maritime activities this is not necessarily the case. The paper discusses the findings from the perception study, in light of maritime and offshore accident statistics inside and outside the arctic regions, and with input from recent environmental risk assessments. A concept for risk communication will be presented and the concept of risk will be discussed. These findings underline the importance of the need for better risk communication. Communication between companies, authorities and policy makers, and the public, has to be improved in order to properly convey the risks and benefits associated with these activities. It is important that policy makers, authorities and the public understand how perceived risks differ from estimates from risk analysis and how this drives decision making, the prioritization of resource distribution, research initiatives and mitigation activities - and ultimately for operators how and if these activities are granted a social license to operate.
Professional fitness of workers in the Arctic in climate change conditions

Yana Korneeva\textsuperscript{1,2}, Natalia Simonova\textsuperscript{1,2}

\textsuperscript{1}Northern (Arctic) Federal University named after MV Lomonosov, Arkhangelsk, Russia, \textsuperscript{2}Northern State Medical University, Arkhangelsk, Russia

At the moment problem of climate change becomes urgent, and therefore the Arctic changes are often viewed as an indicator of this process. The adapt ability to climate and weather changes is determined largely immutable formal dynamic and psycho-physiological characteristics of the human body. In connection with the identification of these characteristics is necessary to construct the professional fitness' optimal model of workers in the Arctic. To work in these areas shift method of a labor organization is used when it cannot be provided workers return to the place of permanent residence every day. Our study aim: the definition of professional fitness shift workers in oil and gas companies in the Arctic in the climate change conditions. To achieve these goals, we used data obtained from research expeditions during the period from 2010 to 2013. Shifts considered different durations (15, 24, 30, 52 - days) in different seasons of year. The study involved more than 300 professionals which shift working in the Arctic. There are specialists of different occupations (153 specialties). Average age is 34.94 ± 9.584. Methods: analysis of documentation, observation, survey, questionnaires and psychological tests. Statistical methods: descriptive statistics, stepwise multi-regression, step-by-step discriminant, two-stage cluster, multivariate analysis (the software package SPSS 22.00). The professional fitness' characteristics of shift workers in the Arctic in climate change conditions are: moderate introversion; rationalistic; increased self-control, especially in interpersonal relationships and health - disease; increased emotional and intellectual and emotional stability.
Geopolitical issues of new Arctic Sea routes – a major consequence of climate change in the area

Camille Escudé

Sciences Po Paris - Doctoral School, Paris, France

The heavy influence of climate change in the Arctic might lead to the disappearance of the summer pack ice, and thus open sea routes during several months in the north of Russia and North America. Thus the ice melting in Arctic seems to bring back the mythical Northwest and Northeast passages, which means nothing less than sea routes between Europe and Asia thousands of kilometers shorter than Panama or Suez Canal. Calculated in theory, the path between London and Yokohama for a commercial ship is for instance 7400 kilometers shorter, using Arctic route. However, my research tried to emphasize the current reality and the reality to come of shipping in those new Arctic routes: does those maritime routes effectively allow the massive shipping regularly announced by plenty of media?

My researches showed that, on the contrary of the common discourses, the Arctic Sea passages are at the moment unequally navigable, and still very little used by commercial transportation. The Northeast Passage is a century-old waterway for Russia, but the Arctic Ocean in the north of Canada is still frozen most part of the year. Taken as a whole, too many obstacles are slowing down the profitable and durable development of Arctic commercial shipping. Most are linked with the very difficult shipping conditions in Arctic, but one of the main is the just-in-time logic of international trade, not compatible for the ship owners with those uncertain routes. If on theory, saving of distance could be made, in reality, saving of distance does not equal saving of time and money. Consequently, in the middle term, I claim that there will be no "Arctic maritime highways".

Nonetheless, if the disappearance of the summer pack ice does not allow a massive commercial shipping in the Arctic, I maintain that the possible development of those sea routes creates a worldwide interest for the region, and open a lot of strategic and economical new prospects: exploration of gas and oil-fields, extended fishing zones, international touristic industry, and military shipping. Arctic routes are already very used for the supply of Arctic villages and an easier access to the Arctic resources, which arouse keen interest all over the world. For me, these development of those sea routes may have serious consequences not only in the Arctic area, but also on the whole world, illustrating the global implication of societal, political and economic challenges in the Arctic region.
Melting Homelands: A Sense of Belonging in the Changing Arctic

Ingrid A. Medby

Durham University, Durham, UK

The world as we know it - as we have learnt that it looks, feels, moves - is changing. No place is this more obvious than in the Arctic; a region known to most as vast expanses of thick, white ice is now rapidly exposing its underlying deep, black sea, as a result of global climate change. A range of new challenges as well as opportunities are thus presented the world, prompting the world to look northwards. Consequently, the question has arisen of who may benefit and whose responsibility it is to ensure development takes place in a sustainable manner.

Aided by principles laid down in international law, the borders of oceanic zones and territories are being established, and gradually the Arctic is divided among states - the eight Arctic states. As such, the changing area is implemented in the system of sovereign nation-states. However, this process has not been - and is still not - as straightforward as it may seem. A number of conceptual challenges faces the Arctic states as they appropriate these spaces of water and ice; these increasingly fluid spaces. Indeed, a status as an "Arctic state" may not necessarily translate to a sense of belonging; a sense of identity tied to this "frontier" region.

Focusing specifically on one such "Arctic state", Norway, this paper examines what it means for a state and for a nation to hold a formal status as such. Through a number of interviews with Norwegian state officials, it sheds light on what it means to hold an Arctic state identity. This is then contrasted with perceptions found through surveying young members of the Norwegian public, which highlights continuities and discontinuities between national and state identity as "Arctic". As such, the paper contributes to our understanding of what it means to belong or not to belong to an area in rapid flux and difficult to define, and how this legitimises and delegitimises action. Slippery, melting, and thawing - it may not be "homeland" as such, but the Arctic is nonetheless increasingly implemented in the spatial perceptions of the nation-state. As ice becomes water and the global climate changes, a coastal and seafarer identity once again comes to the fore, and the Viking and the fisherman take on a new role in the exploration and the harvest of new Arctic resources.
Loss of Arctic and Barents Sea ice in relation to Atlantic inflow

Lars H. Smedsrud

University of Bergen, Bergen, Norway, University Centre in Svalbard, Longyearbyen, Norway

Present global warming is amplified in the Arctic and accompanied by unprecedented sea ice decline. Located along the main pathway of Atlantic Water entering the Arctic, the Barents Sea is the site of coupled feedback processes that are important for creating variability in the entire Arctic air-ice-ocean system. As warm Atlantic Water flows through the Barents Sea, it loses heat to the Arctic atmosphere. Warm periods, like today, are associated with high northward heat transport, reduced Arctic sea ice cover, and high surface air temperatures. The cooling of the Atlantic inflow creates dense water sinking to great depths in the Arctic Basins. Recently, anomalously large Atlantic heat transport has reduced sea ice formation in the Barents Sea during winter and also caused loss of sea ice inside the Arctic Ocean north of Svalbard. The winter sea ice loss in the Barents sector is the major contribution to the overall observed winter Arctic sea ice loss, and is likely connected to changes in the large-scale atmospheric circulation that has caused recent cold continental winters.

Large air-ice-ocean variability is evident in proxy records of past climate conditions. This suggests that the Barents Sea has had an important role in Northern Hemisphere climate for, at least, the last 2500 years. Coupled climate model simulations show that natural climate variability can explain similar sea ice changes in the Barents Sea ice to those that we have seen the last 150 years. However, the recent loss of sea ice has now lasted longer than the natural fluctuations would suggest, and the ice loss is therefore also related to ongoing global anthropogenic warming.
Arctic Warming: Greenhouse gas methane releases on the rise?

Jürgen Mienert¹, Karin Andreassen¹, Catherine Lund Myhre², Giuliana Panieri¹, Alexey Portnov¹, Stefan Buenz¹

Centre for Arctic Gashydrate, Environment and Climate (CAGE), UiT The Arctic University of Norway, Tromsø, Norway, Norwegian Institute for Air Research, Oslo, Norway

Arctic methane hydrate exists on land beneath permafrost regions and offshore in shelf and continental margin sediments. Methane or gas hydrate, an ice-like substrate, consists mainly of light hydrocarbons entrapped by a rigid cage of water molecules. The volume of methane hydrates and thus the CH₄ stored in methane hydrates is enormous if one considers the vast regions of Arctic continental shelves and margins as well as permafrost areas offshore and on land. -- What can we expect in the future and can nature or mankind stop if Arctic methane release is on the run? It is still contentious whether methane ascending from the ocean floor through the hydrosphere reaches the atmosphere. If methane reaches the atmosphere, one can operate at the most fundamental level with green-house gas effects that will be several times more potent than CO₂.

Concentrations of carbon dioxide increased at their fastest rate for 30 years in 2013, despite warnings from the world’s scientists of the need to cut emissions to halt temperature rises. More alarmingly, the methane emissions have also risen significantly, with concentrations of methane now 253% of pre-industrial levels. Methane is a double jeopardy in the atmosphere, a hyper potent greenhouse gas itself, it eventually becomes CO₂.

Huge deposits of methane are stored frozen under the ocean floor, urging many countries to look into a possibility of using it as a clean energy source. At the same time it may pose a major risk to the environment if it is released into the atmosphere due to warming of the ocean. But how much of the Arctic methane will be released? How can the release of methane from the seabed and offshore permafrost impact this environment?

To answer these questions CAGE - Centre for Arctic Gas Hydrate, Environment and Climate started to investigate offshore permafrost regions in the Kara Sea and non-permafrost methane-hydrate charged regions offshore NW-SValbard.
Barents Sea ice changes and the Warm Arctic Cold Eurasia pattern.

Svetlana Sorokina\textsuperscript{1,4}, Camille Li\textsuperscript{2,4}, Justin Wettstein\textsuperscript{2,4}, Nils Gunnar Kvamstø\textsuperscript{2,4}

\textsuperscript{1}Nansen Environmental and Remote Sensing Center, Bergen, Norway, \textsuperscript{2}Geophysical Institute, University of Bergen, Bergen, Norway, \textsuperscript{3}National Center for Atmospheric Research, Boulder, Colorado, USA, \textsuperscript{4}Bjerknes centre for climate research, Bergen, Norway

The strong decline in Arctic sea ice over the last decades has intensified interest in the interactions between sea ice conditions and the atmosphere. Although sea ice decline has been largest in summer, the multiyear ice cover is declining more rapidly in winter, with the most pronounced decreases in the Barents Sea. The decline in Barents Sea ice has been implicated in forcing the “Warm Arctic Cold Eurasia” (WACE) pattern via enhanced ocean-to-atmosphere turbulent heat fluxes, but their exact role and the responsible mechanisms are still unclear. Here, we investigate the nature of the link between Barents Sea ice and the “Warm Arctic Cold Eurasia” pattern by focusing on turbulent heat flux anomalies in the winter season. We apply empirical orthogonal function analysis to various reanalysis (1979–2012) and satellite products. We find reduced ocean-to-atmosphere turbulent heat flux anomalies in association with the WACE pattern and reduced Barents Sea ice cover, a relationship that is inconsistent with the WACE pattern being a direct atmospheric response to sea ice decline. The analyses indicate a substantial atmospheric contribution to observed variability of turbulent heat fluxes and ice cover in the Barents Sea, as well as the out-of-phase temperature signature between the Barents Sea and Eurasia. The results contribute to understanding the relationship between observed sea ice changes and extreme weather conditions in the mid-latitudes, and suggest that the WACE pattern is more complicated than a pure atmospheric response to sea ice loss.
Social impacts of climate change and resource extraction in the Arctic: implications for Arctic governance

Gisele M. Arruda¹, Sebastian Krutkowski²


Climate change has important socio-political implications as the melting ice ignites new debates over territorial sovereignty of Arctic coastal states and poses new jurisdictional problems over maritime navigation. Previously ice-jammed waterways are now open and new geological surveys have identified vast resources of energy in previously inaccessible areas. States began deploying “sovereignty patrols” to ensure effective control of “their” territory although in most cases, these claims depend on historic occupation by indigenous communities dating back to before the nation-state system existed. Arctic indigenous groups, especially the Inuit, made no distinction between the frozen land and the frozen sea. This allows states to put forward their claims to underwater resources that become increasingly accessible as the ice recedes. Jurisdictional problems arise when competition over resources causes what used to be internal waters of one particular state to be referred as international waters by other actors. Arctic governance is currently fragmented across too many different bodies that deal with maritime navigation, tourism or fisheries administration while the largest organisation, the Arctic Council, has only advisory powers. The council has long been a “cognitive forerunner” (Nilsson, 2002), but its current norm-making method of soft-law is trumped by international treaties and international customary law, which is reserved to state actors only (Koivurova & Heinämäki, 2006). Equipping the Council with policy-making powers would help establish effective Arctic-wide policies for responsible management of energy resources. At the same time, social arrangements should follow to ensure the indigenous populations can also participate in the process and mitigate the impact of climate change on their traditional livelihood strategies. Many indigenous organisations in the Arctic were formed out of fear for losing native land to powerful energy companies that see it as nothing more than a commodity. Extractive industries elsewhere in the world have led to evictions, toxic waste, creating conflicts over land and water (Woons, 2014). Fears over aggressive “extractivism” in the Arctic are justified as it is likely to become a major trade corridor and global resource base. Untapped expansionism into resource-rich areas today is a continuation of colonialism, although now this is made in the name of “development” and not “discovery”. Without a reform of Arctic governance and cooperation with indigenous population, the drive for Arctic energy resources, regardless of the economic benefits it may bring, will further exacerbate the negative environmental and social effects of climate change.
Arctic Climate Change and the Polar Archaeological Record.

Hans Peter Blankholm

University of Tromsø, Tromsø, Norway

Archaeology is the only academic discipline that provides long-term perspectives on human cultural and subsistence adaptation.

Well-preserved archaeological sites containing climatic, environmental, socio-economic and cultural data, and analyzed within an interdisciplinary, international framework, thus have great potential for the study of long, particularly Quaternary, chronological sequences of climate and environmental change and of how humans have responded to those.

Such sites are, however, relatively rare within the Polar regions and are basically only found in either anaerobic water-logged, permafrost and/or alkaline locations such as, for instance, bogs or middens.

Sites with good preservation - in contemporary jargon called "Joint Proxies" - are also those most threatened by the detrimental effects of global climate change.

The loss of sites is rapid, ongoing, and derives from several agents, notably:

- Coastal and riverine erosion
- Thawing permafrost
- Industrial development
- Increased tourism

The natural and social sciences are at risk of losing a critically needed mass of data for research on the past, present and future and for the development of adequate cultural and environmental resource management strategies.

In order to remedy the situation, there is an urgent need, on the one hand, to investigate as many as possible of our archaeological sites and base-line climate and environmental data as sources of knowledge before they are gone forever, and on the other hand to initiate more, and carefully designed, interdisciplinary international projects addressing long-term cultural and natural adaptations to climate changes.

This paper outlines how the Polar Archaeology Network (PAN), endorsed by the International Arctic Science Committee (IASC), attempts to meet our mutual natural and social scientific and resource management challenges in order to secure sources and knowledge of long-term cultural and natural changes.
Advection of Atlantic Water and secondary producers into the Arctic Ocean

Sünnje Linnéa Basedow¹, Arild Sundfjord²

¹University of Nordland, Bodø, Norway; ²Norwegian Polar Institute, Tromsø, Norway

The inflow of Atlantic Water (AW) into the Arctic Ocean (AO) is the main mediator of climate change in the Arctic marine ecosystem. Through the inflow of AW changes in temperature and ecosystem structure at lower latitudes are channeled into the AO and impact productivity and carbon cycling there. We aim to quantify seasonal changes in the inflow of AW and the secondary producers contained therein. Data with high spatial resolution were collected along transects across the AW inflow west and north of Svalbard during three cruises in winter (January), spring (May) and summer (August) 2014. Water currents were measured along the transects using a ship-borne acoustic doppler current profiler (ADCP) while steaming, and a rosette mounted lowered-ADCP system at stations. Secondary producers were quantified using a laser optical plankton counter mounted on a moving vessel profiler while steaming and on a rosette frame at stations. Production is estimated based on biovolume spectrum theories, and advection of secondary production into the AO is then quantified by combining the high-resolution current and zooplankton data. Here we present seasonal changes in the productive system of the AW current, and its impact on the marine ecosystem of the Arctic Ocean.
Early Career

Warmer and Wetter Winters: Characteristics and Implications of an Extreme Weather Event in the High Arctic

Brage Bremset Hansen¹, Ketil Isaksen², Rasmus Benestad², Jack Kohler³, Åshild Ønvik Pedersen³, Leif Egil Loe⁴, Stephen J. Coulson⁵, Jan Otto Larsen⁷, Øystein Varpe⁶,⁵

¹Norwegian University of Science and Technology (NTNU), Centre for Biodiversity Dynamics (CBD), Dept. of Biology, Trondheim, Norway, ²Norwegian Meteorological Institute, Oslo, Norway, ³Norwegian Polar Institute, Tromsø, Norway, ⁴Norwegian University of Life Sciences, Ås, Norway, ⁵University Centre in Svalbard, Longyearbyen, Norway, ⁶Akvaplan-niva, Longyearbyen, Norway, ⁷Norwegian University of Science and Technology (NTNU), ⁶Dept. of Civil and Transport Engineering, Trondheim, Norway

One predicted consequence of global warming is an increased frequency of extreme weather events, such as heat waves, droughts, or heavy rainfalls. In parts of the Arctic, extreme warm spells and heavy rain-on-snow (ROS) events in winter are already more frequent. How these weather events impact snow-pack and permafrost characteristics is rarely documented empirically, and the implications for wildlife and society are hence far from understood. Here we characterize and document the effects of an extreme warm spell and ROS event that occurred in High Arctic Svalbard in January-February 2012, during the polar night. In this normally cold semi-desert environment, we recorded above-zero temperatures (up to 7°C) across the entire archipelago and record-breaking precipitation, with up to 98 mm rainfall in one day (return period of >500 years prior to this event) and 272 mm over the 2-week long warm spell. These precipitation amounts are equivalent to 25 and 70% respectively of the mean annual total precipitation. The extreme event caused significant increase in permafrost temperatures down to at least 5 m depth, induced slush avalanches with resultant damage to infrastructure, and left a significant ground-ice cover (~5-20 cm thick basal ice). The ground-ice not only affected inhabitants by closing roads and airports as well as reducing mobility and thereby tourism income, but it also led to high starvation-induced mortality in all monitored populations of the wild reindeer by blocking access to the winter food source. Based on empirical-statistical downscaling of global climate models run under the moderate RCP4.5 emission scenario we predict strong future warming with average mid-winter temperatures even approaching 0°C, suggesting increased frequency of ROS. This will have far-reaching implications for Arctic ecosystems and societies through the changes in snow-pack and permafrost properties.
Early Career

International Legal Implications of Climate Change for Arctic Fisheries Management

Seamus Ryder

K. G. Jebsen Centre for the Law of the Sea, UiT - The Arctic University of Norway, Tromsø, Troms, Norway

The international law of the sea needs to be responsive to new threats, challenges and opportunities in order for it to remain relevant and capable of managing the oceans. Among all of the contemporary challenges, climate change may prove to be the most significant. Climate change is both a global and regional issue, and this is particularly evident in the Arctic, where regional change and global impact coexist.

The anticipated impacts of climate change for the marine Arctic include changes in sea surface temperatures, retreating sea ice cover, changing weather and ocean circulation, and ocean acidification. Although the impact of these changes extends beyond any one particular sector, they influence and may have severe consequences for fish species and their ecosystems in the marine Arctic. The range and distribution of at least some fish stocks that occur in sub-Arctic regions may extend or move into more northerly areas, and other factors, such as increased algal blooms, may similarly influence the ecology of Arctic fisheries.

Of course, not all impacts will necessarily be negative; climate change may have some discrete benefits for Arctic fisheries in particular, such as an increase in marine biodiversity, and commercial opportunities arising from the opening up of areas where marine capture fisheries have not yet taken place or the development of existing fishing areas. With these opportunities, however, come very clear associated risks such as the introduction of invasive species and the potential for unregulated fishing activities. The greatest risks may arise if the existing international legal framework for the management of Arctic fisheries is unable to adapt to climate change; or if global trends contributing to overfishing and the emerging worldwide crisis in fish stocks are not addressed, or permitted to creep northwards.

The purpose of this presentation is to focus on the international legal implications of climate change for Arctic fisheries management. To do so, the international legal framework for Arctic fisheries will be explored, and the various roles, rights and obligations of States and entities in relation to the conservation and sustainable use of Arctic fisheries will be presented. Underlying management principles and methodologies will be identified and the extent to which climate change might affect these legal norms and principles will be considered. Based on this analysis, the presentation will seek to identify a range of normative responses to address climate change and the challenges and opportunities it presents for Arctic fisheries.
Climate change Justice – The Arctic and beyond

Øyvind Stokke

UiT–The Arctic University of Norway, Tromsø, Norway

In their fifth report on climate change the IPCC focuses on the urgent need to introduce measures of adaptation and mitigation (IPCC 2014), and the Arctic has become a test case for global climate change. Anthropogenic climate change and GHG-emissions raise the question: Whom do we harm? From the perspective of global justice, climate change harms presently living people unequally and differentially and is especially detrimental to disadvantaged people in the North and the South. In the North, about four hundred thousand indigenous people living the traditional way by hunting and herding reindeer, and have contributed virtually nothing to climate change, are among the first to suffer from its consequences. There are three reasons that this should be taken into consideration:

First, if people have the human right not to suffer from the disadvantages generated by global climate change (Caney 2005: 768), I argue that the injustice suffered by indigenous people in the Arctic establishes a duty on us to compensate them. Principles like "the polluter pays" and "the benefiter pays" may not, though, be sufficient here, as everybody - including indigenous people - can be said to benefit from increases in welfare resulting from production emitting GHGs. I nevertheless argue that the governance of the Saami commons has to take into consideration the consequences of climate change in securing the two-fold aim of protecting the Saami cultural life-forms and compensating them for 130 years of assimilation policies.

Second, those who will feel the most acute effects of climate change will be our future generations. The question is: Why should our generation take on the burden of mitigating climate change that is caused, in no small part, by emissions from people now dead? I argue that the members of future generations have rights that establish a moral duty on us to take on such a burden.

Third, democracy should be strengthened in both the transnational and local dimensions. Public deliberation can solve collective problems at a high incidence due to its moralizing effect. Environmental quality is a generalizable interest, and problems related to dangerous climate change and future generations are first and foremost moral problems that create duties on our part. We need to develop an arctic public sphere where the proper balance between global climate justice and local justice can be subject to political deliberation. The current climate challenge is an opportunity to embark on such an endeavor.
On the characteristics of climate change in Scandinavia and its association with the Northern Atlantic Oscillation (NAO) and sea ice

Youmin Chen, Stefan Sobolowski

Uni Research Climate, Bergen, Norway

We analyzed some characteristics of climate change over Scandinavia using CRU data (1901-2012), and both temperature and precipitation exhibit well-documented positive trends. However, the spatial variability of the trends is large with some areas showing high significance (northern Norway and Sweden) and others none at all (central Finland). The scenarios simulated by NorESM and ECHAM6 models exhibit continued warming and increased rainfall in the 21st century over Scandinavia. Given the well-known zero-lag relationships between the NAO and both temperature and precipitation, responses of sea ice to external forcing and its potential influence on the NAO are of interest. The summer sea ice, fall-early winter NAO relationship suggests that in a warming climate, and under continued decreasing sea ice conditions, the tendency will be towards more positive NAO conditions leading to a wetter, warmer Scandinavia and potentially drier conditions in central-southern Europe. Initial modeling experiments appear to support such speculation (e.g., Folland et al., 2009) but more research is needed.
Early Career

Should we keep living in the Arctic?

Kristoffer Mällberg

University of Tromsø, Tromsø, Troms, Norway

As the climate changes, and the reductions in emissions necessary to avoid the worst consequences of global climate change become larger and larger, we need to answer an important question. Should we keep living in the Arctic?

A population spread over a large rural territory such as the Arctic poses major challenges for attempts to reduce the greenhouse gas-emissions (GHG). Long distances between cities, towns and households makes transportation, both of goods, services and people an important factor, while providing and distributing power becomes a difficult and often costly endeavor.

As a rule, urban areas have a lower level of greenhouse gas-emission than the more rural. The more easily controlled environment in urban areas makes it easier to minimize the effects of the climate change. Meanwhile, the short distances between households means that not only the transportation of goods and services but also the distribution of power can be done at a fraction of the cost of urban areas. In the long run, reducing the GHG-emissions by a certain amount could be done more cost effectively by moving the population in the Arctic to strategically placed urban areas than by attempting to reduce the emissions of transportation and distribution of power to rural areas. It would also allow for a centralization of social services and open for a higher standard of living. Moving the centers of population would not mean giving up on industry in the Arctic. On the contrary, the higher long-term reduction in GHG-emissions, would probably allow for an expanding industry in the Arctic supported by a migrant workforce.

So why are we willing to pay a premium to continue to live in the Arctic? Why is centralization not the preferred solution to the demand for reduced emissions and the problem of climate change? To answer these questions I will draw on theories of cultural identity and heritage to argue that we should be very hesitant to restrict the freedom of movement and habitation. The connection people have to their homes and environment should not be underestimated, and while global climate change will make us rethink whether we are able to and should continue living in various places, we are still willing to pay the premium for living in these places. Both for the population of the Arctic and the cultural diversity of these areas, it is important that we continue to do so.
Examining the interaction of reproductive traits and landscape characteristics on Arctic shrub expansion using a spatially-explicit simulation modelling approach

Adam Naito, David Cairns, Richard Feldman, William Grant

Texas A&M University, College Station, Texas, USA

Shrub expansion is one of the most recognized components of terrestrial Arctic change. While experimental work has been instrumental in identifying its fine-scale drivers and implications, the contribution of shrub reproductive characteristics to their spatial patterns is poorly understood at broader scales. We developed a C#-based spatially-explicit model that simulates historic landscape-scale shrub establishment in river valleys in northern Alaska between the 1970s and the late 2000s. This model can simulate shrub growth using different reproduction modes (clonal development with and without the "mass effect" and short-distance dispersal). In addition, it can account for hydrological constraints to shrub growth using a topographic wetness index. We examined these treatments in the Ayiyak, Colville, and Kurupa River valleys. After simulating 30 landscape realizations using each treatment, we quantified the spatial characteristics (percent cover, patch density, edge density, patch size variability, area-weighted shape index, area-weighted fractal dimension index, and mean distance between patches) of the resulting shrub patches on the simulation end date using FRAGSTATS. We used Principal Components Analysis to determine which treatments produced spatial characteristics most similar to those observed in the late 2000s. Based upon our results, we hypothesize that historic shrub expansion in northern Alaska has been driven in part by clonal reproduction with the "mass effect" or short-distance dispersal (< 5 m). The interactive effect of hydrologic characteristics, however, is less clear. These hypotheses may be tested in future work involving field observations. Considering that climate change may induce a shift from a clonal to a sexual reproductive strategy, this model can facilitate predictions regarding future Arctic vegetation patterns.
The fleeting glaciers of the Arctic

Jostein Bakke¹,², Øyvind Paasche¹

Dept. of Earth science, Univeristy of Bergen, Bergen, Norway; Bjerknes Centre for Climate Research, Bergen, Norway

Glaciers and snow are the very symbol of the Arctic, covering large parts of its terrestrial surface throughout the year. The cool temperatures that have allowed for the widespread coverage of glaciers are now trending towards a warmer climate, and with this gradual shift we observe a non-linear response in the cryosphere of which glaciers are a key component. This change is manifested in retreating fronts and an overall thinning. Because the typology of Arctic glaciers is rich and varied, the response pattern to the on-going warming is not unison. Instead we observe large spatial variations due to the critical balance between summer temperature and winter precipitation, but also other factors such as aspect, altitude, geographical location, debris cover and so forth. Even so, minor variations is superimposed on a larger trends which suggests that in a not so distant future, glaciers will probably be less abundant than what has been common for the last 100 years. In the context of the last 10 000 years it is evident that arctic glaciers have changed significantly and they have even been smaller than they are today, which was the case 9000 to 5000 years ago. On Svalbard, two glacier lake sediment records foretell of large past variations, indicating a more articulated sensitivity to climate change than what is commonly perceived for the Arctic cryosphere.
Early Career

The potential of the Northern Sea Route (NSR) to reduce carbon dioxide emissions

Ilya Stepanov

National Research University Higher School of Economics, Moscow, Russia

The growth and expansion of the world trade have profoundly contributed to the increasing interest of the world community in the Northern Sea Route (NSR) as the shortest maritime trade and transport route between Europe and Asia. The economic boom in the Asia Pacific together with the need to diversify the export-import flows of goods, in particular, energy resources serve as the factors to foster the large-scale development of a new transport artery in the North. The NSR has many visible odds. Primarily, it enables to reduce the navigation distance from Europe to Asia (London - Yokohama) approximately by a third in comparison to the main maritime transport route through the Suez Canal. This in turn allows transporting companies not only to save time but to cut down the operating costs for fuel as well. Moreover, the use of the NSR permits to avoid various problems associated with navigation through the alternative maritime routes such as threats of pirate attacks, increasing waiting and transshipment time and the need to navigate through territorial waters of unstable countries or regions. On the other hand, there exists a huge range of barriers (administrative, institutional, economic) impeding the further development of the NSR. Its future prospects will largely depend on the effectiveness of Russian strategy and real-life efforts for enhancing and building new infrastructure and increasing the cargo flows. This research focuses on one more advantage that the NSR possesses over the alternative routes. The distance reduction decreases the fuel consumption and, as the consequence, cuts down the carbon dioxide emissions. Hence, the NSR enables transporting companies to cut down the carbon dioxide emissions per a vessel in comparison to the alternative routes, in particular, through the Suez Canal. Apart from this obvious environmental benefit, the transporting companies can take the additional economic advantage. At present, the emissions from the burning of bunker fuel, as opposed to aviation fuel, are not restricted by any international agreement. However, a new pending agreement on climate change regulation in 2015 is likely to consider and restrict maritime transport emissions. The aim of this research is to evaluate the volume of carbon dioxide emissions reduction NSR allows to save compared to alternative routes as well as to assess the potential benefit that the transporters can consequently gain in the next 5-10 years.
Critical Infrastructure in the Arctic and how to prepare for Climate Change

Maj Bæverfjord¹, Anatoly Sinitsyn¹,², Anders Gylland¹, Magne Wold¹

¹SINTEF, Trondheim, Norway; ²UNIS, Svalbard, Norway

The Arctic is a challenging region for living, building and making business due to the cold and harsh climate and due to the remoteness. This relates to the vast distances, the ice cover and the scarce availability of ice free harbours. The situation is made further complicated because of the challenges of ensuring trafficability of roads and airfields built on permafrost soil, especially in the spring season when the active layer of the permafrost thaws. This natural phenomenon, the seasonal thawing of frozen, ice-rich soil, which leads to significant loss of bearing capacity, also poses challenges to the stability and performance of built infrastructure such as buildings and pipelines. Climate change scenarios predict warmer air temperatures in the northern regions, which in turn will affect permafrost soil temperatures. The behavior of the permafrost is highly temperature sensitive and thus future climate change can have severe consequences for existing and future infrastructure. The possible consequences may include thaw settlements, problems associated with frost heave, increased settlement rates of foundations, etc. These processes may cause future damage to infrastructure and increased maintenance costs if remedial actions are not taken during the design and construction phases. Among Arctic actors there is an urgent need to gain competence on the local effects of climate change and to develop a framework for handling, predicting and assessing the potential impact of climate change on existing and new infrastructure. The main topic of this paper is one of the building stones in this process, namely the development of tools and methodology to collect and interpret quality permafrost soil data for engineering purposes, which has been ongoing on Svalbard for a decade. Additionally, relevant research on remote sensing techniques for mapping of permafrost properties as undertaken nationally and internationally is considered.

Further, we show an example on how knowledge of today's permafrost soil parameters can be utilized in the context of permafrost sensitivity to climate change. With a downscaled climate model we improve our knowledge on the impact of changes in air temperature on ground temperature. The effect on permafrost parameters and consequences for infrastructure is discussed, together with how this can be used in decision making for the future.
Quantification of snow and permafrost properties in a changing climate in Svalbard using satellite-borne and field measurements

Eirik Malnes¹, Markus Eckersforfer¹, Heidi Hindberg¹, Hanne H. Christiansen²

¹Norut, Tromsø, Norway, ²UNIS, Longyearbyen, Norway

Permafrost and snow are the two largest components of the cryosphere and thus excellent indicators of global climate change. The spatial extent and temporal variability of the snow cover and snow water equivalent (SWE), as well as the onset of permafrost active layer thawing and freezing are largely determined by freezing degree-days and precipitation. Both freezing degree-days and precipitation are measurable variables of the warming climate and its interannual variability in Svalbard.

Snow properties and the permafrost thermal regime has been monitored very detailed by field campaigns and field instrumentation since 2012 and 2007, respectively, at the IPY cryosphere "supersite" of Kapp Linné, Svalbard. Traditionally, such point observations are extrapolated using spatial models. Satellite remote sensing offers an alternative means for upscaling, and may when used correctly, be used to extend the in situ monitoring both in the spatial dimension, and in the temporal dimension (backward in time).

In this study we show how detailed in situ point measurements can be upscaled using TerraSAR-X data, collected since 2012. The comparison between field and SAR data showed a slight overestimation of SWE on the valley scale, with good correlations on a transect scale and poorer correlations in steeper terrain. The onset of active layer freezing and thawing and its interannual variability is reproduced well by SAR data. To further upscale both temporarily and spatially, we use satellite-borne C-band SAR and optical spectrometers to quantify snow cover fraction and wet snow. We have established a continuous data series since 1991 for Kapp Linné and since 2000 for entire Svalbard. These data series can be used to detect climate change induced changes in snow-covered areas, frequency of mid-winter rain-on-snow events and duration of annual active layer thawing.

In summary, by combining satellite-borne data and in situ data, snow and permafrost properties can be retrieved for entire Svalbard for extended periods and with spatial details. Especially the historic, actual and planned availability of satellite data from Svalbard, due to its location in the satellite polar orbit, allows for building of long data series, critical for climate change studies.
Changes in Fram Strait Sea Ice Volume Export between 1992 and 2012 and Implications for the Arctic Sea Ice Mass Balance

Gunnar Spreen¹, Ron Kwok², Edmond Hansen¹,³, Sebastian Gerland¹

¹Norwegian Polar Institute, Tromsø, Norway; ²Jet Propulsion Laboratory, California Institute of Technology, Pasadena, USA; ³Multiconsult, Tromsø, Norway

The Fram Strait between Svalbard and Greenland is the main gateway for sea ice export out of the Arctic Basin. The Arctic sea ice mass has decreased during recent decades. Changes of the sea ice mass balance can either have thermodynamic (melting) or dynamic (export) causes, or a combination of both. Therefore, to better understand the recent decrease it is of special importance to monitor changes in the sea ice export. Additionally, changes in the sea ice transport through Fram Strait can modify the major water mass formation processes in the Greenland Sea and further downstream with consequences for the deep water formation and global ocean circulation as was seen for the Great Salinity Anomaly observed during the 1960s-70s. To estimate the sea ice volume export through Fram Strait the three variables sea ice drift, area, and thickness have to be known and combined. We combine satellite observations of ice drift and area with ice thickness data from moored Upward Looking Sonars (ULS) in Fram Strait to retrieve a consistent sea ice volume export time series for the years 1990 to 2012. The absolute sea ice export shows a negative trend of 2.3%/year in respect to the mean export of 2307 km³/year. From this one can conclude that the recent Arctic sea ice volume decrease is not caused by an enhanced sea ice volume export. There is no "flushing out" of the Arctic Basin and the decrease can be attributed mainly to processes within the basin (e.g. melting). However, inter-annual variability in ice export is high and large export events at the beginning of the time series could have preconditioned the Arctic sea ice thickness decrease in the face of a warming trend. In addition, the Fram Strait sea ice volume export can be expressed as fraction of the total sea ice volume available in the Arctic Basin. About 1% of the Arctic sea ice volume is exported through Fram Strait every month and we find a small increase in this fractional ice export. This means that the Arctic Basin sea ice volume is decreasing at a faster rate than the sea ice volume export is decreasing.
Methane emissions in the Arctic Ocean: from the past to the future

Giuliana Panieri, Tine Rasmussen, Chiara Consolaro, Andrea Schneider, Kamila Sztybor, Katarzyna Zamelczyk

Centre for Arctic Gas hydrate, Environment and climate - CAGE, Department of Geology, UiT The Arctic University of Norway, Tromsø, Norway

The Centre for Arctic Gas hydrate, Environment and Climate (CAGE) is investigating the role of gas hydrates in arctic areas, and the effects that their dissociation will have on oceans and our global climate in the future. All IPCC warming scenarios suggest that methane reservoirs are becoming destabilized by increased temperature then in the near future the rising atmospheric concentration of methane (CH4), and carbon dioxide (CO2) is expected. It is, therefore, critical to resolve the periodicity of methane seafloor emissions through time, in relation to past climate change with a special focus on periods of climate warming. The vast amount of methane in the Arctic is considered vulnerable to climate change and when emitted into the marine realm is metabolized by microbial activity in CO2 contributing in the context of ocean acidification. One of the six Work Package at CAGE, the WP 6: “Pleistocene to present – Methane, ocean temperature and CO2”, uses micropaleontology to detect marine methane emissions. Thus, in an effort to track changes of past methane emissions from the Arctic seafloor, we are conducting geochemical analyses of benthic foraminifera, Secondary Ion Mass Spectrometry (SIMS), Scanning Electron Microscopy (SEM) imaging and elemental mapping of foraminiferal shell samples for diagenesis investigations together with other geochemical, micropalaeontological and sedimentological analyses, on sediment cores collected from the Vestnesa Ridge (west of Svalbard at ~79° N), a large sediment drift in the Fram Strait representing one of the northernmost gas hydrate provinces along the Arctic continental margins. On-going results indicate that the geologic record in the Vestnesa Ridge is punctuated by several methane emission events (MEEs) occurring at the site during the last 23,000 years. The MEEs show an apparent correlation with global or regional climatic events and may provide clues about future interactions between methane hydrates and climate change.

Details on the CAGE research plan and organization can be found on www.cage.uit.no to foster opportunities for cross-disciplinary collaboration. Based in Tromsø, at the world’s northernmost University, CAGE establishes the intellectual and infrastructure resources for studying the amount of methane hydrate and magnitude of methane release in Arctic Ocean environments on time scales from the Neogene to the present. The Centre of Excellence is funded by the Norwegian Research Council (grant No. 223259) over a period of ten years.
Arctic glaciers – status quo or rapidly shrinking?

Geir Moholdt¹, Alex S. Gardner², Bert Wouters³

¹Norwegian Polar Institute, Tromsø, Norway, ²Jet Propulsion Laboratory, California, USA, ³University of Bristol, Bristol, UK

Glaciers and ice caps respond directly to climate variations, and studying their behaviour can give important insights to the patterns and consequences of recent climate change. Field measurements from the last ~50 years indicate that glacier mass losses are increasing over most of the world, but there are few records from the Arctic and they vary greatly from site to site. This presentation will show how satellite measurements can be used to derive reliable estimates of regional glacier changes and contribution to sea level rise. We use satellite altimetry (ICESat and CryoSat-2) to determine glacier elevation changes along repeated surface profiles, and satellite gravimetry (GRACE) to estimate large-scale glacier mass changes after removing other gravitational signals. The results show a general glacier imbalance with current climate, characterized by rapid thinning at the lower parts of glaciers where surface melting is stronger. Unlike the Greenland ice sheet, we find no widespread difference between glaciers that terminate on land and those that terminate in the ocean. There are, however, several examples of rapid glacier dynamics or surging with localized iceberg calving rates that are orders of magnitude higher than normal. These isolated events may have a major impact on their local environments, but on a larger scale their associated mass losses are relatively insignificant. For the Arctic as a whole, excluding the Greenland ice sheet, we estimate a total glacier mass loss of ~175 gigatons per year between 2003 and 2009, which represents about 20% of the observed sea level rise over the same period. This is likely higher than in previous decades and may suggest a further increase in the future. However, we observe no persistent trend across the Arctic, and regional glacier mass changes seem to be strongly dependent on atmospheric circulation patterns, with some regions being in ‘status quo’ and others experiencing rapid shrinkage of unknown duration. This surprising variability will be a major challenge in predicting the future evolution of Arctic glaciers and their contribution to global sea level.
Loss of sea ice during winter north of Svalbard

Ingrid Husøy Onarheim\textsuperscript{1,2}, Lars Henrik Smedsrud\textsuperscript{1,3}, Randi B. Ingvaldsen\textsuperscript{4}, Frank Nilsen\textsuperscript{3,1}

Geophysical Institute, University of Bergen, Bergen, Norway; Bjerknes Centre for Climate Research, Bergen, Norway; University Centre in Svalbard, Svalbard, Norway; Institute of Marine Research, Bergen, Norway

Sea ice loss in the Arctic Ocean has up to now been strongest during summer. In contrast, the sea ice concentration north of Svalbard has experienced a larger decline during winter since 1979. The trend in winter ice area loss is close to 10\% per decade, and concurrent with a 0.3°C per decade warming of the Atlantic Water entering the Arctic Ocean in this region. Simultaneously, there has been a 2°C per decade warming of winter mean surface air temperature north of Svalbard, which is 20-45\% higher than observations on the west coast. Generally, the ice edge north of Svalbard has retreated towards the northeast, along the Atlantic Water pathway. By making reasonable assumptions about the Atlantic Water volume and associated heat transport, we show that the extra oceanic heat brought into the region is likely to have caused the sea ice loss. The reduced sea ice cover leads to more oceanic heat transferred to the atmosphere, suggesting that part of the atmospheric warming is driven by larger open water area. In contrast to significant trends in sea ice concentration, Atlantic Water temperature and air temperature, there is no significant temporal trend in the local winds. Thus, winds have not caused the long-term warming or sea ice loss. However, the dominant winds transport sea ice from the Arctic Ocean into the region north of Svalbard, and the local wind has influence on the year-to-year variability of the ice concentration, which correlates with surface air temperatures, ocean temperatures, as well as the local wind.
Changes in iceberg size and distribution in Greenland’s coastal waters

Jessica Scheick¹,³, Gordon Hamilton¹,³, M. Brady Butler¹, Jakob Abermann², Eva Mätzler²

¹University of Maine, Orono, ME, USA, ²Asiaq, Greenland Survey, Nuuk, Greenland, ³Climate Change Institute, Orono, ME, USA

Climate change is readily manifest in the Arctic, yet many of the drivers and impacts of these changes remain poorly documented and poorly understood, making prediction of future changes and policy development difficult. Recent observed changes in the flow regime and calving behavior of numerous outlet glaciers draining the Greenland Ice Sheet have led to changes in the size and distribution patterns of icebergs in coastal waters. These changes have a number of impacts, such as altering freshwater fluxes to the ocean and presenting a hazard to coastal navigation. The projected increase in maritime traffic in the Arctic requires detailed analysis of iceberg distribution patterns in order to provide marine navigators/operators with relevant information for safe and efficient navigation. We are developing an algorithm for use with optical satellite imagery to automatically delineate icebergs and provide information about their size and location. Preliminary analysis based on several Landsat images suggests that over the course of the past decade, Disko Bay in West Greenland has seen a shift towards an increasing number of smaller icebergs, a trend consistent with the observed changes of nearby outlet glaciers. This information on iceberg size and distribution will be useful for maritime operators in a number of sectors, including shipping, tourism, fishing, and offshore exploration.
The International Tundra Experiment ITEX - more than 20 years of vegetation monitoring in Arctic and alpine ecosystems

Christian Rixen

Swiss Federal Institute for Forest, Snow and Landscape Research, Davos, Switzerland

The International Tundra Experiment is a scientific network of experiments focusing on the impact of climate change on selected plant species in tundra and alpine vegetation. Currently, research teams at more than 40 circumpolar sites carry out similar, multi-year plant manipulation experiments that allow them to compare annual variation in plant performance with respect to climate conditions.

The ITEX research model combines long-term and short-term experimentation with monitoring and has the elegance and simplicity called for to understand ecosystem response and vulnerability to change. The experiment is designed to examine the effects of temperature change; maximize geographic representation, by minimizing technical and equipment requirements; be long-term and focus primarily on species. Participation may be at several levels of complexity and sophistication depending on interests and available funding support. Each ITEX site operates however some form of warming experiment. Most sites use open-top chambers to warm the tundra vegetation. These passive chambers affect plant growth and phenological development, i.e. the timing of flowering, growth of leaves etc., in a variety of ways.

Each ITEX study site is expected to collect similar data following established protocols provided in the ITEX Manual. Collectively the ITEX network is able to pool its data sets to examine vegetation response at varying levels, for example across space (from habitats to ecosystems) and over time.

In control plots across all study sites, it was found that changes in vegetation height and abundance of growth forms were largely consistent with predictions based on warming experiments. Inter-site comparisons indicated that shrubs (particularly deciduous shrubs), were increasing over time primarily in sites that were warming rapidly over the study period, but this pattern was only apparent in locations that were already quite warm. In contrast, the vegetation in the coldest tundra sites was relatively insensitive to climate warming.

Understanding changes in vegetation and biomass production under climate change will be crucial for people and animals of Arctic and alpine regions.
Ecological winners and losers in future Arctic marine ecosystems

Scientific committee

Leader: Associate Professor Janne E. Søreide (Leader), The University Centre in Svalbard (UNIS), Norway
Professor Paul Wassmann, UiT, The Arctic University of Norway, Norway
Professor Rolf Gradinger, Leader of the Barents Sea Ecosystem Programme, Institute of Marine Research, Norway / University of Alaska Fairbanks, USA
Special Adviser Dr. Christian Wexels Riser, The Research Council of Norway, Norway
Professor Jean Eric Tremblay, ArcticNet, Québec-Océan & Takuvik / Laval University, Canada
Mar Fernández Méndez, APECS / Alfred-Wegener-Institut Helmholtz-Zentrum für Polar und Meeresforschung, Germany
Overwintering survival in a warmer ocean may ultimately determine the winners and losers in zooplankton communities on Arctic shelves

Robert Campbell¹, Carin Ashjian², Stephen Okkonen³

¹University of Rhode Island, Narragansett, RI, USA; ²Woods Hole Oceanographic Institution, Woods Hole, MA, USA; ³University of Alaska, Fairbanks, Fairbanks, AK, USA

Our understanding of winter biological conditions in the Arctic is severely limited. In particular, we have a poor understanding of how zooplankton survive the long winter period on the shallow Arctic shelves with little food. We conducted an early winter cruise in November-December 2011 on the USCGC Healy to the Chukchi and Bering Seas. Our objectives included describing hydrography and associated zooplankton species and population distributions, and identifying the overwintering habitat, activity, and grazing rates of Calanus spp. and euphausiids. Distinct groups of zooplankton types were observed that were associated with specific water mass types and characteristics. Advection of water and zooplankton from the Bering Sea was a prominent feature structuring the spatial distributions of zooplankton types and abundances. Zooplankton communities along the Chukchi Sea shelf break were distinct in species and, for Calanus glacialis/marshallae, life stage composition. Both Calanus spp. and euphausiids appeared to be active and feeding, with Calanus spp. not in diapause but rather continuing to develop. The smaller copepods Pseudocalanus spp., Acartia longiremis, and Oithona similis were recently reproductively active, evidenced by the presence of naupliar stages. Based on estimates of metabolically required lipid expenditures and observed lipid stores, Calanus glacialis/marshallae may not successfully overwinter on the shallow Chukchi Shelf unless they can further reduce their metabolism as the season progresses. Future warmer overwintering conditions would certainly put them at greater risk.
Ringed seals (*Pusa hispida*) in the Arctic: Future ecological losers in Svalbard

Charmain Hamilton¹,², Christian Lydersen¹, Rolf Ims², Kit Kovacs¹

¹Norwegian Polar Institute, Tromsø, Norway; ²University of Tromsø, Tromsø, Norway

The Arctic is currently warming faster than any other region on the planet. Sea-ice extent has declined drastically in recent decades and future declines are expected. Many predictions have been made about the consequences of this decline for arctic marine mammals, but at present little hard evidence of impacts exist. Ringed seals (*Pusa hispida*) are an endemic, circumpolar keystone species in the arctic ecosystem because of their importance in the food web, both as a predator and a prey. They are the primary prey species for polar bears (*Ursus maritimus*) and they are an important food source for coastal Inuit communities. Ringed seals are intimately associated with sea ice for almost every aspect of their existence: pupping, nursing, moulting, resting and some of the foraging all take place associated with sea ice. In this study, twenty-two ringed seals were equipped with Satellite-Relay Data Loggers (SRDLs) in 2002-2003 in Svalbard, Norway when sea-ice conditions were historically "normal." In 2006, the sea-ice situation in Svalbard changed dramatically and the new reduced-ice situation has prevailed in the years since. Following the shift, summer sea-ice extent changed from a position over the continental shelf to a new northward retracted position over the deep Arctic Ocean Basin and the amount of land-fast ice forming in the fjords in western Spitsbergen decreased sharply. In 2010-2012, 38 additional ringed seals were equipped with SRDLs in order to study the effects of this sea-ice decline. Ringed seals in the two time periods exhibited similar habitat preference with regard to environmental factors such as ice concentration and distance to glacier fronts. However, we document a sharp increase in foraging costs for ringed seals in Svalbard in 2010-2012 compared to 2002-2003. Dive durations have increased and surface intervals between dives have decreased for all observed months (July-April). Seals in the latter period also swam greater distances per day, rested less on the sea ice and performed more searching and less area-restricted search (which they do when foraging intensely in an area) when on offshore trips in the late-summer. If these increased foraging costs are not compensated for by increased energetic returns, growth, age at sexual maturity, reproduction and survival will be affected. Ringed seals are a central component of the arctic food web and changes in their abundance will reverberate through the arctic ecosystem.
The Arctic Basins: An integrated physical and biological perspective

Bodil Bluhm\textsuperscript{1,2}, Ksenia Kosobokova\textsuperscript{3}, Eddy Carmack\textsuperscript{4}

\textsuperscript{1}University of Tromsø, Tromsø, Norway, \textsuperscript{2}University of Alaska Fairbanks, Fairbanks, USA, \textsuperscript{3}P.P. Shirshov Institute of Oceanology, Moscow, Russia, \textsuperscript{4}Department of Fisheries and Oceans, Sidney, Canada

The Arctic Ocean (AO) is integral to the global ocean by exchange flows with the subarctic Atlantic and Pacific, with the Atlantic dominating by mass and heat fluxes, and the Pacific dominating in terms of impact on vertical stratification. Here, we summarize the status of knowledge on the Arctic Basins from a bio-physical perspective. Two basic water mass assemblies differ in the absence/presence of Pacific Water (PW) sandwiched between Arctic Surface Water above and Atlantic Water (AW) below, with characteristic expatriate planktonic biota in PW and AW, and strongly vertically structured zooplankton communities. The four basic large-scale circulation systems of the Arctic basins include (1) the northern thermohaline circulation that drives PW through Bering Strait into the Canada Basin (CB), and counter-flowing AW through Fram Strait (FS) across the Barents Sea into the Nansen Basin, (2) wind-driven circulation which forces the cyclonic Trans-Polar Drift from Siberia to FS and the anticyclonic Beaufort Gyre in the CB; (3) the topographically-trapped Circumpolar Boundary Current which carries AW cyclonically around the basin boundaries and PW along the southern boundary of the CB; and (4) slow exchanging Arctic Ocean Deep Waters which form in the Greenland Sea, enter through FS, and spread within the basin interior. Massive submarine ridges act as barriers to the free exchange of deep and bottom waters and constrain circulation, although they do not appear to fully prevent biotic dispersion. Owing to stratification-related nutrient limitation and light limitation mediated by snow, ice cover and sun angle, primary production is low, characterized by small phytoplankton and a sub-surface chlorophyll maximum in the Pacific Arctic. Advective inputs add food supplies to pelagic and benthic biota near the basin perimeter with decreasing pelagic and benthic biomass at increasing depths, and long food webs at great depths driven by refractory organic matter in a diverse, endemic benthos. The accelerating pace of change over the basins in the past decades is most obvious in the loss of ice volume and extent resulting in sea ice annually retreating past the shelf break, facilitating shelf-break upwelling of nutrients from subsurface basin-waters onto the shelves. Reduced ice cover has also spurred substantial geopolitical, industrial and other interests in the central Arctic, which carry with them the potential for environmental stress and international conflict. Instead, we encourage pan-Arctic collaboration and integration for fruitful management and conservation of ecosystem and climate system services that reach beyond the region.
Management of living resources in a changing Arctic

Harald Gjøsæter¹,²

¹Institute of Marine Research, Bergen, Norway, ²Hjort Centre for Marine Ecosystem Dynamics, Bergen, Norway

Are there differences between management of living marine resources in the Arctic and elsewhere? What characterizes the Arctic areas as compared to more temperate regions? Are existing management bodies, conventions and advisory systems sufficient for handling the challenges we are met with in the Arctic? The Arctic is changing faster than more southern areas and the effects of global warming may well induce more profound changes there. What challenges do this changing environment pose in terms of management needs? What do we mean by ecosystem based management, and how can this be achieved in the Arctic? These and similar questions will be discussed in the invited lecture "Management of living resources in a changing Arctic"
The contiguous domains of Arctic Ocean advection: trails of life and death

Paul Wassmann

UiT Norways Arctic University, Tromso, Norway

The central Arctic Ocean is not isolated, but tightly connected to the northern Pacific and Atlantic oceans. In turn, it influences the physical, chemical and biological oceanography of adjacent subarctic waters. Advection of nutrient-, detritus- and plankton-rich waters into the Arctic Ocean forms lengthy contiguous domains that connect subarctic with the Arctic biota, supporting both primary production and higher trophic level consumers. Exports of biomass out of the Arctic Ocean into both the Pacific and Atlantic oceans is thought to be far smaller than the northward influx, Arctic Ocean ecosystems are thus net beneficiaries through advection. The biotic impact of Atlantic- and Pacific-origin taxa in Arctic waters depend on their ability to survive in the new environment. Thus, advective transport can be thought of as trails of life and death in the Arctic Ocean. This overview presents information about the advection and fate of zooplankton in the Arctic Ocean, now and in the future. It characterises the various organism types that interact along the contiguous domains and show how life derived from subarctic production regimes fuels life in the Arctic Ocean. The Arctic Ocean is thus, at least in some regions, a net heterotrophic ocean that – during the foreseeable trend towards global warming – will obtain an increased balance between local and advective production and consumption.
Harbour seals in the Arctic: Future ecological winners on Svalbard?

Marie-Anne Blanchet¹,², Christian Lydersen¹, Andrew D. Lowther¹, Rolf A. Ims², Kit M. Kovacs¹

¹Norwegian Polar Institute, Tromsø, Norway; ²Arctic University of Norway, Tromsø, Norway

Harbour seals are generally regarded as a temperate species, but the world northernmost population inhabits the arctic waters of Svalbard year-round. The general warming of air and sea in this region combined with dramatic changes in sea ice composition, thickness and extent are expected to cause shifts in species’ distributions and abundances particularly in marine communities. In this study we document at-sea movements and diving behaviour of 30 adult harbour seals instrumented with Conductivity Temperature and Depth-Satellite Relay Data Loggers in two successive years (2009-2010). The seals showed strong preference for the west side of the archipelago, staying mainly in coastal areas (<50 km) on the continental shelf, but seldom entering deep fjord systems. Areas with shallow waters (<100 m) and intermediate slope were preferred to deep-waters or flat-bottom areas. Season influenced greatly movement patterns and diving behaviour. Distance swam per day, individual home-range size, and trip duration increased throughout the winter compared to fall values. Sea ice influenced movement patterns but not diving behaviour directly. Animals avoided high ice concentration (>50%) and had to navigate more in order to avoid being trapped into too heavy ice when the drift ice extent was at its maximum on the West coast of Spitsbergen. Dives were deeper, longer, less numerous, and animals spent proportionally less time at the bottom during the winter compared to the fall/early winter. The seals seemed to target the mixed layer which likely concentrates prey during the fall/early winter and dove deeper to reach warmer more saline layers during winter months. These seasonal changes in diving behaviour were linked to the average wind stress from northerly or northeasterly directions occuring the preceding week on the shelf. Sustained winds from this direction are typically linked to upwelling events through offshore Ekman transport. During these events the West Spitsbergen Shelf was flooded with warm saline Atlantic waters bringing Atlantic-associated preys such as Atlantic cod or haddock. It is likely that harbour seals were switching prey type from Arctic to Atlantic under such events. The presence of Atlantic waters combined with the richness and productivity found on the West Spitsbergen Shelf due to intense mixing of water masses at the polar front are contributing factors to the existence of this seal population year-round. Increased influxes of AW and decrease of the sea-ice cover are predicted to occur in the future potentially favouring the growth in this harbour seal population.
Impacts of sea-ice retreat on primary production in the Central Arctic Ocean

Mar Fernández-Méndez\textsuperscript{1,2}, Christian Katlein\textsuperscript{1}, Benjamin Rabe\textsuperscript{1}, Marcel Nicolaus\textsuperscript{1}, Ilka Peeken\textsuperscript{1,3}, Karel Bakker\textsuperscript{4}, Hauke Flores\textsuperscript{1}, Heidi Louise Søreksen\textsuperscript{5}, Ronnie Nøhr Glud\textsuperscript{5}, Frank Wenzhöfer\textsuperscript{1,2}, Antje Boetius\textsuperscript{1,2}

\textsuperscript{1}Alfred-Wegener-Institut Helmholtz-Zentrum für Polar und Meeresforschung, Bremerhaven, Germany, \textsuperscript{2}Max Planck Institute for marine Microbiology, Bremen, Germany, \textsuperscript{3}MARUM Center for Marine Environmental Sciences, Bremen, Germany, \textsuperscript{4}Royal Netherlands Institute for Sea research, Texel, The Netherlands, \textsuperscript{5}University of Southern Denmark, Odense, Macao

The ice-covered Central Arctic Ocean is changing rapidly due to the recent reduction in ice cover. The shift from multi-year to first-year sea ice and to large areas of open waters has the potential to enhance phytoplankton primary productivity due to increased light availability. In addition, these changes may also affect the relative importance of sea-ice algae for Arctic productivity, and the sources and sinks of nutrients. During the sea-ice extent minimum record in summer 2012, we sampled a wide range of Arctic environments: sea ice, melt ponds and water column north of 78°N. Net primary productivity (NPP) was measured by 14CO\textsubscript{2} uptake at different irradiances and the photosynthesis vs. irradiance (PI) curves were used to upscale measured NPP to the entire Eurasian Basin. Results obtained for the nutrient-limited late summer season show that ice-covered water column had lower NPP rates than open water probably due to light limitation. Sea-ice algae contributed up to 60\% to total NPP in the Central Arctic at the end of the season. When sub-ice algal aggregates, such as Melosira arctica, were present, sea-ice algae could contribute by up to 90\%. Under favorable conditions, Melosira and other aggregate-forming sub-ice algae remain floating below the ice by trapping the photosynthetically produced oxygen. However, upon ice melt a large proportion of these algal aggregates sink below the surface layer. This could represent a substantial export of organic carbon and nutrients from the surface towards the deep-sea environment. For instance, new annual production in the central Eurasian Basin calculated from the seasonal nutrient drawdown in the mixed layer during 2012, was similar to estimates from previous years with more extensive ice cover. However, when including the contribution by algal aggregates, the annual production doubled. However, overall despite potential local increases in NPP, annual new production is not likely to increase substantially in the Central Arctic as long as it is constrained by the supply of nitrate and silicate to the surface waters.
Effect of ocean warming on the dynamics of the Barents Sea food web.

Benjamin Planque¹, Ulf Lindstrøm¹, Sam Subbey²

¹Institute of Marine Research, Tromsø, Norway, ²Institute of Marine Research, Bergen, Norway

There is currently much concern over the possible effects of future ocean warming on the spatial distribution, phenology, productivity or even survival of individual marine species. Studies conducted on individual marine species are sometimes raised to community or ecosystem level, but this is a difficult task given that individual species will respond simultaneously to changes in temperature conditions and to changes in other species dynamics, thereby creating intricate feedbacks and complex dynamics. To examine the potential effects of temperature increase on food webs requires that the dynamics of multiple species and their interactions be considered simultaneously. In the present study, we investigate how the Barents Sea food web dynamics may respond to ocean warming by combining two complementary approaches. We use a non-deterministic network dynamics model (NDND) as a reference for the variability of the Barents Sea food web dynamics. In complement, we use the metabolic theory of ecology (MTE) to derive some key parameters for the NDND model and define how these can vary under warming scenarios. We compare food web properties under current climate and expected warming scenarios and show that temperature will qualitatively affect the stability of the Barents Sea ecosystem and the distribution of biomass and productivity between the different trophic groups.
Intrapopulation diet variation in beluga whales: implications for bottom-up impacts of a changing Arctic ecosystem

Cory Matthews¹, Steven Ferguson²

¹University of Manitoba, Winnipeg, Manitoba, Canada; ²Fisheries and Oceans Canada, Winnipeg, Manitoba, Canada

Long-term reductions in Arctic sea ice will influence marine primary productivity patterns, as well as zooplankton and fish community compositions. Changes at these lower trophic positions of Arctic marine food webs will have bottom-up impacts on marine mammals that rely on predictable, often seasonal aggregations of high-energy prey. Beluga whales (Delphinapterus leucas) are an ice-associated species with a generalist diet comprising a range of invertebrate and fish prey. While their broad diet, and by extension, perceived adaptability, places belugas among the least vulnerable of Arctic marine mammals to ongoing and anticipated ecosystem changes, considerable gaps in our understanding of beluga diet exist (e.g. how does diet vary between sexes and among age classes, which are spatially segregated?). Here, we reconstruct multi-year diet and habitat use histories of individual eastern Canadian Arctic beluga whales using isotopic profiles of annual growth layers in teeth. While sex and age class were significant predictors of both stable nitrogen and carbon isotope ratios (δ¹⁵N and δ¹³C), an unexpectedly high degree of isotopic variation occurred among individuals within sex and age classes. Comparison of beluga isotope values with published prey values, along with a positive correlation between δ¹⁵N values and body length among adult males, suggests enhanced diving capacity allows larger animals to access deep-water or benthic fishes like Greenland halibut (Reinhardtius hippoglossoides), whose larger size may be more energetically profitable for whales large enough to efficiently capture and consume them. Persistent diet and habitat use differences among individuals over periods spanning 25 years indicate impacts of climate-induced changes in Arctic marine ecosystems will not be uniform within beluga populations, with changes in the prey base potentially having disproportionate impacts on larger individuals. Although a generalist as a species, individual variation in diet and habitat use should be incorporated into models of beluga-prey dynamics and Arctic marine ecosystem structure.
Recent state of zooplankton communities in the Kara Sea in the warm period

Andrey Dolgov, Irina Prokopchuk, Valentina Nesterova, Aleksandr Benzik, Anna Orlova

Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Murmansk, Russia

Based on the data of several research surveys, conducted by PINRO in August-September 2007 and 2013, recent state of zooplankton communities in the Kara Sea in recent warm period was investigated. Juday net and trawl net were used as sampling gears. In total approximately 60 taxa were registered in plankton samples in the Kara Sea, including both warm-water boreal and cold-water arctic species. High spatial variability of plankton distribution, as well as differences in abundance, biomass and stage composition of some species were revealed in relation to distribution of waters with different temperature. Copepods dominanated in mesoplankton communities. *Calanus finmarchicus*, *Calanus glacialis*, *Metridia longa*, *Pseudocalanus minutus*, *Oithona similis* and *Microcalanus* spp. were the most important species in terms of abundance, and *C. finmarchicus*, *C. glacialis*, *Calanus hyperboreus* and *M. longa* in terms of biomass. Hyperiids were the dominant group in macroplankton communities in the northern Kara Sea, while euphausiids prevailed in the southern areas. In some areas of the Kara Sea chaetognaths and pteropods were also abundant groups.
Recent warming leads to a rapid borealization of fish communities in the Barents Sea

Maria Fossheim¹, Raul Primicerio², Edda Johannesen³, Randi Ingvaldsen³, Michaela Aschan², Andrey Dolgov⁴

¹Institute of Marine Research, Tromsø, Norway, ²The Arctic University of Norway, Tromsø, Norway, ³Institute of Marine Research, Bergen, Norway, ⁴PINRO, Murmansk, Russia

At high latitudes climate warming is expected to expand the northern distribution ranges of many boreal species, whereas Arctic species will increasingly experience unfavourable conditions. In the last decade, water temperatures in the subarctic Barents Sea have been the warmest on record, and the Arctic sea ice has retreated. Further, the hydrographical boundary where Atlantic and Arctic water masses meet has weakened. This boundary also separates boreal from Arctic fish species. We found that the recent rapid warming led to a change in spatial distribution and coverage of fish communities, with boreal communities expanding northwards. Increased abundance and dispersal of large motile predatory fish species from southern areas explain the community-wide shifts observed. The boreal fish species are probably able to take advantage of increased production and prey unfavoured by Arctic fish species, as the food chain is becoming more subarctic. The community shifts change the ecological interactions experienced by Arctic fish species. Arctic fish species suffer from increased competition and predation from boreal species and are retracting north and eastward, and to deeper areas bordering the deep polar basin. Depth might limit further retraction of the Arctic shelf community, leading to local biodiversity loss. We conclude that climate warming is inducing rapid structural change over large spatial scales at high latitudes, leading to a borealization of fish communities in the Arctic.
Temporal and geographical variation in body condition of common minke whales (*Balaenoptera acutorostrata*) in the Barents Sea

Hiroko Solvang¹, Hirokazu Yanagihara², Nils Øien¹, Tore Haug¹

¹Institute of Marine Research, Bergen, Norway; ²Hiroshima University, Hiroshima, Japan

Minke whales are one of the most abundant cetacean species during summer in the Northeast Atlantic. Their migration pattern brings them from overwintering locations at lower latitudes where they are supposed to spend the energy deposited at high productive arctic latitudes in summer. It is therefore expected that their body condition on the summer grounds will reflect food availability during their most intensive feeding period and thus indicate how well the Barents Sea ecosystem can support the population. During the commercial catch operations in Norwegian waters, data have been collected from all animals caught from 1993 to 2013. The data collected include year, month (May to September), day, latitude / longitude, sex, girth and three blubber thickness measurements (millimeter). We use the blubber thickness measured at three specific sites and the girth as describing the body condition. To investigate association between these data and time/area, we applied the following three models: 1. Multiple regression models with covariates; sex, year, latitude and longitude to find significant coefficients of the covariate; 2. Random effect model involving the random effects of variations by year or area and with sex as a fixed variable; 3. Varying coefficients models (VCMs) were applied to investigate variation with year/area and to interpret covariate effects by visualizations. The VCM is represented by combinations of polynomial expressions for year and area, which represent the variation of them. The significance of the estimated coefficients can be assessed by statistical tests. The applied three models were evaluated by Bayesian information criteria and the best model was selected. The obtained results for our four body condition measurements are as follows: 1. The best multiple regression model involving all covariates and years is always significantly negatively associated with the body condition; 2. The best random effect model involves the random terms both by year and area, but the random effect by year is not always higher than by area. 3. Estimated variance coefficients for year by the best VCM for each data set indicated significant variation by year in blubber thickness, and significant variation by area in dorsal fin blubber thickness. In conclusion, the trend appears to be a decrease in minke whale condition over the two decades data are available.
Diet and feeding behaviour of bowhead whales in the Eastern Canadian Arctic under current environmental conditions.

Sarah Fortune¹,³, Steve Ferguson², Andrew Trites¹, Bernard LeBlanc², Mark Baumgartner³

University of British Columbia, Vancouver, Canada; Fisheries and Oceans Canada, Winnipeg, Canada; Woods Hole Oceanographic Institution, Woods Hole, USA

Changes in zooplankton species diversity and relative abundance are expected to occur as a consequence of climate change, which may affect the foraging success of bowhead whales (Balaena mysticetus). However, relatively little is known about bowhead diet and foraging ecology in the Eastern Canadian Arctic. Consequently, it is unknown whether these climate-induced changes in prey will negatively or positively affect bowhead whales. We sought to collect information about bowhead prey and feeding behaviour by opportunistically combining zooplankton and bowhead-dive data in Cumberland Sound, Nunavut in August 2013 and 2014. We tracked movements of bowhead whales and collected depth-temperature profiles using satellite telemetry from archival SPLASH tags in 2013 (n=1) and 2014 (n=1). We also collected zooplankton samples (n=12) near whales in Kingnait Fiord (in Cumberland Sound) using two 333-µm mesh conical nets (30 cm and 60 cm in diameter) fitted with a General Oceanics helical flow meter and temperature depth recorder (TDR). The nets were used to sample surface waters (0.5 m), and the water column using oblique (15 m) and vertical (180-200 m) hauling methods. We also conducted successive vertical tows of progressively shallower depth strata; and obtained zooplankton samples (n=16) in 2014 from discrete depths near bowhead whales using a 50-cm diameter close-open-close net equipped with a Sea-Bird TDR and Star-Oddi conductivity, temperature and depth recorder. Analysis of diving records from one whale tagged in 2013 indicated that it likely fed near the sea bottom in Kingnait Fiord (90% of its dives were deep at ~197 m and square-shaped, with bottom times exceeding >50% of total dive duration). Adjacent surface waters were found to be devoid of prey. However, vertical samples collected from depths >100 m contained high concentrations of Arctic calanoid copepods (i.e., Calanus hyperboreus and C. glacialis) compared to those collected from shallower depths. Zooplankton samples collected during August 2014 yielded similarly high densities of prey near the sea bottom of Kingnait Fiord. These results suggest that bowhead whales feed at depth on Arctic calanoid copepods in Kingnait Fiord during the summer. Future fine-scale tagging and zooplankton sampling will be conducted in 2015 to validate assumptions regarding bowhead foraging behaviour.
Early Career

Environmental drivers of Benthic Biomass Size Spectra in Arctic fiords

Barbara Górska, Maria Włodarska-Kowalczuk

Institute of Oceanology PAS, Sopot, Poland

Body size is a fundamental biological unit that is closely coupled to key ecological properties and processes. Decline in organisms' body-size has been recently predicted to be "the third universal response to global warming" (alongside changes in phenology and distribution of species) in both aquatic and terrestrial systems. Benthic Biomass Size Spectra (BBSS) is an important descriptor of functioning of the community, especially in terms of productivity and energy flow. As already described in temperate systems, disturbance could cause the elimination of larger, long-lived species and dominance of smaller, short-lived opportunistic species. The climate changed induced changes in water temperature, productivity and glacial meltwater inflows can result in modification of size structure in benthic communities and thus influence the functioning of the Arctic marine ecosystems. The present study is the first comprehensive assessment of the patterns and environmental controls of BBSS (across both meio- and macrofauna) in Arctic fjord sediments. Here we present an the BBSS patterns in soft sediments of two fjords off west Spitsbergen - one influenced by the warm Atlantic waters of west Spitsbergen Currents (Kongsfjorden) and one of more "Arctic" character - influenced by waters transported from the Barents Sea by East Spitsbergen Current (Hornsund). BBSS in Kongsfjorden and Hornsund differ between each other in terms of shape of size spectra and number of size classes (in Hornsund 27 classes, in Kongsfjorden 31 classes). We also explore the effects of glacial disturbance (sedimentation of minerals transported with meltwater, iceberg sediments scoring) in the size structure of Arctic benthic communities. In Kongsfjorden we can observe clear difference in BBSS between stations localized across fiord - at stations localized close to glacier we do not observed the biggest size classes. We can also observe differences in taxonomic and functional (feeding and mobility types) composition of the benthic fauna among stations. As both the hydrological settings and the intensity of glacial disturbance are foreseen to change in the course of the climate warming, the results of this study can be used to predict the climate change effects on benthic communities structure and function in Arctic coastal waters.
The battle for food in the Barents Sea: Cod vs. marine mammals

Bjarte Bogstad¹, Harald Gjøsæter¹, Tore Haug², Ulf Lindstrøm²

¹Institute of Marine Research, Bergen, Norway, ²Institute of Marine Research, Tromsø, Norway

Cod, harp seal and minke whale are the main top predators in the Barents Sea ecosystem. In the last decade, the abundance of cod has increased considerably, and is at a record high level. In spite of this, the growth and condition of cod has remained rather stable. In the same period, the abundance of harp seals has declined whereas the minke whale stock has been at a stable level. The body condition (blubber thickness) of these two mammal stocks has, however, decreased, with harp seals showing the strongest decrease. A possible hypothesis for explaining this is that cod outperform the marine mammal stocks in the competition for food. We investigate this hypothesis based on available data on feeding, geographical distribution and condition, also taking into account that harp seal and minke whale are not only competitors with cod for food, but also predators on young cod.
Past and future distribution of Barents Sea Greenland halibut in relation to climate change

Elvar H. Hallfredsson¹, Randi Ingvaldsen², Ole Thomas Albert¹

¹Institute of Marine Research, Tromsø, Norway, ²Institute of Marine Research, Bergen, Norway

The North East Arctic stock of Greenland halibut has its main spawning grounds along the continental slope west off Bear Island, approximately from 68°N-78°N. These are also common fishing grounds. Spawning peaks in December at depths between 500 to 800 meters at water temperatures of approximately 2°C. Eggs are pelagic until gastrulation but sink and are transported more bathypelagic afterwards. The eggs are large (approx. 4 mm) and the larvae survive on yolk sack until spring blooming starts around April. Thus a deep layer of water with right density and temperature for eggs to float, and yolk sac to last until spring blooming of prey for the larvae in the area they end up in, are conditions that need to be met at suitable spawning grounds. Location of such water layer is conditioned by currents and can be expected to vary with climate. Preliminary analysis of survey data in 1992-2012 implies a northward trend in distribution of mature Greenland halibut, possibly indicating a somewhat more northerly spawning. This study combines survey data with results from general circulation models to investigate if the northward trend is linked to climatic changes and to make prediction on whether NEA Greenland halibut is likely to extend its spawning grounds to the continental slope in the Arctic Ocean north of Svalbard. Spawning grounds would most likely mean commercially interesting fishing grounds in the same area.
Methane and climate change: Exploring the impacts on seabed ecology in Svalbard

Michael Carroll¹, Mette Marianne Svenning³, Guiliana Panieri², Janne Søreide⁴, Will Ambrose⁵, Emmelie Åström², Friederike Gründger², Tveit Alexander Tøsdal³, Starrlight Augustine⁶, Ellen Damm⁷, Martin Graeve⁷, Wei-Li Hong⁸, Tjalling Jager⁹, JoLynn Carroll¹,²

¹Akvaplan-niva, Tromsø, Norway; University of Tromsø - CAGE, Tromsø, Norway, ²University of Tromsø - BFE, Tromsø, Norway; UNIS, Longyearbyen, Svalbard and Jan Mayen, ³Bates College, Maine, USA; ⁴Technical University of Denmark, Charlottenlund, Denmark; ⁵Alfred Wegener Institute, Bremerhaven, Germany; ⁶Oregon State University, Oregon, USA; ⁷Vrije University, Amsterdam, The Netherlands

Vast reservoirs of methane (CH₄) exist in the Arctic, in terrestrial systems as peat and permafrost, and in marine systems as free gas and methane hydrate (ice gas). Methane has a 25x stronger effect on climate than CO₂. All IPCC warming scenarios suggest that methane reservoirs are destabilizing due to increasing temperature and leading to the mobilization of methane from sedimentary reservoirs into the marine ecosystem. We are investigating the role of gas hydrates in the arctic, and the effects they will have on oceans and our global climate at the Norwegian Centre of Excellence - CAGE - Centre for Arctic Gas Hydrate, Environment and Climate.

While the impact of methane on climate is escalating, methane's role as a large-scale driver of ecosystem change is relatively unknown. Western Svalbard in particular, is warming rapidly and there are numerous recently documented locations of methane emissions from the seafloor in this region. The biological communities associated with these methane habitats (seeps) represent a 'canary in the mine-shaft', with respect to methane, marine ecosystems, and climate change. A transition may already be underway from today's predominantly solar energy driven Arctic marine ecosystem to one in which methane becomes an important alternate energy source. The aim of this presentation is to describe our on-going investigation of the early warning signs of climate-driven Arctic ecosystem change and to discuss how increasing methane release may lead to a restructuring of the classic Arctic marine food web in ways not currently predicted by climate change models.
Early Career

Vertical nitrate fluxes and large-scale Arctic primary production in a changing Arctic

Jon Lawrence, Ekaterina Popova, Andrew Yool, Meric Srokosz

National Oceanography Centre, Southampton, UK

Nitrate annually limits Arctic primary production in surface waters, the basis of ecosystem structure and functioning and important in ocean carbon sequestration. As a result, the Arctic exports excess phosphate to the North Atlantic where it contributes substantially to nitrogen fixation. Density-nitrate relationships and lateral advection timescales indicate nitrate supply for new primary production in the Arctic is predominantly vertical, tapping into nitrate-rich subsurface waters. This is supported by observations of subsurface advection pathways of Barents Sea Opening inflow waters — the dominant source of nitrate to the Arctic (~75%) — and observations of seasonal and inter-annual nitrate drawdown.

Here we present a scaling analysis and a global ocean biogeochemical model that indicate that entrainment during winter mixing dominates the vertical supply of nitrate, sustaining the intense Arctic spring bloom. Ekman and diffusive fluxes are insufficient to maintain surface supply of nitrate throughout the growing season, resulting in nitrate drawdown and substantial (up to 60%) subsurface production, largest in the marginal ice zone. Observations are then used to calculate vertical nitrate fluxes for each component (entrainment, Ekman and diffusive) at a 1x1° resolution across the Arctic. These are used to explain observed large-scale horizontal spatial variability in depth-integrated Arctic primary production and its vertical distribution in the water column. Further, we assess vertical nitrate flux components at decadal intervals for any trends induced by climate change.

Collectively, we suggest that Arctic primary production is governed by nitrate supply through vertical fluxes. We calculate these vertical fluxes by component and assess them for any climate-induced changes, highlighting the importance of long-term Arctic nitrate measurements in monitoring ongoing changes in Arctic ecosystems.
Long-term dynamics of macrobenthic communities in the Baydaratskaya Bay (Kara Sea)

Valentin Kokarev¹, Vladislav Kozlovsky², Margarita Chikina², Andrey Azovsky¹

¹Lomonosov Moscow State University, Moscow, Russia; ²P.P. Shirshov Institute of Oceanology RAS, Moscow, Russia

Macrobenthic communities have been routinely used as indicators of changing environment. Such studies are of current interest in Arctic since global climate change and human activities can lead to significant biotic alteration of the region. Though examples of long-term changes in benthic community structure are numerous, it is still hard to identify whether such changes are driven by natural spatio-temporal variability, climate shifts or by direct anthropogenic impacts, or by a combination of all these factors.

Baydaratskaya Bay is situated in the southwestern part of the Kara Sea. It is characterized by the low level of freshwater runoff and long ice-coverage period. The area suffered from relatively low anthropogenic activity up to the year 2011, when the seafloor pipeline laying-out began across the bay (the Yamal-Center gas pipeline project). We used the data obtained during six surveys at 1992-2013 and the archive data from the 1946 year expedition to trace the natural and human-influenced changes in benthic communities.

The results showed that benthic community structure was significantly influenced by the depth, and three assemblages could be clearly distinguished occupying different depth ranges (shallower 10 m, 10-20 m, and deeper 20 m, respectively). For each of the assemblages, the composition of dominant species, as well as the integral parameters (total biomass and abundance, species diversity, ABC-index) remained quite stable during the whole period of investigation, except for the deepest (over 20 meters) stations 2013. This group of stations showed significant changes at 2012-2013 years, then the total biomass, mean individual weight and species diversity decreased sharply. In 2013, the absence of large bivalves and increased abundance of small polychaetes had been recorded at these stations. It is more likely that just the recent human activity (dumping of dredged sediments) caused these local but considerable changes in the benthic communities, while their structure remained stable during the past decades.
Winners and loosers in a changing environment: an appraisal of modelling approaches

Øyvind Fiksen

University of Bergen, Bergen, Norway

Our ability to look into the future is limited, even with the best scientific methods available. Is it at all possible to make scientific predictions or scenarios on the future of biological systems in a changing environment? Here I present an overview of alternative modelling tools applied to predict adaptations in organisms if the environmental context changes. Organisms have a considerable ability to adapt their behaviour and life histories with no alterations of the genetic makeup. This is in the domain of evolutionary theory, and scenarios of future states of organisms and ecosystems must be grounded in evolutionary reasoning. I review the different strengths, weaknesses and roles of optimality-, individual-based- and trait-based models in the development of our common reasoning about winners and loosers in a future world, including examples of how these tools can be applied in the Arctic.
Explaining body size and reproduction of the copepods *Calanus* spp.: predictions from a life history model

**Maciej Ejsmond**¹,², John McNamara³, Janne Søreide¹, Øystein Varpe¹,⁴

¹University Centre in Svalbard, Department of Arctic Biology, Longyearbyen, Svalbard, Norway, ²Jagiellonian University, Institute of Environmental Sciences, Krakow, Poland, ³University of Bristol, School of Mathematics, Bristol, UK, ⁴Akvaplan-niva, Trømso, Norway

Life history theory predicts that organism schedule activities and allocate time and resources, so that the number of descendants left far in the future is maximized. Because a change in the life cycle at one point drives changes in the rest of life cycle, a life history approach is very valuable for predictions on animal responses to changing phenology of their food or predators. Here we report from an annual routine model focused on the genus *Calanus*, abundant, large and lipid rich marine copepods inhabiting Arctic and sub-Arctic regions. The species *C. finmarchicus*, *C. glacialis* and *C. hyperboreus* differ with respect to size at maturity and degree of capital breeding. The seasonality of their environment, with duration and timing of food availability changing with latitude is one potential explanation for observed life history variability. For instance, the more pronounced the seasonality the less time the animals will have for activities and potentially instead of one year, need two or even three years dedicated to growth and gathering reserves used later for reproduction. Ultimate explanations of the observed life history variability should take into account variability in body size and its interactions with time and mode (capital vs. income breeding) of reproduction. In our life history model we allow individuals to schedule growth, storage and reproduction during the year. The modeled animals also decide about timing of diapause. To obtain the optimal strategy, i.e. the one that maximizes fitness, we use dynamic optimization. The state space of our model is large enough to predict all of the observed *Calanus* spp. strategies, from the smaller and short lived *C. finmarchicus* to the large and long-lived *C. hyperboreus*. We can predict under what conditions each of them are more likely to occur, helping us to understand the geographical distribution of the three species. The model is also a strong general tool for investigation of the trade-off between current and future (residual) reproductive investment represented in our model by three components: reproduction, growth and storage.
Patterns and drivers of bacterial production in the marginal ice zone northwest of Svalbard

Lena Seuthe¹, Maria Vernet², Maria Lund Paulsen³, Marit Reigstad¹

¹Institute of Arctic and Marine Biology, UiT- The Arctic University of Norway, Tromsø, Norway; ²Scripps Institution of Oceanography, UC San Diego, San Diego, USA; ³Institute of Biology, University of Bergen, Bergen, Norway

Heterotrophic bacteria play a crucial role in the balance between primary and secondary production in planktonic systems. A thorough understanding of patterns and drivers of bacterial production is therefore of utmost importance if we are to understand the future productivity of an increasingly ice-free Arctic Ocean. Yet, measurements of bacterial production are still limited from Arctic marine systems. Here we present bacterial production rates from a variety of stations within, or within the vicinity of the marginal ice zone north-northwest of the Svalbard, measured during field campaigns within the frame of the NFR-funded research project "CarbonBridge" during spring and summer 2014. Strong gradients in water column stability, biomass and production were found, representative of conditions typical for Arctic systems during different stages in the growth season. We will discuss the observed patterns in bacterial production in relation to hydophysical and -chemical conditions, as well phytoplankton biomass, size structure and production.
Seasonal Changes in Sinking Particles' Qualitative Characteristics (Size, POC: Volume Ratio and 18S rDNA Composition) and the Impact on the Vertical Carbon Flux in Arctic Marine Ecosystems

Ingrid Wiedmann1, Marit Reigstad1, Miriam Marquardt2,1, Tove Gabrielsen2

1UiT The Arctic University of Norway, Tromsø, Norway; 2UNIS The University Centre in Svalbard, Longyearbyen, Norway

A detailed understanding of the major carbon pathways in the Arctic marine ecosystem is crucial to identify ecological winners and losers in a situation of climate warming. It is commonly assumed that particulate organic carbon (POC) is predominantly exported as large, fast sinking particles during a (late) diatom spring bloom. In contrast, a winter situation with negligible production or a summer post-bloom phase dominated by smaller cells with low sinking speed, strong grazing pressure and efficient recycling in an intensified microbial loop is assumed to promote retention of organic material in the upper water column. These conclusions are however mainly based on quantitative measurements of the vertical carbon flux with sediment traps, while qualitative assessments of the sinking material (like the size, POC: volume ratio or 18S rDNA composition from 454 amplicon pyrosequencing) are rare. We suggest that these qualitative parameters could help to clarify the origin and composition of particles and identify organism groups regulating the pelagic Arctic ecosystem with respect to carbon export or retention. Therefore we investigated this question in two field studies. First, we deployed sediment traps along a stratification and phytoplankton bloom gradient in the Barents Sea. These results showed a strong POC export (60 m: 923 mg C m-2 d-1) at a deep-mixed, post-bloom station in the southern, Atlantic-influenced part, although small particles (0.05-1.0 mm equivalent spherical diameter, ESD) dominated in the sediment traps and grazers were highly abundant. Further north, in the late diatom bloom of the marginal ice zone, particles were on average larger (0.5-2.8 mm ESD), but the POC export was here lower (60 m: <823 mg C m-2 d-1) due to a lower POC: particle volume ratio. The second study was conducted in the Arctic fjord Adventfjord, Svalbard. Here, suspended and sedimented water samples (short-term sediment trap deployment) were collected during different hydrophysical and biological conditions (e.g. stratification, bloom situation, grazer abundance) in winter, spring and autumn. Analyses are now conducted to investigate (1) how the seasonal variation influenced the particle size spectra and POC: volume ratio of sinking particles and (2) how the contribution of protists &gt;10 µm to the vertical flux changed under the different
situations. By investigating the role of different sized particles and small cells for the vertical carbon flux under contrasting situations, we want to provide a better understanding to evaluate possible changes in the Arctic marine carbon pathways in a future warming climate.
Unveiling the hidden: Seasonality of Arctic pelagic protist communities in Adventfjorden (West Spitsbergen)

Miriam Marquardt¹,², Anna Vader¹, Tove M. Gabrielsen¹

¹University Centre in Svalbard, Longyearbyen, Norway, UiT The Arctic University of Norway, Tromsø, Norway

Isfjorden, western Spitsbergen is alternatingly influenced by warm and saline Atlantic water (AW) and colder and less saline Arctic water (ArW), and is thus well suited for studying the effects of climate shifts on pelagic protist communities. The Adventfjorden time series station (ISA) in Isfjorden was sampled monthly to weekly or daily from December 2011 to 2012, and pelagic protists sized 10 - 0.45 μm from 25 m depth were barcoded using 454 sequencing (Roche) of the 18S V4 region amplified from both DNA and cDNA. At every sampling date, biotic (fractionated Chl a biomass, nutrients, POC/PON) and abiotic (salinity, temperature, PAR) parameters were recorded to describe the environmental conditions. Dinophyceae were most predominant throughout all seasons at the study site. The winter communities were diverse and fairly stable, whereas the composition of the spring and summer protist communities varied considerably. The abundance of MALV II was high in the spring based on DNA amplicons, but considerably lower based on cDNA amplicons. On the other hand, Cercozoa and Bacillariophyceae genera such as Skeletonema and Thalassiosira were found more present in the cDNA samples than the DNA samples could reveal. The photosynthetic biomass was dominated by cells < 10 μm most of the year apart from the spring and early summer period (mid April to mid July), when larger cells took over. The whole water column at the ISA station was well mixed throughout the year, and influenced by AW during periodic influxes both during spring and fall. Statistical analyses indicated that salinity, light and Chl a biomass were important determinants for the observed changes over time in the ISA protist communities. Although Arctic pelagic protist communities seem to have a strongly seasonal determined life style, a thorough knowledge of the hydrography of the area is necessary to fully understand the changes of these communities.
The Impact of Climate Change on reproduction and Population Dynamics of Northwest Atlantic Harp Seals, *Pagophilus groenlandicus*.

Garry Stenson¹, Alejandro Buren¹, Mike Hammill², Mariano Koen-Alonso¹

¹Fisheries and Oceans, Canada, St. John's, NL, Canada; ²Fisheries and Oceans, Canada, Mont Joli, QC, Canada

As the northern hemisphere continues to warm, the associated decline in sea ice will have serious impact on species that rely on ice for reproduction and/or feeding. Harp seals feed and give birth on ice along the southern edge of the seasonal pack ice, Canada. Unfortunately, little is known about the impact of climate change on ice-dependent species, even though the associated ecosystem changes are likely to be most rapid along the ice edge. In the northwest Atlantic, climate change has impacted harp seals directly through reduced sea ice that has resulted in increased mortality of young. However, climate change may also have indirect impacts through changes in prey and, hence reproductive rates. Estimates of late term pregnancy and abortion rates of Northwest Atlantic harp seals were obtained from samples collected off the coast of Newfoundland, Canada. Since the 1950s, pregnancy rates have declined while inter-annual variability has increased. Using a beta regression model to explore the importance of biological and environmental conditions, we found that fecundity rates were influenced by both density-dependent and independent factors. While the general decline in fecundity is a reflection of density-dependent processes associated with increased population size, including the late term abortion rates captured much of the large inter-annual variability. Changes in the abortion rate is described by a model that incorporates ice cover in late January and capelin, a major prey of harp seals, biomass obtained from the previous fall. A previous study has shown that capelin abundance is correlated with ice conditions suggesting that late January ice conditions should be considered a proxy for environmental conditions that influence a number of prey species.
Forecasting winners and losers of the Arctic environment: the potential Population Consequences of Disturbance (PCoD) for marine mammals

Cormac Booth¹, John Harwood¹,³, Stephanie King², Rob Schick², Carl Donovan²

¹SMRU Marine, St Andrews, UK; ²Centre for Research into Ecological and Environmental Modelling, St Andrews, UK; ³Sea Mammal Research Unit, St Andrews, UK

As the Earth’s population grows, there is an increased demand for energy. The potential for both fossil fuels and green energy sources in the Arctic are great. With increased development, comes the need for impact assessment at project and strategic levels to determine the most sustainable path ahead. In the UK, the expansion of marine development has led to an increase in underwater noise that may injure some marine mammals and may cause behavioural disturbance to many more (e.g. explosive use, pile-driving, geophysical surveys etc.). There are, however, inherent difficulties in observing marine mammal responses to disturbance and understanding the levels at which these occur. It is widely acknowledged that short-term behavioural responses may become biologically significant if animals are exposed for sustained periods of time, but the interpretation of the biological consequences of disturbance is limited by uncertainty about what constitutes a meaningful response, both at the individual and the population level. Unfortunately data on the effects of disturbance on an animal’s survival or ability to breed, are unavailable for most marine mammal species and there is no standardised framework for assessing the consequences of these effects at a population level in these circumstances. To address this problem, we have developed a generalised Population Consequences of Disturbance (PCoD) model (first proposed by a US Office of Naval Research working group), which uses stochastic population models to assess the long-term trajectory of both undisturbed and ‘disturbed’ (i.e. those exposed to a change in their environment - e.g. increased noise) populations the determine the population level impacts of disturbance. In the absence of empirical data to inform the link between disturbance and vital rates, we elicited expert opinion to provide provisional data for these high priority questions. Our approach allows the daily effects of disturbance to be scaled up to cover the entire duration of a development, and the cumulative effects of multiple developments on populations can be evaluated. This tool is primarily focused on the impacts of noise disturbance, but the generalised framework has broad applications across geographic regions and industries. We cannot fully understand the population consequence of disturbance for marine mammals without more reliable, quantitative and evidence-based data. The
interim PCoD framework therefore can be used to identify key sensitivities and knowledge gaps to be filled and crucially the data that need to be collected, thus prioritising future research.
Digestive enzyme activities during ontogenetic vertical migration of *Calanus glacialis*

Barbara Niehoff¹, Daniela Freese¹,², Janne Søreide²

¹Alfred-Wegener-Institut, Bremerhaven, Germany; ²University Center in Svalbard, Longyearbyen, Norway

*Calanus glacialis* is one of the dominant calanoid copepod species of the zooplankton communities of the Arctic Shelf. As a primarily herbivorous species on the one hand and as an important prey organism for large zooplankton, fish and seabirds on the other, it plays a key role in the Arctic food web. In spring and early summer, *C. glacialis* inhabits surface waters. At that time feeding on ice algae and phytoplankton fuels reproduction and growth. In late summer, the copepods migrate to deeper waters to overwinter in a state of reduced metabolism (diapause) based on internal energy reserves. The relationship between food availability and the transition from activity to diapause (and vice versa) is not yet well studied. We therefore sampled *C. glacialis* in a high-Arctic fjord in monthly intervals from June 2012 to July 2013 and analysed their proteinase and lipase/esterase activities to estimate their potential to digest and assimilate dietary components. In addition, chlorophyll a concentrations were measured in the upper water column. Both enzyme classes exhibited low activities in winter and high activities in summer. The main descend of *C. glacialis* was in July/August, and coincided with a significant decrease in digestive enzyme activity. Algal food was still available, suggesting that prolonged algal growth due to climate change would not be beneficial for *C. glacialis*. As early as January/February, lipolytic activities increased in females and copepodite stage V. This was ~2 months prior to the phytoplankton bloom. Early investment in enzyme synthesis indicates that the copepods can immediately utilize food when it becomes available in spring, suggesting that *C. glacialis* will be able to cope with shifts in primary production regimes related to decreasing ice coverage in the Arctic.
Seasonal oscillations in benthic larvae release in high-Arctic fjords with different primary productive regimes

Eike Stübner, Janne Søreide

The University Centre in Svalbard (UNIS), Longyearbyen, Norway

Pelagic larvae of benthic organisms may comprise a substantial part of the zooplankton community, but their often short-term residency in the pelagic combined with poor seasonal sample resolution makes meroplankton a poorly described component of the zooplankton community. High seasonal resolution data sets from 3 fjords around Svalbard Archipelago were investigated. The sea ice free Adventfjorden in 2012 and 2013 and the seasonal sea ice covered Billefjorden in 2011, 2012 and 2013 and Rijpfjorden in 2007 provided us with the unique opportunity to study the timing, magnitude and duration of meroplankton in fjords with very different primary production regimes. The hypothesis, that the timing of peak occurrence of different phyla is steered largely by the timing of the phytoplankton blooms in combination with changes in water masses is tested. The timing of the blooms varied greatly between the 3 fjords, with main peaks between April and June. High variability in total and relative abundance and composition of the meroplankton community was observed both between years and fjords. Data from Adventfjorden in 2012 showed extremely high total and relative abundances compared to all other data available, with meroplankton contributing up to over 90% of the whole mesozooplankton community during spring. Otherwise, contributions were considerably lower. Densities were lower in the two deep locations, Billefjorden and Rijpfjorden (>100m depth) compared to Adventfjorden during the years investigated and meroplankton densities were generally highest in the upper layers (above 100m). Numerically most important were Bivalvia, Cirripedia and Echinodermata larvae. Most groups had their peak occurrence during the productive season, with Bryozoa being an exemption. Several relatively short density peaks were detected in all phyla. Cirripedia nauplii and Polychaeta larvae co-occurred, and their peak occurrence coincided roughly with the bloom. Bivalvia veliger peaked slightly later and were present in the water column over a longer period, while Echinodermata larvae had their main occurrence after the bloom. This pattern was apparent both in Rijpfjorden and Adventfjorden, were bi-weekly and monthly samples were taken. In Rijpfjorden, the bloom occurred over a month later and the occurrence of the different meroplanktonic groups was delayed as well. We discuss the importance of the spring bloom for the timing of larval release in benthic organisms and potential consequences of a shift in primary production regime.
Pelagic and sea ice biota in the Central Arctic – 2011-2012- Two contrasting years!

Ilka Peeken¹,², Karel Bakker³, Kattner Gerhard¹, Krumpen Thomas¹, Fernández Méndez Mar¹,⁴, le Guitton Marie³, Uhlig Christiane¹

¹Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany,²MARUM Center for Marine Environmental Sciences, University of Bremen, Germany,³Bremen, Germany,⁴Royal Netherlands Institute for Sea research, Texel, The Netherlands,Max Planck Institute for Marine Microbiology, Bremen, Germany

The Arctic Ocean is currently one of the key regions where the effect of climate change is most pronounced. Massive reduction of sea ice thickness and extent will result in large cascading changes for the entire Arctic ecosystem. In general it is assumed that the pelagic system will be favored by the changing sea ice conditions but little attention has been paid to the reaction of sea ice biota and particular to the under ice algae Melosira arctica, which used to be a common feature of multiyear ice in the Central Arctic. Two consecutive cruises in late summer 2011 and 2012 with the RV Polarstern to the Central Arctic allow to contrast two years of greatly different sea-ice extent and its effect on the standing stocks of sea-ice biota and the pelagic ecosystem. Based on the low nitrate inventories in the Pacific sector the algae standing stocks in water and ice including melt ponds were low in 2011, while in the Eurasian sector high standing stocks, under ice algae blooms and high biomass accumulations in various melt ponds were observed with concurrent higher nitrate concentrations. The study 2012 was confined to the Eurasian basin and despite the so far largest decrease in sea ice extent, standing stocks of 50 m integrated phytoplankton remained in the same range as 2011 and local under ice blooms were absent. The most obvious difference were the strong occurrence of sea ice aggregates particular of the under ice algae Melosira arctica (Boetius et al. 2013, Science). The lack of under ice blooms suggests a strong competition of nutrients between the pelagic and sea ice algae in 2012. But although the receding sea ice might have favored the strong appearance of Melosira arctica in 2012 its absence in 2011 might be explained by the different origin of the studied sea ice floes. Based on tracking algorithms of different remote sensing and ice drift products the sea ice floes 2011 were originating far from the Siberian shelf's which are known to be seeding areas for Melosira arctica. In contrast, 2012 the ice floes were developed in the Polynias of the North East Laptev Sea and during the freeze up process in the Kara Sea. So despite other environmental constraints the origin of the ice floes seems to be a crucial parameter to predict future changes in the Central Arctic sea ice biota development.
Climate warming impact on Barents Sea ecosystem vulnerability and functioning

Raul Primicerio¹, Michaela Aschan¹, Andrey Dolgov², Maria Fossheim³, Edda Johannesen⁴, Lis Lindal Jørgensen³, Susanne Kortsch¹, Magnus Wiedmann⁵

¹ UiT The Arctic University of Norway, Tromsø, Norway, ² PINRO, Murmansk, Russia, ³ Institute of Marine Research, Tromsø, Norway, ⁴ Institute of Marine Research, Bergen, Norway, ⁵ Akvaplan-NIVA, Tromsø, Norway

The Barents Sea ecosystem is undergoing rapid structural change driven by climate warming. The documented changes in species composition and community structure, particularly prominent towards the Arctic, are expected to affect ecosystem vulnerability and functioning. Based on the Barents Sea Ecosystem Survey Data collected by the Institute of Marine Research (Norway) and PINRO (Russia) over the last ten years, we assessed the spatio-temporal variation in ecosystem vulnerability and functioning, relying on trait-based methods and foodweb analyses. Three main components of ecosystem vulnerability, functional diversity and redundancy, and foodweb modularity, all display rapid change driven by poleward shifts of boreal species. In particular, functional diversity and redundancy increase in the Arctic water masses, whereas foodweb modularity decreases. The detected changes in functional characterization and foodweb configuration driven by climate warming bring about substantial alterations in the Barents Sea ecosystem functioning.
The Arctic's role in the global energy supply and security

Scientific committee

Leader: Research Director Dag Eirik Nordgård, SINTEF Energy Research, Norway
Professor Peter Haugan, University of Bergen, Norway
Professor Bjørn Helge Hjertager, University of Stavanger, Norway
Director Leiv Lunde, Fridtjof Nansen Institute, Norway
Consultant Coco Smits, APECS / Royal HaskonigDHV, The Netherlands
Special advisor Ingrid Anne Munz, The Research Council of Norway, Norway
New Renewable Energy in Northern Norway – what is the potential?

Tobias Boström

UIT The Arctic University of Norway, Tromsø, Norway

What new renewable energy resources do we have in Northern Norway and in what quantities. Boström will focus especially on wind and solar energy, he will give examples and make some thought experiments on their potential as well as point out the challenges.
The role of energy in a complex understanding of security in the Arctic

Gunhild Hoogensen Gjørv

UiT The Arctic University of Norway, Tromsø, Norway

Security in the Arctic is still often framed as an exclusive, if not isolated, and top priority zone of power and high politics, with claims that security is really first and foremost about the protection of states through the use of military means, and geopolitics about the resulting military prowess playing out between states and regions. Without this narrow definition breaking stride, energy has been coopted (when convenient) into this security discourse, generating further discourses of heightened fears for a resource race if not eventual conflict. The cooptation of energy into a narrow, exclusive understanding of security is problematic. In the best case, energy resources are a tool of the state to ensure its future supply (and continued reliance) upon particular energy resources, as well as (for energy producers) an increased economic security in a demanding but fickle market economy. In the worst case, energy becomes militarized, as a resource that needs protection and can fuel conflict.

At the same time, energy resources and their use are tightly interconnected to not only the state and national economies, but to the environment and to Arctic communities that are impacted as users, producers, and as well as ethical opponents and potential “victims” of the pursuit of energy resources, where livelihoods, identities, and life meanings can be at stake or threatened. Security, in its less exclusive sense, reflects a contestation and dialogue between multiple actors about expectations and those values (material and immaterial) that are deemed most important to survival for the future. Security in the Arctic, what can and should survive for the future, intimately links multiscalar and multi-actor perspectives on environment, energy, economy and identity (from state to individual). These dynamics (and tensions) provide a rich case for international politics and the role of energy. Particularly as international interest in the Arctic for energy resources has increased over the years, the complex Arctic region might have important lessons about how to understand both Arctic and global resources into the future.
Arctic oil and gas: challenges and solutions

Alfred Hanssen

Aker Solutions, Tromsø, Norway

The Arctic is a vast and very inhomogeneous geographical area covering about 6% of the world's total area. It has been estimated by the US Geological Survey (USGS) that the Arctic contains about 30% of the world's undiscovered gas and about 13% of the world's undiscovered oil.

The climatic conditions in the Arctic vary substantially with space and time. In this invited presentation, we will review and compare the key meteorological and geophysical parameters in the Arctic. We will identify challenges related to weather, ice and ocean dynamics, and we will provide some examples of functional technological solutions from past and ongoing Arctic offshore projects. Finally, we will address some technology gaps that require further R&D efforts to materialize.
Invited talk

Arctic petroleum resources in a global and regional perspective

Arild Moe

Fridtjof Nansen Institute, Norway
Silenced, sidelined and simplified: The "social" in the Arctic energy sustainability debates

Hanna Lempinen

Arctic Centre, University of Lapland, Rovaniemi, Finland

Projected growth in global energy demand, dwindling resources at known production sites, warming climate and technological developments are pushing energy extraction activities further towards the previously inaccessible northern areas. At least on the level of rhetorics, the Arctic region is on its way to become the world's new energy province.

In political and popular debates revolving around energy, sustainability is a key argument both for and against different energy sources as well as individual energy projects. However, these debates tend to focus on the economic and environmental sustainability aspects of planned and ongoing developments. As a result, the social and cultural sustainability concerns associated with Arctic energy developments become silenced and sidelined.

This presentation takes an explicit focus on the vague and elusive "social" both in the context of Arctic energy and broader sustainability debates. Projecting empirical materials on Arctic energy debates against a conceptual backdrop of 1) existing literature on the social dimensions of sustainability; 2) the conceptualizations the "social" in general; 3) and the linkages between energy developments and social sustainability concerns, the presentation draws attention to the violent manners in which the social impacts of Arctic energy developments are ignored or reduced into socioeconomic indicators at the expense of the Arctic cultures and communities. Building on a broader understanding of the "social", alternative ways more capable of grasping the diversity of social (and) sustainability in the north and the broad range of potential social impacts of Arctic energy developments are sketched.
MIFIS – a deep offshore pollution containment system

Fivos Andritsos

European Commission – JRC, Ispra, VA, Italy

The demand for hydrocarbons and other mineral resources worldwide is increasing steadily. It is met primarily by tapping the vast seabed resources in ever more difficult and risky environments, like the abyssal oceanic depths or the arctic regions. The development of suitable means for safe underwater operations is a fundamental requisite for their sustainable exploitation, in particular on the delicate polar environments, where any major accident could have planetary impact.

In the aftermath of the “Prestige” disaster, a novel method for the containment of the pollutants directly on the shipwrecks, even at abyssal depths, was conceived. It claimed to be simple, entirely passive and, once deployed, weather independent. It was object of the DIFIS[1] project, which, through extensive numerical simulations and scale experiments, provided the proof of concept including the technical and economic feasibility. The “Deepwater Horizon” catastrophe triggered investigations on its applicability for containing deep offshore well blowouts. The main issue to investigate has to do with the presence of gas that, under certain conditions, could compromise the stability of the system.

MIFIS[2] is a modular, re-engineered version of DIFIS that has the capacity to handle the gas present in most offshore blowouts as well as the formation and dissociation of hydrates. Such system, suitably configured, can serve for the containment of offshore blowouts as well as for interventions on underwater hydrocarbon sources such mud volcanoes, leaking shipwrecks or the extraction of natural gas from hydrate deposits. It can also provide containment of lighter than water pollutants from any deep seabed mining activity.

The object of the present paper is to outline the results from the DIFIS project (engineering design, experiments and simulations), present the MIFIS concept and elaborate on its applicability, in particular at the harsh arctic conditions.

Acknowledgments: DIFIS has been an FP6 collaborative project, funded under the Sustainable Surface Transport (SST) scheme.

[1] Double Inverted Funnel for Intervention on Ship-wrecks

The EU regulatory framework for Arctic offshore operations: safety, security and sustainability

Claudia Cinelli

University of Tromso, Tromso, Norway

This paper studies the EU recent developments in the energy sector, with a focus on legal and political conditions for sustainable exploration and production of Arctic energy. It concentrates its analyses specifically on the EU directive 2013/30 on safety of offshore oil and gas operations and its normative context.

On 5 March 2014 the European Parliament (EP) adopted a resolution on EU strategy for the Arctic and, having regard with the aforementioned directive, called ‘on the EU to promote strict precautionary regulatory standards in the field of environmental protection and safety for oil exploration, prospection and production internationally’. In the same document, the EP moreover called ‘for a ban on oil drilling in the icy Arctic waters of the EU and the EEA and for promotion by the EU of comparable precautionary standards in the Arctic Council and for Arctic coastal states’.

There is no doubt that the EU has a vital interest in ensuring maximum safety of offshore oil and gas operations and the protection of the marine environment. Nevertheless, the extent of the legal basis for such a ban is not yet clear. The EP’s approach also seems to differ with the European Commission’s perspective, which proposed strengthening international cooperation on environmental standards for the extraction of Arctic hydrocarbons within all the region, according to the current international framework of the law of the sea.

Moreover, the future EU Arctic policy should be consistent with the strategy of the Arctic Council and each Arctic State, so that Arctic governance can be developed and implemented on the basis of effective cooperation with countries and key partners. This seems to be also the concern of the European Commission. A huge potential for EU governance innovation can be indeed be disclosed in the Arctic.

This paper addresses two main questions: 1) How is the EU directive 2013/30 affecting the overall regime of the Arctic Ocean, the sustainable development and political cooperation for the harmonization of offshore international regulations related to offshore oil and gas operation? 2) What are the prospects to harmonize existing national corporate environmental responsibility standards across the Arctic? What is the future of Environmental Impact Assessment models for oil and gas operations in the Arctic?
I discuss efforts to implement risk-based approaches to OCS oil and gas development in the US Arctic in light of the Deepwater Horizon (DH) well blowout. The US National Research Council (NRC), with others, has long advised governmental bodies on how best to chart a course towards improved safety management of offshore oil and gas operations. The role of NRC’s Marine Board in particular, which I chaired the past two years, will be highlighted. The compatibility of efforts to advance oil production in the Arctic with Administration goals to curb greenhouse gas emissions is also discussed.

The 2010 DH blowout has neither deterred public support for offshore oil development nor dampened efforts to push offshore oil exploration into such environmentally challenging areas as the US Arctic. Extensive examination of the causes and consequences of DH has been undertaken by a variety of public and private bodies and efforts to promote occasionally contending models for enhanced safety are ongoing.

A major thrust of these studies is that the underlying causes of DH were organizational and managerial in nature and not the result of simple mechanical failure, contrary to the emphasis in the prescriptive regulatory framework heretofore relied upon in the US. A few clear directions are now emerging, prominent among them adoption of the performance-based Safety and Environmental Management System (SEMS) approach by the Bureau of Safety and Environmental Enforcement (BSEE), which aims to create a pervasive culture of safety. How to determine whether SEMS implementation in fact generates the desired safety culture remains a challenge, even as Shell Oil has recently filed revised plans to develop its Chukchi Sea leases.

At least since the 1988 Piper Alpha accident, it has been recognized that complex and difficult-to-anticipate interactions among human, organizational and technical factors—that precipitate mechanical failures—are prime causal factors of catastrophic events like the DH blowout. One broad conclusion of this study is that the policy-making and political landscape where refinements in safety management are introduced, debated and iteratively modified—perhaps ultimately to be adopted and implemented—is similarly constructed. Efforts to redirect traditional regulatory oversight toward promotion of a ‘safety culture’ should therefore include a
comprehensive evaluation and adjustment component. How do we know that a safety culture is in fact ‘safe’ and which metrics and evaluation strategies should guide performance assessments? Funding and the related problem of maintaining continuity of organizational effort remain challenges however.
Improving Oil Spill Response in the Arctic - Building on Decades of Research

Joseph Mullin¹, Hanne Greiff Johnsen²

¹International Association of Oil and Gas Producers, London, UK; Statoil AS, Trondheim, Norway

Prevention of oil spills remains a top priority for industry. The Arctic Oil Spill Response Technology Joint Industry Programme (JIP) was established to further enhance industry knowledge and capabilities in the area of arctic oil spill response and builds upon the progress industry has made during its many decades of research and development. Ten international oil and gas companies support the JIP including BP, Chevron, ConocoPhillips, Eni, ExxonMobil, Gazprom-neft, North Caspian Operating Company (NCOC), Shell, Statoil, and Total - making it the largest pan-industry programme dedicated to this area of research and development.

This JIP is conducting response research projects to advance the application and understanding of dispersant effectiveness, environmental effects; trajectory modelling; remote sensing; mechanical recovery; and in situ burning (ISB) in arctic and ice-prone regions. Significant work is being conducted to improve the scientific base for the use of Net Environmental Benefit Analysis (NEBA) for response decision-making and environmental impact assessments related to the Arctic environment.

This JIP has brought together the world's foremost experts on oil spill response research, development, and operations from across industry, academia, and independent research centers to undertake the technical work and scientific studies. Solid progress was made throughout 2012 and 2013 with technology assessments in dispersants; environmental effects of oil spills; remote sensing and in situ burning being completed. Existing research and knowledge was gathered, compiled and put into reports easily accessed through the JIP website.

Research efforts are now underway that include laboratory and meso-scale dispersant effectiveness tank testing; evaluation of various surface and subsea remote sensing technologies with crude oil on, encapsulated in, and under ice in conditions that include low visibility. The JIP is also conducting laboratory and meso-scale tank testing of chemical herders to extend the window of opportunity for spill response and construction of a test tank facility in Alaska for experiments using manned and unmanned helicopters to prove the operational feasibility of a chemical herder/in situ burn strategy. Recent progress from the laboratory and field work will be presented.
China’s energy interests in the Arctic: how to understand China’s foreign policy in a multipolar world

Cecile Pelaudeix¹,²

¹Aarhus University, Aarhus, Denmark; ²Arctic Research Center, Aarhus, Denmark; ³PACTE-Sciences Po, Grenoble, France

The Arctic region is witnessing new development opportunities in fossil energy whereas uncertainties of the changing global energy landscape are growing. Calling itself a “near-Arctic state”, China has been granted observer status to the Arctic Council and is advancing its interests in key energy sectors through free trade agreement, investment in companies and in infrastructure. The rise of China in the globalized world and in the Arctic in particular, is raising questions about Beijing’s strategy in the new geo-economic and geopolitical region of the Arctic, and in particular its adherence to international norms. The energy sector is a paramount sector for China. Its energy mix is primarily coal-based; still energy security is putting oil supply at the centre of the debate. Furthermore, China controls more than 90% of the market of rare earth elements market which are essential to sustainable development and green technologies. This paper tries to understand China’s foreign policy in the Arctic by examining China’s perspective on energy security and the context shaping this perspective, focusing on oil and gas sectors and on the rare earth elements. I argue that China’s foreign policy in the Arctic does not substantially differ from other regions in Beijing’s perspective for which first, foreign policy does not stand at the top level of decision making and second, foreign policy might be ambiguous depending on the issue at stake. Relying on academic literature, official declarations and interviews, this paper examines the internal and external challenges that China faces in a multipolar world in developing its energy policy in the Arctic, in order to assess the geopolitical and geo-economic implications for the region.
The intricate economic, geopolitical and environmental equation of the Arctic

Paraskevi Baxevani, Petros Siousiouras

University of the Aegean, Chios, Greece

Among the greatest challenges in hand today one finds climate change. Its course and consequences are more evident as time passes by, yet they are unprecedented, thus unpredictable. Human activities have acted as a catalyst to natural processes disturbing what is described as earth's temperature cycle, leading to higher averages. The Arctic, covered in multiyear ice is experiencing dramatic transformation, while its sensitivity is such it is used as climate index. However, what is catastrophic for the environment and spurs fears for non-reversible situations, for business it translates into profit opportunities. USGS research estimates 15 and 30% of oil and natural gas undiscovered resources respectively; for an industrialized world in constant need for energy, this means pursuing access and exploitation rights of the Arctic wealth.

Only, this is a remote part of the global, until recently inaccessible all year round. Even today, that navigation is possible for a short time span, there are strong winds, ice floes, unreliable nautical charts, freezing temperatures, inadequate infrastructure for support and communication and of course, arctic night. In addition, there is an ongoing process for the maritime delimitation among the coastal states, namely Russia, Norway, Canada and Denmark whereas the United States has not yet ratified UNCLOS, which provides the existing legal framework.

At the same time, the Arctic has always been a field of power projection and the current situation is no exception, evinced through military exercises, scientific expeditions and legal claims. Russia, a reinstated superpower, has been very active, pursuing the expansion of its continental shelf and investing in infrastructure in order to have good mainland connection for the transport of oil and natural gas to the energy thirsty markets. The interest of proximate and remote actors is revealed by pursued scientific cooperation, participation at the Arctic Council and the first voyages of cargo ships through these north waters.

Due to the nontrivial difficulties, the Arctic is not expected to play an important role as an energy source in the short-term. It would take continued ice melting, major investments, securing that the region won't become a seedbed for illegal activities or prohibitive dangers in using the traditional maritime routes due to piracy or volatile political situations.

Complicated as it may be, the Arctic is definitely going to be a stage not only for economic, political and environmental evolutions, but for the appearance of new interstate cooperation schemes as well.
Early Career

With License to Pollute. Rearranging the granting of permission to discharge drilling waste.

Heidi Rapp Nilsen, Sindre Myhr
Norut, Tromsø, Norway

The Barents Sea is regarded as one of the cleanest and richest marine areas in the world, and the expansion and regulation of petroleum activity on this part of the Norwegian Continental Shelf has been a controversial issue for decades. A physical zero discharge regime was imposed for the petroleum industry in the Barents Sea in 2006, implying that all drilling waste had to be either re-injected or taken on-shore. However, already in 2011 the rules for the Barents Sea were softened and aligned with those applicable to the rest of the Norwegian Continental Shelf.

Still, there are arguments that environmental regulations should be stricter in the Barents Sea than elsewhere, also regarding permissions to discharge drilling waste at sea. In this paper we investigate the possible effects of an adjustment of the Norwegian regime for licensing drilling wells for the Barents Sea and deciding on the conditions for the associated pollution permits.

Under the current regime the Ministry of Oil and Energy announces licenses to drill wells, and the companies that get such licenses must apply to the Norwegian Environment Agency for permission to pollute. As the companies are required by law to utilize the licenses, this puts the Norwegian Environment Agency in a position where they must negotiate with the firm on the size and type of permission. Taking drilling waste to shore is a much more expensive operation for the firm than emissions to sea. This is an essential element in the bargaining position of the firm. Other firm-specific challenges as technical capabilities may also affect the bargaining position of the firm. Ultimately, one of the factors being negotiated upon is the environmental standard of the deep sea area in general, and of the sea-bed of this area in specific. We employ a cost-benefit approach to investigate the effects for the authorities, individual petroleum companies and the environment of announcing the pollution permit conditions for each block as the licencing round for explorative drilling is announced. This will change the bargaining process for the pollution permit, and imply other processes and various effects for the environment and the different actors.
Bridging the gaps of our understanding of the Triassic of the northern Barents Shelf

Ingrid Anell¹, Alvar Braathen¹,², Snorre Olaussen², Jan Inge Faleide¹

¹University of Oslo, Oslo, Norway; ²UNIS, Longyearbyen, Norway

The northern Barents Shelf potentially hosts prolific plays. Middle to Late Triassic sandstones, sourced largely from the Urals and Baltic Shield, were deposited atop Early Triassic organic rich source-rocks. However, the formation and development of basins, platforms and highs remains partly unclear and the influence of fault-movement, compression, uplift and erosion has yet to be fully understood. The lack of good well-control coupled with poor seismic resolution in many near-shore and deep areas, creates challenges. Many of these knowledge-gaps have a direct link to formation, migration and entrapment of oil and gas.

The age of the deepest foundations of the Barents Shelf are mainly Carboniferous, probably also Devonian. While extensional faulting played an important role much infill of the shelf is characterized by non-faulted sagging. Changes in influx rate and direction has impacted the formation of various depocentres but the reasons for the changes is not always clear. The Triassic succession shows signs of normal faulting but also compression, truncation, erosion and structural influence on sedimentation.

The Early Triassic clinoforms in the southeastern part of the northern shelf are well developed and reveal a comparatively slowly advancing platform edge. Faster advance due to limited accommodation is inferred across the structurally higher area of the Edgeøya platform which influenced drainage patterns and resulted in rapid deposition across Svalbard. Regionally limited accommodation is inferred to have controlled sedimentation during the latest Triassic-Middle Jurassic with periods of condensation, sediment starvation, erosion and reworking.
Is Three a Crowd? Arctic resource strategy in Russia, China, and Japan

Timothy Magner
Fletcher School of Law and Diplomacy, Medford, MA, USA

A new dimension of relations between Russia, China, and Japan is emerging around the development of Arctic energy resources. China and Japan are highly dependent on imported energy, with Japan relying on imports for more than 95 percent of its oil and gas consumption and China projected to import over 65 percent and 45 percent of its oil and natural gas, respectively, by 2020. Currently, these imports must travel through a geopolitical minefield: the Straits of Hormuz and Malacca, and the increasingly tense South China Sea. However, it is estimated that the Arctic contains 30 percent of the world’s undiscovered gas and 13 percent of its undiscovered oil, much of which is believed to lie within or just outside Russia’s continental shelf.

The draw of Arctic resources, which are widely forecast to become commercially viable in the coming decades, gives these countries little choice but to welcome both a Russian pivot to Asia and prospects of deeper regional energy ties. Certainly, the May 2013 admission of Japan and China to the Arctic Council as permanent observer states reinforces a desire by East Asian nations to position themselves as key participants in Arctic issues.

With Sino-Japanese relations in a tenuous state, how this reorientation plays out with their shared northern neighbor remains to be seen, especially given a history of conflict. How do sustainably lower oil prices hinder development? How do Sino-U.S. relations influence this trend? Will this game be characterized by cooperation or competition? And, how do Western sanctions against Russia impact Chinese and Japanese involvement in Russian Arctic resource development? This paper answers these questions through expert interviews, scenario analysis, and examination of key stakeholders. Since the existing literature has seldom taken these issues into account, this paper will examine how energy demand, climate change, and the contentious history between the three nations may distort development of this nascent frontier.
Energy, Inuit, and Security in the Canadian Arctic

Wilfrid Greaves

University of Toronto, Toronto, ON, Canada

Energy is at the heart of some of the most challenging policy questions concerning the transforming Arctic region. As climate change enables access to energy resources in the circumpolar region, many environmentalists and indigenous peoples are increasingly concerned over the potential local and global ecological consequences of expanded hydrocarbon extraction. This paper examines this debate in terms of competing accounts of energy security versus human and environmental security in the Canadian Arctic. It examines how energy and security are defined and understood by the Canadian state and by Inuit people in northern Canada. Employing a wide variety of primary and secondary research - including polling data, public documents, articles, speeches, interviews, and academic sources - its findings suggest that Inuit primarily articulate a conception of energy and Arctic security that not only differs from that employed by the Canadian state, but stands in opposition to it. Whereas Canada sees hydrocarbon resources as contributing to energy security for the Canadian and global economies, Inuit tend to see them as further endangering the fragile Arctic ecosystem, and the indigenous ways of life that rely upon it. This raises important questions of how and by whom security is defined in the Arctic region, and what role energy and hydrocarbon extraction play in understandings of who is to be made secure and through what means.
Towards an Arctic energy superpower? Canada, Arctic, and international energy relations

Petra Dolata

University of Calgary, Calgary, AB, Canada

This paper analyses the significance of energy resources in Canada’s Arctic policy and circumpolar politics. In 2007 Canada proclaimed itself as an energy superpower, a claim that was invoked again recently in light of the Ukrainian crisis offering to provide alternative supplies to the Baltic States and Eastern Europe. However, much of this energy superpower discourse is linked to the oil sands and shale gas reserves in Western Canada and not so much to potential oil and gas exploration in the Canadian Arctic. Thus, energy security has not become a dominant part of the Canadian security narrative with regards to the Arctic. This is not surprising considering its rather modest significance in overall Canadian oil and gas production. Currently, only a fraction of Canadian energy production originates in the Arctic, the heydays of oil and gas exploration in the region date back to the 1960s and 1980s. However, new drilling licenses have been issued over the past couple of years, mainly in the Beaufort Sea, and pipeline and LNG shipping plans are discussed. The question is what kind of an impact these developments have on circumpolar security but also whether energy issues in the Arctic should be considered regional or global. Because of the involvement of International (IOCs) and National Oil Companies (NOCs), especially in an open and investment-friendly country such as Canada, as well as the international nature of hydrocarbon energy markets the Arctic becomes only one region in a much bigger game. Not surprisingly, scholars disagree whether this game would lead to cooperation or conflict in the Arctic. Critically engaging with current geopolitical arguments in international politics literature that highlight the centrality of energy resources in explaining the reemergence of the Arctic as a political space I will use Canada as a case study to show that such a generalization is not helpful in understanding individual state behavior in the Arctic. I will focus on both domestic and foreign aspects of Arctic and energy policy and highlight the linkages between them.
Developing regulations for sustainable petroleum production in the Arctic

Ann-Magnhild Solås, Maaike Knol, Peter Arbo
UiT The Arctic University of Norway, Tromsø, Norway

Offshore oil and gas makes up a growing share of world petroleum production. Today, about 30 percent of total oil and gas production comes from offshore wells, and this proportion is expected to increase in the future. Petroleum exploration and exploitation are extended to new and more challenging ocean areas around the globe, and the Arctic is one of the areas believed to hide large untapped reserves. The oil industry affects the marine ecosystems in all phases of activity. A key issue is therefore how the Arctic energy potential can be utilized in a safe and environmentally sound way.

This paper focuses on the management regimes for handling of waste from the routine operations of the oil and gas industry (produced water, drill cuttings and drilling mud). We take the Norwegian management regime as our point of departure. The management of environmental waste from petroleum activity on the Norwegian Continental Shelf (NCS) has generally been based on a zero-harm principle, implying that no discharges of environmentally hazardous substances are permitted. In 2004, as part of the preparation of the integrated marine management plan for the Barents Sea – Lofoten area, stricter regulations were imposed for this Arctic area. A physical zero discharge regime was introduced for all normal operations, meaning that drill cuttings, drilling mud and produced water had to be re-injected or taken ashore for treatment (with a few exceptions). However, when the integrated management plan was revised in 2011, the regulations for the Arctic were aligned with those that apply to the rest of the NCS.

This paper highlights how sustainability concerns have been addressed, and discusses the rationale behind the various measures that have been launched. It investigates the design and implementation of instruments for the management of environmental waste generated by the petroleum industry. More specifically, it looks into the co-production of relevant knowledge between science, policy and industry, and how this knowledge is translated into management measures and government requirements. It also discusses the effects of different management regimes for the development of new technology and operational solutions, which again have consequences for the marine ecosystems. The aim of the paper is to clarify the conditions for establishing effective management systems that can reduce the potential harmful effects of the petroleum industry. Based on the Norwegian experiences, we conclude by drawing lessons that can be applicable to the Arctic in general.
Cleantech energy and the Arctic: How could it be a game changer in the world energy supply?

Florian Vidal

Paris-Descartes University, Paris, France

In the light of the ongoing development of cleantech energy, the Arctic may become a true openfield laboratory in order to apply new technologies as well as the long-term energy mix policy.

As sustainability will necessitate significant changes in public policy in areas of development practices, transportation options and resource consumption, the Arctic region appears to take first steps toward this new model of sustainable energy consumption. The Arctic region holds substantial renewable energy generation potential and hydrocarbon reserves. The region may be a key player in the long-term transfer from conventional energy (including oil, gas and shale gas) to sustainable energy (wind, tidal, solar, wave and geothermal).

Blooming energy cluster within the Arctic ring:

All along the Arctic, several projects have been implemented in recent years aiming to develop energy clusters. Several cities are engaged to promote and invest in a new sustainable and efficient energy system. Oulu, Oslo and Reykjavik are driven synergies which emerge to build and engage the society in an environmentally friendly technologies system. These energy clusters expertise related to energy efficiency and renewable energy sources. The Arctic region needs new electricity transmission lines and decentralised energy production.

The Icelandic case:

As a tantamount example, Iceland can symbolize this cluster strategy and more broadly this U-turn toward an efficient and sustainable energy society provided by clean technologies. It may be illustrated with Iceland Geothermal Cluster. This local organization aims to promote Iceland’s unique qualities as the land of geothermal energy and geothermal energy production. Furthermore, it value opportunities to export its clean technologies abroad.

Consequently, the current energy policy on the move in the Arctic countries may influence other parts of the world. Potential success in this energy transition may offer strong opportunities for emerging powers to invest in such technologies in fast tracks. Indeed, on the one hand, China seems to be on the frontline to implement significant projects for sustainable energy (i.e.: geothermal). On the other hand, China aims to
invest and develop new technologies to extract conventional energy in the Arctic region.

Finally, the current energy policy trend in the Arctic may noteworthy contribute to affect the global energy supply system. It implies risks but surely offers unique opportunities to resolve this dramatic energy crisis which is facing our contemporary civilization.
Changes in oil exposure of fish early life stages when using dispersants to combat oil spill

Frode Vikebø¹, Petter Rønningen², Sonnich Meier¹, Bjørn Einar Grøsvik¹, Vidar Lien¹

¹Institute of Marine Research, N-5817, Bergen, Norway, ²SINTEF, Strindvegen, 7465 Trondheim, Norway

Coupling an oil drift and fates model (OSCAR) in an offline environment with an individual-based model (IBM) for Northeast Arctic cod (Gadus morhua) eggs and larvae enables us to quantify the exposure of eggs and larvae to oil from various oil spill scenarios. The oil spill scenarios are situated at Haltenbanken, Lofoten, and Vesterålen, and are repeated both with and without the use of dispersants. Early life stages of fish are particular sensitive to polycyclic aromatic hydrocarbons (PAHs). Adding dispersants speeds up the transition from large droplets to smaller droplets and increase the levels of PAHs in the water accommodated fraction (WAF), before the oil components dilutes and degrades further to concentrations below threshold levels for effects. While some studies indicate elevated toxicity as a result of introducing dispersants, this may not be representative for a situation at sea where dilution and biodegradation decrease concentrations of toxic components. Our results indicate that the introduction of dispersants results in higher concentrations of dissolved PAHs, but more rapid dilution and degradation. Also, the PAHs are displaced deeper in the water column. Added dispersants results in a moderate change in the fraction of individuals either exposed to levels corresponding to acute or sublethal effects.
Net Environmental Benefit Analysis support Tool to Assess Oil Spill Response Technologies and the Environmental Effects of Arctic Oil Spills

Lionel Camus¹, Jack Word², Stephane Le Floch³, Robbert Jak⁴

¹Akvaplan niva, Tromso, Norway, ²Environ International, Port Gamble, USA, ³Cedre, Brest, France, ⁴IMARES, Den Helder, The Netherlands

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. 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 on recovery). 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 an internationally 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 (OGP), 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 of the project 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 oil spills and OSR technologies 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.
China–Russia Arctic Energy Cooperation: Timing, Reality and Prospects

Beixi Deng, Xia Zhang

Polar Research Institute of China, Shanghai, China

Due to insufficiency in an Arctic regional security mechanism, the spill-over effects of interstate conflicts of global geopolitical dynamics onto the Arctic region in the aftermaths of the Ukrainian Crisis, re-evoke the "East-West" tension, which arises to its climax with U.S.-EU sanctions of investments and technology transfer on Russia's Arctic oil industries. The containment policy of U.S. and its allies to China from East and South, and to Russia from West, compel the two states to strategically approach, as demonstrates that the two state-leaders have met 9 times since 2013. Though not officially and specifically proposed, China-Russia Arctic cooperation has been concretely addressed, e.g. the CNPC's holding of stakes in Novatek's Yamal LNG Project.

The strategic approaching of the two states in face of U.S. containment, and the integration of Russia's goal to diversify its energy flow and China's objective to diversify its energy supply, jointly shape the appropriate timing for China-Russia Arctic energy cooperation. If the Ukrainian crisis hadn't taken place or exacerbated, Russia would have nevertheless prioritized Europe, North America, and Japan for Arctic energy cooperation rather than turning towards the East. Despite positive speculations and high expectations on China-Russia Arctic energy cooperation interpreted by international media, implementation in reality far lags behind political willingness. Russia's reluctance in engaging non-Arctic states, the prudence of China's energy companies in investing in the markets unfamiliar and immature, as well as the feasibility and profitability of cross-border pipelines over shipping, all constitute impediments for China-Russia Arctic energy cooperation from achieving concrete fruits in the short term. The prospects and potentials for future China-Russia Arctic energy cooperation are subject to various factors, e.g. the China-Russian-U.S. triangular relations, the evolution of China's Arctic strategy and Russia's Arctic development policy, etc, which will be further examined and elaborated in this presentation.

Note: This presentation will be elaborated collaboratively with Prof. ZHANG Xia, Head of Division of Polar Strategic Studies, Polar Research Institute of China (PRIC)
The role of human capital and knowledge institutes for the development of an energy sector in Iceland, Faroe Islands, and Greenland

Coco Smits¹, Rasmus Gjedssø Bertelsen²,³, Jens Christian Svabo Justinussen⁴

¹Royal HaskoningDHV, Amersfoort, The Netherlands, ²UiT The Arctic University of Norway, Tromsø, Norway, ³Aalborg University, Aalborg, Denmark, ⁴University of the Faroe Islands, Torshavn, Faroe Islands

Like many Arctic states, Iceland and the Faroe Islands used to be the resource-based economies which Greenland is today. Remotely located in relation to the World economy, Iceland and the Faroe Islands have succeeded in developing a knowledge-based economy, also related to their energy sector. By maximising local benefits via human capital development, societies create a more sustainable basis for resource exploitation. To create a knowledge-based economy a sufficient mass of human capital is of crucial importance. In forming this critical mass, higher education and knowledge institutes play a central role. The cases of the Faroe Islands and Iceland show that it is possible to create a critical mass of human capital by developing strong knowledge institutes and stimulating the exchange of knowledge. Iceland has successfully developed a knowledge-based energy sector based on hydropower over the last century. Icelanders bringing home knowledge gained via graduate education at top institutes abroad, appeared of major importance. More recently the Faroe Islands have developed human capital based on oil and gas exploration activities, while no economically viable resources have been found yet. Greenland on the other side has made some important steps in creating and strengthening strong knowledge institutes, but is still far from a full-fledged knowledge-based economy such as the one in Iceland. Are there lessons to be learned from Iceland and the Faroe Islands, and how much do historic path-dependencies matter in this context? These are questions that this article will explore.
Seasonal analysis of marine icing in the Norwegian Barents Sea

Sigurd Henrik Teigen, Eirik Schrøder Hansen, Jens Christian Roth

Statoil ASA, Bergen, Norway; Statoil ASA, Stavanger, Norway

During periods of low temperature and strong wind, marine icing by freezing sea spray is a typical phenomenon in the Barents Sea. The frequency and severity of these marine icing events need to be taken into account by oil and gas projects in the area. An efficient numerical model for estimating marine icing on vessels and offshore structures has been used for evaluation of the seasonal marine icing severity across the geographical extent of the Norwegian Barents Sea. The analysis is performed for the entire period between 1957 and 2013, using meteorological input from the NORA10 hindcast archive. Extremal (100-year) values of icing are derived for generic structural geometries. Spatial and temporal trends are discussed, along with the overall influence of the distance to the ice edge and typical weather patterns during marine icing events. A comparison is made against the simple semi-empirical algorithms that are typically used by meteorological agencies to forecast marine icing today.
Ice Risk Management during exploration drilling in the Hoop region

Kenneth Eik, Pavel Liferov, Jens Christian Roth, Richard Hall

Statoil, Oslo, Norway

The drill rig Transocean Spitsbergen drilled three wells in the Hoop region in the Barents Sea during the summer 2014. Two of the wells were drilled at locations which statistically are visited by sea ice once every ten years and a small possibility for iceberg intrusions. In order to ensure a safe distance between the rig and any ice, an ice risk management system was prepared and implemented. The system comprised systematic ice surveillance (by use of satellites, fixed wing flights and marine radars), ice forecasting, threat assessment and routines to cease operations as a function of the ice threat.

The ice risk management system ensured that the marine crew had a good understanding of the ice risk continuously throughout the operations. The established procedures would have ensured that no drilling took place closer than 50 km from 40% ice concentration. The minimum distance to ice during drilling was however always larger than 80 km. With exception of the first few days, the distance from drill rig to closest sea ice was about 400 km.

The ice risk management system was implemented for relatively low costs and can easily be adopted in other operations in the Barents Sea at sites where ice intrusions may take place.
Distributed renewable energy production in the high North.

Peter Haugan

University of Bergen, Bergen, Norway

Sparsely populated areas like the high North typically have renewable energy resources which are larger than the local demand. High cost of energy transmission limits energy export from the region. Due to difficulties with storing energy from variable renewable sources, traditionally import of fossil fuel such as diesel has played a significant role supplemented by local hydropower and in some cases coal production. This contribution explores the hypothesis that ongoing improvements in local energy storage technology and renewable energy production technology may rapidly and significantly change this situation. Will the future bring selfsufficient communities in the high North exploiting local renewable energy sources and energy storage avoiding expensive import of fuel? May we even see industries with high energy demand move to the high North to exploit renewable energy sources?

A progress report from an ongoing survey will be presented. We are looking for drivers and early movers that exploit technology developments elsewhere, transferring them and developing applications in the high North.
Challenges regarding electricity supply to offshore oil and gas installations in the Arctic.

Dag Eirik Nordgård

SINTEF Energy Research, Norway

Fossil fuels will still be an important part of the global energy supply in the long-term perspective, and it is important to develop more sustainable ways of providing and utilizing oil and gas reserves. Solutions for offshore electricity supply and electrification is a part of this puzzle.

The presentation will highlight some technical challenges regarding electricity supply to future oil and gas installations in the Arctic.
Arctic climate change – global implications

Scientific committee

Leader:
Professor Tor Eldevik (Leader), Geophysical Institute, University of Bergen and Bjerknes Centre for Climate Research, Norway
Research Director Nalan Koç, Norwegian Polar Institute, Norway
Director Jenny Baeseman, Cryosphere and Climate Project, Norway
Dean Kjell Magne Mælen, UiT - The Arctic University of Norway, Norway
Senior advisor Einar-Arne Herland, Norwegian Space Centre, Norway
Associate Professor Janike Kampevold Larsen, Oslo School of Architecture and Design, Norway
Inga May, APECS & Alfred-Wegener-Institut Helmholtz-Zentrum für Polar und Meeresforschung, Germany
Special advisor Torill Engen Skaugen, The Research Council of Norway, Norway
Head of Conservation Martin Sommerkorn, WWF, Norway
The influence of climate change on the spread of parasitic diseases among the population of the Russian Arctic

Natalia Bobyreva, Galina Degteva, Yana Korneeva

Research Institute of Arctic Medicine Northern State Medical University, Arkhangelsk, Russia

The report shows the relationship impact of climate change on the spread of parasitic diseases of the population in the Arctic north of Russia as an example of the Nenets Autonomous Okrug. It is shown that climate change is an increase in precipitation, moisture leads to an increased incidence of parasitic diseases of the county's population, as the alien and the native as well as the emergence of new characteristics not previously for county species of parasites. Pediatric population is particularly vulnerable in this regard.

We examined between 2002 and 2013 at parasitosis microscopic methods 217,417 people, by enzyme immunoassay - 11,556. Material for the study were as follows: serum, emulsion feces. We used methods of descriptive statistics (mean values $\bar{x}$, the percentage error of the mean, the construction of the trend line) made in Excel 2010, the method of analysis of official statistical reporting hospitals survey on parasitic diseases for the period from 2002 to 2013 and data of their research over the same period. Criteria for sampling were taken: Nationality, occupation, place of residence, age categorie. The criteria for inclusion in the sample was the presence of a written informed consent to participate in the study, specifically designed for this purpose. The criteria for inclusion was not a refusal to participate in the study; disability. Type of study: cohort (longitudinal, retrospective).

A statistically significant correlation was established between the rise in air temperature, increased precipitation and an increase in the number of registered parasitic diseases, especially in children under the age of 17 years, such as diphyllobothriasis, giardiasis, toxocariasis. We observed excess morbidity for certain types of parasites (lyablioz) compared with the Russian Federation 47.7 times ($y =100,8-366,0$ at $R^2 =0,529$). We have observed that the incidence of giardiasis among the indigenous population is much less than -5% than in those of other nationalities - 15%.

We have found that due to climate change has been a sharp increase in morbidity parasitosis, new, not typical for county species of parasites. The dynamics of the population ascariasis suggests that ascariasis may be in the Nenets Autonomous Okrug is not an imported infection, but is a consequence of climate change, which resulted in the winter roundworm eggs safely overwinter in cold conditions.
Planktonic foraminifera response to climate and ocean chemistry changes during the past two millennia in the Arctic

Kasia Zamelczyk\textsuperscript{1}, Tine Rasmussen\textsuperscript{1}, Clara Manno\textsuperscript{2}

\textsuperscript{1}CAGE-Centre for Arctic Gas Hydrate, Environment and Climate, UiT, the Arctic University of Norway, Tromsø, Norway, \textsuperscript{2}British Antarctic Survey, Cambridge, UK

Multiple stressors and their interactions are generating substantial challenges for marine organisms. The most influential stressors are climate changes and associated ocean acidification. Many calcareous organisms may show adverse effects to ocean acidification as their ability to calcify and maintain shells is reduced. Planktonic foraminifera constitute one of the major groups of calcareous marine microplankton. Their shells are highly sensitive to changes in carbonate chemistry, sea surface conditions, and preservation shifts in sedimentary records. This sensitivity makes them one of the most prominent sources of knowledge on past changes in ocean chemistry, climate and ocean circulation.

In the Arctic Ocean, acidification occurs faster than the global average because cold waters absorb more carbon dioxide than warm water and melting sea ice enhances the process by lowering the carbonate ion concentration. In the Fram Strait, the European part of the Arctic Ocean, sea ice and water masses of contrasting properties interact. The eastern Fram Strait is occupied by warm and saline Atlantic waters, whereas the western Fram Strait is dominated by cold and fresher Polar water and sea-ice. The central Fram Strait is dominated by Arctic surface water where Polar and Atlantic waters mix. The three different water masses generate oceanic fronts causing additional environmental stress factors for surface water dwelling planktonic foraminifera. Samples from zooplankton nets and sediment cores from the eastern Fram Strait (Storfjorden Fan) were used to investigate the effects of the changing arctic environment on planktonic foraminifera. The distribution patterns of fossil and living planktonic foraminifera show strong variability. Preliminary results indicate that the distribution of planktonic foraminifera and their preservation follow general climatic changes during the last 2000 years. Carbon and oxygen isotopic signatures recorded in Neogloboquadrina pachyderma, Turborotalita quinqueloba and Globigerinita uvula – inhabiting three different water masses – implies that the subsurface water masses remained unaffected by climatic changes through the entire studied time span.
Fram Strait Spring Ice Export and the September Arctic Sea Ice Cover

Mari H. Halvorsen\textsuperscript{1}, Lars Henrik Smedsrud\textsuperscript{1,2}, Kjell Kloster\textsuperscript{3}

\textsuperscript{1}Geophysical Institute, University of Bergen, Bergen, Norway, \textsuperscript{2}Bjerknes Center for Climate Research, Bergen, Norway, \textsuperscript{3}Nansen Environmental and Remote Sensing Center, Bergen, Norway

Every year about 10\% of the sea ice cover in the Arctic Basin is exported southwards through the Fram Strait between Greenland and Svalbard. Because quite thick ice is lost this way a larger than normal export decreases the remaining mean thickness in addition to the area inside the basin.

A new time-series from 1979-2013 of Fram Strait sea ice area export has been constructed based on observed cross-strait surface pressure along 79°N. The ice area export has overall been increasing until today, and for 2010-2013 more than 1 million km\textsuperscript{2} has been exported annually. A robust positive trend of 8\% increase each decade is found for the annual ice area export since 1979.

The increase in ice area export is much larger during the spring and summer months than in autumn and winter. The cumulative export from March through August has a trend of 18\% per decade. In these months little growth occurs inside the basin and an influence on the following September minimum could be expected. We find such an influence, and estimate that a third of the variations in observed September Arctic sea ice extent onwards from 1979 can be directly explained by variations in this ice export. An anomaly created by export would be further enhanced by positive feedback mechanism during summer such as the ice-albedo feedback.

The new and updated time series of Fram Strait sea ice area export is based on high resolution sea ice drift observations across 79°N from 2004 to 2010 derived from radar satellite data regressed on the observed cross-strait surface pressure difference. On the Greenland side surface pressure has been constructed from two different stations that had high internal correlation. The increasing ice export is thus directly related to higher southward ice drift speeds, due to stronger southward geostrophic winds, largely explained by an observed increase in surface pressure on the Greenland side.

When producing the best fit between the geostrophic wind and the observed ice speed, a seasonal difference of \textasciitilde 3 cm/s was found. This difference suggests that the ice speed and export is higher in winter, and lower during summer, than can be explained by the local winds. A likely explanation is a seasonal variation in the underlying East Greenland Current consistent with the generally stronger winds in the entire region during winter.
Implications of future climate change: phase shifting the seasonal rhythmicity in mammals from different climatic zones

V.A. Ilyukha¹,², E.A. Khizhkin¹, I.A. Vinogradova², S.N. Sergina¹, L.B. Uzenbaeva¹, T.N. Ilyina¹, I.V. Baishnikova¹, A.G. Kizhina¹, A.V. Morozov², S. Lapinski³, M. Lis³

Institute of Biology, Karelian Research centre of the Russian Academy of Sciences, Petrozavodsk, Russia; Petrozavodsk State University, Petrozavodsk, Russia; Agricultural University of Krakow, Krakow, Poland

In most species daily and seasonal changes in the light-dark cycle are the most important synchronizers of daily and seasonal rhythms. But the world’s climate is changing rapidly, disrupting the rhythmicity on which so much life depends (Goldman et al., 2004; Bradshaw & Holzapfel, 2007). The available information suggests that as our climate changes the small rodents of the world may adapt rather easily but the longer lived mammals whose reproduction is regulated by photoperiod may not do so well (Bronson, 2009). Organism adaptation to change of ambient light conditions is realized via hormone melatonin synthesized by pineal gland during dark. Besides the mediating of seasonal changes in many traits including reproduction and body mass melatonin participates in regulation of metabolism of free radicals, immune response, cells proliferation and differentiation, etc. However, exogenously administered melatonin can phase shift the endogenous melatonin cycle and therefore modulates seasonal and circadian rhythms.

The aims of this study are threefold: first, to investigate the age-dependent effects of exogenous melatonin (daily supplied with water or subcutaneous implanted) on the tissue antioxidant capacity, activities of gut digestive enzymes and morphophunctional parameters of leucocytes in Wistar rats and some farm-breeding Carnivora species; second, to relate the knowledge gained on the small rodents to the kinds of long-lived mammals’ reaction; third, to use the information generated by the rst two objectives to consider how mammals including typical arctic species as Polar fox (Alopex lagopus L.) might or might not adapt seasonally to global climate change.

The age- and species-dependent sensitivity of physiological traits to light conditions and exogenous melatonin was discussed. It was suggested that the photoresponsive, longer lived mammals of the mid and higher latitudes will probably be hard hit by climate change but there is no way of predicting whether they will be able to successfully adapt to the new conditions.

This work was supported by President of the Russian Federation Grant for Leading Scientific School N-1410.2014.4.
Ocean floor methane seeps in the North-western Svalbard – A snapshot of the oceanography and benthic methane release

Pär Jansson¹, Bénédicte Ferré¹, Anna Silyakova¹, Jens Greinert¹,², Jürgen Mienert¹

¹CAGE - Centre for Arctic Gas Hydrate, Environment, and Climate at UiT - The Arctic University of Norway, Tromsø, Norway, GEOMAR – Wischhofstraße 1-3, Kiel, Germany

Research in the Centre of excellence CAGE (Centre for Arctic Gas hydrate, Environment and Climate) focuses on the role of the Arctic Ocean methane hydrates in the context of environmental and climate issues. Warming of ocean temperatures is expected to reduce the stability of gas hydrates in continental margins, which may destabilize sediments and cause slope instabilities. Further, vast amount of methane that emanates from gas hydrates can have a significant impact on ocean chemistry and global warming if it reaches the atmosphere. By understanding the variability of methane release on time scales from hours to years and its dependence on oceanographic changes, we can quantify local and regional methane leakages.

We collected hydroacoustic and traditional hydrographic (temperature and salinity) data as well as water samples analysed for methane and nutrient content during a cruise performed offshore North-West Svalbard in June 2014. Split beam echosounder data showed substantial bubble release at several sites offshore Prins Karls Forland, accompanying increased levels of dissolved methane concentration.

We present data from a 70 km long section comprising 24 stations extending from the deep end of the Svalbard margin up onto the shallow shelf showing two locations with noticeably increased methane concentrations, which may be associated with the outcrop of the gas hydrate stability zone, at approximately 400 m depth. The second site showing high methane levels in this section is known from previous cruises as a persistent bubble seep site at 250 m depth.

A unique 65 station grid survey covering an area of 30 by 15 km offshore Prins Karls Forland showed methane levels ranging from slightly increased background values up to levels around 100 times the background level.
New monitoring of physical and biochemical environment in the area north of Svalbard

Vladimir Pavlov¹, Arild Sundfjord¹, Randi Ingvaldsen², Marit Reigstad³

¹Norwegian Polar Institute, Tromsø, Norway;²Institute of Marine Research, Bergen, Norway;³University of Tromsø–The Arctic University of Norway, Tromsø, Norway

The Arctic shelf seas contain some of the most biologically productive ecosystems in the world, and also play globally significant roles in heat exchange, ocean circulation, and geochemical cycling. The inflow of Atlantic water (AW) along the shelf break of Svalbard is a major source of heat and biological energy to the Arctic Ocean. Monitoring of this AW slope current with current meter moorings is essential to assess the transport and variability of AW, and associated tracers, into the Arctic Ocean. In 2012, nine moorings were deployed, including three from Fram Centre (Norway), four from WHOI (USA) and two from IOPAS (Poland). Four moorings were re-deployed in the same region in 2013. In addition in the period 2012-2014 years, about 300 CTD, biological and chemical stations were conducted around the mooring array. Thus during these years we have established new representative site for long-term monitoring of the warm Atlantic Waters north of Svalbard. Based on the data obtained from the mooring stations in 2013 we discuss seasonal changes of the important parameters like water temperature, salinity, currents, heat and salt fluxes of the Atlantic water to the Arctic Ocean.
Arctic Engineering Mitigates Challenges Relating to Climate Change

Hannele Zubeck1, Riitta Kamula2, Kai Ryynänen3, Pernille Erland Jensen4, Sven Knutson5

1 University of Alaska Anchorage, Anchorage, Alaska, USA; 2 University of Oulu, Thule Institute, Oulu, Finland; 3 Lapland University of Applied Sciences, Rovaniemi, Finland; 4 Centre of Arctic Tecnology, Technical University of Denmark, Copenhagen, Denmark; 5 Luleå University of Technology, Luleå, Sweden

Changes in the Arctic climate affect life and societies of all ecosystems and environment in the Arctic. For sustainable future, we need to find mitigation and adaptation measures and new resource management technologies. Engineers and engineering are often ignored in the discussions on Arctic issues. Sometimes engineers are even considered as the "bad guys" causing the problems. However, it is noteworthy to realize that engineers react, not just observe, and provide solutions for the challenges relating to climate change.

In many fields, engineering can offer new angles to the problems, and solutions for e.g. safety and security issues. Sustainability in the Arctic means in most cases sustainable management of the region's rich natural resources planned to be extracted in the future. Modern infrastructure and built-up environments require knowledge on engineering to create and maintain sustainable communities. Arctic engineering offers remediation and mitigation tools to adapt the rapid changes and to find ways to ensure sustainable development in arctic conditions with snow and ice, frost, and permafrost.

Arctic engineering follows the recommends of the arctic research goals and objectives of the US Arctic Commission (USARC) by e.g. by moving from knowledge to actions to respond to environmental changes in the Arctic; advancing infrastructure research to develop sustainable infrastructure; and by developing Arctic-specific technology, design and engineering for rapidly changing environment.

The Arctic engineering education of the University of the Arctic (UArctic) Thematic Network is multidisciplinary giving the students good knowledge on the challenges we are facing in our everyday life Arctic environment. In addition, the studies provide tools and measures to mitigate the unwelcome outcomes of the climate change. The subjects cover sustainable use of resources, environmental-friendly energy production, energy efficiency and renewable energy; modern infrastructure and built-up environment; water supply and waste water. Decision-making support methodologies like environmental impact assessment and multi-criteria analysis methods gather up and complement the graduate's tool box.
This paper introduces the principles of Arctic engineering, and describes the activities of the UArctic Thematic Network of Arctic Engineering giving also examples how engineering benefits the Arctic environment.
Analysis of ice mass balance buoys and radiative fluxes in summers 2012 and 2013 in the central Arctic Ocean

Caixin Wang, Mats A. Granskog, Alexey K. Pavlov, Sebastian Gerland, Stephen R. Hudson

Norwegian Polar Institute, Tromsø, Norway

During the ongoing satellite era, 2012 reached an all-time minimum September sea-ice extent in the Arctic and 2013 reached the seventh lowest on record. An Ice Mass Balance buoy (IMB) and a Spectral Radiation Buoy (SRB) were deployed side by side on drifting first-year sea ice near the North Pole prior to melt onset in mid-April 2012 and 2013. After deployment, the buoys drifted southward, reaching the Fram Strait in early fall and covering the complete melt season in both summers. An IMB automatically measures sea-ice and snow thickness, as well as air pressure and temperature in the air, through the snow and ice and into the upper ocean. An SRB autonomously measures the spectral incident, reflected, and transmitted solar radiation (350 to 800 nm) above and below sea ice. Surface evolution, weather and sky conditions were additionally captured by NPEO (North Pole Environmental Observatory) webcams installed nearby our SRB site. There were some significant differences between the two summer melt seasons, such as, (1) snow was much thicker before mid-June in 2012 than 2013; (2) snow melt onset was earlier in 2012 than in 2013; (3) it took less time for snow to melt completely in 2012 than in 2013; (4) the melting season was longer and melt ponds formed earlier and refroze later in 2012 than in 2013; (5) albedo was lower and transmittance was higher between June and August 2012 than in 2013. These differences might be attributed to a variety of causes, including the higher summer air temperature in 2012, differences in the extent of melt ponds that were in the field of view of the SRB, differences in the wind pattern over the Arctic Ocean or differences in the incoming longwave and/or shortwave radiation near the SRB region. These differences and effects will be presented through analysis of the ERA-interim reanalysis data in combination with the data collected by these buoys.
Propagation and Modification of Ocean Heat Anomalies in the Nordic Seas

Marius Årthun\textsuperscript{1,2}, Tor Eldevik\textsuperscript{1,2}, Kjell Arne Mork\textsuperscript{3,2}, Øystein Skagseth\textsuperscript{3}

\textsuperscript{1}Geophysical Institute, University of Bergen, Bergen, Norway; \textsuperscript{2}Bjerknes Centre for Climate Research, Bergen, Norway; \textsuperscript{3}Institute of Marine Research, Bergen, Norway

The Atlantic region exhibits distinct interannual to (multi-)decadal variability, reflected in upper-ocean thermohaline anomalies that propagate persistently through the North Atlantic and the Nordic Seas towards the Arctic Ocean. A better understanding of the circulation and modification of these anomalies is a prerequisite for skillful climate predictions for the North Atlantic/Arctic sector. Here, we use the fully coupled Bergen Climate Model to assess the propagation and modification of ocean heat anomalies within the Nordic Seas. In agreement with observations, heat anomalies are found to circulate the rim of the basin with a dominant time scale of about 10-15 years. The magnitude of heat content variability within the Atlantic water core shows a northward increase towards the western Barents Sea continental slope, a result which is corroborated by new observations. Along the coast of Norway the heat anomalies result from sub-surface temperature variability associated with the depth of the northward flowing Atlantic water, whereas further north, along the western Barents Sea continental slope, the temperature anomalies are surface intensified, suggestive of strong air-sea interaction. A heat budget analysis reveals that the changes in heat content are mainly forced by ocean heat transport convergence brought on by changes in advection speed of the northward flowing Atlantic water, while air-sea fluxes act to damp ocean heat anomalies.
Recent highlights from the Fram Strait Arctic Outflow Observatory.

Laura de Steur\textsuperscript{1}, Paul Dodd\textsuperscript{1}, Mats Granskog\textsuperscript{1}, Gunnar Spreen\textsuperscript{1}, Colin Stedmon\textsuperscript{2}

\textsuperscript{1}Norwegian Polar Institute, Tromsø, Norway; \textsuperscript{2}Technical University of Denmark, Copenhagen, Denmark

Fram Strait is the only deep connection allowing exchange between the Arctic Ocean and the Nordic Seas. The exchanges of e.g. heat, freshwater and carbon are expected to change as the Arctic climate evolves with - at present - unknown consequences for the Arctic and Subarctic climate and ecosystems. Polar water, recirculating Atlantic Water and denser water masses exported from the Arctic Ocean and recirculated with the East Greenland Current in western Fram Strait are monitored year-round by an array of moored instruments along 78°50′N, which has been maintained by the Norwegian Polar Institute since the 1990s. Annual hydrographic sections have been completed along the same latitude every September. Since 2008 tracer measurements have been collected along annual sections to identify the sources of the freshwater outflow and to relate variations in the freshwater flux to upstream changes in the Arctic climate system. Additionally, measurements of colored dissolved organic matter (CDOM) and dissolved organic carbon (DOC) have been collected to determine the composition of carbon exported from the Arctic Ocean since 2009. Upward looking sonars (ULS) provide continuous monitoring of the sea-ice thickness across the array. As in the Arctic Basin the mean sea ice thickness is decreasing. However, the ULSs also allow to observe the high inter-annual variability in ice export events and the shift in ice thickness classes with a strong reduction in thickness for old and deformed ice. A more recent theme within the observatory is the study of the circulation of warm Atlantic Water in the Belgica-Norske-Westwind trough system on the East Greenland Shelf and its effect on marine terminating glaciers in NE Greenland which has shown in 2012 the presence of warmer water close to the 79N glacier than previously observed. This talk will give an overview of highlights from the Fram Strait Arctic Outflow Observatory in recent years, as well as new developments in this observing system.
Effect of the North Atlantic on climate change in the Barents sea

Natalia Glok, Genrikh Alekseev, Alexander Smirnov, Anastasia Vyazilova

Arctic and Antarctic Research Institute, St.Petersburg, Russia

Atlantic water (AW) flows into the Norwegian and the Greenland seas through the Faroe-Shetland, the Faroe-Icelandic straits and, in a less degree, through the Danish Straits around Iceland. Then AW extends along the eastern periphery of the seas and flows into the Arctic Basin and the Barents Sea. Impact of fluctuations in the inflow of warm and saline Atlantic water and its boundaries distribution shifting is most noticeable on the climate in the Barents Sea. Based on correlation analysis, areas where the sea surface temperature (SST) changes in North Atlantic is most closely related to changes in SST in the Barents Sea were detected. Information about SST were obtained from the archives of Hadl SST. PINRO data about water temperature in the section along the Kola meridian (KM) were also used in this research. Interannual water temperature on the Kola meridian correlate with the interannual SST of the Barents Sea (coefficient 0.79), that indicates PINRO data representativeness for the entire sea. Correlation between the interannual temperature on the KM and SST in the Gulf Stream is 0.67. When the lag is one year the correlation coefficient is 0.62, that indicates predictable potential of this regard. Correlation of monthly temperature on the KM and the extent of sea ice in the Barents Sea from 1951 to 2009 is maximum in May (0.86), because warm water flows into the southern part of the sea, and prevents the spread of ice to the south, maximum of which is in April and May, as well as to more intensive retreat of the ice edge in the melting period. Effect of water temperature anomalies on air temperature anomalies over the Barents Sea is characterized by a correlation coefficient 0.81 for the interannual data and 0.74 for the spring.

This research is supported by Russian Fund for Basic Research (grant 13-05-01006A)
Climate change debate and the ‘Russian proposal’: on the way from Durban 2011 to Paris 2015

Iuliia Goman

St. Petersburg State University, St. Petersburg, Russia

Climate change debate is being hot nowadays; it also serves as a means of international unification for certain countries as well as disintegration for the representatives who are less eager to accept this problem and start to act. Greenhouse gas emissions, concerns over temperature rise produced polar perception and no unified approach towards climate change. Groups of actors perceive climate change differently; hence, even domestic public debate on climate change may lack coherence.

The population in Russia is not aware of the challenges for the environment. According to the opinion poll conducted in Russia in 2005-2010 1% of Russian citizens worry about climate change issues, 4% did not have an opinion on the matter (Russian Analytical Digest, 2010). It seems essential to mention that in 2009 president D. Medvedev introduced considerable changes in the perception of climate change issue announcing more concerted efforts on the level of government to address these issues, calling for active participation by different actors: decision-makers (business, authorities) and society. The appearance of the Climate Doctrine of the Russian Federation in 2009 stated the main task of the climate policy of Russia: ‘the provision of solid scientific reasoning and reliability of information…; the development and implementation of mitigation (increase in energy efficiency, development of renewable energy sources, market stimulation for lowering emissions, proper forestry management) and adaptation measures in climate change’ (Climate Doctrine, 2009). Nowadays researchers associate the attitude to the climate change issues in Russia as well as to mitigation measures with ‘quiescence’ (Kokorin, Korppoo. Russia’s Greenhouse Gas Target. Projections, Trends, Risks, 2014).

International perception of climate change is evolving, more concrete measures are needed. In the Durban Climate Meeting in 2011 the preparation for Paris Climate Meeting in 2015 seemed to start; Russia did several announcements that were even regarded as the ‘Russian Proposal’. It is expected now that more drastic steps will be taken. The perception of Russian position in the climate change debate has certain peculiarities.

1. It is shaped now in the situation of tense relationship with the EU, the USA over the Ukrainian conflict;
2. It is comprised of the positions of different internal actors, and there is no unified approach so far even on the level of acknowledgement of the problem when international community has started the stage of implementing mitigation.
Expansion of Extractive Industries and Its Influence on Indigenous Communities in the North-West of Russia

Anna Varfolomeeva

Central European University, Budapest, Hungary

The paper aims to analyze the current and possible future influences of climate change in the Arctic region on the daily activities of indigenous communities in the North-West of Russia (with the focus on Sami of the Murmansk region and Vepses of the Republic of Karelia). Both regions have rich deposits of subsoil natural resources. During the period of 1920-1940, 49 types of minerals were discovered at the Kola peninsula, among them apatite, copper, iron and nickel. Karelia is famous for its rare decorative minerals. Thus, I would like to specially emphasize the effect of climate change on natural resources’ accessibility in the area.

The research will also concentrate on the local indigenous communities’ perception of the expansive development of extractive industries in the respective regions. As both regions are included into Barents Euro-Arctic Region (BEAR) and particularly into Permanent Working Group on Indigenous Peoples (WGIP), the paper aims to study the influence of BEAR and WGIP on the environmental policies in the respective regions, specifically the ones dealing with climate change and natural resources’ accessibility.
Adaptive capacities of Arctic urban design – from current weather variability to climate change

Essi Oikarinen

Department of Architecture, University of Oulu, Oulu, Finland

Harsh, cold weather conditions with huge seasonal variation pose challenges for Arctic, urban environments both structurally as well as for the broader scope of human well-being and livability. The proceeding climate change is at the same time deepening the problem, yet also adds a new dimension to it. The poster connects reacting to current weather variability and climate change into a dynamic framework, to be used for further comparative case studies.

Poster explores the adaptive qualities that different temporal framings of weather variability in urban design imply. Adaptive capacities are discussed both inductively and deductively, leaning on a literature review on urban design and planning solutions in the Arctic context. The discussion is also reflected on the theories and concepts on adaptive capacity in climate change context. Sustaining, recovering, adapting and supple approaches are found to describe different ways of framing weather variability and reacting to it. These result in different kinds of adaptive capacities in the spatial urban landscape.

Three main conditions characterize the presented framework. (1) A balance between the approaches is needed to achieve both adaptive capacity and maintain the identity of a place. (2) Framing weather variability as a seasonal cycle might have possibilities to act as a mediator between current challenges and preparing for future climatic changes in urban design and planning processes. (3) Management cannot be separated from spatial adaptive qualities. In the Arctic context, urban spatial landscape seems to become a process rather than a form.
Facilitating Collaborative Problem-Solving for a Changing Arctic: the Case of the Devising Seminar on Arctic Fisheries

Danya Rumore\textsuperscript{1,2}, Lawrence Susskind\textsuperscript{1,2}

Massachusetts Institute of Technology, Cambridge, Massachusetts, USA, \textsuperscript{1}Program on Negotiations at Harvard Law School, Cambridge, Massachusetts, USA

Retreating sea ice and other ongoing changes in the Arctic are likely to have far-reaching effects on ecosystems, resource utilization, indigenous livelihoods, and societies in and around the Arctic. How should the global community respond to and manage the threats and opportunities posed by these changes, particularly given scientific uncertainty and unstable geopolitics?

We argue that Devising Seminars provide a powerful new approach through which collaborative problem-solving in the Arctic can be facilitated. A Devising Seminar is an off-the-record, facilitated face-to-face workshop involving high-level public officials and key stakeholder representatives. The intent of such interactions is to generate “good ideas” and potential solutions that seek to balance science and politics. To illustrate the potential of Devising Seminars, we report on the outcome of a fall 2014 Devising Seminar on Arctic Fisheries, which generated significant agreement on a variety of difficult questions related to fisheries science, monitoring, and management.

The fall 2014 Devising Seminar on Arctic Fisheries was hosted by the Program on Negotiations at Harvard Law School and the Massachusetts Institute of Technology Science Impact Collaborative. Two dozen participants—including representatives from all the Arctic Council member states and a range of science organizations, non-governmental organizations, indigenous communities, and industry representatives—participated in a two-day problem-solving discussion about risks to existing and potential Arctic fisheries, gaps in basic scientific understanding and monitoring needs, and possible strategies for implementing a precautionary approach to emerging Arctic fishery concerns. Prior to the Devising Seminar, a Stakeholder Assessment was conducted. This consisted of in-depth interviews with more than 40 people from a broad range of stakeholder groups around the world. The findings of this assessment informed the Devising Seminar discussion. The good ideas and widely supported approaches that emerged from the event have been included in a Devising Seminar Summary that will be shared at the 2014 Arctic Circle Assembly.

In light of the positive response to and productive outcomes of the Devising Seminar on Arctic Fisheries, we anticipate hosting future Devising Seminars on other emerging Arctic
governance issues, such as concerns about expanding navigation and oil and gas development. In addition to reviewing the methodological features of the Devising Seminar process and the ideas generated during the Devising Seminar on Arctic Fisheries, this paper will share information about how policy-makers, scientists, and others working on the Arctic can be involved in future Devising Seminars.
Long-term monitoring of marine environmental changes by mooring system in the Pacific sector of the Arctic Ocean

Takashi Kikuchi¹, Motoyo Itoh¹, Shigeto Nishino¹, Eiji Watanabe¹, Jonaotaro Onodera¹, Naomi Harada¹, Kazuo Amakasu², Minoru Kitamura¹, Michiyo Yamamoto-Kawai²

¹Japan Agency for Marine Earth Science and Technology (JAMSTEC), Yokosuka, Kanagawa, Japan, ²Tokyo University of Marine Science and Technology, Minato-ku, Tokyo, Japan

Over last few decades, Arctic sea ice rapidly decreases due to global warming and significantly influences the Arctic marine environment. In order to clarify on-going changes of oceanographic conditions and its impact of Arctic marine environment, we have been conducting long-term monitoring using mooring system in the Pacific sector of the Arctic Ocean. Volume, heat, and freshwater fluxes through Barrow Canyon where is a major conduit of Pacific-origin water-masses into the Canada Basin have been observed since 2000. We show from an analysis of the mooring results that volume flux through Barrow Canyon was about 60% of Bering Strait volume flux. Averaged heat flux ranges from 0.9 to 3.07 TW, which could melt 88,000 to 300,000 km² of 1m thick ice in the Canada Basin, which likely contributed to sea ice retreat in the Pacific sector of the Arctic Ocean. A sediment trap mooring system has been deployed in the Northwind Abyssal Plain of the Canada Basin since 2010, in order to understand impact of sea ice reduction to marine biological properties. Using a combination of the sediment trap mooring data and three-dimensional numerical model, we showed early winter maximum of sinking biogenic and illustrate an importance of shelf-break eddies to biological pumping from the shelf to adjacent deep basins. In collaboration with Distributed Biological Observatory (DBO) project, which is one of the tasks of Sustaining Arctic Observing Network (SAON), we initiated year-long mooring observation at biological hotspots of the Chukchi Sea since 2012. In particular, Multi-Frequency Acoustic Zooplankton Fish Profiler (MF-AZFP) has been used in the mooring systems to monitor presence and abundance of zooplankton and fish in the water column by measuring acoustic backscatter. Year-long observation by MF-AZFP revealed a seasonal change of diurnal motion of zooplankton at the biological hot spot in the southern Chukchi Sea. Furthermore, we found from the mooring data that under-saturated water with aragonite-type calcium carbonate was found at the bottom of the southern Chukchi Sea. For better understanding of on-going changes of both Atlantic and Pacific sectors of the Arctic Ocean, international collaboration should be discussed in this presentation.
Is the Arctic an economic time bomb? The role of Integrated Assessment Models?

Jimena Alvarez¹, Dmitry Yumashev¹, Gail Whiteman²

¹Erasmus University Rotterdam, Rotterdam, The Netherlands; ²Department of Business–Society Management, Rotterdam School of Management (RSM), Erasmus University Rotterdam, Rotterdam, The Netherlands

The rapid retreat of the sea-ice cover might bring about unprecedented changes to the global climate and, consequently, result in disruptive economic impacts. The ICE-ARC (Ice, Climate, Economics - Arctic Research on Change) project is looking into potential consequences of the Arctic changes for the planet.

Its Work Package 4 objectives are:

• “To adapt the leading integrated assessment model (IAM), PAGE, to include the main influences of changes to the Arctic marine environment.

• To assess the social and economic impacts of changes to the Arctic marine environment and identify key socio-economic vulnerabilities and opportunities globally and regionally for the Arctic.

• To value the impacts of Arctic-related climate change and the costs of policies to abate and adapt to the changing Arctic marine environment.”

PAGE is one of the top three IAMs used for climate change policy analysis. IAMs are simplified representations of some or all of different relevant systems such as “emissions and their socioeconomic determinants, the atmosphere-ocean-climate system, ecosystems, socioeconomic impacts, and policy and responses”. In order to combine different systems within one model, assumptions and trade-offs are required. Despite IAMs being a very useful tool to address climate change impacts and policies to abate and adapt to it, and despite the fact that IAMs are periodically updated to incorporate the latest scientific knowledge, they are also the subject of a number of criticisms. According to Lord Stern, IAMs “add further underassessment of risk on top of the underassessment embodied in the science models, in particular because they generally assume exogenous drivers of growth, only modest damages from climate change and narrow distributions of risk”.

In order to adapt PAGE to include the main influences of these changes and “value the impacts of Arctic-related climate change and the costs of policies to abate and adapt to the changing Arctic marine environment”, it might be worth examining the above criticisms to IAMs. Our research proposal is (i) to address these criticisms by looking into the key areas of the climate change economics associated with growth,
damages and risks, and (ii) to investigate if and how we should update the economics component of PAGE IAM in order to better assess the impacts of the Arctic changes on the global economy.
The wisdom of using the Arctic in visual communication of climate change

Katrine Claassens

University of Cape Town, Cape Town, South Africa

Images of the Arctic proliferate in the media's communication of climate change. While on the one hand the area's responses to climate change make it uniquely positioned to provide visual evidence of climate change, on the other it frames the issue as being distant in both time and place. This poster traces the origins of the use of the Arctic as an emblematic landscape for climate change and questions whether this inspires action or despondency.
MyOcean Services

Sian de Koster¹, Iréne Lake¹, MyOcean Consortium²

¹SMHI, Norrköping, Sweden, ²Mercator Océan, Toulouse, France

MyOcean is a marine core service, with the objective of providing users with the best generic information available on the state of the global ocean and European seas. The MyOcean project, which began in 2009, is committed to develop, run and continuously improve a European service based on a worldwide capacity for ocean monitoring and forecasting, using observations data, modelling and assimilation systems. MyOcean offers users a reliable and easy way to access core ocean information (past, present and forecast).

The MyOcean service is open and freely available for any user requesting generic information on the ocean, and especially downstream service providers who can use this information as an input to their own value-added services to end-users. MyOcean products and services are meant to serve all marine applications: marine resources, maritime safety, coastal and marine environment, seasonal forecasting, and climate. The EU Copernicus vision is for MyOcean services to be sustainable and user-driven. The MyOcean Follow-on projects ends in March 2015, and the MyOcean services will then move to a fully operational Copernicus Marine Environmental Monitoring Service.

Arctic-related products are available for the 3D physical ocean, including observations and forecasts of ice extent, and forecasts of ice thickness, salinity and temperature. A biogeochemistry forecast and analysis is also available, including nutrients and algae.
Mercury, Sulfur-Reducing Bacteria and Organic Matter in the Sediments of Subarctic Kusawa Lake, Yukon Territory, Canada.

Jocelyn Joe-Strack

University of Northern British Columbia, Prince George, B.C., Canada

Recent studies of Arctic and Subarctic environments have detected rising levels of natural and anthropogenic mercury (Hg) attributed to atmospheric mercury depletion events and/or increases in algal-mercury scavenging. Within the oxic/anoxic transition boundaries of lake sediments, mercury can be methylated to produce bioaccumulating methylmercury by certain species of Sulfate-Reducing Bacteria (SRB). To date, there has been limited baseline and investigation into the role of SRB in Hg methylation at Subarctic latitudes. This study assess the controls of Subarctic SRB-Hg methylation from two sediment cores collected from proglacial Kusawa Lake, Yukon (60°36'43"N, 136°07'40"W). The particle size, isotope dating, organic matter content, quantity of sulfur bacteria and total bacteria and the sulfur bacterial community was described from the core sediment samples. Under ice limnology measurements were also measured. The result is that Kusawa Lake is highly oligotrophic, with low primary productivity and an orthograde oxygen profile; all conditions that inhibit Hg methylation. As well, a novel strain of psychrophile SMB was isolated from the bottom sediments and no known mercury methylating SRB strains were detected. Overall, the main controls influencing SRB-Hg methylation are: (i) the rate of primary productivity and algal-derived organic matter Hg-scavenging; (ii) the availability of sulfate and sulfide at oxic/anoxic boundaries; and (iii) the diversity of sulfur-metabolizing bacteria and selection for SRB capable of Hg-methylation. This work is important regarding management and decision-making implications regarding establishing a baseline for proglacial, oligotrophic Subarctic lakes, especially regarding the influence of climate. Culturally, the local First Nations relied on the lake for food harvesting, trade and migration pathways. Today, it is a recreational site used by Yukoners and tourists for hunting, fishing, hiking, canoeing, boating and other activities. Determination of the potential for Hg methylation and bioaccumulation through the food chain will be important for future management and research directives for the Kusawa and other Subarctic Lakes.
Ecological winners and losers in future Arctic marine ecosystem

Scientific committee

Leader: Associate Professor Janne E. Søreide (Leader), The University Centre in Svalbard (UNIS), Norway
Professor Paul Wassmann, UiT, The Arctic University of Norway, Norway
Professor Rolf Gradinger, Leader of the Barents Sea Ecosystem Programme, Institute of Marine Research, Norway / University of Alaska Fairbanks, USA
Special Adviser Dr. Christian Wexels Riser, The Research Council of Norway, Norway
Professor Jean Eric Tremblay, ArcticNet, Québec-Océan & Takuvik / Laval University, Canada
Mar Fernández Méndez, APECS / Alfred-Wegener-Institut Helmholtz-Zentrum für Polar und Meeresforschung, Germany
Capelin (*Mallotus villotus*) early life stages - effects of acute exposure to mechanically and chemically dispersed oil

Luca Tassara, Marianne Frantzen

Akvaplan-niva, Tromsø, Norway

The aim of the present study was to examine the effects of short-term exposure to mechanically and chemically dispersed oil on capelin early life stages. Newly fertilized embryos were exposed for 48 hours to three different concentrations of either mechanically or chemically dispersed oil reflecting small oil spills (THC; ≤0,5 mg/L, SUM 26 PAH; 10-15 µg/L), severe oil spills (THC; 10-20 mg/L, SUM 26 PAH; 150-400 µg/L) or environmentally unrealistic oil spills (worst-case scenarios) (THC; ≤50-200 mg/L, SUM 26 PAH; 500-2500 µg/L). Effects were measured throughout embryonic development in terms of embryonic developmental rate, incidence of developmental deformities, embryonic mortality and larvae hatching success.

No lethal or sub-lethal effects were observed in capelin embryos exposed oil concentrations reflecting small oil spills whereas all embryos died before reaching hatch when exposed to environmentally unrealistic high dispersed oil concentrations. Short-term exposure to dispersed oil at concentrations reflecting a severe oil spill resulted in significant lethal and sub-lethal (i.e. reduced developmental rate, developmental deformities) that most probably will affect the survival and further recruitment of any exposed capelin population. Chemically dispersed oil was, however, no more toxic to capelin embryos than mechanically dispersed oil.
Adaptive Management of Arctic Marine Mammal Populations in RESPONSE TO Changing Arctic Conditions

Suzanne Ban

ENVIRON, International, Anchorage, Alaska, USA

Adaptive Management is a discretionary, learning-based approach to structured decisionmaking that can be used in conjunction with the environmental assessment and permitting processes. Adaptive Management includes the following steps: predict, mitigate, implement, monitor, and adapt. The Adaptive Management process considers appropriate adjustments to management actions (i.e., decisions related to the issuance of permits and authorizations under multiple statutes). It also can be used to suggest innovative mitigation and monitoring tools as the results of current mitigation and monitoring procedures, as well as new science, become better understood.

What role does climate change play in developing an agile Adaptive Management strategy for Arctic marine mammal populations? This presentation examines tools for managing the uncertainty that is inherent in any decision-making process, and presents a decision framework for integrating uncertainty due to changing Arctic conditions into Adaptive Management strategies for Arctic marine mammal populations. Climate change impacts must be addressed over broad spatial and temporal scales, and consideration will need to shift from historic species assemblages to a broader range of ecosystem services. Potential climate change scenarios such as the reduced extent of sea ice and altered air and water temperature regimes must be used to guide active adaptive strategies that will become a part of everyday management decisions.

Adaptive Management allows resource managers to test assumptions, adjust policy, and incorporate learning into future decision making and management goals. By implementing a process to integrate potential climate change scenarios into the management of marine mammal populations, policies can be enacted to enhance conservation of these populations that may be facing serious declines. These declines may be due not only to climate change, but also to multiple stressors such as prey limitation and habitat reduction. Potential climate change scenarios, as they apply to polar bear and walrus, are presented to show how active Adaptive Management can close some of the uncertainty gaps by using feedback loops during monitoring and implementation.
Diet of non-target fishes in the northern Barents Sea and the Kara Sea

Andrey Dolgov, Aleksandr Benzik, Irina Prokopchuk, Olga Chetyrkina, Anna Gordeeva

Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Murmansk, Russia

Feeding intensity and diet composition of non-target fish species in the northern part of the Barents Sea (30 species) and in the Kara Sea (16 species) during August-September 2007-2012 were considered. Only 8 species in the northern Barents Sea and 3 species in the Kara Sea are predatory – Gaidropsarus argentatus, Myoxocephalus scorpius, Triglops murrayi, Triglops pingelii, Liparis bathyarcticus, Lycodes reticulatus and Lycodes seminudus (including commercially important Greenland halibut). 8 and 4 species respectively are planctivorous fish – Arctozenus risso, Arctogadus glacialis, Triglops nybelini, Icelus bicornis, Eumicrotremus derjugini, Eumicrotremus spinosus, Liparis fabricii, (including commercially important capelin and polar cod). Most other species from families Cottidae, Agonidae, Zoarcidae etc. in both areas are benthivorous species (17 and 10 respectively).
The Pelagic Algocenosis in the Ob–Yenisei Shallow Zone of the Kara Sea: Productive Potential and the Features of the Succession Cycle

Pavel Makarevich, Viktor Larionov, Denis Moiseev

Murmansk Marine Biological Institute, Murmansk, Russia

We analyzed data about the taxonomic composition and spatial distribution of planktonic microalgae in the Ob Bay and the southern Kara Sea in north Russia during all hydrological seasons over 11 years (1996–2006). Data were obtained through detailed in situ observations. These data are part of our arctic phytoplankton database. Phytoplankton inhabiting the nearshore continental area of the Kara Sea exhibited four phases in the annual succession cycle: a prevernal phase (cryoflora bloom), a vernal phase (ice–edge bloom), a summer–fall phase (mixed synthesis phase), and a winter phase (dormant phase). These phases were clearly differentiated based on the composition of dominant phytoplankton species complexes and quantitative characteristics (i.e., microalgal number and biomass). In the study region, which is completely covered by ice for most of the year (from October to June), the process of primary production begins at the same time as in ice-free coastal areas. Sub-ice blooming and growth of cryoflora initiate beneath the ice cover, long before it breaks down. In addition, from July to October, high phytoplankton biomass was recorded in the Ob Bay and in areas adjacent to the Ob-Yenisei shallows. This information provides quantitative evidence for the higher productivity of waters off the Ob estuary, compared to other coastal areas in the Kara Sea. The main factor responsible for this phenomenon is the permanent (during the warm season) transport of living and dead organic matter by river runoff to shelf waters.

This work was partially funded by the European Commission 7th framework program through the GreenSeas Collaborative Project, FP7-ENV-2010 contract No. 265294 and by the Presidium of Russian Academy of Sciences program through the project “Bioresources of the Russian Arctic Seas”.
The role of lipids and their fatty acids in formation of "winners" and "losers" among marine organisms in the Arctic: species comparative aspect

S.A. Murzina¹, Z.A. Nefedova¹, S.N. Pekkoeva¹, S. Falk-Petersen²,³, O.J. Lonne⁴, J. Berge³,⁴, N.N. Nemova¹

¹Institute of Biology, Karelian Research centre of the Russian Academy of Sciences, Petrozavodsk, Russia;²Akvaplan-niva, Fram Centre, Tromso, Norway;³The Arctic University of Norway, UiT, Tromso, Norway;⁴The University Centre in Svalbard, Longyearbyen, Norway

The role of lipids in organisms is diverse and essential. Fatty acids (FA) as the biochemical components of lipid metabolism are the most sensitive, mobile and significant in terms of adaptive reactions that take place on the level of macromolecules and cells. FA change and transformation during life cycle are one of the central for the ecological, physiological and biochemical mechanisms of adaptation especially for organisms living in severe environment as high latitudes. Annual and seasonal dynamic of lipids and their FA of the key marine organisms of the White Sea and Svalbard that are connected by food relations: invertebrates, copepods (Calanus glacialis) and vertebrates, fishes from family Stichaeidae, daubed shanny (Leptoclinus maculatus) and slender eelblenny (Lumpenus fabricii) collected in different seasons (winter, summer and autumn) and bays of the Sea and fjords of Spitsbergen were analyzed. These marine aquatic organisms have an important ecological role in the marine ecosystems studied and have specifics in their life cycles. The research was carried out using the facilities of the Equipment Sharing Centre of the Institute of Biology, KarRC of RAS. As general as specific features of seasonal and annual FA dynamic in copepods and fishes under study were revealed. The multidirectional variations of FA were found to be dependent on the species, the seasonal and annual changes in ecological factors, and the habits. The results demonstrate the differences in the trophoecological and hydrobiological conditions of habitations of these species, physiological importance of lipids, and indicate the features of genetically determined processes of biosynthesis and modifications of certain lipids and FA.

The research was supported by The Presidium of RAS 'Searching fundamental research for development of the Russian Arctic', "Ecological and biochemical characteristics of sustainability of aquatic organisms in the Russian Arctic in the Era of climate change" project (2014-2016); international project «Timing of ecological processes in Spitsbergen fjords», the President of the Russian Federation Grant NSh-1410.2014.04, RFBR 14-04-00473.
Environmental safety of sea routes in the Arctic Region of the Russian Federation

Vladimir Masloboev¹,³, Andrey Masloboev²

¹Institute of the Industrial Ecology Problems of the North, Kola Science Center, Russian Academy of Sciences, Apatity, Murmansk region, Russia; ²Institute of Informatics and Mathematical Modeling of Technological Processes, Kola Science Center, Russian Academy of Sciences, Apatity, Murmansk region, Russia; ³Kola Branch of Petrozavodsk State University, Apatity, Murmansk region, Russia

The current situation in the Arctic is a case example of how climate change influences the geopolitics. Nowadays this giant region is open for commercial shipping and production of energy resources. Therefore the international community gets new opportunities but faces some problems which require solutions. The question is: will these common challenges result in collaboration of the international community or will they turn into dangerous competition in the Artic?

The development of the Northern Sea Route for the purposes of national and international shipping will demand infrastructure development, which in it turn is an important development challenge for the Russian Far North under condition of the economic sanctions imposed by the USA and the EU.

The development of the Arctic shelf and shipping involves risks of oil spills and other emergencies. In case such accident happens on the shelf the environmental effects will be more serious. This fact is supported by the results of the study "Modelling of oil spills during the exploitation of OIFP "Prirazlomnaya". Assessment of emergency management capabilities related to oil spills." The study was conducted in 2012.

For reason of inevitable dangerous and extreme natural phenomena it is important to establish an ice condition control system in the areas of hydrocarbons production and shipping, the goals of such system are:

- safety control of oil extraction operations;
- record of unfavorable factors during the planning of oil extraction and shipping;
- loss minimization during the production shut down.
- The Arctic region is especially vulnerable to climate change effects due to:
  - extreme natural and climate conditions;
  - fragile ecosystems;
  - poor development of transportation lines and the infrastructure as a whole;

It is necessary to develop and put into practice the compensatory programs for reproduction of valuable commercial hydrobionts, based on efficient collaboration of different industries involved into the development of the sea shelf resources. It is also
necessary to develop ecosystem-based approach to marine resources management and sustainable exploitation of marine ecosystems.

It is urgent to work out an environmental legislative basis for development of arctic resources acting as a joint compulsory standard for construction and placing of drilling equipment, to identify the lists of pollutants forbidden for discharge in the environment, to identify lowest standards for discharge of oil, oil-water mixtures and drilling solutions from the platforms, to bring under regulation the operator's obligations regarding the environmental monitoring and emergency response during oil spills.
Environmental risk assessments of oil spills in a changing Arctic environment

Marte Rusten, Odd Willy Brude, Øyvind Endresen, Delphine Laborde, Torild Nissen-Lie

DNVGL, Oslo, Norway

In ice infested waters the potential oil exposure of marine life will be different compared to in open water. Arctic species travel long distances to feed, breed and often gather in colonies where food is abundant. Many species feed on the highly productive marginal ice zone during the spring bloom. They can also gather in polynyas and leads. Rapidly changing Arctic ice and weather conditions, is an additional factor affecting the concentration of species. The existing knowledge of marine species linked to the marginal ice zone and the dynamics of these systems and how they respond to climate change need to be better reflected in risk assessment methodologies for Arctic regions. In addition climate change will be an additional stressor that has to be taken into account for key species such as ringed seals and polar bears. Due to the constantly changing Arctic environment there is a need for updated and more accurate data on the distribution on biological resources. This paper addresses how the species and ice-metocean conditions are coupled, and suggest how this can be adopted into the well-established industry standard for environmental risk assessments towards oil spill. Such knowledge is instrumental for establishing risk-scenarios in a changing environment.
From 'benthos-dominated' to 'zooplankton-dominated' mode- is it plausible scenario for Spitsbergen fjords?

Katarzyna Grzelak, Marta Gluchowska, Jan Marcin Weslawski

Institute of Oceanology Polish Academy of Sciences, Sopot, Poland

The present work was carried out in a frame of Face2Face project (From ‘benthos-dominated’ to ‘zooplankton-dominated’ mode? - Two faces of Arctic fjords in the changing world) whose main goal is to evaluate the response of benthic communities to pelagic assemblages and processes occurring in the water column, in high latitude west Spitsbergen fjords with contrasting hydrological conditions. We hypothesized that in Arctic coastal waters the structure of pelagic assemblages, which are conditioned by inflowing water masses characteristics, determine organic matter flux and export to the seabed, what leads to enhanced benthos abundance and functionality. We analyzed wide spectrum of water column organisms (bacteria, nano- and microplankton, mesozooplankton), composition of benthic components (bacteria, meiofauna, macrofauna) as well as biochemical characteristics of sediment and water column of two model Arctic fjords. Despite being geographically closely located, they are differently exposed to Atlantic and Arctic water inflow, main force which shape oceanographic conditions in the fjords. The studied fjords were Hornsund, which is dominated by the cold coastal waters derived from Barents Sea and Kongsfjorden which is to a larger degree influenced by warm Atlantic waters. For each fjord two stations were selected and sampled during summer season in 2013. Fjords resulted very different in terms of major biogeochemical characteristics of the water column, like suspended particles. Nano- and microplankton biomass was several times higher in Hornsund, while bacteria numbers and biomass up to 2 times. It is going in accordance with higher concentration of phytoplankton pigments suspended in a water column and in the surface sediments of the Hornsund fiord. In contrast, zooplankton abundance (especially ‘boreal’ and ‘ubiquitous’ species) and consequently grazing pressure was higher in Kongsfjorden in comparison to Hornsund. Higher availability of organic particles in Hornsund sediment is in turn reflected by significantly higher biomass of filter feeders macrobenthic organisms. Our observations give a good argument for the initial hypothesis, however part of the observed functional differences might be attributed to the differences in seasonality in two investigated fjords. This problem needs to be addressed in future studies.
Benthic macro fauna in Svalbard methane seeps: Community structure and signs of novel methane-associated species.

Emmelie K Åström¹,², Michael L Carroll¹,³, William G Jr Ambrose¹,⁴, JoLynn Carroll¹,³, Anna Silyakova¹,², Karin Andreassen¹,²

¹CAGE - Centre for Arctic Gas Hydrate, Environment and Climate, UiT The Arctic University of Norway, Tromsø, Norway; ²Department of Geology, University of Tromsø, Tromsø, Norway; ³Akvaplan-niva, Fram Centre for Climate and Environment, Tromsø, Norway; ⁴Bates College, Department of Biology, Lewiston, USA

The recent discovery of extensive methane seepage fields in several locations in western Svalbard has led to a broadly focused effort through CAGE (Centre for Arctic Gas Hydrate, Environment and Climate) to investigate the response of gas hydrate reservoirs to future Arctic climate change. The primary aim of the centre is to understand sources and sinks of methane from sub-seabed reservoirs to the atmosphere. Gas hydrates are hydrocarbons (often methane) enclosed in ice, also called clathrates, which are stable at high pressure and low temperatures. Warmer temperatures in the Arctic induce destabilization of hydrates, leading to increasing methane release from sediments to seawater, and potentially to the atmosphere. Leaking methane from sub-seabed reservoirs provides the potential setting for chemosynthetic-based ecosystems. Unique benthic biological associations in connection with diverse sulphur and methane-fuelled ecosystems have been reported from tropic and temperate vents, seeps, and craters. Few studies, however, have documented the influence of submarine methane release on Arctic benthic communities.
During the summer of 2014, we conducted the first preliminary field investigations of benthic macro faunal community structure associated with methane release in western Svalbard and the Barents Sea. Target areas were selected based on seabed features such as gas plumes and craters, recorded by echo sounder, multibeam sonar, chirps and 2-D seismic. We measured highly elevated methane concentrations (up to 100x background levels) in the water column and surface sediments at several locations. We report results from qualitative and quantitative benthic biological sampling at methane seep sites and paired control locations, including species composition, abundance, biomass, and biodiversity as well as sedimentary characteristics i.e. total organic carbon, grain size and pigment concentrations. Our preliminary results indicate the presence of unique benthic communities associated with methane seeps, including high densities of seep related polychates (e.g. Siboglinid tubeworms) and shells of two undescribed species of thyasirid bivalves. Our continuing work will focus on in-depth studies of Arctic methane seep ecosystems and the biological responses to future climate change.
Pelagic visitors: Seasonal dynamics of meroplankton groups in a subarctic fjord

Helena Kling Michelsen, Camilla Svensen, Marit Reigstad

University of Tromsø, Tromsø, Norway

Many benthic organisms produce pelagic larvae, meroplankton, which spend anywhere from hours to months in the pelagic before settling on the sea floor. The timing and strategies of larval release is complex and not fully understood for all species. Currently, there is limited knowledge about timing and composition of meroplankton within fjord systems at high latitudes. Therefore, we investigated the taxonomic composition and seasonal dynamics of meroplankton abundance within the subarctic Porsanger Fjord, in northern Norway. The study examines the seasonal composition of mero- and holoplankton together with environmental parameters (temperature and salinity) within the fjord. Samples were collected monthly or bi-monthly during a 1.5-year period from February 2013 to August 2014 at six stations. Data from two contrasting stations are presented here. A total of 26 meroplanktonic taxa from 8 phyla were identified. There were two peaks in meroplankton abundance found within the fjord, the first occurring in April dominated by cirripeds and the second occurring in August where bivalves and echinoderms dominated. The different meroplanktonic groups had clear peaks of abundance through the year. During winter, meroplankton were still present in the pelagic but at considerably lower numbers. It is thought that timing and duration in the pelagic is linked with temperature, and, for many, coincides with the phytoplankton bloom. Our investigation indicate the same trends within the Porsanger Fjord. However, the occurrence of meroplankton during winter could indicate that some organisms display different spawning strategies and utilize other forms of nutrition than phytoplankton. Holoplankton dominated the abundance of zooplankton and, like meroplankton, displayed seasonal variability through the study period.
In an era of climate change, more information is needed on the different functional groups of zooplankton and their role in the carbon cycle. The zooplankton community across the polar front (PF) in the northern Barents Sea was investigated in June, covering a gradient from cold Arctic water in the north (78 °N) to warm Atlantic water in the south (75 °N). Our main objective was to investigate the relative contribution of small copepods (approx. body size < 2 mm) and protozooplankton versus larger-sized zooplankton in surface waters. In high-latitude areas, the group of smaller zooplankton, including copepod eggs, nauplii, young zooplankton stages and small copepod taxa are generally underestimated due to sampling with nets with mesh size > 180 µm. We therefore supplemented the traditional WP-2 net with a 30 L Go-Flo water bottle at 4 stations across the PF. The WP-2 net and the Go-Flo bottle sampled different size-fractions of the zooplankton community: The net collected the larger-sized calanoid copepods, while a high surface concentration of eggs, nauplii and zooplankton other than copepods was found in the Go-Flo samples. There was a clear difference in zooplankton species composition from dominance of the large *Calanus* spp. in Arctic water to a majority of protozooplankton and small copepod taxa in Atlantic water. Copepod nauplii were found in high abundances across the PF, and changed gradually from a dominance of calanoids in Arctic water to a complete dominance of cyclopid/harpactiociocid nauplii in Atlantic water. This could indicate differences in copepod reproductive strategies and recruitment in Atlantic versus Arctic waters. By combining data from both sampling tools, it is evident that the biomass of protozooplankton and small-sized copepods in the upper 50 m was significant across the PF, ranging from 30% at the Arctic station to nearly 100% of total zooplankton biomass at the Atlantic station. We show that a major compartment of the zooplankton population is lost when sampling only with the traditional zooplankton net, limiting the advancement of understanding the functional role of zooplankton communities in the arctic.
Delivering knowledge to improve environmental risk management for Northern Norway’s marine ecosystems

JoLynn Carroll¹,², Paul Renaud¹, Paul Wassmann³, Jasmine Nahrgang³, Roger Flage⁴, Thierry Baussant⁵, Martin Biuw¹

¹Akvaplan-niva, Tromsø, Norway; ²University of Tromsø – Geology, Tromsø, Norway; ³University of Tromsø – BFE, Tromsø, Norway; ⁴University of Stavanger, Stavanger, Norway; ⁵International Research Institute of Stavanger, Stavanger, Norway

The exploration and development of resources in the Arctic is often characterized as involving greater risk and severity of impacts to the environment relative to many other regions. This requires development of environmental risk management approaches tailored to the unique exploration and future operational challenges for Arctic areas. Environmental risk management is one of five core research themes established in the new Centre for ARctic Petroleum Exploration (ARCEx). This research theme specifically addresses the need for improved assimilation of new ecosystem and ecotoxicology knowledge through field studies and experiments. In addition this research theme addresses the development of improved impact and risk assessment methods tailored for the Arctic. These environmental activities are designed to further close existing knowledge gaps by: creating new knowledge and data on Arctic ecosystems and food webs and on key species’ sensitivities to petroleum discharges; improving impact assessment models; creating a theoretical risk uncertainty framework for the Arctic; and developing strategies to minimize the impact on living organisms during geophysical data acquisition. Taken together, the Centre’s environmental activities support the establishment of sound environmental practices in the Arctic.
Sea ice-pelagic-benthic links of bacterial diversity during the Arctic summer sea ice record minimum in 2012

Josephine Zora Rapp\textsuperscript{1,2}, Mar Fernández-Méndez\textsuperscript{1,2}, Christina Bienhold\textsuperscript{1,2}, Antje Boetius\textsuperscript{1,2}

\textsuperscript{1}Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany;\textsuperscript{2}Max Planck Institute for Marine Microbiology, Bremen, Germany

In summer 2012 the Arctic sea-ice extent declined to a record minimum. The observed rapid sea-ice melt resulted in the sinking and widespread deposition of fresh ice algal aggregates of the centric diatom Melosira arctica to the deep-sea floor (Boetius et al. 2013, Science 339: 1430). Elevated rates of oxygen consumption were measured in sediments with algal deposits to depths of 4400m, indicating remineralization by bacteria, and evidencing a response of the entire ecosystem down to the deep sea to elevated carbon flux rates. Microbial communities play an essential role in carbon and nutrient cycling not only at the seafloor but also in the sea ice and in the water column, contributing significantly to Arctic ecosystem functioning. Although warming and its associated physical changes in the Arctic will also affect bacterial communities, we still lack baseline information regarding their community composition in different Arctic environments. In this study, we sampled a wide range of Arctic environments from the surface to the deep sea during RV Polarstern expedition ARK XXVII-3 to the Central Arctic in summer 2012, in order to compare bacterial communities from sea ice, melt ponds, surface seawater, deep-sea sediment with and without algal aggregates. Analyses included molecular fingerprinting and next generation sequencing to test for differences in bacterial community structures and to identify the most abundant bacterial groups in each environment. Although certain bacterial classes (Flavobacteria, Gammaproteobacteria, Alphaproteobacteria) were identified as pre-dominant community members across different environments, the structure and composition of bacterial communities showed strong environmental specificity, with distinct differences between surface and deep-sea environments. Furthermore, differences were detected between multi-year ice and first-year ice, with specific bacterial taxa only being present in multi-year ice, e.g. Verrucomicrobia, possibly entailing implications for the ongoing decline of multi-year ice in the Arctic. The detection and relatively high contribution of the genus Polaribacter in algal aggregates found both in melt ponds and at the seafloor, indicated a transport of surface-derived bacterial cells to the deep sea with the rapidly deposited aggregates. With the continuing thinning
and retreat of Arctic sea ice during summers, export events as observed in 2012 may
repeat and cause shifts in bacterial community diversity and functioning in the future.
Growing of the Arctic Marine Ecosystem - food-web traits of the West Spitsbergen fjords ecosystems

Marta Gluchowska¹, Maciej T. Tomczak², Slawomir Kwasniewski¹, Maria Wlodarska-Kowalczuk¹, Joanna Legezynska¹, Jan Marcin Weslawski¹

¹Institute of Oceanology Polish Academy of Sciences, Sopot, Poland, ²Stockholm University, Stockholm, Sweden

There is little doubt that Arctic ecosystems will continue to face unprecedented change in the coming decades. The identification of food web structures and trophic interactions of these systems is, therefore, a priority.

Here we present the first ecosystem models representing the West Spitsbergen fjords using the Ecopath with Ecosim modelling approach. The aim of present study is to recognise and compare trophic structures, their linkage and mass balance flows in the two West Spitsbergen fjords, which are influenced by different oceanographic conditions, representing contrasting Arctic and Atlantic environments. We constructed comparable energy budgets for each ecosystem based on data collected in summer 2013 during ‘GAME’ project sampling campaign as well as monitoring data collected by IO PAN since 1997.

Our food web model shows immature, young unstable system in Hornsund (Arctic influenced) compared to more balanced Kongsfjorden (Atlantic influenced). The results are discussed in the viewpoint of natural experimental setup, where ‘warm’ Kongsfjorden today may simulate ‘cold’ Hornsund after the warming induced change. This ‘space for time analogue’ approach is employed to predict the potential climate change impact on Arctic fjordic ecosystems function.
Early Career

Effects of ocean acidification and warming on growth and food consumption of juvenile Polar cod, *Boreogadus saida* and Atlantic cod, *Gadus morhua*

Kristina Kunz, Rainer Knust, Felix C. Mark

Alfred-Wegener-Institute for Polar and Marine Research, Bremerhaven, Bremen, Germany

In the course of global warming, sea water temperatures rise, eliciting a northward moving trend of several fish species in the North Sea and North Atlantic waters. In this context, Atlantic cod (*Gadus morhua*) expanded its northern distribution area to the waters around Svalbard, entering the distribution area of the endemic Polar cod (*Boreogadus saida*). Although the impact of rising water temperatures on fish species is well studied, little is known about the effects of the combined factors ocean warming and acidification as well as potential interactions between both key species. In general, changing abiotic conditions are considered to cause an increasing metabolic energy demand at the expense of growth and reproduction. In this study, we investigated growth performance and food consumption of juvenile Polar cod and Atlantic cod originating from the Svalbard region.

132 Polar cod and 96 Atlantic cod were incubated under different stable temperature/PCO2 scenarios for 4 months. The chosen temperatures (Polar cod: 0, 3, 6, 8°C; Atlantic cod: 3, 8, 12, 16°C) covered the widest range of the species’ thermal window. The PCO2 values were based on the present atmospheric concentrations as well as on the predictions of the current IPCC report (Polar cod: 390, 780, 1,170 μatm; Atlantic cod: 390, 1,170 μatm). Each temperature/PCO2 treatment comprised 12 replicates in single aquaria. Each fish was fed ad libitum every fourth day with a determined amount of high protein feed.

Both species revealed different strategies while being exposed to future ocean water conditions: Polar cod showed a non-significant trend for poorer growth performance under hypercapnic conditions. Atlantic cod - in turn - grew better under elevated PCO2 values at the highest temperatures. The food consumption of Polar cod remained stable throughout the temperatures with an exception at the lowest temperature investigated. Nevertheless, the feed conversion appeared to be affected at the highest temperature only, especially under hypercapnia. Although the food consumption of Atlantic cod increased with temperature, the feed conversion ratio...
remained comparable throughout the temperatures with an exception at 3°C at which it appeared to be distinctly, yet not significantly less efficient.

The results demonstrate the impact of ocean acidification on fish species in synergy with the overriding warming effect. Atlantic cod seem to possess a potentially higher plasticity towards moderate abiotic changes in comparison to Polar cod. I will discuss these findings in a particular focus on differing metabolic rates.
Distribution of algal aggregates under summer sea ice in the Central Arctic

Christian Katlein\textsuperscript{1}, Mar Fernandez\textsuperscript{1,2}, Frank Wenzhöfer\textsuperscript{1,2}, Marcel Nicolaus\textsuperscript{1}

\textsuperscript{1}Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany; \textsuperscript{2}Max Planck Institute for Marine Microbiology, Bremen, Germany

Arctic sea ice is changing dramatically in the last decades and the consequences for the sea-ice associated ecosystem are difficult to assess. Sea ice is observed to become thinner, younger, and more pond covered. It also allows more light to transmit into and under the ice. Intensive melting might impact the life of sea ice algae within the brine channels. Algal aggregates underneath the sea ice of the central Arctic have been described sporadically, but the frequency and distribution of their occurrence as well as their role in the ecosystem remain unknown due to the lack of large-scale observations. During the TransArc and IceArc expedition of RV Polarstern in the late summers of 2011 and 2012, we observed ice algal aggregates with a remotely operated vehicle (ROV) underneath various ice types in the central basins. We observed different types of ice algal aggregates floating underneath and attached to the underside of the sea ice. Maps of the distribution of aggregate abundance could be obtained by complementing the upward looking imagery with synchronously recorded ROV attitude and position data. Besides the analysis of spatial distribution patterns and estimates of total biomass of the algal assemblages, this data allowed for shape analysis and the extraction of size distributions. Our results show, that the floe scale spatial distribution of ice algal aggregates is determined by the ice topography.
Supplemental foraging by Eastern Canada–West Greenland bowhead whales during seasonal periods of reduced prey availability

Cory Matthews¹, Steven Ferguson²,¹

¹University of Manitoba, Winnipeg, Manitoba, Canada; ²Fisheries and Oceans Canada, Winnipeg, Manitoba, Canada

Bowhead whales (Balaena mysticetus) occur within Arctic and sub-Arctic waters year-round, where distinct seasonal pulses of primary productivity support large biomasses of their zooplankton prey. Optimal foraging conditions for bowhead whales persist into late summer and fall, when zooplankton descend to overwintering depths. While there has been general consensus that winter feeding contributes little to overall bowhead nutrition, studies have provided mixed results on foraging across different seasons. Clarifying seasonal foraging behaviour of bowhead whales therefore remains a priority for understanding individual energy budgets and seasonal habitat selection, and for assessing bowhead vulnerability to climate-driven changes in Arctic zooplankton phenology and community composition. We measured stable nitrogen, carbon, and sulfur isotope composition (δ¹⁵N, δ¹³C, and δ³⁴S) along continuously growing baleen plates (n = 14) to assess alternative hypotheses of Eastern Canada-West Greenland (EC-WG) bowhead whale seasonal foraging behaviour. Synchronous δ¹⁵N and δ¹³C cycles, with periods of enrichment corresponding to foraging on the summer grounds, were inconsistent with standard fasting predictions, although could reflect unique metabolic adaptations to fasting coupled with supplemental foraging during the winter fasting period. Correlations between δ¹⁵N and δ³⁴S values, potentially mediated through metabolism of sulfur amino acids, also suggested limited foraging during periods of reduced prey availability. Reasonably good agreement between baleen isotope oscillations and regional zooplankton δ¹⁵N and δ³⁴S variation also indicated foraging occurs within isotopically distinct food webs across the summer and winter ranges. Collectively, these results are consistent with evidence of foraging by EC-WG bowheads on wintering grounds in Hudson Strait and off western Greenland, and by Bering-Chukchi-Beaufort bowheads at core foraging areas throughout their range where oceanographic features concentrate zooplankton densities. Foraging by EC-WG bowhead whales outside of periods of peak productivity therefore appears to be important for supplementing annual protein requirements and determining winter habitat selection. Bowhead populations may therefore be impacted by climate-induced changes in Arctic zooplankton communities throughout their range, and not just during the open-water season when intense foraging occurs.
Summer plankton of Franz Josef Land archipelago in 2013

Daria Martynova1,2, Ekaterina Bloshkina3, Valentina Nesterova4, Emma Orlova4, Olga Tyukina4, Andery Dolgov4

Zoological Institute, Russian Academy of Sciences, St.Petersburg, Russia, National Park “Russian Arctic”, Archangelsk, Russia, Arctic and Antarctic Research Institute, St.Petersburg, Russia, Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Murmansk, Russia

Archipelago Franz Josef Land is one the poorly studied areas of the Arctic. In July & August 2013, the expedition of the National Park “Russian Arctic” (Russia) and the National Geographic Society (the USA) has studied this area.

The period of late July—August of 2013 was the onset of the Arctic summer, and the status of the phytoplankton community was after-bloom. This was clearly seen by the dominance of Chrysophyceae by biomass. Dinoflagellates were characterized by the highest biodiversity (more than 50% from the total species number), and Protoperidinium genus comprised the most of the species diversity and dominated by the biomass. Chaetoceros genus was the most diverse within the Diatomea. In the neritic areas, the ratio of Dinoflagellates was minimal, at the deep stations, the opposite pattern was observed. The minimal biomass was registered for the neritic stations. The pycnocline was characterized by the highest biodiversity, population density and biomass of the microalgae comparing to the sub-surface and twilight water depths. 19 copepod species were found in 2013. Only 13 species were common - Calanus finmarchicus, C. glacialis, C. hyperboreus, Pseudocalanus minutus, Microcalanus pygmaeus, Chiridius obtusifrons, Gaidius tenuispinus, Pareuchaeta norvegica, Metridia longa, Scolecithricella minor, Oithona similis, O. atlantica, and Triconia borealis. Heterorhabdus norvegicus, Gaidius brevispinus, Pleuromamma robusta, Acartia sp., Metridia lucens, and Centropages hamatus occurred only in 2013. All the copepods have finished the reproduction period and were ready for the dormancy carrying the large lipid drops.

All three Calanus species was found in all sample stations and water masses, however, their ratio was different and referred to the water masses. The deep-dwelling Arctic species, C. hyperboreus, has been found in relatively unusual environment (near-surface layers) disregarding its dormancy that have started already. This is either explained by the species rareness or by particular reference to the specific water mass. C. glacialis dominated by biomass, up to 75 % in Barents Sea — North Atlantic origin waters and Surface Arctic waters. Deep Arctic waters, Shallow Mixed waters and Bottom Atlantic waters seems to have more impact of each rare species by its biomass, although C. glacialis still comprises more than a half of the total biomass (54—69%). However, both C. hyperboreus and were found
in each studied sample. *Metridia lucens* and *M. longa* (North Atlantic species), *Microcalanus* sp. and *Scoleithricella minor* (Deep Arctic species) refers greatly to the specific waters. *Pseudocalanus minutus* was nearly absent in Deep Arctic waters.
Early Career

Effects of crude mineral oil on biotransformation, lipid homeostasis and oxidative stress in polar cod (Boreogadus saida)

Ireen Vieweg¹, Eider Bilbao², Ibon Cancio², Miren P. Cajaraville², Maura Benedetti³, Francesco Regoli³, Jørgen Schou Christiansen¹, Haakon Hop⁴, Jasmine Nahrgang¹

¹The Arctic University of Norway, Tromsø, Norway, ²University of the Basque Country, Bilbao, Spain, ³Polytechnic University of Marche, Ancona, Italy, ⁴Norwegian Polar Institute, Tromsø, Norway

Lipid homeostasis, i.e. the maintenance of an internal steady state of lipids, plays a paramount role in the physiology of Arctic species. Energy reserves in form of lipids are essential for reproductive success and survival during winter months of food shortage and highlight the importance of a balanced lipid metabolism in Arctic fishes. The polar cod (Boreogadus saida) is an abundant Arctic key-stone species for which little is known about the effects of crude oil on essential physiological processes and ultimately lipid homeostasis. In a 4-week experiment, 246 polar cod were weekly force-fed environmentally relevant doses of crude oil (0 [control], 15, 60 and 100 µg crude oil·g⁻¹ fish). Liver tissues were sampled weekly during the course of the study for subsequent analyses. The mRNA levels were measured for a set of genes related to the biotransformation of polycyclic aromatic hydrocarbons (PAHs) (cytochrome P450 1-A 1 [cyp1a1]) and disruption of lipid homeostasis (peroxisome proliferator activated receptor α [ppar-α], retinoic X receptor [rxr-β], palmitoyl-CoA oxidase [aox1]). In addition, oxidative stress was examined by measuring the total oxyradical scavenging capacity (TOSC). Analyses of the PAH levels in the food given to the fish showed a linear relationship between PAH levels in food and nominal exposure concentrations. In the fish liver, we observed a significant accumulation of PAHs and aliphatic hydrocarbons. Furthermore, we found a significant responses at the transcriptional level with a dose-dependent up-regulation of cyp1a1, reflecting the activation of the PAH biotransformation pathway. Genes involved in lipid homeostasis were either down-regulated (ppar-α) or up-regulated (rxr-β, aox1) after 32 days of exposure compared to previous sampling dates (days 0, 8, 16 and 24). Oxidative stress evaluated with TOSC showed limited and transitory variations, especially toward peroxyl radicals and peroxynitrite, suggesting the capability of polar cod to counteract the increase of prooxidant pressure. This observation will be tested against analyses of oxidative damage such as lipid peroxidation. In conclusion, our
study shows that putative oil spills in Arctic waters may affect the essential physiological pathways and lipid homeostasis in polar cod.
Transfer of ice algae-based energy in a summerly Arctic Ocean: Food web insights revealed by state-of-the-art biomarker approaches

Doreen Kohlbach, Martin Graeve, Carmen David, Benjamin A. Lange, Hauke Flores

Alfred Wegener Institute, Bremerhaven, Germany; University of Hamburg, Hamburg, Germany

The underside of sea ice in polar regions represents a natural habitat for zooplankton organisms, e.g. copepods and amphipods. The entire under-ice fauna plays a key role in transferring ice algae-produced carbon and thus ice algae-derived energy into pelagic and benthic food webs of polar ecosystems. Animals at higher trophic levels are adapted to feed on the under-ice fauna as well as on pelagic zooplankton and nekton. Therefore, they show an indirect dependency on microalgae-produced biomass. Polar ecosystems thrive significantly on carbon synthesized by sea ice-associated microalgae depending on different periods of the year. On that account, the under-ice community and the associated pelagic food webs are largely affected by multi-scale climate changes accompanied by the reduction of sea ice coverage and increase in the duration of the melt season. Until now, the degree to which pelagic food webs depend on sea ice-derived carbon is still unclear. In order to improve our understanding of the potential ecological consequences of a changing sea ice environment, we aim to quantify the transfer of ice algae-produced carbon into the under-ice community and from there into pelagic food webs. Trophic interactions of abundant under-ice zooplankton were studied by means of stable isotope ratio analysis of 13/12C and 15/14N isotopes, compound-specific stable isotope analysis of fatty acid trophic markers. Sample collection was carried out during a RV Polarstern expedition of during summer within the Amundsen and Nansen Basins of the Eastern Central Arctic Ocean north of 80°N. Based on preliminary results of fatty acid compositions and carbon stable isotope signatures, we found the Arctic copepods Calanus glacialis and Calanus hyperboreus feeding on both, ice algae and pelagic phytoplankton. Several amphipod species demonstrated a high dietary dependency on ice algae.
Seasonal differences in transfer of algae-based energy in an experimental food chain: Thalassiosira weissflogii (diatom) - *Calanus glacialis* (CLEOPATRA II)

Martin Graeve¹, Janne Søreide², Lauris Boissonnot¹, Barbara Niehoff¹

¹Alfred Wegener Institute, Bremerhaven, Germany, ²University Centre in Svalbard, Longyearbyen, Norway

Polar oceans are characterized by an enormous lipid accumulation in the pelagic food web from phytoplankton to zooplankton with an intensive and fine-tuned energy transfer from copepods via fish to seabirds and marine mammals. This lipid-based energy flux in the Arctic ecosystem may be easily disturbed, since these regions are especially sensitive to global changes. One major part of the Norwegian project (Cleopatra II) is, to characterize carbon flux between phytoplankton and zooplankton and to study transfer and biosynthesis of lipids and individual fatty acids of the herbivorous copepod *Calanus glacialis*. We took animal from Billefjord in November 2009, July 2012 and May 2013 and fed them with 13C-enriched diatoms. The amount of 13C was quantified by gas chromatographic-combustion-IRMS technique. The atom percent values of 13C, accumulated in the copepods, provide detailed information about their lipid biosynthesis. The long-chain fatty acids and alcohols, which are synthesized de novo, were enriched in the 13C isotope showing that they are derived from metabolic precursors. These values are comparable to those of phytoplankton fatty acids, which are incorporated unchanged into the copepod lipids. Major part of the ingested carbon was used for the biosynthesis of wax esters. The isotope studies are an efficient tool to investigate carbon accumulation and turnover of lipids, seasonal carbon accumulation and hence life cycle strategies of zooplankton.
The effect of food access on investment in offspring in *Calanus glacialis*

Maja Karoline Hatlebakk\(^1,2\), Janne Søreide\(^2\), Geir Johnsen\(^1,2\)

\(^1\)Norwegian university of science and technology, Trondheim, Norway; \(^2\)University center in Svalbard, Longyearbyen, Norway

The focus is on the investment of lipids in *Calanus glacialis* eggs and how it is affected by food access to see potential effects of changed timing of the spring bloom in Arctic waters.

Females utilized both stored lipids and input of food for reproduction, showing a mixed strategy between capital and income breeding strategy. When food is scarce, the females invest more lipids on fewer eggs as opposed to more eggs, but less lipid per egg when food is abundant. This suggest a life strategy not previously described for *Calanus glacialis* i.e. when food is absent or low females invest in fewer but more lipid-rich eggs to increase the likelihood for this offspring to survive longer and thus increasing the chances to be present when more favorable food conditions finally appear. The fatty acid composition appears to be more important than total lipid content for the hatching success of the eggs, and 16:0, 18:0, 20:5(n-3) and 22:6(n-3) seems to be particularly important.
Shape matters: Ecomorphology informs on functional traits and diversity of Barents Sea fish.

Charlotte Weber, Magnus Wiedmann, Michaela Aschan, Raul Primicerio

The Arctic University of Norway, Tromso, Norway

Functional diversity describes the range and value of species traits that influence the functioning of an ecosystem, with implications for adaptability and resilience under stress such as climate change and fishing pressure. Body shape reflects functional characteristics of fish, and shape analysis thereby provides easily accessible functional information. We performed geometric morphometric analyses on 72 fish species of the Barents Sea. We analyzed the resulting shapes and shape variation via multivariate analyses and related shape components to existing functional traits data for functional interpretation. We combined functional traits data with information about the species' spatial distributions to map the Barents Sea spatial variation in fish functional characteristics and functional diversity. Shape variation was strongly associated with dietary specialization and other traits relevant for ecosystem functioning providing beneficial information for the functional characterization of different areas of the Barents Sea. The Arctic and Atlantic areas of the Barents Sea differed with regard to functional characterization and diversity. For integrated ecosystem assessment, shape represents an easily accessible approach to obtain functional trait and diversity information.
SPECIFIC LIPID SPECTRUM OF POSTRALVAE (STAGE1-STAGE5) OF THE DAUBED SHANNY LEPTOCLINUS MACULATUS DURING POLAR NIGHT IN KONGSFJORD (SVALBARD)

Svetlana Pekkoeva¹, Svetlana Murzina¹, Zinaida Nefedova¹, Pauli Ripatti¹, Tatjana Ruokolainen¹, Stig Falk-Petersen²,³, Ole Jørgen Lønne³,⁴, Jorgen Bergen³,⁴, Nina N. Nemova¹

¹Institute of Biology of the Karelian Research Centre of the Russian Academy of Sciences, 185000 Petrozavodsk, Russia; ²Akvaplan-niva AS, Fram Centre, N-9296 Tromsø, Norway; ³Department of Arctic and Marine Biology, UiT The Arctic University of Norway, N-9019 Tromsø, Norway; ⁴The University Centre in Svalbard, N-9171 Longyearbyen, Norway

Lipids and fatty acids are known to be as biochemical indicators of the development of the embryo and juvenile of fish especially in severe polar ecosystems. Lipids are highly important for Arctic marine organisms. They are be able reflecting processes of normal development and differentiation, and the variations in the lipid composition of the body contributing to the optimal process of life and adaptation to changing environmental factors. Leptoclinus maculatus (daubed shanny) is widely distributed and ecologically important in Arctic and sub-Arctic ecosystems. The fish has a complex life cycle that maintained sustainable presence and adaptation to the Arctic environment. Postlarvae being pelagic have an unusual part of their body called "lipid sac". The lipid sac is an evolutionary adaptation enabling postlarvae to growth and develops as a pelagic organism. The research is aimed to study the role of lipids and their fatty acids constituents in postlarval development of the daubed shanny (from stage 1 to stage 5) during polar night in Svalbard with special attention to their function during development. Specific lipid and fatty acid composition of studied postlarval developmental stages of the daubed shanny reflect their selectivity and as general as specific functions that aimed to maintenance physiological activity of metabolic systems, moving activity, slow accumulation of lipids due to scarce feeding resources and growth, and development. All these processes realized at low temperatures and darkness. The different content of lipids in the postlarvae stages displays unique growth and morphological traits adapted to the challenges of these the Arctic marine environments. The research was supported by The President of the Russian Federation Grant NSh 1410.2014.4; The Presidium of RAS 'Searching fundamental research for development of the Russian Arctic', "Ecological and biochemical characteristics of sustainability of aquatic organisms in the Russian
Arctic in the Era of climate change" project (2014-2016); «Timing of ecological processes in Spitsbergen fjords» project.
Bridging marine productivity regimes: How Atlantic inflow affects productivity, carbon cycling and export in a melting Arctic Ocean (CarbonBridge)

Marit Reigstad¹, Paul Wassmann¹, Camilla Svensen¹, Lena Seuthe¹, Sünnje Basedow², Ingrid Ellingsen³

¹UiT the Arctic University of Norway, Tromsø, Norway, ²University of Nordland, Bodø, Norway, ³SINTEF, Trondheim, Norway

A large and new interdisciplinary project, CarbonBridge, aims to identify the impact of the Atlantic Water (AW) inflow to the Arctic Ocean on the ecosystem productivity north of Svalbard. The project focus on the lowest trophic levels through the composition, biomass combined with process measurements of trophic interactions and production to evaluate the carbon flow pathways. Model simulations predict increased productivity along the shelf break north of Svalbard as the ice retreat and leave the AW inflow region ice-free. Through four WPs we 1) characterize the advection of carbon and organisms with the AW into the Arctic Ocean, 2) identify carbon pools through composition, production export and burial, 3) investigate regulating factors for C-cycling, retention and air-sea exchange, and 4) identify large scale patterns in past and future productivity. The integration of these components can help us to assess future Arctic ecosystems.

Through three interdisciplinary cruises in winter, spring and summer 2014, field data has been collected in the AW inflow and contrasting Arctic water stations. This presentation will mainly focus on the overarching aim of the project, while the first specific results is presented in separate presentations. The Norwegian partners involved includes University of Nordland, Norwegian Polar Institute, Institute of Marine Research, SINTEF, UNIS, University of Bergen. Also eight international partners are involved from Poland, Denmark, Spain, USA, Estonia, Russia, Canada and Germany.
The small harpacticoid copepod Microsetella norvegica in a high-latitude ecosystem: overlooked but highly abundant

Maria Terese Antonsen, Marit Reigstad, Camilla Svensen

Arctic Marine Biology, Tromsø, Norway

Seasonal population dynamics and vertical distribution of the small (< 0.5 mm) harpacticoid copepod, Microsetella norvegica, was investigated through monthly sampling at station Svartrnes in Balsfjord, Northern Norway from May 2013 to June 2014. M. norvegica is a pelagic particle feeder, and distributed from temperate waters to sub-arctic fjords, but frequently underestimated because of its small size. The species is therefore often overlooked and its biology poorly understood. In order to sample all stages of M. norvegica, from nauplii to adult appropriately, we used both a WP-2 net with 90 µm mesh size (175-50 and 50-0 m), and a 20 L Go-Flo water bottle (5, 20, and 50 m depth). Nauplii and copepodite stages from CI to adult were identified to determine total abundance, population structure, vertical and seasonal distribution. There were great differences in abundances and stage distribution dependent on sampling method. The Go-Flo bottle sampled all stages, from nauplii to adult stages, while the WP-2 net collected mostly adult stages of M. norvegica. The discrepancy in sampling efficiency between the two gears is also clearly reflected when comparing the abundances. For example, in June 2014 the maximum abundance of M. norvegica integrated from 50-0 m was 7.8 x 10^6 ind. m^-2, and 1.2 x 10^6 ind. m^-2 when sampled with the Go-Flo and WP-2, respectively. Minimum abundances of M. norvegica were recorded in January 2014 with 4.2 x 10^5 ind. m^-2 (Go-Flo) and 2.5 x 10^5 ind. m^-2 (WP-2). Females carrying egg-sac were observed in two periods only, in April to June (161 000 m^-3) and in August (150 m^-3). Nauplii and small copepodite stages peaked in the upper 50 m in spring and summer, suggesting that their main reproductive period takes place in May and June. The older copepodite stages from CIV to adults dominated in winter from October to March. M. norvegica was highly abundant year-round in Balsfjord, but the sampling design is crucial for accurate determination of their true abundance and population dynamics. We believe that appropriate sampling may reveal that M. norvegica is numerous also in other ecosystems. Furthermore, accurate estimation of their abundance may be a first step towards improving our knowledge about the biology and ecological role of this tiny but potentially important copepod.
Variations in *Calanus finmarchicus* and *C. hyperboreus* abundances in the Nordic Seas in relation to local and large-scale environmental factors

Marina Chelak¹, Claudia Halsband², Øystein Varpe²,³, Astthor Gislason⁴, Stig Falk-Petersen⁵, Ketil Eiane¹

¹University of Nordland, Bodø, Norway,²Akvaplan-niva AS, Tromsø, Norway,³University Centre in Svalbard, Longyearbyen, Norway,⁴Institute of Marine Research, Reykjavik, Iceland,⁵Norwegian Polar Institute, Tromsø, Norway

Zooplankton are sensitive to climate change, as they respond quickly to fluctuations in their environment, while they are not subject to fishing pressures. For example, warming has been shown to cause great changes in the distribution and abundances of the pelagic copepods *Calanus* spp. in the North Atlantic. However, the underlying mechanisms for potential basin-scale changes in the *Calanus* spp. populations are not well understood. Here, we compare abundance variations of *Calanus finmarchicus* and *C. hyperboreus* from three different locations around the sub-arctic north-eastern Atlantic basin: coastal stations at the west coast off Svalbard, a transect north of Iceland, and from a northern Norwegian fjord. We describe and compare the dynamics of the annual abundances of both congeners over the last two decades in these locations and test how they are affected by local and large-scale environmental factors. We found that the variability of *C. hyperboreus* abundances was higher than that of *C. finmarchicus* in all locations. Observed variations of both species were largest at the transect north of Iceland. The most stable abundances were found in the northern Norwegian fjord. Over the time studied, a significant decrease in the abundance of *C. finmarchicus* was observed in the north Norwegian fjord, while an increase in *C. finmarchicus* was found in the transect north of Iceland. *C. finmarchicus* from Svalbard waters showed no significant trend. For *C. hyperboreus*, no temporal trends were detected in any location. Using Redundancy Analysis, we sought to relate the long-term variations in *Calanus* spp. abundances to local environmental factors such as temperature, salinity, chlorophyll a concentration (where available), the start date of the spring bloom (available from 1998), and to large-scale climate indices (the North Atlantic Oscillation and the Arctic Oscillation). The included environmental variables explained only a little amount of the year-to-year variation in total *Calanus* spp. abundances, but given these results, we hypothesize that *C. finmarchicus* may be a winner in the transect north of Iceland, but a loser in the northern Norwegian Sea under the current environmental conditions. In contrast, *C. hyperboreus* does not show any trends in the studied locations, but higher overall variability which may represent both risks and opportunities for the species populations development. We suggest that future studies should test the role
of food availability and predation risk to better explain *Calanus* spp. dynamics in the Nordic Seas.
Fate of the key Arctic copepod *Calanus glacialis* in a changing Arctic

Janne E. Søreide¹, Maja Hatlebakk¹, Malin Daase², Lauris Boissonnot³, Daniela Freese³,¹, Martin Graeve³, Barbara Niehoff³

¹The University Centre in Svalbard, Longyearbyen, Norway; University of Tromsø, Tromsø, Norway; Alfred Wegener Institute, Bremerhaven, Germany

A warmer climate with less extensive ice cover will lead to higher total primary production, which has the potential to increase the overall secondary production in the Arctic. However, altered climate conditions will affect 1) organisms’ metabolism due to increased temperatures and 2) ice algal and phytoplankton food availability and quality. Depending on the grazers’ ability to adapt to these new conditions, some organisms will be favored more than others, resulting in ecological winners and losers. *Calanus glacialis* comprises up to 80% of the zooplankton biomass in Arctic shelf seas and plays a key role in Arctic marine ecosystems. It is primarily a grazer, accumulating essential polyunsaturated fatty acids from its algal diet as well as converting low-energy carbohydrates and proteins in algae into high-energy wax ester lipids. *C. glacialis* is known to take advantage of the early sea ice algal bloom for reproduction, which secures its offspring access to the later occurring phytoplankton bloom. This extremely lipid-rich copepod is able to survive long periods without food by descending to depth and lower its metabolism to a minimum, referred to as diapause. In the project CLEOPATRA II: Climate effects on planktonic food quality and trophic transfer in Arctic Marginal Ice Zones II we study the capability of *C. glacialis* to tune its seasonal migration, reproduction, and growth to a changing light, primary production and temperature regime in Arctic shelf seas. We have combined intensive year-round field studies with targeted experiments to identify potential bottlenecks in this species life cycle to predict its fate in a future warmer Arctic.
Greenland Sea hooded seals – a climate change loser?

Anne Kirstine Frie1, Vladislav Svetochev2, Garry B. Stenson3, Tore Haug1

1Institute of Marine Research, Tromsø, Norway, 2Murmansk Marine Biological Institute, Murmansk, Norway, 3Department of Fisheries and Oceans, St. Johns, Newfoundland, Canada

The Greenland Sea hooded seal population is thought to have been reduced by about 85% from 1946 to 1980 and has not since recovered. In spite of this dramatic decrease in abundance, a recent study of female reproductive rates has not found any sign of density dependent changes during the study period from 1958-2010 based on ovary data from a total of 1810 animals. On the contrary, reproductive rates have been consistently low over the study period and there are even indications of a small increase in mean age at primiparity from the late 1980s to present. In addition, our study has found a significant decrease in age at primiparity between females sampled in the periods 1958-1980 and 1987-1999. Both the reproductive data and the growth data suggest a significant reduction in hooded seal habitat quality, which could be mediated by either decreased prey availability, increased energy expenditure or both. Oceanographic shifts and developments in human exploitation patterns have significantly changed the environment utilized by Greenland Sea hooded seals. In this presentation we discuss the possible impacts of these two drivers on hooded seal habitat quality as indicated by concurrent data on female growth and reproductive rates.
Functional redundancy in Barents Sea fish: winners and losers in a changing Arctic

Magnus Aune Wiedmann\textsuperscript{1,2}, Michaela Aschan\textsuperscript{2}, Michael Greenacre\textsuperscript{2,3}, Andrey Dolgov\textsuperscript{4}, Raul Primicerio\textsuperscript{2}

\textsuperscript{1}Akvaplan-niva, Troms\o{}, Norway, \textsuperscript{2}University of Troms\o{}, Troms\o{}, Norway, \textsuperscript{3}Universitat Pompeu Fabra and Barcelona Graduate School of Economics, Barcelona, Spain, \textsuperscript{4}Knipovich Polar Research Institute of Marine Fisheries and Oceanography, Murmansk, Russia

When facing environmental change and intensified anthropogenic impact on marine ecosystems, extensive knowledge of how these systems are functioning is required in order to manage them properly. However, in high-latitude ecosystems, where climate change is expected to have substantial ecological impact, the functionality of the constituent species has received little attention, partly due to limited biological knowledge of Arctic species. The functionality of biological communities can be assessed by means of functional redundancy, i.e. the number of species that contribute similarly to ecosystem functioning. Ecosystems with higher functional redundancy are expected to be less affected by species loss, and thereby less sensitive to disturbance such as fishing and environmental change. Based on functional traits and fish community composition data, we assessed functional redundancy of the Barents Sea fish community for the period 2004-2009, a period during which the region was characterized by warming water masses and declining sea ice coverage. We identified eight functional groups of species which likely play distinct functional roles in the ecosystem. Some functional groups, such as the pelagics and the small demersals, displayed persistent spatial patterns of functional redundancy, whereas the long demersals group showed decreasing redundancy and the redfish group showed an expansion towards the north-east. Presently, the observed patterns of functional redundancy would seem to provide sufficient scope for buffering against local diversity loss. Yet, the rapid borealization of the northern Barents Sea is associated with a functional reconfiguration that may affect future ecosystem functioning in the area. In a period of rapid environmental change, ecosystem monitoring programs will be pivotal in providing the information on structural and functional properties needed for a sustainable ecosystem management.
Biological effects of the Skjervøy diesel oil spill: a sub-Arctic case study

Ekaterina Korshunova¹,², Kjetil Sagerup¹, Perrine Geraudie¹, Jasmine Nahrgang², Marianne Frantzen¹

¹Akvaplan-niva, Tromsø, Norway, Department of Arctic and Marine Biology, UiT The Arctic University of Norway, Tromsø, Norway

Anthropogenic activities are increasing in the Arctic and sub-Arctic environments along with an increasing risk for both accidental diesel oil spills and leakages. On December 14th 2013, 180,000 L of marine diesel was accidentally spilled into Skjervøy harbor, Troms county, Norway. In order to evaluate the impact and recovery capability of the local marine fauna, blue mussels (Mytilus edulis) were selected as indicator species. Blue mussels from the spill area as well as a reference station were sampled 5 days, 1 and 5 months following the spill. Bioaccumulation of polycyclic aromatic hydrocarbons (PAHs) in blue mussel soft tissues was determined along biomarker responses for oxidative stress (lipid peroxidation) and neurotoxicity (acetylcholinesterase AChE). Water samples were taken to analyse the residual diesel concentrations of the PAHs in water column. Chemical analyses of the water samples showed that the diesel concentration in the seawater rapidly decreased after the diesel spill with 3.5 mg/L PAHs detected 5 days after the spill and levels below detection limit 1 month after the spill. Bioaccumulation of PAHs was shown in blue mussel soft tissues with concentrations reaching 4500 μg per kg of the wet weight 5 days after the spill. These accumulated levels decreased significantly over time, however they did not reach the levels of the reference blue mussels 5 months after the spill. Effect biomarkers showed that lipid peroxidation levels in digestive glands of the blue mussels collected at the diesel spill site were significantly higher than in the blue mussels collected from the reference site 1 month after the accident. Five months after the spill the lipid peroxidation levels in mussels from the contaminated site decreased, however, they still remained higher than in the reference blue mussels. These results indicated that the blue mussels were still experiencing high levels of the oxidative damage 5 months after the diesel spill. Ongoing analysis of AChE will also be presented. This study shows that Skjervøy blue mussel population had not been completely recovering 5 months following the spill. There is still a need for monitoring and evaluation of long-term effects of diesel on the ecosystem.
Influence of climate on the quality of foraging grounds for little auk on West Spitsbergen

Kaja Ostaszewska

1Institute of Oceanology Polish Academy of Sciences, Sopot, Poland, 2Centre for Polar Studies, Leading National Research Centre, Sosnowiec, Poland

Temperature of Atlantic origin waters has increased in recent years, changing climate and ice cover in fjords. Different hydrographical system and ocean circulation are leading to quality-quantitative transformations of zooplankton communities. Very sensitive to such changes is the planktivorous seabird - little auk (*Alle alle*), which is considered a keystone species in the Arctic ecosystem owing to its huge population number and main predatory role on zooplankton. Feeding in the sea and breeding on land by little auk results in a transfer of huge amounts of organic matter fertilizing nutrient-poor Arctic tundra. It is believed that the little auk has the highest weight-specific metabolic rate of all seabirds, due to its small size and high energy costs of flying and swimming underwater. To cover the extreme energy demands, its preferred food is the energy-rich *Calanus glacialis* of Arctic origin, rather than the less energy-rich *C. finmarchicus* associated with Atlantic water masses. For this reason, little auks are expected to respond rapidly to changes in distribution of the water masses and related zooplankton communities. Little auks that breed in the vicinity of waters under the influence of the warm Atlantic water current appear to forage in suboptimal conditions and this increases their foraging effort and lowers their breeding success. The aim of our study was to estimate the quality of little auks major foraging grounds on Svalbard considered as a resultant between high abundance/biomass of the birds preferable prey (*C. glacialis* CV) but also low proportion of non-targeted zooplankton prey. The samples were collected during two summer seasons (2009-2010) by Polish-Norwegian extensive sampling (WP-2 net, 500 µm mesh size) in the vicinity of four Spitsbergen fjords (Hornsund, Isfjorden, Kongsfjorden and Magdalenefjorden) representing different hydrographical regimes.

In this study we propose a novel index to rank the importance of little auks prey based on composition of zooplankton in diets and estimated using algorithm build with Neuralnet library of R. Our results indicated that seawater 'quality' concerning little auks energetic demands might be estimated routinely in relatively quick and simple approach.
COPPY: Fate of COPePod secondary production in a changing Arctic

Ksenia Kosobokova¹, Barbara Niehoff², Galina Abyzova¹, M. Hatlebakk³, Martin Graeve², Janne Søreide³

¹P.P.Shirshov Institute of Oceanology RAS, Moscow, Russia; ²Alfred Wegener Institute, Bremerhaven, Germany; ³The University Centre in Svalbard, Longyearbyen, Norway

A decline in ice algae and an increase in duration and magnitude of phytoplankton production are anticipated in the Arctic Ocean, which could result in an either negative or positive impact on different species of secondary producers. The project COPPY ("Fate of COPePod secondary production in a changing Arctic") is designed to study the reproductive strategy and production rates of two *Calanus* species, which compose as much as 80% of the zooplankton biomass in Arctic seas. Transitional water masses between the Arctic and sub-Arctic, such as found in the Barents Sea and Svalbard region, contain both the endemic key Arctic grazer *C. glacialis* and its sibling species *C. finmarchicus*, an expatriate from the North Atlantic. Where the two species co-occur, their reproductive cycles are thought to be separated in time. However, evidence of natural hybridization between *C. glacialis* and *C. finmarchicus* has recently been described in the Pacific Arctic, which confounds our knowledge of *Calanus* taxonomy and, thus, life cycle events including reproduction. Within our project we therefore aim to: 1) investigate the extent of *C. glacialis* and *C. finmarchicus* hybridization using new innovative molecular methods, 2) analyze gonad maturation in *Calanus* spp. in existing and new zooplankton samples collected near Svalbard and 3) test the dependence of gonad maturation time and egg production on temperature variability and food quantity in controlled laboratory experiments. This project is closely linked to CLEOPATRA II ("Climate effects on planktonic food quality and trophic transfer in the Arctic marginal ice zone"). Both projects are funded by the Norwegian Research Council, CLEOPATRA II by "Norklima" (2012-15) and COPPY by "PolarProg" (2013-16).
Capelin (*Mallotus villotus*) early life stages - effects of acute exposure to mechanically and chemically dispersed oil

Luca Tassara, Marianne Frantzen

Akvaplan-niva, Tromsø, Norway

The aim of the present study was to examine the effects of short-term exposure to mechanically and chemically dispersed oil on capelin early life stages. Newly fertilized embryos were exposed for 48 hours to three different concentrations of either mechanically or chemically dispersed oil reflecting small oil spills (THC; ≤0,5 mg/L, SUM 26 PAH; 10-15 µg/L), severe oil spills (THC; 10-20 mg/L, SUM 26 PAH; 150-400 µg/L) or environmentally unrealistic oil spills (worst-case scenarios) (THC; ≤50-200 mg/L, SUM 26 PAH; 500-2500 µg/L). Effects were measured throughout embryonic development in terms of embryonic developmental rate, incidence of developmental deformities, embryonic mortality and larvae hatching success.

No lethal or sub-lethal effects were observed in capelin embryos exposed oil concentrations reflecting small oil spills whereas all embryos died before reaching hatch when exposed to environmentally unrealistic high dispersed oil concentrations. Short-term exposure to dispersed oil at concentrations reflecting a severe oil spill resulted in significant lethal and sub-lethal (i.e. reduced developmental rate, developmental deformities) that most probably will affect the survival and further recruitment of any exposed capelin population. Chemically dispersed oil was, however, no more toxic to capelin embryos than mechanically dispersed oil.
The Arctic's role in the global energy supply and security

Scientific committee

Leader: Research Director Dag Eirik Nordgård, SINTEF Energy Research, Norway
Professor Peter Haugan, University of Bergen, Norway
Professor Bjørn Helge Hjertager, University of Stavanger, Norway
Director Leiv Lunde, Fridtjof Nansen Institute, Norway
Consultant Coco Smits, APECS / Royal HaskonigDHV, The Netherlands
Special advisor Ingrid Anne Munz, The Research Council of Norway, Norway
The Satellite War – Norway’s doble standard on security in the high north

Baard Wormdal

NRK, Vadso, Norway

Modern warfare is instantly getting more dependent on satellites - for intelligence, weapon guidance, communication and many other functions. Norway’s new ground stations close to the North- and South Pole have a unique strength - they can communicate with polar satellites more often than other ground systems in the world. At the same time Norway is obliged by international treaties not to use these areas for warlike purposes. Norwegian supervision related to these treaties do not control the content of the downloading av satelitte data. Journalist Bård Wormdal investigate the case: He speaks with the participants on all sides of the table, he traces what kind of satellites are using the ground stations, what kind of information they give, and he shows how vital the information is in modern warfare today, especially american.
Arctic Governance Regime: The Last Frontier for Hydrocarbons exploitation

Gisele M. Arruda¹, Wayne Renke²

¹GSM London, London, UK; ²University of Alberta, Canada, Canada

The development of oil and gas resources in the Arctic is not optimally constrained within the current governance regime, policies and legal frameworks - but large-scale structural change to this mode of governance is unlikely. Nonetheless, the current de-centralized multiform regime can be recalibrated: Arctic-specific natural ecosystems, the presence of indigenous communities and the commercial interest in the region will require an innovative model of development based on the highest level of responsible exploitation. Multidisciplinary dialogue and research on all aspects of offshore oil and gas development will require a shift in the conceptual view of the Arctic as well as in the multilateral efforts to negotiate and design efficient regulatory systems that go beyond the setting of new standards of spill prevention, preparedness and safety, while taking into account the interests of both Arctic and Non-Arctic nations and workforces.

Energy development will have both positive and negative impacts on micro and macro levels. The first relevant contribution of these operations in the Arctic, undoubtedly, is the benefit for global energy security. However, the framework comprising legal cooperation agreements, policy-making, and technological innovation will define new patterns of governance, Arctic citizenship, geopolitics, and, consequently, the region’s destiny.
The role of RuBisCO in mass cultivation of Arctic diatoms

Andrea Gerecht, Gunilla Eriksen, Hans Christian Eilertsen

UiT Norges arktiske universitet, Tromsø, Norway

Diatoms are aquatic primary producers that generate organic matter from CO2 and light energy. This makes them a renewable resource that can be employed e.g. as feed in aquaculture, as lipid producers for biofuel, and as a source of essential fatty acids and other high value molecules. Diatom species living in Arctic waters are exposed to surface water temperatures below zero for parts of the year. Locally adapted species have therefore had to alter physiological processes by modifying enzyme structure and function to be able to survive at low temperatures. An important enzyme involved in carbon sequestration and thereby cell growth is Ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBisCO) which catalyzes the first step in CO2 fixation. Diatom RuBisCO in general has high specificity and turnover rates compared to RuBisCO from other photosynthetic organisms. Cold-water species should have efficient enzyme systems due to the need of functioning at low temperature, yet little is know about the RuBisCO of Arctic species.

This study therefore tests the hypothesis that Arctic diatom species contain low amounts of a highly efficient RuBisCO. Furthermore it examines how RuBisCO content relates to division rates in monoclonal species grown in large (100 L) tanks and how both physiological features are influenced by changing environmental parameters. Knowledge about RuBisCO content and efficiency of different species can help select productive strains for mass cultivation. It may further point out Arctic diatom species as promising candidates for a locally harvestable renewable feed source for aquaculture and more generally, for addressing global food and energy demands in a sustainable manner.
Yamal as a gateway to the future sustainable Arctic energy prosperity?

Nadezhda Filimonova¹, Svetlana Krivokhizh²

Russian State Hydrometeorological University, Saint-Petersburg, Russia, Saint-Petersburg State University, Saint-Petersburg, Russia

For several decades high prices on oil and gas have been a major driving force for Russia’s economic growth and state’s prosperity. During the period the state mostly relied on natural resources production in Western Siberia. Today Russian economy is still much dependent on energy sector; however, the traditional areas of energy production cannot satisfy the demand any longer.

The paper represents an analysis of implications of Russian policy towards the development of Arctic on-shore projects as an alternative for Western Siberia in the long run. The study will focus on Yamal-Nenets Autonomous district which is accounted for 93% of Russia’s natural gas and 12 % of oil production.

In 2011 regional government adopted a Strategy prescribing energy industry to be main source for the region’s socio-economic development in mid-term perspective. In long-term perspective, Yamal is also viewed as an important catalyst for diversification of gas import markets and for lowering Russia’s dependence on European energy demand through LNG production. LNG supply will also partly contribute to the development of shipping industry since the produced gas is planned to be shipped through the Northern Sea Route to Asian consumers.

In global perspective, production is linked to international market energy demands and energy supply competition; in particular, certain countries (including Australia) have started to develop LNG supply oriented on Asian markets. Energy production on Yamal represents therefore an intersection of political and economic interests of the Russian state, oil/gas companies, regional power, local population, environmental organizations, states-energy importers and energy exporters.

Therefore a key issue is what is the role of Yamal region in Russian state and business energy strategies in national and international contexts? What does energy production on Yamal mean for socio-economic development of the region and local community, in particular?

In the study qualitative method will be applied and it will be an explanatory case study in nature. The analysis will be based on available primary sources and interviews with relevant researchers and political officials.
In summary, the paper will provide insights about state and business interests and policies on Yamal and their correlation with international gas market development. In addition, the paper will discuss whether or not Yamal will become a future LNG production hub and how energy sector will contribute to socio-economic growth of the region.
Computer models and technologies for information monitoring and control of socio-economic and ecological security of the industrially-explored Arctic regions

Andrey Masloboev\textsuperscript{1,2}, Vladimir Putilov\textsuperscript{1,2}

Institute for Informatics and Mathematical Modelling of Technological Processes of Kola Science Center of the Russian Academy of Sciences, Apatity, Murmansk region, Russia; Kola Branch of Petrozavodsk State University, Apatity, Murmansk region, Russia

Afterwards discovery of heavy carbohydrates and other minerals reserves in the Arctic region the circumpolar Arctic zone becomes an escalation object of the Arctic states and observers national interests. Intensive external investment flows in the industrially-explored Arctic regions development impair Russian Federation (RF) position presence in the Arctic, which possesses considerable part of its territories. This forms RF national interest threats vector in the Arctic region: geopolitical, socio-economic, defence and environmental. Thus, nowadays RF national security and defence problems solving in the Arctic is an actual research direction. Arctic territories large-scale industrial exploration provides emergency situations occurrence probability increasing for anthropogenic impact reasons. Risk minimization and security threat localization problems operative solving of the Arctic regional components development, adequate reaction on emergency situations and sustainable development predicting management trajectories implementation require high-level computer-aided processing of great heterogenous information content for different ministries and authorities, timely information confidence assessment and appropriate security organizational structures coordinated information interaction. Thereby, the most important goals of the RF public policy in the Arctic is research works in the field of information technologies and environmental safety methods development. In this work we represent research-out results and application issues of the problem-oriented technologies for socio-economic and environmental safety management support of the industrially-explored Arctic regions (by example of Murmansk region). A special attention is given to Arctic regional development management information support based on cognitive information technologies in application to unified multi-agent virtual spaces implementation for control functions virtualization of the regional security subjects in the unified information environment. Multi-agent virtual spaces are a new framework of regional development cognitive management support in the Arctic. The main goal of regional development management process virtualization is sustainable functioning adequate trajectories formation and security control circuit coordination of regional socio-economic systems in the Arctic subject to its internal dynamics and external impacts via
cognitive agent-based models and technologies used for real-time scale security level assessment and control of regional components. The purpose functionality of unified virtual information environment is informational needs (computational resources, data, web-services, etc.) satisfaction of different user categories in the field of socio-economic development management of Arctic regions and coordinated information communication support between the regional security authorities. The access point to unified virtual space is implemented as a multi-domain web-resource - an integrated Arctic Internet-portal (www.ru-arctic.net) intended both for socio-economic and environmental setting coverage in the RF Arctic regions, and regional management information-analytical support.
A prototype of BarentsNet professional social network for management information support of Barents Euro-Arctic region innovation and risk-sustainable development

Andrey Masloboev¹,², Alena Fedorova², Anatoliy Smirnov³, Remi Strand⁴

¹ Institute for Informatics and Mathematical Modelling of Technological Processes of the Kola Science Center of Russian Academy of Sciences, Apatity, Murmansk region, Russia; Kola Branch of Petrozavodsk State University, Apatity, Murmansk region, Russia; National Institute of Research of Global Security, Moscow, Russia; Arctic Development AS, Vardø, Norway

The research considers engineering problems and application perspectives of professional social networks as virtual pro-active intelligent systems for information support of interagency activities in the field of innovation and risk-sustainable development management of Barents Euro-Arctic region.

For agent of management activities information support, participating in developing and resource potential settling process management of the Barents Euro-Arctic region, a research prototype of professional social network BarentsNet has been developed. BarentsNet system is implemented as multi-domain web-service and provides formalized ontology-based expert knowledge integration of the Arctic and sub-Arctic territories development features, and professional contacts linking automation within the system for cooperation and joint project realization in this sphere. The functionality organization model, executive core and software components of the BarentsNet system have been developed. BarentsNet is a virtual integration platform connecting and joining experts of different knowledge domains, interested business structures and governmental (municipal and regional) authorities for cooperation in the field of Barents region innovation and risk-sustainable development. As an open system, integrated in the global information infrastructure, it will be used for information retrieval and processing for executing resources identification for concrete management problem-solving realization concerned with Barents region and the Arctic development. Specific system functionality provides:

1) provision of specialized interfaces for different types of users and tasks;
2) providing funding of operational information processing and forecasting by means of computer simulation;
3) information visualization with territorial bound-based interactive electronic maps;
4) integration of heterogeneous information resources;
5) semantic analysis of the content;
6) problem-oriented information retrieval (individuals, groups, ideas, contacts, profiles, projects, etc.);
7) structured storage of information, ensuring its integrity and relevance;
8) formation of virtual organizational structures "for the concrete problem-solving".

The BarentsNet system development will be the first step on the way to shared information environment of the Barents region formation within the Northern IT-cluster.

In addition to BarentsNet, a research prototype of virtual cognitive center for regional security management in crisis situations, implemented as hybrid cloud service based on IaaS architectural framework and assisted by multi-agent and web-service technologies, has been developed. Virtual cognitive center corresponds bundled training simulator software system and is intended for based on distributed simulation following problem solving such as strategic planning and forecasting of risk-sustainable development of regional socio-economic systems, agents of management interaction specification synthesis for regional components safeguarding in different crisis situations within the planning stage of joint anti-crisis actions coordination.
Jojoba oil biorefinery using a green catalyst. Part I: Simulation of the process

Marcos Sánchez¹,², Jorge Marchetti², Noureddin El-Boulifi¹, José Aracil¹, Mercedes Martínez³

Complutense University, Madrid, Spain, Norwegian University of Life Sciences, As, Norway

The concept of a biorefinery is focused on the use of Jojoba oil together with a catalyst produced from waste derived from the fish industry to obtain Jojobyl alcohols as main product and Fatty Acid Methyl ester (FAME) as co-product. The overall process is divided in three steps: transesterification step, crystallization step and purification step. For the study of this process, two different simulation softwares were used to run the mass and energy balances. In addition, the main properties of transesterified Jojoba oil, Jojobyl alcohols and FAME were also determined. On one hand, the Jojobyl alcohols (11-eicosenol, 13-docosenol and 15-tetracosenol), which are obtained through two-step crystallizations, have many pharmaceutical applications and a high-added value as main product. From these results, it is concluded that the FAME obtained as co-product during the process is not suitable to be sold as biodiesel, but it might be used in the biorefinery to produce electricity making the overall process energy more efficient.
Jojoba oil biorefinery using a green catalyst. Part II: Feasibility study and economical assessment

Marcos Sánchez¹,², Jorge Marchetti², Noureddin El-Boulifi¹, José Aracil¹, Mercedes Martínez¹

Complutense University, Madrid, Spain; Norwegian University of Life Sciences, As, Norway

In this work the study of market and economic variables for a Jojoba Oil biorefinery is conducted. The raw materials used in this process have been the Jojoba oil, methanol, a green catalyst derived from the fish industry, hexane and diethylether. The products obtained in this process are the Jojobyl alcohols, which have pharmaceutical applications, and the FAME which is used to generate energy in the own plant. The economical sensitivity analysis have been performed for the Internal return rate (IRR) and Payback time when the prices of Jojobyl Alcohols, Jojoba Oil, management and treatment of the diethylether:hexane stream and methanol vary in fixed ranges. In addition, the influences of the product failure, the tax percentage, the advertisement and selling expenses and the royalties over the economy of the process have been studied as well. The variables which have the more impact over the economy of the process have been the Jojobyl alcohols and Jojoba Oil prices because small modifications in these variables provide great changes on the economy of the biorefinery. However, the price of the methanol is not significant for the profitability of the plant because the 85% of the excess of alcohol used in the transesterification step is being recycled.
Optimization of homogeneous acid-catalysed esterification of free fatty acids from fish oil by response surface methodology

Marta Serrano¹, Jorge Mario Marchetti², Mercedes Martínez¹, Jose Aracil¹

Complutense University, Madrid, Spain; Norwegian University of Life Sciences, Ås, Norway

In an attempt to substitute fossil fuels, researchers are focusing on renewable raw materials as a main source of energy. Vegetable sources are used all over the world to produce energy via thermochemical, biological or chemical processes. In the specific case of diesel substitution, the technology has patently proved its ability to transform vegetable oils to a high quality diesel fuel. However, there is an increasing concern on the full scale implementation of this technology, which would mainly concern the availability of arable lands, negative effects of changes of land use, and the still highly dependence of cultivation process on fossil fuels, among other factors. In this context, waste biomass is a promising alternative as energy source. One major drawback of this approach is that pretreatment operations are needed in order to adapt this raw material to the existing technology. The aim of this study was to optimize the pretreatment of oil recovered from fish processing factories in Norway. Fish oil directly obtained from salmon silage in a tricanter centrifuge has elevated free fatty acids content, which would interfere in a typical basic-catalysed transesterification. Two step processes are usually used. In the first step, analysed in the present study, free fatty acids are esterified to esters, avoiding subsequent problems in basic transesterification reaction. This pretreatment step is commonly carried out via homogeneous acid-catalysed methanolysis, using sulphuric acid as catalyst. Factorial design and response surface methodology (RSM) were used to optimise esterification process, based on the wide information provided while minimizing the number of experiments. The influence of temperature, methanol quantity and reaction time was analysed. At the chosen operation conditions, methanol quantity showed the highest effect on free fatty acid conversion. Temperature and reaction time were second and third factors in importance. Leaving aside economic factors, this study has shown that mild operation conditions would be enough to reduce the FFA content until acceptable values for a following basic-catalysed transesterification.
How to survive if you’re outdated, environmentally unfriendly and unprofitable? Sustainability paths for Barentsburg

Andrian Vlakhov

European University at St.Petersburg, St.Petersburg, Russia

The Russian town of Barentsburg in Svalbard archipelago that was built in the mid-20th century had been serving two major aims — to sustain Soviet and then Russian strategic presence in the Arctic and to supply Northern Russian regions with coal. After the end of the Cold War the political reasons were diminished, and the coal has also lost its significance as a fuel. Russia still maintains Barentsburg, the only one of three its towns in Svalbard, but the coal produced by its mine is mainly used at the local power and heating plant. There are plans and attempts to convert Barentsburg to a tourist and/or research town, but they have so far been unsuccessful.

The local community is fully dependent on the mine operation since there are no other major workplaces in the town. There is, however, a discussion on whether the mine should continue working; the main reasons for its closure are the environmental unfriendliness and coalfields depletion. The anthropological field study conducted in Barentsburg in 2014 suggests that such perspectives are of great concern for local residents: the mine closure means that they would lose their workplaces and have to relocate; there is a considerable grass-roots opposition to the closure plans. Despite that, the steps taken by the authorities are the gradual reduction of coal mining and the depopulation of Barentsburg, because ‘coal mining is outdated and has no global perspectives’. We can see that the economic and environmental reasons outweigh the community needs and leave little space for its sustainable future.

Nevertheless, there are several paths of solving these major problems. The first and the most obvious is the continued development of research and tourism, a path that was taken by the authorities several years ago. The coal mining would be then converted to a service facility for a multifunctional settlement. However, this path is long and would require much effort from many stakeholders. An alternative strategy is to include Svalbard mining fully to the major Russian energetic strategies, which would allow the settlement to serve larger goals than the local heating and to be included in the national – if not global – Arctic energy market.
The ongoing transformations occurring in the Arctic region are deeply intertwined with regional and global processes, both in the sense of the Arctic affecting and being affected by broader regional and global processes reaching beyond the Arctic's southern borders. Natural sciences generally and climatology specifically have produced a vast amount of literature as to the ongoing and likely feedback loops between the climatic, environmental and atmospheric systems of the Arctic and the rest of the globe. Interdependencies between more social science aspects - such as economic developments, legal frameworks and patterns of livelihoods and generally organization of societies - affecting and being affected by the ongoing changes in the Arctic region have so far received less attention. This poster aims to illustrate the interdependencies and feedback loops between social processes and systems within and outside the Arctic, focusing especially on the determining factors of Arctic energy developments. Concretely, the aim is to take a close look at the Arctic in a global energy picture, illustrating the determinants of Arctic oil and gas development including: the market set up in supply countries (subsidies, incentive structures, development of energy mix, e.g. outlooks for renewable energy development), market developments especially in Europe and Asia (demand side), competition with other resources (e.g. shale gas) and with same resources elsewhere (e.g. oil sands in Alberta, Gulf of Mexico, LNG from Australia and Qatar), operational and environmental risks, insurance and re-insurance perspectives and offerings, role and influence of international financial investors, technological developments, and how to balance stakeholder concerns and shareholders’ interest. The aim of this poster is to contribute to a broader research effort to develop a new framework and understanding of the Arctic in the age of the Anthropocene, i.e. as embedded in and interacting with broader regional and global processes. Among other feedback loops and interdependencies between Arctic and non-Arctic regions, this poster especially intends to show the bigger picture of the Arctic's (actual and potential) significance in global energy supply and security, and the role of global energy trends for Arctic energy scenarios.
Best practice reporting and sustainability benchmarking in Arctic shipping: An exploratory study

Daria Gritsenko

University of Turku, Turku, Finland

The Arctic is widely being promoted as a valuable and accessible energy extractive frontier and perspective shipping route for energy and natural resources. Multiple stakeholders are salient on the matter that sustainable development in the Arctic shall rely on safe and environmental operations based upon reliable infrastructure. As awareness of negative social and environmental impacts of the Arctic shipping has risen, media and public increased their attention towards maritime infrastructure and operational practices, demanding wider disclosure of information on companies' environmental and social performance. Best practices and sustainability reporting initiatives in Arctic shipping industry developed in an interaction with public scrutiny and media critique, yet this phenomenon remained relatively understudied in academic research. This study aims at documenting and categorizing best practice reporting and sustainability benchmarking in Arctic shipping. The study has an exploratory character and builds upon the hypothesis that different segments of the shipping industry set different priorities in sustainability management and indicate different patterns in operation quality which is mirrored in their communicative practices. Examining the quality management strategies and practices reported by ship operators working in the Arctic in publicly available documents and official websites, this study seeks to reveal reporting patterns in different segments of Arctic shipping (liquid bulk - oil and gas carriers, dry bulk - coal and minerals, and auxiliary fleet - icebreakers, tugs, bunkering vessels). The results of the study present a detailed categorization of environmental and safety responsibilities already assumed and practices by the shipping companies operating in the Arctic seas. This information has potential to bring valuable insights about scope and range of reporting in different shipping segments, about gaps in existing governance system, and about voluntary measures for environmental protection. The results will benefit different groups of stakeholders, including policymakers (as a basis for policy recommendations), companies and other researchers, as well as local communities in the Arctic region. Finally, on the basis of this exploratory study the changes the upcoming IMO Polar Code will bring can be better projected and understood.
The Ethical Responsibilities of Northern Resource Development

Caroline Inglis

University of Manitoba, Winnipeg, Manitoba, Canada

The warming climate has led to the increase in resource development in Northern Canada because as the ice melts it is easier to access non-renewable resources. As industry moves into the Northern territory it is imperative that the way of life of the people who currently inhabit the territory are taken into account and that this economic development benefits the Inuit people of Canada. Nunavut has a young and growing population which is eager to participate in the resource development, they are also concerned with how the increase in economic activity will be felt within the communities. One of the manners in which energy companies can work with and directly benefit communities is to invest in better housing. The current housing stock in Nunavut is insufficient and inadequate and is cited as the root cause of many social issues including: low education rates, high suicide rates, an increasing requirement for government support, and the highest rates of domestic violence in the country. Inuit women in Canada experience a rate of victimization 2.5 times greater than non-aboriginal women. A suitable housing design which is appropriate for the specific environmental and cultural context of the Canadian North has not yet been developed because of the logistical complications of building in the North. The research investigates the relationship between the current housing conditions and the elevated rate of domestic violence in order to propose ways that resource development firms can improve the social conditions of the areas they are developing. Appropriate and sufficient housing is not the only area that requires development in the North but it is central to all other issues and advancements in this sector have the potential to improve many other social issues. Providing evidence for the connection between housing and domestic violence to organizations and individuals within Nunavut equips them with the tools to demand and advocate for improved housing models from companies who wish to develop resources in the North. If companies want to develop resources in the Arctic it is their ethical obligation to ensure that communities directly benefit socially and economically from these activities.
Assessing mining impacts from dust and black carbon on Arctic snow in Svalbard, Norway

Alia Khan¹, Heidi Deerson³, Yan Ding², Joshua Schwarz⁴, Rudolf Jaffe², Mark Hermanson⁵

¹University of Colorado, Boulder, Colorado, USA; ²Florida International University, Miami, FL, USA; ³University of Connecticut, Mansfield, CT, USA; ⁴National Oceanic and Atmospheric Agency, Boulder, CO, USA; ⁵University Center in Svalbard, Longyearbyen, Svalbard, Norway

Coal mining in Svalbard has been ongoing since the early 1900’s. In this study, spectral reflectance of undisturbed seasonal surface snow near an active coal mine closest to the largest settlement of Longyearbyen (78.2° N) with particulate black carbon (PBC) up to 345 ppb are compared to a non-contaminated pristine site at Woodfjorden (79.5° N) near the northern end of Svalbard with PBC ~1 ppb. Dissolved black carbon (DBC) measurements are also assessed as carbon passing through a 0.7 um filter and vary from 1 to 75 ppb. Reflectance spectra decreased dramatically across all wavelengths up to 1400 nm with corresponding increases in black carbon concentration. The reflectance spectra also did not converge at infrared wavelengths. At the most contaminated site with PBC of 345 ppb and DBC of 75 ppb, absolute reflectance was much lower than previously published results with values between 10 and 20% in blue wavelengths. This indicates the potential impact of DBC on natural long-term contaminated snow spectra subject to melt and refreezing and serves as a natural end member for global remote sensing studies. These results are also significant because there is increasing pressure being put on Arctic communities to increase mining exploration. Additionally, diminishing sea-ice resulting in increased shipping traffic will also contribute to BC impacts in the Arctic.
Russian Military Build-up in the Arctic: Strategic Shift in the Balance of Power or Bellicose Rhetoric Only?

Barbora Padrtová¹,²

¹ Centre for European and North Atlantic Affairs (CENAA), Bratislava, Slovakia,
² Masaryk University Brno, Brno, Czech Republic

Russian military activities in the Far North has significantly increased in recent years. Combined with political assertiveness the intensified presence of the Russian naval and air forces has drawn much of the international attention. In strategic context, the Arctic military capabilities and their modernization play a crucial role for Russia to maintain current favourable status quo and deter potential challengers. While the increase of military presence is often perceived as game changer of regional military balance, the majority of advertised military programmes are launched to modernize of current capabilities and replacing decommissioned weapon systems. It means, in best case, they slower the gradual downsizing of armed forces. The icebreaker fleet is an exclusive example of the continuously shrinking capabilities, which will not be possible to keep at current level even by already declared modernization. Altogether, these changes have little or nothing to do with power projection outside of Russian territory. Most of them are supporting border patrolling and protecting of national territories that are becoming more accessible. Therefore, Kremlin´s strong announcements about large acquisition of military capabilities are misleading and have little prospect of being completely realized (mainly for financial reasons). The Russian shortfalls in transparency about long-term military ambition could also have a negative impact on region´s security and at the end on Moscow´s strategic position as well. Russia´s unclear and insufficient sources about the current status of their armed forces, modernization plans could lead to serious concerns of other Arctic states. If their concerns will reach critical level, the reaction would be further securitization of the region, in the atmosphere which lacks confidence-building measures. Despite, "political dances" are mostly addressed as a message for domestic audience, Russian strategic interest is to keep the status quo (Arctic as a zone of peace and cooperation), as from the current situation they have the most benefit.
Biofuel is one of the key energy resources in the Arctic Region

Pavel Maryandyshev, Aleksandr Chernov, Viktor Lyubov

Northern (Arctic) federal university named after M.V. Lomonosov, Arkhangelsk, Russia

Arctic region of the Russian Federation including Arkhangelsk region, Murmansk region and Republic Karelia has huge resources of the wood biofuel. This renewable energy resource can remove fossil fuels and solve many energy problems.

Wood biofuel is the oldest fuel but the problem of its effective combustion is still very relevant in the whole world. Very important properties of wood biomass are that biomass almost has no sulfur and phosphorous, that is why final products of its combustion are carbon dioxide and water vapors. Furthermore, wide usage of biofuels - products included in the closed cycle of the production and consumption of carbon dioxide is very attractive for sustainable development.

Pyrolysis is a process of the thermal decomposition of biomass without oxygen. Pyrolysis regime is fully influencing on combustion products but with other equal conditions depends on type of treated biofuel and part of wood being involved in pyrolysis. During the pyrolysis process carbon monoxide, unburned hydrocarbons (saturated and unsaturated hydrocarbons), hydrogen, water, and acids (formic, acetic, high acids of the same rate, methanol, ketones and ethers) are produced. All the mentioned components are emitted in the form of gas steam mixture. Thus, studying the pyrolysis process is very important for the effective energy usage of biofuels.

Institute of energy transport of the Northern (Arctic) federal university named after M.V. Lomonosov is performing biofuels investigation from elemental analysis to complex thermal analysis.

Some results will be displayed on poster with curves describing the ignition and combustion processes and scanning electronic microscopy.

Results of the experiments are used in calculations of processes and equipment used for thermal and energy treatment, combustion of different kinds of biofuels and optimization of startup, operation measures. It leads to the improvement of the energy usage of biofuels.
Index of presenters

Alvarez, 128
Andritsos, 84
Anell, 92
Antonsen, 166
Årthun, 118
Åström, 143
Bakke, 35
Ban, 135
Basedow, 28
Baxevani, 90
Blanchet, 51
Blankholm, 27
Bluhm, 48
Boetius, 11
Bogstad, 60
Booth, 72
Boström, 79
Campbell, 46
Camus, 100
Carroll, 62, 147
Chelak, 167
Chen, 32
Cinelli, 85
Claassens, 130
de Koster, 131
de Steur, 119
Deng, 101
Dolata, 95
Dolgov, 55, 136
Eik, 104
Ejsmond, 66
Escudé, 21
Fernández-Méndez, 52
Fiksen, 65
Fortune, 58
Fosheim, 56
Frie, 170
Gerecht, 179
Gjøsæter, 49
Glok, 120
Gluchowska, 150
Goman, 121
Górska, 59
Græve, 159, 160
Greaves, 94
Gritsenko, 191
Grzelak, 142
Hallfredsson, 61
Hamilton, 47
Hansen, 29
Hanssen, 81
Hatlebakk, 161
Haugan, 105
Hemmersam, 15
Hogenboom, 19
Hoogensen Gjørv, 80
Ilyukha, 111
Inglis, 192
Jansson, 113
Joe-Strack, 132
Keil, 190
Khan, 193
Kikuchi, 127
Kokarev, 64
Korneeva, 20, 108
Korshunova, 172
Kosobokova, 174
Krivokhizh, 180
Kunz, 151
Laborde, 141
Lawrence, 63
Lempinen, 83
Leschke, 160
M.Arruda, 26, 178
Magner, 93
Makarevich, 137
Mällberg, 33
Malmes, 38
Marquardt, 70
Martynova, 155
Maryandyshyev, 195
Marzeion, 18
Masloboev, 139, 182, 184
Matthews, 54, 154
Medby, 22
Michelsen, 145
Mienert, 24
Moe, 82
Moholdt, 41
Molden, 13
Mullin, 88
Murzina, 138
Naito, 34
Niehoff, 74
Nilsen, 91
Nordgård, 106
Oikarinen, 124
Onarheim, 42
Ostaszewska, 173
Padrtová, 194
Panieri, 40
Pavlov, 114
Peeken, 76
Pekkoeva, 163
Pelaudeix, 89
Planque, 53
Primicerio, 77
Rapp, 148
Reigstad, 165
Risebrobakken, 16
Rixen, 44
Ryder, 30
Sánchez, 186, 187
Scheick, 43
Serrano, 188
Seuthe, 67
Smidsrud, 23, 110
Smits, 102
Solás, 96
Solvang, 57
Søreide, 169
Sorokina, 25
Spreen, 39
Stenson, 71
Stepanov, 36
Stokke, 31
Stroeve, 12, 17
Stübner, 75
Svensen, 146
Tassara, 134, 175
Teigen, 103
Varfolomeeva, 123
Vidal, 97
Vieweg, 157
Vikebø, 99
Vlakhov, 189
Wang, 117
Wassmann, 50
Weber, 162
Wiedmann, 68, 171
Wold, 37
Wormdal, 177
Zamelczyk, 109
Zubeck, 115