ISTAS

Integrating Spatial and Temporal scales in the changing Arctic System: towards future research priorities

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Sea Ice in the Arctic Ocean - the challenge of observing basic properties and assessing changes

Over the past 30 years, we have seen a decline of the Arctic sea ice cover happening at a rate unprecedented in the last ~1500 years. This decline is most notable and most easily observed in sea ice extent, through pan-Arctic satellite observations since the 1970s and from proxies before that. However, other sea ice properties are more difficult to assess over longer time and larger spatial scales. Given the increasing interest in the Arctic for example regarding exploitation of natural resources and shipping, we have to improve our knowledge of the current state and ongoing changes as well as our understand of the physical drivers behind these changes. In this talk, I will focus on sea ice thickness: why is measuring ice thickness so difficult? What records do we have and what do we know? What are the challenges, and what could (should?) be the way forward? In the last few years, an increasing number of different studies looked at sea ice thickness in the Arctic, however, they were often limited to particular regions, periods of time, and methods of measurements. To make full use of the different measurements, we need to develop a way to combine these observations into a consistent dataset.

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Oceanographic Challenges from an Arctic Scavenger

In ecology, organisms are usually termed ‘specialists’ or ‘scavengers’, depending on how specific their diets are. Each has their strengths and the community needs both. The same is true in science, except that we tend to use the term “cross-disciplinary” instead of ‘scavenger’ – it sounds better! In this presentation I’ll given some examples of specialist research in arctic oceanography discussing the associated advances and challenges. I’ll also give examples of where a scientific scavenger can thrive and the excitement of working in a cross-disciplinary manner. In such a relatively poorly understood environment that is experiencing rather rapid change there is a need for both specialists and scavengers. To detect change and understand the processes impacted by that change, the use of long time series or proxies is essential. The focus of the talk will be on oceanographic processes, often recorded in long term observations, but will demonstrate the close linkage between the physical environment and other disciplines.

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Coastal and Subsea Permafrost of the Siberian Arctic: Dynamics, Evolution and Risk

The coastal-shelf zone of the Arctic Seas is a place of dynamic interaction of the atmosphere, sea and permafrost. This zone of the Siberian Seas is known for active dynamics of erosive processes and subsea permafrost transformation.

Shore dynamics directly reflecting the complicated land-ocean interactions plays an important role in the balance of sediments, organic carbon and nutrients in the Arctic basin. Thermal abrasion is the most important destructive phenomenon in coastal retreat in this area. The Laptev and East Siberian coasts consist mainly of different types of Quaternary sediments including ice-rich deposits, which are characterized by extremely high ice contents, fine-grained texture, rapid coastal retreat (1 to 20 m/yr), and high concentrations of organic matter. Long-term observations of coastal erosion on the key sites with ice-rich shores show that the coastal retreat rates within the study area have significantly increased (1.5-2 times) between 2000 and 2014. Among others the Laptev and East-Siberian Seas are of greatest interest. Due to erosion of their coasts a large volume of sediment and organic carbon is supplied to the sea. Based on the estimates of coastal sediment input and on the average organic carbon concentrations of the coastal sections, the total organic carbon supplied to the Laptev and East Siberian Seas by coastal erosion can be quantified as ca. 4 x 106 t/yr. Other European, Asian and American Arctic Seas are characterized by considerably lower coastal retreat rates, as well as lower sediment and organic input. The organic carbon, which originates from eroded coastal permafrost deposits, might be an important agent of increasing the greenhouse gas flux to the atmosphere.

Subsea permafrost is still poorly understood, due mainly to the lack of direct observations. Studies of permafrost evolution in the coastal zone allow us to better understand the on-shore/off-shore permafrost system evolution. Coastal and offshore drilling studies in the Laptev and East Siberian Seas confirm the existence of frozen sediments on the shelf. On the basis of geocryological, thermal, and pore water/ice salinity data, it is possible to understand the evolution of subsea permafrost during and after sea level rise. An average sub-sea permafrost table inclination in the near-shore zone at the key sites of the Laptev and East Siberian Seas is about 0.011 (0.002-0.038). New formations of sub-sea permafrost are available within the shallows surrounding delta areas and shallow accumulative bays, on conditions that a water depth is less then 2.5m. One of the main indicators of sub-sea permafrost table inclination at the eroded coastal segments is a coastal retreat rate. Peculiarities of evolution of upper layers of sub-sea permafrost depend on a number of factors: near-bottom water temperature, water salinity; coastal erosion retreat rates (or rate of accumulation/accretion), shoreface inclination, general coastal morphology and shoreline configuration, coastal and shoreface sediment composition, ice-content of deposits, submerged bellow sea level, hydro-lithologic near-shore dynamics.

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Multidisciplinary Arctic Research

Given the manifold developments at play in the changing Arctic region, we also need manifold disciplines to tackle the challenges on the way towards sustainable Arctic futures. For example, natural sciences observe and model the changing nature of the Arctic sea ice, environment and atmosphere. Social sciences like law, economics and political science can provide valuable input as to the likely development of, for example, the pace and extent of Arctic resource exploration and exploitation. This data informs natural science models as to the expected amount of pollutants and black carbon from Arctic sources and thus how we can expect Arctic air pollution to develop, the role of black carbon for the future development of Arctic sea ice, and the possibility of long-range transport of pollutants between Arctic and non-Arctic regions. It further provides data as to the possible and likely effects on Arctic societies and cultures. Multidisciplinary research work is also indispensable to disclose the ever-tightening connections between Arctic and non-Arctic actors, processes, systems and stake- and rights-holders. The involvement of more and more non-Arctic actors in Arctic governance on the one hand provides insights in the possible investments and social development of the region. On the other hand, it discloses the delicate relationship between opportunities and responsibilities that non-Arctic actors have in relation to Arctic changes.

While multidisciplinary research is indeed indispensable to achieve advances in Arctic research, this should not be understood as replacing disciplinary research. State-of-the-art research from all disciplines is of course still invaluable and very often forms the very basis for fruitful multidisciplinary research or synergies between separate disciplines.

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Paleo-reconstruction and biological archives: decade to millennium

Arctic sea-ice plays several key roles in global climate, from increasing the density of seawater through brine rejection, contributing to deep water formation, to influencing gas and heat exchange, releasing nutrients and increasing planetary albedo. With rising concern about changing sea-ice duration and extent in the near future, it's imperative that we understand how the climate system can change, by how much, and how quickly. Palaeoclimate studies can give us a window into the sensitivity of the ocean and climate system to change. Here, I will give a brief overview of the key components of a changing Arctic system that we need to reconstruct and – ideally – combine with models in order to understand how Arctic changes will influence climate in the future. I will then discuss some of the palaeoclimate tools and archives that we have to use, and their limitations, before discussing what the archives show us about the Arctic in a changing world –and its contribution to global climate change - over decades, to millennia, and longer timescales.

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Arctic marine seafloor fauna in a time of environmental change: biodiversity, community distribution and food webs on regional to pan-Arctic scales

On Arctic shelves, benthic communities often receive a larger fraction of water column production that falls to the seabed than at lower latitudes because of comparatively low pelagic grazing pressure. As a result, Arctic benthos provides important ecosystem services including carbon and nutrient cycling, prey base for marine mammals, and providing long-term records of climate variability and change as recorded by a long-lived fauna. We provide examples of spatial patterns in benthic seascapes from recent regional and pan-Arctic syntheses. Spatial distribution of benthic biomass, invertebrate assemblages, and biodiversity are determined through a combination of water mass characteristics, advective transport of food and larvae, biogeographical history, bathymetry, and sediment characteristics. Biogeographical affinities on shelves reflect their proximity to sub-Arctic regions, while deep-sea basins are more connected to the recent North Atlantic fauna. Regional differences in Arctic deep-sea communities are only moderate despite prominent trans-Arctic ridges that could act as dispersal barriers. Stable isotope analysis indicates that food webs are primarily based on phytoplankton and sea-ice algae, but terrestrial sources and microphytobenthos can also play a role in coastal regions. Climate models of water temperatures in combination with known species thermal tolerance windows predict that warming bottom temperatures are likely to particularly change distributions of boreal and Arctic organisms on inflow shelves and in shallow waters, but could also have visible effects in seabed habitats of >500 m. Observing networks have been established to track these biological changes in some areas.

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In the dark: paradigms of Arctic ecosystems during polar night challenged by new understanding

Several recent lines of evidence indicate that the polar night is key to understanding Arctic marine ecosystems. First, the polar night is not a period void of biological activity even though primary production is close to zero, but is rather characterized by a number of processes and interactions yet to be fully understood, including unanticipated high levels of feeding and reproduction in a wide range of taxa and habitats. Second, as more knowledge emerges, it is evident that a coupled physical and biological perspective of the ecosystem will redefine seasonality beyond the "calendar perspective". Third, it appears that many organisms may exhibit endogenous rhythms that trigger fitness-maximizing activities in the absence of light-based cues. Indeed a common adaptation appears to be the ability to utilize the dark season for reproduction. This and other processes are most likely adaptations to current environmental conditions and community and trophic structures of the ecosystem, and may have implications for how Arctic ecosystems can change under continued climatic warming.

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Sustainability and Resources in the Arctic

This talk will give a thorough overview of the different resources existent and expected in the Arctic, focusing especially on the hopes towards developing offshore oil and gas resources on the five Arctic coastal states' continental shelves, the increasing usage of Arctic shipping routes especially along the Northern Sea Route along Russia's northern coast, and the expectations towards increasing fishing opportunities in so-far untapped areas of the central Arctic Ocean. The focus of analysis will be, first, on the question of how likely is it that these resources will be developed in the short- to mid-term and second on what the outlooks are for developing these resources sustainably and to the benefit of the people living in the region.

Important future directions for Arctic research in this connection include a more detailed and realistic approach towards the potential role and future of Arctic resources. What is especially needed is a broader outlook, focusing on how the Arctic generally and Arctic resources specifically are embedded in broader regional and global processes. We further need a clearer approach to sustainability and sustainable development in Arctic research. It more thoroughly needs to be clarified what are specific goals and aims (sustainability meaning specifically what in which special case or context?) and what tools and concepts are needed in order to achieve these goals (what does sustainable development have to entail in order to achieve the formulated goal? What are conflicts, trade-offs, effects of power relations involved in this process?).

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What legal regime for the Arctic Ocean?

The legal regime of the Arctic Ocean has long been blurred because of the lack of an apparent human presence.
However, the residents developed land claims as the sector's theory advanced by Canada or the USSR, or the application of international law in the USA and Norway. Most of the maritime space remained without any real legal system. The scarce cases of navigation in the North West and North East passages have still led to a reaction from the riparian states, Canada and the USSR, who were not willing to recognize a right of free passage along their coasts. The low exploitation of living and non-living resources was led by the citizens of the riparian states and did not result in the building of rules of international law. From 1970 the most directly concerned states have begun to develop rules limiting the use and protecting the environment. The partial melting of ice in the summer due to global warming will change this timid approach. Since 2000 the passages are regularly used and not only by riparian and states most directly concerned (United States, Russia, Canada, Denmark) intend to develop the exploitation of natural resources. All riparian reject the idea of an internationalization of this ocean and see it as exclusively submitted to their emerging and still hesitant legal framework. The chosen legal regime will be the one desired by riparian although observers (mainly European) are admitted to the Arctic Council. The protection of this fragile and already damaged area represents a real international issue. In these circumstances, would it be possible to consider a response of the international law? The IMO will adopt in November 2014 a "Polar Code" which will intend to enforce specific rules to ships and shipping. Regarding the exploitation of resources and the protection of the environment it seems essential to find an international framework which would satisfy either the interests of riparian as those of the environment. Therefore it is hoped that a "regional seas" agreement would emerge between riparian and which could although associate observer countries.

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Trends in Arctic Ocean carbon fluxes as documented using remote sensing

Environment changes resulting from climate change are expected to affect significantly carbon fluxes in the Arctic Ocean. The decrease in the extent of the icepack may lead to an increase in primary production in some regions, and a decrease in others. The positive trend in precipitations over the Arctic Ocean drainage basin combined with the permafrost thaw during the recent decades may boost the export of dissolved and particulate carbon from land to the ocean and, therefore, the activity of marine bacteria. I will present trends over the last 10 to 15 years in pan-Arctic primary production and export of dissolved and particulate organic carbon by rivers, derived from remote sensing data using algorithms we developed in the frame of the Malina project. I'll show that, while the export of terrestrial DOC has increased only slightly, PP has increase by >20% and the export of terrestrial POC by 50%. I will conclude by presenting our near-future research avenues.

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Status of the ecosystem and fish stocks in the Barents Sea

Session 1: Sea Ice in the Arctic Ocean: from microphysics to large scale dynamics

(Chair: Angelika Renner, Co-chairs: Alexey Pavlov and Matthieu Chevallier)

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Predicting sea ice conditions in the Arctic ocean and subbasins a few months ahead: state-of-the-art and future challenges

Seasonal forecasts of the sea ice conditions (extent, thickness, age) in the Arctic ocean may become increasingly useful in the future to a large variety of stakeholders (shipping, tourism, research). There are evidences, in observational datasets and model reconstructions, of some persistence patterns and coupled air-ice-sea interactions that may result in predictability of sea ice area and volume over a few months, provided a good knowledge of the system initial state (including thickness, melt pond coverage, snow cover).

I am going to discuss the ability of current coupled atmosphere-ocean-sea ice global climate models in producing accurate sea ice seasonal forecasts in the Arctic Ocean over the last two decade. I will illustrate my talk with results from Météo-France coupled model CNRM-CM5.1, focusing on predictions of pan-Arctic September sea ice extent, and predictions of March sea ice cover in the marginal ice zones, especially in the Barents sea. I will discuss some limitations of current approaches, and suggest future possible developments that may help improve pan-Arctic and regional sea ice predictions using fully coupled models. Part of these developments may also help increase our knowledge of the temporal scales of predictability of the Arctic climate system.

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Sea ice navigation: statistics and forecast

Real sea ice navigation situation can be different from the ice maps data due to the selective way of navigation – ship looks for easier sea ice conditions. Comparison of sea ice onboard observations with ice maps has given an integrated result showing, on the one hand, the real sea ice distribution and, on the other hand, giving an idea about the influence of captain behavior in certain ice conditions. This onboard observations statistics (1986-2011 years) helped to improve the AARI forecast model and to predict the easiest and fastest way in given ice conditions according to the ice map. The model uses empirical functions of different sea ice characteristics (sea ice concentration, height, fractures zones size, hummocking, etc) and Monte Carlo method. Finally the user is provided with probability distribution of time and velocities spent on the suggested route.

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Linking MODIS satellite and airborne thermal infrared imagery to assess polynya characteristics in Storfjorden, Svalbard

Spatial and temporal characteristics of the Storfjorden polynya, which forms regularly in the proximity of the islands Spitsbergen, Barentsøya and Edgeøya in the Svalbard archipelago under the influence of strong north-easterly winds, have been investigated using thermal infrared satellite and airborne imagery.

Thin ice thicknesses were calculated from MODIS ice surface temperatures, combined with ECMWF ERA-Interim reanalysis atmospheric data in an energy balance model for the winters of 2002/2003 to 2013/2014 (Nov.-Mar.). Based on calculated thin ice thicknesses, associated quantities like polynya area and total ice production were derived. Calculated values underline the importance of this relatively small coastal polynya system considering its contribution to the cold halocline layer through salt release during ice formation processes.

Airborne thermal infrared scanner data were collected during the field campaign LEAST (Lead and ABL study in the Transpolar System) in March 2014 using the POLAR 5 aircraft (Basler BT-67). Spatial distributions of the ice surface temperature were acquired with a swath-width of approximately 2 km and a spatial resolution of 2.7 m at nadir for an area of roughly 16x18 km². In addition, in-situ meteorological measurements were performed (including turbulent flux measurements at low levels). This aircraft–based dataset is used for an improvement of remote sensing methods, the verification of the MODIS-derived quantities and investigations of sub-grid effects on the scale of a satellite pixel. A case study is presented for 16th March 2014 in the Storfjorden polynya area.

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Sea Ice leads seasonal dynamic from SARAL/AltiKa altimeter

Sea Ice leads play an essential role in ocean-ice-atmosphere exchange, in ocean circulation and geochemistry and in ice dynamics. Their precise detection is crucial for altimetric estimations of sea ice thickness and volume. This study evaluates the performance of the SARAL/AltiKa altimeter to detect the leads and to monitor their spatio-temporal dynamics. We show that a pulse peakiness parameter (PP) used to detect the leads by Envisat RA-2 and ERS-2 altimeters is not suitable because of saturation of AltiKa return echoes over the leads. The signal saturation results in 6-10% of PP data loss over sea ice. We propose the new parameter: maximal power of waveform, and define the threshold to discriminate the leads. Our algorithm can be applied from December until May. It detects well the leads of small and medium size. So, the combination of the high resolution altimetric estimates with low resolution TIR or radiometric lead fraction products could enhance the capability of remote sensing to monitor the sea ice fracturing.

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Radar altimetry to study water regime of large boreal rivers

Boreal rivers strongly impact Arctic sea ice dynamics through a large discharge of freshwater. In order to better understand the impact of river water and ice regime changes in acceleration of the arctic sea ice shrinking, it is necessary to be able to estimate precisely the inter-annual variation of these parameters.

Many studies have proved the efficiency of satellite altimetry to monitor water level of large rivers at low latitudes. At higher latitudes, the presence of river ice biases the altimeter signal and makes the water level estimation non-trivial. By investigating ENVISAT waveform parameters over the Ob' river in Western Siberia, we develop an approach that permits to improve the water level monitoring of arctic rivers.

We also study the seasonal evolution of the backscatter coefficient over the Ob' estuary and use optical imagery to demonstrate the high capability of the ENVISAT altimeter to detect ice formation and melt in narrow bays and estuaries. We assess the inter-annual variability of ice regime in different part of Ob estuary in context of the last climatic changes observed on the Ob' river basin and in the Kara Sea.

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Arctic melt ponds evolution and sea ice-albedo feedback

Understanding how sea ice melts is critical to climate projections. In the Arctic, melt ponds that develop on the surface of sea ice floes during the late spring and summer largely determine their albedo − a key parameter in climate modeling. Here we explore the possibility of a simple sea ice climate model passing through a bifurcation point −an irreversible critical threshold as the system warms, by incorporating geometric information about melt pond evolution. This study is based on a nonlinear phase transition model for melt ponds, and bifurcation analysis of a simple climate model with ice -albedo feedback as the key mechanism driving the system to a potential bifurcation point.

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Changes, variability, and seasonality of sea ice energy budgets

Changes in the Arctic sea ice result in a thinner and younger ice cover with changing physical properties and strong impacts on the energy budget. In addition to long-term trends, the physical properties of sea ice and its snow cover underlay a strong seasonal and spatial variability that impact observations and conclusions. Here, I present methods and results of recent studies to observe the sea ice energy budget on different time and length scales. Radiation measurements over and under sea ice reveal changes in the optical properties of sea ice and their implications for the energy and mass budget. The combination of different measurement platforms, incl. remotely operated vehicles (ROV) and autonomous stations, with large-scale observations and parameterizations allows discussing key processes over large regions and during different seasons.

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Seasonal cycle and long-term trend of solar energy fluxes under Arctic sea ice

Arctic sea ice has not only decreased considerably during the last decades, but also changed its physical properties towards a thinner and more seasonal cover. These changes strongly impact the energy budget and might affect the ice-associated ecosystem of the Arctic. But until now, it is not possible to quantify shortwave energy fluxes through sea ice sufficiently well over large regions and during different seasons. Here, we present a new parameterization of light transmittance through sea ice for all seasons as a function of variable sea ice properties. The annual maximum solar heat flux occurs in June, then also matching the under ice ocean heat flux. Furthermore, our results suggest that 96% of the total annual solar heat input occurs from May to August, during four months only. Applying the new parameterization on remote sensing and reanalysis data from 1979 to 2011, we find an increase in light transmission of 1.5% per year for all regions. Sensitivity studies reveal that the results strongly depend on the timing of melt onset and the correct classification of ice types. Hence, these parameters are of great importance for quantifying under-ice radiation fluxes and the uncertainty of this parameterization. Assuming a two weeks earlier melt onset, the annual budget increases by 20%. Continuing the observed transition from Arctic multi- to first year sea ice could increase light transmittance by another 18%. Furthermore, the increase in light transmission directly contributes to an increase in internal and bottom melt of sea ice, resulting in a positive transmittance-melt feedback process.

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Regional albedo of Arctic first-year drift ice in advanced stages of melt from the combination of in situ measurements and aerial imagery

The paper presents a case study of the regional (150km) broadband albedo of first year Arctic sea ice in advanced stages of melt, estimated from a combination of in situ albedo measurements and aerial imagery. The data were collected during the eight day ICE12 drift experiment carried out by the Norwegian Polar Institute in the Arctic north of Svalbard at 82.3 N from 26 July to 3 August 2012. The study uses in situ albedo measurements representative of the four main surface types: bare ice, dark melt ponds, bright melt ponds and open water. Images acquired by a helicopter borne camera system during ice survey flights covered about 28km2. A subset of > 8000 images from the area of homogeneous melt with open water fraction of 0.11 and melt pond coverage of 0.25 used in the upscaling yielded a regional albedo estimate of 0.40 (0.38; 0.42). The 95% confidence interval on the estimate was derived using the moving block bootstrap approach applied to sequences of classified sea ice images and albedo of the four surface types treated as random variables. Uncertainty in the mean estimates of surface type albedo from in situ measurements contributed some 95% of the variance of the estimated regional albedo, with the remaining variance resulting from the spatial inhomogeneity of sea ice cover. The results of the study are of relevance for the modeling of sea ice processes in climate simulations. It particularly concerns the period of summer melt, when the optical properties of sea ice undergo substantial changes, which existing sea ice models have significant difficulty accurately reproducing.

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Interaction of solar radiation and first year sea-ice in the Arctic Ocean: insights from autonomous radiation buoys

State of the sea-ice in the Arctic Ocean is one of the main indicators of global climate change. At the same time, through a number of feedbacks sea-ice plays a substantial role in shaping climate variability in the Arctic and globally. Spatial and temporal variability in sea-ice thickness, extent and area affects the amount of solar light reflected by the sea-ice and transmitted through it into the Arctic Ocean. Over the past years, thinner first-year ice has become a dominant ice type in the Arctic Ocean, replacing thicker multi-year ice. This has implications for physical, biogeochemical and biological processes. Advances have been made in quantifying the seasonal evolution of sea-ice albedo, based on observations and modeling. However, transmission observations under ice in the high Arctic, especially under the seasonal ice, are far more limited, so a good overview of the seasonal evolution of the transmission of sunlight to the ocean beneath is still lacking.

To investigate seasonality in solar transmission at many locations in the Arctic Ocean, several autonomous drifting platforms are to be deployed during 2014-2016 as a part the STASIS project (http://www.npolar.no/en/people/stephen.hudson/projects/stasis.html). Platforms allow for a real-time data transfer on broadband incident, reflected, and transmitted solar radiation. It is expected that the result of the project will be a detailed understanding of processes that affect the availability of sunlight in the Arctic Ocean. This will prove valuable to biologists examining current and future changes to the Arctic ecosystem, to sea-ice modellers trying to explain large-scale changes in sea ice, and therefore to those studying the natural and human systems that are impacted by sea ice. During the workshop, a concept of the autonomous radiation buoy platforms and first results from a year 2014 will be presented.

Session 4: Marine biodiversity

(Chair: B Bluhm, Co-chairs: M. Kedra and S. Majaneva)

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Cydippid ctenophores in the coastal waters of Svalbard: is it only *Mertensia ovum*?

Threat of potential arrival of non-indigenous species is increasing, particularly in the high Arctic, due to ecological shifts expected from climate change and increasing shipping traffic, facilitating long-distance transport of invaders. Hence, knowledge on the species present currently is crucial to assess the potential ecological impact of the non-indigenous species in the future. Ctenophores, and gelatinous zooplankton generally, are poorly known due to identification challenges and lack of systematic monitoring programmes. Yet, they are known to play important roles in the world's ocean ecosystems and share physiological attributes making them exploit the changing environmental conditions better compared to most other zooplankton groups. Here, we report the co-occurrence of *Mertensia ovum*, *Euplokamis* sp. and an unidentified mertensiid-like species in the high Arctic, in the Svalbard archipelago region, based on a combination of morphological and molecular identification methods. This is a valuable first step toward establishing a baseline for future ecological studies, monitoring of climate impacts and assessing the threat of introduced species in the high Arctic.

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Spatial investigation of plankton in the European Arctic

As part of the Tenace expedition, from the 20th of August to the 10th of October 2014, the scientific project ARTEX will focus on the study of plankton, micro-organisms at the basis of the marine food web. The following questions will be addressed: 1)What are the abundance and latitudinal succession of planctonic species from the North Atlantic, along the Norwegian coast towards the Barents and Kara Seas? 2) How do the structure and dynamic of the planctonic food web vary between water masses of Atlantic versus Arctic origin? 3) What is the impact of terrigenous material discharged by Arctic rivers and glacier melting on the growth of micro-algae and microzooplankton?

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Impact of various sea ice extend in the Central Arctic on the sea ice and pelagic biota

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 artica*, 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 contrasting 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 almost exhausted low nitrate inventories concentrations in the surface waters of 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 in 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 *M. 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. These findings are contrary to the assumed beneficial of phytoplankton due to climate change and suggest, that the role of sea ice biota need urgently to be understood to be able to predict any climate change scenario in the Arctic.

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The under-ice distribution, population structure and feeding ecology of polar cod *Boreogadus saida* in the Eurasian part of Central Arctic Ocean

In the Arctic Ocean, sea ice habitats are undergoing rapid environmental change. Polar cod is the only abundant fish that resides inside the pack-ice of the central Arctic Ocean. Polar cod spend a significant part of their life cycle in association with sea ice. The under-ice distribution, population structure and feeding ecology of polar cod over the deep basins of the Central Arctic Ocean, however, have barely been studied. During summer 2012, we used for the first time in the Arctic Ocean a new device for under-ice fishing, the Surface and Under-ice Trawl, equipped with a sensor array. Elevated densities of polar cod under ice were associated with relatively low salinity and thick ice. Back-tracking of ice floes suggested that the under-ice abundance of polar cod in Eurasian Basin was strongly related to the origin of ice formation. Sea ice formed along the Laptev Sea shelf-break and the Svalbard archipelago supported higher fish densities than ice floes originating from the Barents and Kara Sea sectors. Stomach content analysis of the under-ice fish indicated as dominant food source the ice-associated amphipod *Apherusa glacialis* and in a lower extent the pelagic amphipod *Themisto libellula* and copepods (*Calanus* spp). We will further present the progress of our group in linking stomach content with carbon and nitrogen stable isotopes data of polar cod from the Central Arctic Ocean.

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Chlamys islandica biology studied in field experiments

During two years of field works we focused our observations on *Chlamys islandica*, mainly at 20 m depth at the opening of the Kongsfjord. We investigate: 1) links between calcification rate and growth checks ; 2) links between growth and environmental variations, and 3) we assessed the effects of ecological and growth rate using growth striae width and 4) we measured also trace elements and stable isotopes (C and O) within the shell carbonates to calibrate "classical" biogeochemical proxies. We propose here to expose our difficulties and our main results.

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Distribution of benthic megafauna in the Barents Sea: baseline for an ecosystem approach to management

Arctic marine environments are experiencing many human-induced and natural pressures, including climate change, harvest, introduced species, pollution from ship traffic, fossil fuel exploitation, etc. The complexity of the Arctic benthos poses many challenges to predict how these potential cumulative pressures affect benthic species and to detect biodiversity changes. The Barents Sea, one of the shelf oceans in the Arctic, represents: 1) a transition from warm Atlantic to cold Arctic waters and consequently an area for climate change studies; 2) a commercial bottom trawling fleet gradually moving northward together with expanding fish stocks potentially effecting new pristine bottom areas, and 3) invasion by the large snow crab (*Chionoecetes opilio*) a generalistic benthic predator with the potential to reach several millions of individuals. Since 2007, the Norwegian-Russian annual ground fish surveys in the Barents Sea, were expanded to include an standardized monitoring of invertebrates from the fish trawls. The intension has been to develop a time and cost efficient method with simple and transparent analyze tools that easily can be adopted by other ground fish surveys. The data base, including 3073 stations, 23 Phyla, 49 taxon groups, 590 species, abundance and biomass, are continuously developing and improving. Coding species vulnerability toward trawling, temperature affinity, and preference to invasive top-predators can indicate geographical areas of particular concern.

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Diversity and ecological functioning of Arctic benthos along a gradient of depth and latitude

The discussion about the correlation of diversity and ecosystem functioning in marine systems is long and ongoing, but empirical studies are scarce. Especially the Arctic is widely unexplored in that context, although the shift towards a seasonally ice-free Arctic Ocean raises many questions relating to the future of diversity and function of the Arctic ecosystems. We use biological trait analysis (BTA) to tackle these questions as it links species, environment and ecosystem processes (Bremner 2005). We examine how taxonomic diversity and the potential of function in macrozoobenthic communities change along gradients of increasing water depth, latitude and sea ice cover. The dataset based on modeled production data comprises ten stations ranging from the productive shelf area down to the permanently ice covered and food limited Arctic Basin. Although the number of species per station decreases by 95% towards the Arctic basin we did not find such a pronounced trend in functional richness, which remained comparatively high. We conclude that benthic communities in the Basins are well adapted to food limitation by covering all potential niches and thus maintaining ecosystem functioning.

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Identifying the Diet and Physical Condition of the Beaufort Sea Belugas using Fatty Acid Signatures

Beluga whales (*Delphinapterus leucas*) are potential indicator species for Arctic climate change. The Beaufort Sea beluga population is one of the world's largest and is an important traditional food to the people from the Inuvialuit Settlement Region. During the summer, belugas migrate from the Bering to the Beaufort Sea and segregate by sex, reproductive status, and size into different habitats based on sea ice concentration. The differences in habitat use are defined largely by beluga length and predict their diets and exposure to mercury. Comparison of fatty acid profiles have revealed Arctic cod (*Boreogadus saida*), a sea ice associated fish, to be an important prey, but the contribution of other prey to the diet of Beaufort Sea belugas remains unknown. Changes in sea ice due to climate change may have indirect effects on the primary production of Arctic food webs and affect the availability of important energy-rich prey, such as Arctic cod, to belugas. The resilience of Beaufort Sea beluga whales to climate change will depend on their ability to adapt to changes in prey dynamics.

In this study, we established a baseline for health and physical condition of Beaufort Sea belugas and investigated dietary linkages using fatty acid signatures. Indicators of physical condition, such as blubber thickness, hemoglobin and hematocrit concentrations were measured from harvested whales at Kendall Island, Hendrickson Island, Paulatuk, and East White fish during summer subsistence hunts in 2011, 2012, and 2013. Beluga tissues were also collected for fatty acid and stable isotope analysis. Fatty acids in beluga blubber were stratified with blubber depth. The percentages of monounsaturated fatty acids were lowest in the inner blubber layers and highest in the outer layers. On the other hand, polyunsaturated fatty acids increased with increasing blubber depth, and were found predominately in the inner blubber layers. My overall objective will be to provide a better description of body condition and diet for future comparisons to assess the impacts of climate change on the Beaufort Sea beluga population and marine ecosystem.

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"DWARF - Declining size - a general response to climate warming in Arctic fauna?" – a Polish-Norwegian Research Project

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.

DWARF (Declining size - a general response to climate warming in Arctic fauna?) is a project funded from Norway Grants in the Polish-Norwegian Research Programme. It aims to provide a basic understanding of the effects of the global warming on the size of the Arctic organisms of terrestrial, limnetic and marine ecosystems. The main hypothesis of the project is that elevated temperatures will induce size reductions in a large range of high latitude ectotherms. The main goal is to test this in Arctic environments, and also to analyze causations for possible exceptions to this proposed general trend. This will be achieved by relating size responses in biological structures at different levels (genome, cell, body, population and community) to changing thermal regimes. The project will explore the temperature effects on the size structure at a range of levels of biological organization. The study will focus on a selected range of animal taxa, including both invertebrates in terrestrial, limnetic and marine habitats, as well as selected marine and freshwater fish species. Thus, the study will encompass the different dimensions of the possible climate warming impacts on biological sizes (related to organization level, taxonomic group and habitat). Biomass size spectra will be used to assess the secondary production of studied communities. Environmental drivers of the possible climate warming impacts on biological sizes and possible effects at various organization levels, taxonomic groups and habitats will be determined. The synthesis of the data generated within the scope of this project will provide a comprehensive view of the effects of the climate change on the size – a fundamental property of the biological compartments of the ecosystems. Documentation of the patterns of spatial variability of biota size distribution and determination of the environmental drivers of this variability are especially important in the Arctic, where effects of the global changes are predicted to occur more intensively and earlier than at lower latitudes.

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Will the Benthic Biomass Size Spectra in the Arctic change with climate warming?

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 Kongsfiorden and Hornsund differ between each other in terms of shape of size spectra and number of size classes (in Hornsund 27 clasess, in Kongsfiorden 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 Kongsfiorden 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.

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Evaluation of the Chukchi Sea ECOSYSTEM vulnerability to extended human activities

The key threat for deterioration of conditions of Arctic sea ecosystems is anthropogenic impact as a result of developing oil and natural gas deposits and shipping. The aim of the research is to identify ecologically important areas in the Chukchi Sea for their future protection (minimize interference from any shipping and offshore oil activities).

The location of the Chukchi Sea between the Bering Sea and the Arctic Ocean determines the mixed character of its fauna [1]. Modern environmental conditions of numerous components of the Chukchi Sea ecosystem can be considered as being close to average long-term norms [2, 3]. However, the stability of biocenoses can be considered as vulnerable because in the eastern part of the sea and along the coast of the Chukchi Peninsula relatively favorable conditions for accumulation of pollutants are observed [3].

In this research, we conduct assessment of vulnerability from the potential oil impact for two parts of ecosystem: the coastal zone and water area. Vulnerability of ecosystem in water area from oil spills was connected to biotic components of the Chukchi Sea ecosystem such as zoo-plankton and phytoplankton, benthos, fish, marine mammals and birds. We showed that birds in cold climate are most vulnerable to oil pollution as well as marine mammals have the smallest vulnerable because they can be adapted to impact of oil spills. Also the base on relative vulnerability we indicate the regions of the Chukchi Sea which can be vulnerable from oil spills. Most of the determined vulnerable areas are located in coastal areas where there are human activities or potential human activities in the future. Analysis of relative vulnerability for various types of oil shows that film and dispersed oil are the most dangerous to the coastal part of the Chukchi Sea ecosystem. Birds are the most vulnerable to film oil impact because they are concentrated in the coastal part of the Chukchi Sea ecosystem.

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What can Physiology tell us about the future ecology and biodiversity of a changing arctic ocean?

The maintenance of future biodiversity will depend, in part, on the continued function and fitness of ecosystem engineers in response to climate change. The function and fitness of such organisms is dependent on energetic trade-offs between the physiological costs of maintaining cellular homeostasis in a changing ocean (e.g. protein synthesis, ion-regulation and acid-base status) and other energetically demanding processes that determine life-history traits and, therefore, performance, fitness and how organisms regulate their environment (e.g. reproduction, growth, activity, grazing). As these responses may be limited not only by a species' physiological plasticity but also by energy availability, it is vital to understand the mechanisms underlying their spatial and temporal physiological plasticity in the face of environmental change and their energetic limitations. We show that polar species compared to temperate species are not only limited by mechanistic plasticity but are also limited in their ability to up-regulate their metabolic rate to meet the elevated ATP demands associated with climate change. Such differences could be related to phylogenetics and ancestral thermal histories, as well as variations in fitness costs associated with elevated metabolic rate within a limited energy environment. These differences in energetic trade-offs may make polar species not only less physiologically resilient to climate change but will likely effect life-history traits that will have an impact on their fitness, distribution and function in modulating future polar biodiversity.

Session 5: Paleo-reconstruction and biological archives: decade to millenium

(Chair: K. Hendry, Co-chairs: K. Werner and M. O'Regan)

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Arctic Sediments and the resolution of paleo-environmental change

Many high latitude sedimentary and ice core records provide high-resolution time series of climate changes during the last glacial cycle (120 ka). These climate archives suggest a series of rapid warming events to near-interglacial conditions, followed by gradual cooling (Dansgaard-Oeschger events). Given the sensitivity of the Arctic marine system to modern climate change, we would expect these global events had a profound impact on sea ice, circulation, and productivity patterns in the past. However, there have been few studies in the Arctic Ocean that capture this millennial scale variability. This presentation provides an overview of the challenges associated with acquiring these records from the Arctic Ocean. It also reviews existing records that capture some of this variability, and discusses promising regions where high resolution paleo-climate time series may be acquired in the near future.

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The Northwest Passage: Ice Age to present

The Canadian Arctic Archipelago (CAA), characterized by an extensive network of marine channels ("the Northwest Passage"; ~1.1 million km^2), represents a fundamental link in the global climate system via large-scale oceanic and atmospheric circulation, heat transport, and freshwater budgets. Data from five marine (piston and trigger weight) sediment cores across main W-E axis of the Northwest Passage provide crucial insights into the climatic, environmental, oceanographic, and ecosystem development of this region since the last deglaciation to the present day. These records were investigated in a multiproxy approach [sedimentology, micropalaeontology (dinocysts, non-pollen palynomorphs, benthic and planktonic foraminifera, ostracods), biogeochemistry (stable isotope ratios, total organic carbon, biogenic silica); 52 AMS 14C dates]. They reveal a dynamic marine climate throughout the Holocene, with rapid deglaciation (~11.0-10.8 cal ka BP = calibrated years before present) and particularly pronounced environmental shifts during the early to mid-Holocene. One of the most striking signals is the penetration of deeper (Atlantic-derived) Arctic Intermediate Water (AIW) into the region immediately following deglaciation, facilitated by higher sea-levels permitting increased flow across inter-channel sills. Postglacial amelioration (open-water season greater than at present) is subsequently recorded at ~10.0-7.0 cal ka BP, corresponding to a previously proposed regional "Holocene Thermal Optimum". The exclusion of AIW due to glacioisostatic shallowing, coupled with generally cooling climate, eventually leads to increased sea-ice and modern-day oceanography and ecosystem configuration by ~6 cal ka BP. Our data indicate that although climate ultimately forces long-term environmental shifts, regional dynamics, especially sea-level changes, exert a significant control on marine conditions throughout the CAA. In contrast to the majority of terrestrial (ice core, lake sediments) climate records from the region showing unprecedented warming since AD ~1850, marine cores show relatively small changes throughout the latest Holocene.

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Development of Mg/Ca-temperature calibrations for benthic foraminifera in the central Arctic Ocean

The Arctic region is experiencing a relatively higher temperature increase compared to the rest of the Earth. This Polar Amplification is triggered by climatic feedbacks that require a better understanding for improved future-climate projections. Responses of a warmer central Arctic Ocean to climatic warming include sea ice shrinkage and carbon-greenhouse gas release from methane hydrates that are stored in the seafloor and destabilize with changes in bottom water temperatures. Therefore, understanding of how Arctic Ocean bottom temperatures have changed over the past is of critical importance and proxy-based temperature reconstructions are needed. A first step towards this goal is to produce benthic foraminifera Mg/Ca bottom water temperature calibrations for the Arctic Ocean. Here I present modern core-top samples from 16 sites on the Lomonosov Ridge (central Arctic Ocean), dated using radiocarbon, covering a depth range of 611-4228 mbsf. Trace metals, including Mg/Ca, Sr/Ca, Li/Ca, B/Ca, U/Ca were measured on 10 monospecific benthic foraminifera samples. Mg/Ca bottom water temperatures (BWTs) were calculated and compared to modern in-situ BWTs obtained from cruise-derived CTD casts. This data suite was used to produce Mg/Ca temperature calibrations for central Arctic bottom waters. Future research will apply these new calibrations to down-core foraminifera sequences from the Lomonosov Ridge and new sediment cores obtained as part of the SWERUS-C3 expedition to the Eastern Siberian Arctic Ocean.

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Evaluating the role of Atlantic Water advection to the Arctic Ocean on geological, historical, and observational timescales

Recent observations of enhanced oceanic heat transfer into the Arctic concomitant with the rapid sea-ice decrease temptingly suggest a direct relationship between both features. However, except for marginal areas of the Arctic Ocean where warm and saline Atlantic Water (AW) reaches the surface, the majority of AW heat is presently isolated from the sea-ice cover by a cold and fresh halocline layer. No evidence has been found to suggest a weakening of the halocline across the central Arctic basins that would enhance the AW heat transfer to the surface. A more direct link between sea-ice reduction and AW inflow is, however, seen in the inflowing Barents Sea branch in both historical and observational time series. In this presentation the AW advection into the Arctic Ocean and its influence on sea-ice variability will be reviewed from a geological point of view. Records from the geologic past are of great value as the time span of modern observations and historical data is often too short to comprehend long-term trends and causes of AW variability, changes in the marginal ice zone, and the vertical structure of the Arctic water column. Paleoceanographic studies from the recent interglacial indirectly suggest that the strength of AW advection and its propagation into the Arctic interior is effective in melting sea ice in combination with other factors such as insolation, sea level, freshwater input, and upper water mass stratification. However, to date, very little paleoceanographic work in the Arctic has focused on how the strength and position of the halocline has changed during previous interglacial periods. More direct reconstructions of the Arctic's vertical stratification in the geologic past are needed to provide a longer-term view on the stability of the halocline, and more generally, the role of Atlantic Water inflow on the stability of sea ice in the interior basins.

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Efforts to constrain extent and dynamics of past glaciation on broad western Arctic shelves

Recent mapping efforts have reignited the discussion of the past presence and extent of grounded glacial ice on the East Siberian (Niesen et al., 2013) and Chukchi (Dove et al., 2014) continental margins. Swath bathymetry and shallow sub-bottom profiler data provide insights into the dynamics, extent, and relative event chronology of past glaciation, which has been shown to have widely impacted the outer continental shelf, adjacent slopes, as well as several outlying ridges beyond the shelf break. Bathymetry data frequently reveal glacigenic landforms at seabed across the region, down to 900 m water depth, though obscured in shallower water to the south by iceberg scouring. Sub-bottom data reveal multiple till units, debris flows, as well as erosional surfaces. Studies over the last 20 years have documented occurrences of similar features relying on opportunistically collected datasets, but scarcity of data have hindered paleo-ice sheet reconstructions. Influenced by the findings from terrestrial-based research (largely suggesting large ice masses could not be present in the Chukchi region), these studies largely related these features to ice impinging only from the Laurentide ice sheet, with possible small ice cap(s) on the Chukchi Plateau. Despite the resulting uncertainty with the southern extent of glaciation, the newly acquired data indicate a widespread grounded-ice presence on the northern Chukchi and East Siberian shelves, which makes the region an important, previously underestimated component of the Arctic paleo-glacial system.

Absolute timing however remains largely unconstrained. Seabed geomorphology has perhaps become the most reliable tool for mapping the extent and pattern of past glaciations, but is limited (e.g. cross-cutting landforms) in terms of providing chronological information. Seismic stratigraphy provides a further relative chronology through the 3rd dimension but presents challenges when extrapolating between broadly-spaced survey lines, compounded by the difficulty in dating key horizons in high latitudes (e.g. Polyak et al., 2007). Despite these limitations, further mapping and sampling in the region will provide a more accurate assessment of the extent and magnitude of past glaciations in the region, with significant implications for previous oceanic, atmospheric, and land interactions.

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14C Ages of Bulk Organic Matter in Offshore Sediments in the Laptev and East Siberian Seas

Terrestrial organic carbon (Corg) is a significant player in the global carbon cycle, and the balance between terrestrial Corg remineralisation and sequestration in marine sediments is an important factor controlling atmospheric CO2 levels. The type of terrestrial Corg, the mode of its delivery, and the efficiency of its burial vary significantly depending on the source regions and the structure of sedimentary sinks. Because of a high proportion of continental shelves in the Arctic Ocean, the combined effect of global and regional climate changes has a profound effect on the fate of Corg in this basin. The history and accumulation patterns of terrestrial Corg delivered to the Arctic Ocean by the major Siberian Rivers in the Russian Arctic, however, remain largely unexplored.

To address this issue we chose to investigate 9 cores that were obtained along two transects in the Laptev and Eastern Siberian Seas. The cores are up to 3 m long and were taken from water depths between 43 and 2740 m. The research plan included 14C dating of bulk and individual organic compounds recovered from surface sediments as well as down the cores along the two transects. One of the main tasks of this project was to identify and isolate individual organic compounds that represent different terrestrial Corg fractions: vascular plant-derived lignin phenols and plant wax lipids.

The preliminary data obtained for 6 samples from 3 cores (at two stratigraphic positions in each core) showed that the pattern of bulk 14C ages of Corg are consistent with the patterns observed in Feng et al (2013) for the surface estuarine sediments in the vicinity of the major Siberian Rivers in the Arctic. Organic C is younger in the western part of the Arctic in comparison with that further east. Further work on bulk and compound-specific 14C dating of Corg from the 9 cores will provide information regarding the relative importance of “young” vs. “ancient” carbon through time and space in the Arctic during the Late Quaternary.

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Tracing the interplay of oceanographic variability and glacial activity in two fjords of northern Spitsbergen through the Holocene

The Arctic reacts very sensitive to climate and oceanographic changes since positive feedback mechanisms amplify the ongoing global warming trend in the high latitudes. The Svalbard area can be considered as a key region in this context, as the advection of warm subpolar waters is reaching further north here than at any other location at similar latitudes. The Holocene history of the advection of these Atlantic Waters to western Svalbard is well documented, however, marked by comparably low sensitivity indicating the presence of Atlantic Waters for most of the Holocene. New sedimentary records from the northern rim of the Svalbard archipelago, where the inflow of Atlantic Waters into the Arctic Ocean is gradually fading out, are most likely much more sensitive in recording temporal variations in the strength of oceanographic heat advection to the high North. Two sediment cores collected in fjords along the northern Svalbard coast are investigated for their benthic foraminiferal faunal composition, in order to trace the Atlantic Water inflow, and for their content in ice rafted detritus, in order to trace the activity of the glaciers entering these fjords. It is assumed that there is a direct link between the strength of Atlantic Water inflow and the activity of these glaciers.

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Tree-ring tales: snow-avalanche history in three Icelandic paths revealed over the 20th century

Tree rings are used to highlight the occurrence of snow avalanches in three remote paths of central North Iceland, where the activity of this geomorphic process impedes the growth of Betula pubescens Ehrh., trees exhibiting heavily damaged stems. From the analysis of internal growth disturbances of 106 trees, each site is documented with 30 to 56 winters with attested snow-avalanche activity since 1903; four to six winters at each site are regarded as extreme, and two of them are common to the three sites. The spatial distribution of snow avalanches during those two major events is derived from the location of trees providing robust tree-ring signals. The temporal distribution of major growth disturbances also reveals the frequency and return period of winters releasing different scales of snow avalanches. The largest events have return periods of only 15 to 26 years in the area, and snow avalanches fluxes reaching the distal part of the cone, with a lateral extent limited to the narrower path, can be expected with a 4-year return period.

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The specificity of the structure and properties of permafrost-affected soils developed under peat circles (the Russian European Northeast)

The specificity of the structure and properties of permafrost-affected soils developed under peat circles were characterized in the Russian European Northeast. It is shown that the formation and existence of peat circles developed on peat mounds are resulted from permafrost heave, wind erosion, surface cryogenic processes. These processes have actively been affecting peat plateaus during Subatlantic period of Holocene. The three-layer structure of soil-geocryological complex system has been revealed as the system «Active layer - upper permafrost - lower permafrost». The soils of peat circles are rather different from typical oligotrophic peat soils, which are widespread in permafrost peatlands. The studied soils are characterized by lower soil acidity, higher decomposition and humification degree of organic matter.

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Ecological sustainability of permafrost peatlands in the European North-East

A comprehensive assessment of the environmental state and sustainability of peatlands from the European North-East of Russia in view of the ongoing climate change was developed. Analytical results revealed the heterogeneity of organic carbon composition and properties in peat horizons in active and permafrost layers. Carbon in permafrost peatlands is relatively safe (not decomposed) and peat can theoretically start its rapid mineralization as its thawing begins. At approximately 64-78% of the total lifetime of peatlands all organic carbon was unfrozen and unpreserved. Hereby, the most important reason of peat reservation is the presence of anaerobic conditions, and not the presence of permafrost. Current decomposition of peatlands relates to the leading role of wind abrasion and thermal erosion, but in practice does not lead to thermokarst. Despite the global warming permafrost peatlands occurring in anthropogenically undisturbed environments are sustainable ecological systems.

Session 8: The responses of law and economics in a changing Arctic

(Chair: A. Cudennec, Co-chair: M. Jacquot)

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Developing a regulatory framework for navigation safety in the Arctic, the end of an ever-recurring issue?

The Arctic area has long benefited from its natural protection from ice, ships preferring not to venture into dangerous waters. Today we are witnessing the opening of new routes and the development of human activities in the Arctic Ocean. The number of open water days increases at the same time as applications for commercial activities (transport, resources exploitation and tourism).

Due to the fragile Arctic marine life, pollution, including pollution of the marine environment, taking proportions other than those that would experience another part of the globe. Arctic waters are facing, significantly, the risk of pollution arising, above all, the presence of vessels in this area.

Disasters such as the Exxon Valdez have dramatically demonstrated that the transport of oil in polar waters can present a real risk and expensive cost.

The Arctic Ocean is continuously exposed to an ecological disaster. It is, therefore, to prevent it. To this end, States have adopted a much preventive and precautionary position and seek to develop a strict regulation of maritime activities in the region.

States have realized the importance of developing binding legal instruments to ensure not only the safety of navigation activities in sensitive areas such as the polar regions but also protect people, wildlife and local flora. They have chosen to negotiate, within the International Maritime Organization (IMO), a mandatory International Code of safety for ships operating in polar waters (Polar Code). It is important to come back to this ever-recurring issue, mainly by identify how States try to reconcile the fundamental principle of freedom of the seas with an effective protection of the marine environment.

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"The United States and Article 76 of the UNCLOS"

The United States is the only coastal State of the Arctic Ocean which is not party to the UNCLOS. The paper interrogates whether the US is nonetheless bound by the definition and methods of delimitation of the continental shelf given by Article 76 of the Convention, and whether it has the right to have recourse to the procedures set up by this article. Article 76 is crucial when considering the Arctic Ocean because the latter is a small and circular basin where coastal States' claims over their extended continental shelf are likely to overlap and to be challenged by the other coastal States. Yet, the question of the law applicable to the US concerning the continental shelf has been quite eluded so far. Firstly, this contribution recalls that the **definition** of the continental shelf is part of customary international law binding the US. Secondly, the US seems to consider that the **methods of delimitation** is of customary nature, although this has not been determined by an international tribunal. Lastly, the contribution argues that the **procedures** instituted by Article 76 are not open to the US.

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The European Union's interests on the Arctic ocean

The Arctic region has been for the last twenty years the theater of important climate and environmental changes. It results the progressive melting of polar ice. This disappearance of sea ice is the center of numerous claims over this environment by few states.

In this context, the European Union (EU) in view of its status as a major international economic actor has taken over the Arctic question. The EU numbers among its members states one of the five sovereign states of the Arctic Ocean: the Denmark with Greenland, and two states belonging to the Arctic region: Sweden and Finland, as well as Norway and Iceland partners of the European Economic space. Furthermore, Denmark, Finland and Sweden are permanent members of the Arctic Council, intergovernmental forum which deals with matters such as environment protection and sustainable development.

Considerably involved on these issues through its member states belonging to the Arctic region and in accordance with one of the main principle of the Integrated Maritime Policy, the Union urges to consider each maritime zone as unique and requiring individual attention when it comes to find a sustainable balance between its different uses, the Union has no other choice but to develop a policy for the Arctic.

Considering the legal means the EU has at its disposal, we need to explore to what extent this latter succeeds to build a real policy for this region.

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Science in the public and legal decision-making process: an example of interdisciplinarity

This talk is initially based on a paradoxical observation: if the environment is in danger it is in large part because science has given humanity the illusion that it could have control over nature. At the same time it is science that allows men to take into account the dangers they face. So we slide from a Cartesian logic in which "science allows to carry out a project to control nature" to a relativistic logic which involves the idea that nature is not always manageable and it is sometimes necessary not to try to control it. The talk will then illustrate how the dialogue between the scientific and legal disciplines assumes the following paradigm: science control, through the legitimacy it confers to legal norms and legal attitudes, the influence of man on the Nature.

To do so, the talk will focus first on the transfer of legitimacy from the Scientific Authority to the political one. This will show the growing importance of scientific expertise in the process of developing standards including in the case of "uncertain science" via the precautionary principle.

Then, the same analysis will be conducted on the transfer of legitimacy from the scientific authority to the legal authority. It will then be question to highlight the growing importance of scientific expertise in the litigation context.

In each of these assumptions which constitute the dialogue between science and law, the talk will attempt to clarify both the positive elements and the pitfalls in order to identify useful lines of thoughts.

Session 2-3-7: Oceanography – physics, atmospheric interactions, and biogeochemistry

(Chairs: F. Cottier, Co-chairs: H. Findlay, P. Bourgain, N. Morata, Q. Shao, R. Hindshaw, S. Rastrick)

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Sulphur cycling

One of the primary sources of sulfur, an essential plant macronutrient, is the weathering of pyrite. Quantifying the overall release of sulfur from mineral weathering is essential, not only on an ecosystem level, but also for constraining the contribution of coupled sulfide oxidation – carbonate dissolution to the global carbon cycle. This requires knowledge of how oxidation and reduction reactions of sulfur species are modified by external parameters such as temperature, runoff and biological activity. In order to investigate the effect of local environmental conditions on pyrite weathering we collected stream water samples from two small catchments (each approximately 3 km2) in Svalbard. One catchment is glaciated and the other catchment is un-glaciated but is affected by permafrost and a seasonal snow-pack. The two catchments are situated next to each other with identical bedrock (shale with minor siltstone and sandstone). The proximity of the catchments to each other ensures that meteorological variables such as temperature and precipitation are very similar. Sampling was conducted early in the 2012 melt-season when there was still significant snow-cover and in mid-summer when most of the seasonal snow-pack had melted. The water samples were analysed for □34S-SO4, □18O-SO4 and □18O-H2O, together with major anions and cations. Two pyrite mineral separates were analysed for □34S. Bacterial 16S rRNA genes were amplified from two sediment samples using PCR techniques and BLAST (basic local alignment search tool) was performed to assign species. Despite the nominally identical lithology and meteorological parameters, there were significant differences in the stream water chemistry and bacterial composition between the two catchments. In the glaciated catchment, stream water □34S-SO4 values were higher than pyrite, which, together with a significant positive correlation with □18O-SO4, suggests that sulfate reduction is occurring. Sulfate reduction occurs under anaerobic conditions and this is corroborated by the detection of 16S rRNA genes associated with the class Deltaproteobacteria, in particular the genera Geobacter, which are known to respire anaerobically. In contrast, no Deltaproteobacteria were detected in the unglaciated stream sediment and stream □34S-SO4 values were identical to pyrite suggesting pyrite oxidation under aerobic conditions and therefore limited sulfate reduction. This difference in sulfur cycling, arguably microbially mediated, results in marked differences in the major ion chemistry of the two streams, particularly in the ratio of SO4:HCO3, which is higher in the unglaciated catchment. The combination of glaciation and bacteria adapted to living in those environments fundamentally alters weathering processes and the resultant stream water chemistry, with potential downstream impacts on seawater chemistry.

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Monitoring of snow and glacier (satopanth)

In the Indian Himalayan Mountain contains important natural resources of frozen fresh water in the form of snow and glacier. These glaciers are unique as they are located in the tropics, high altitude regions, predominantly valley type and many are covered with debris. The great northern plains of India sustain on the perennial melt of snow and glacier meeting the water requirements of agriculture, industries, domestic sector even in the months of summer when large tracts of the country go dry. Therefore it is important to monitor and assess the state of snow and glacier and to know the sustainability of glacier in view of changing global scenarios of climate and water security of the Uttarakhand. The present paper containing to monitor seasonal snow cover, an algorithm based on Normalized Difference Snow Index with collaboration of Space Applications Centre using visible and short wave infrared data of AWiFS sensor of Resourcesat satellite. Snow cover was monitored for Alaknanda basin distributed in different climatic zones of Himalaya. The results of snow cover monitoring show variations in patterns of snow accumulation and ablation for different basins falling in different climatic zones. The temporal information of snow cover derived of 5 and 10 days temporal information form Indian Remote Sensing Satellite IRS-P6- AWiFS sensor of Resourcesat satellite of snow cover of Uttarakhand Himalaya for obtaining the information of snow accumulation of the valley glacier as well as piedmont glacier of the Himalaya.

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Marked biotic gradient in the sediments of a dominated-glacier fjord (Kongsfjorden, Svalbard)

Arctic marine ecosystem is characterized by strong seasonality of the sea-ice cover, light and food availability. The ecosystem functioning and carbon cycling will be affected by the climate change of whom the effects are enhanced in Arctic. It is currently unclear how the benthos will be affected by changes of environmental conditions as changes in the organic matter supply from the water column. Kongsfjorden, a high Arctic fjord in the western part of Svalbard, is highly influenced by several glaciers and Atlantic water inflow. In the last decade, this fjord has received great interest since it is considered as highly sensitive to climate change. Its ice cover and volume of surrounding glaciers have drastically decreased. In opposition, inputs into the fjord of melting freshwater with high amount of eroded material seem to increase.

In 2012/2013, the ECOTAB project aimed to investigate how spatial and seasonal changes in vertical fluxes can impact benthic compartment of the Kongsfjorden. During four field campaigns (May, August, October and January), the organic matter characteristics and prokaryotic distribution in sediments along a gradient “glacier-outer” fjord were studied through a multi-biomarker approach. The results indicated that biogeochemical parameters (organic carbon, total nitrogen, lipids, proteins, carbohydrates) exhibited a well-marked glacier-outer fjord gradient throughout all seasons with organic-poor sediments near the glacier and organic-enriched sediments close to the fjord mouth. At the station near the glacier, spring events of surface primary production were however particularly well recorded in sediments, as indicated by the high ratio of chlorophyll a to organic carbon. These steep environmental biochemical gradients influenced the prokaryotic distribution in the sediments. Overall, the spatial variability prevailed over the temporal variability in the sediments of Kongsfjorden.

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Pore water analyses in Arctic Ocean sediments – Bridging the gap between biogeochemistry and paleoceanography

The effects of modern climate change on the Arctic Ocean and sub-Arctic seas are unmistakable, changing not only the sea ice cover, but also biogeochemical cycles of nutrient elements (Si, P, N, trace metals) that directly interact with marine ecosystems. In the context of changing biogeochemical cycles, the analysis of high-latitude marine sediments provides valuable insights into the mode of operation of the Arctic environmental system during periods of past global warmth (e.g., the Eemian interglacial, the Pliocene), and interdisciplinary studies are the only way to correctly interpret the sedimentary record. Interstitial pore waters are a crucial, yet often neglected component of any sedimentary system. The chemical composition of pore waters provides unique information about diagenetic reactions within the sediments, and how those may affect paleoceanographic proxy records. It also allows for estimations of benthic element/nutrient fluxes from the sediment back into the water column, and these benthic fluxes are not currently taken into account in basin-wide nutrient budgets for the Arctic. In this presentation, I will show examples of recent pore water studies in the Arctic Ocean, focusing on (a) manganese diagenesis in Arctic sediments and its potential impact on chemostratigraphic age models, and (b) benthic recycling of silicic acid from Arctic pelagic sediments into the overlying bottom waters. I will further provide a perspective of how more extensive pore water analyses of Arctic Ocean sediments could fit into a wider, interdisciplinary research context to better understand and quantify past and present biogeochemical cycles and processes in the ever changing Arctic environment. The effects of modern climate change on the Arctic Ocean and sub-Arctic seas are unmistakable, changing not only the sea ice cover, but also biogeochemical cycles of nutrient elements (Si, P, N, trace metals) that directly interact with marine ecosystems. In the context of changing biogeochemical cycles, the analysis of high-latitude marine sediments provides valuable insights into the mode of operation of the Arctic environmental system during periods of past global warmth (e.g., the Eemian interglacial, the Pliocene), and interdisciplinary studies are the only way to correctly interpret the sedimentary record. Interstitial pore waters are a crucial, yet often neglected component of any sedimentary system. The chemical composition of pore waters provides unique information about diagenetic reactions within the sediments, and how those may affect paleoceanographic proxy records. It also allows for estimations of benthic element/nutrient fluxes from the sediment back into the water column, and these benthic fluxes are not currently taken into account in basin-wide nutrient budgets for the Arctic. In this presentation, I will show examples of recent pore water studies in the Arctic Ocean, focusing on (a) manganese diagenesis in Arctic sediments and its potential impact on chemostratigraphic age models, and (b) benthic recycling of silicic acid from Arctic pelagic sediments into the overlying bottom waters. I will further provide a perspective of how more extensive pore water analyses of Arctic Ocean sediments could fit into a wider, interdisciplinary research context to better understand and quantify past and present biogeochemical cycles and processes in the ever changing Arctic environment.

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Recent Arctic Ocean sea ice loss triggers novel fall phytoplankton blooms

Recent receding of the ice pack allows more sunlight to penetrate into the Arctic Ocean, enhancing productivity of a single annual phytoplankton bloom. Increasing river runoff may, however, enhance the yet pronounced upper ocean stratification and prevent any significant wind-driven vertical mixing and upward supply of nutrients, counteracting the additional light available to phytoplankton. Vertical mixing of the upper ocean is the key process that will determine the fate of marine Arctic ecosystems. Here we reveal an unexpected consequence of the Arctic ice loss: regions are now developing a second bloom in the fall, which coincides with delayed freezeup and increased exposure of the sea surface to wind stress. This implies that wind-driven vertical mixing during fall is indeed significant, at least enough to promote further primary production. The Arctic Ocean seems to be experiencing a fundamental shift from a polar to a temperate mode, which is likely to alter the marine ecosystem.

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Analysis of the food web of an algal belt in Kongsfjorden

The analysis of the food web of an algal belt in Kongsfjorden is based on the investigation of 3 transects at Hansneset. The transsects are located in the same place as during a study in 1996-1998 allowing the demonstration of possible alterations in community structure due to global climate changes. Species composition of plants and animals and their biomass had been studied. Samples were taken quantitatively by divers and were further processed in the Marine Lab. Data on basic ecological processes and parameters of the dominant components of the system as biomass, production, respiration and excretion have been measured. Diet analysis of heterotrophs has been done via analysis of stable isotope ratios C and N, and analysis of fatty acids. In a synthesis of the existent data on Kongsfjorden and the additionally gathered new data on the bentho-pelagic system of the habitats on hard bottom, a first model of the food web has been constructed with the “Ecological Network Analysis (ENA)”. ENA gives an analysis of the food web interactions and a characterization of the system in respect of stability, sensitivity to disturbance, with respect to energy flow and material cycling. Since climate warming is changing coastal arctic systems, the changing functioning of these ecosystems is discussed.

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Biogeochemistry of coastal water in the Canadian shelf of the Beaufort Sea (Arctic Ocean) during summer 2009

Aerosols as well as surface waters samples were collected during the MALINA field campaign (30 July to 27 August) from the Beaufort Sea in the Arctic Ocean, the Mackenzie River and atmosphere. Seawater samples were evaluated for nutrient content, primary production, dissolved and particulate organic carbon (DOC, POC) and optical characteristics including UV (ultraviolet) radiation and PAR (photosynthetically active radiation) diffuse attenuation (Kd), and chromophoric dissolved organic matter (CDOM). Our estimates for 2009, a year of high discharge by the Mackenzie River, indicate that river nutrients had a small impact on primary production at the annual time scale and a moderate one during summer, while a quarter of the estimated annual nutrient supply by the Mackenzie River occurred during July-August. Only the Mackenzie River delta and localized shelf areas directly affected by upwelling were identified as substantial sources of CO2 to the atmosphere (>10 mmolCm−2 d−1). Collectively, the data indicate that the coastal Beaufort Sea is an active regenerative system during summer, probably fueled by large pools of organic matter brought by rivers. But subsurface chlorophyll maximum sustained surprising high new production at the base of the photic zone. This study indicated CDOM as the dominant attenuator of both UV and PAR solar radiation and suggests its use as an optical proxy for DOC concentrations in this region. The discharges of DOC and its chromophoric subset (CDOM) by the Mackenzie River during the MALINA cruise are estimated as ca. 0.22 TgC and 0.18 TgC, respectively. Our results showed that carbohydrate composition (TDCHO) of dissolved organic matter (DOM) did not follow DOC patterns, which decreased from shelf to basin areas, indicating an accumulation of carbohydrates in surface waters (0–80 m). TDCHO carbohydrate component of the DOM appears to have a more pronounced marine autochthonous origin with an important contribution of terrestrial sources, especially for the shelf stations. Suspended particles results allowed us to demonstrate that in surface waters of the Beaufort Sea biodegradation and especially autoxidation processes strongly affect vascular plant lipids and probably also the other components of terrestrial organic matter delivered by the Mackenzie River. In this zone, the assumption that prior degradation of terrestrial organic matter during transit to the sea should result in good preservation of the remaining material within the marine environment is clearly not appropriate. Lipid content of sinking particles collected with sediment traps across the Canadian Beaufort Shelf showed that despite the slow irradiance measured in this zone during the summer period, Type II photooxidation processes acted strongly on senescent phytoplanktonic cells, heterotrophic bacteria and zooplanktonic faecal material. Diatoms, which dominated the phytoplanktonic assemblage, appeared to be remarkably sensitive to photodegradation. In contrast, phytoplanktonic cells seemed to be relatively preserved towards biodegradation processes in sinking POM.

Organic molecular composition of marine aerosol samples showed that primary saccharides were found to be dominant organic compound class, followed by secondary organic aerosol (SOA) tracers formed from the oxidation of biogenic volatile organic compounds (VOCs) such as isoprene, α-pinene and β-caryophyllene. This study indicates that primary organic aerosols from biogenic emissions, both from long-range transport of mid-latitude aerosols and from sea-to-air emission of marine organics, as well as secondary organic aerosols formed from the photooxidation of biogenic VOCs are important factors controlling the organic chemical composition of marine aerosols in the Arctic Ocean.

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Carbon export fluxes in the Central Arctic at different time scales using 234Th/238U and 210Po/210Pb during summer 2012

The impact of sea ice decline on primary productivity and subsequent carbon export in the Central Arctic remains unclear. Previous studies have revealed low carbon export fluxes over the central basins (<1 g C m-2 yr-1), while a massive ice algal export event was reported in the Central Arctic associated to rapid ice melt in June-July 2012 (median 9 g C m-2). Here we present results on Particulate Organic Carbon (POC) fluxes and export efficiency from the same cruise in August-September 2012 coinciding with the record minimum of sea-ice extension. To capture the export fluxes that occurred during the entire summer in 2012, we used the natural radionuclide pairs 234Th/238U and 210Po/210Pb as particle tracers integrating a time scale of weeks to months, respectively. The POC fluxes at 25 m ranged from negligible to 7 mmol m-2 d-1, averaging 2 ± 2 mmol m-2 d-1. In general, these results are in good agreement with the POC fluxes measured with short-term sediment traps deployed during the same time period, and will be discussed in relation to the net primary productivity and the overlying food web structure. Additionally, further discussion will be based on some differences observed between techniques, which suggest that 210Po/210Pb provides information about the ice-algal export that had occurred several weeks before the sampling, a time scale missed by 234Th/238U and sediment traps.

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Ocean acidification in the Arctic – the ecosystem respond to multiple stressors arising from ocean warming and chemistry changes. POLNOR project presentation – THE CHANGING OCEAN OF THE POLAR NORTH

The Arctic study area is the region most influenced by ongoing global climate change. Sea ice retreat in the central Arctic Ocean is due to warming and is leading to increased pCO2 values in the surface waters, reduced CaCO3 saturation states and increased biological production. The proposed project will provide an assessment of how the Arctic ecosystem will respond to multiple stressors arising from ocean warming, and chemistry change caused by ocean acidification (OA). OA is a decrease in pH in the oceans caused by the uptake of anthropogenic CO2 from the atmosphere and is recognized to have had negative effects on many groups of marine invertebrates with calcareous skeletons. These effects may be expressed as changes in calcification rate, decrease in abundance, and recruitment and survival rates. The project will investigate the control of ocean carbonate chemistry, hydrology, primary productivity, and energy transfer on biogenic carbonates and carbonate producers. It will investigate the effects of ocean acidification on the biodiversity and structure of benthic systems through analysis of spatial patterns of diversity, coupled with geochemical properties of the water column. By investigating records of geochemical signatures in marine sediments and organism skeletons, which can indicate anthropogenic changes over time, including OA, warming and food supply, we will be able to build comprehensive predictive models. Such information will improve simulations of future changes. Our goal is to progress new knowledge of future tipping points and thresholds for marine production and resource management. Fulfilment of the project objectives will be done through five individual but closely related and inter-dependent work packages:
1. Baseline ocean observations and contemporary modeling,
2. Marine biodiversity and ecological function,
3. Recent and subfossil geochemistry of carbonate sediments and organisms,
4. Future Arctic Ocean change and society,
5. Synthesis of the Results."

Session 6: Land-Ocean interactions: from coastal to submarine permafrost including gas hydrates

(Chair: M. Grigoriev, Co-chairs: M. Fritz and D. Mercier)

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Arctic coastal erosion mobilizes dissolved organic carbon (DOC) from permafrost

Arctic permafrost coasts make up ~34% of the world's coastline (ca. 400,000 km) and are often made of ice-rich unconsolidated sediments. This makes them highly susceptible to coastal erosion, and it is likely that large quantities of carbon are released, because permafrost soils are considered to hold approximately 50% of the global soil organic carbon pool. Current estimates of the carbon released by coastal erosion focus solely on particulate organic carbon (POC). Dissolved organic carbon (DOC) is generally not included in these calculations, because estimations of DOC contents in ground ice, which is overwhelmingly present along Arctic coasts, do not exist. In some cases, ground ice occupies as much as 90% of coastal bluffs with 40 m in height, where the coastline erodes at rates approaching 20 m/yr at its maximum. Here, we report DOC contents within permafrost from different ground ice types throughout the Arctic (Canada, Alaska, Siberia). We put them into context of Arctic organic carbon pools and fluxes, and evaluate their contribution to the Arctic carbon budget against the background of increasing permafrost degradation and enhancing coastal erosion in the future.

For example, DOC concentrations in massive ground ice bodies including ice wedges range between <1.0 and 28.6 mg/L, while ice wedges have the greatest potential as DOC pool due to their wide spatial distribution in late Pleistocene and Holocene polygonal ground. Siberian Ice Complex deposits (Yedoma) are thought to consist of up to 50% of ice wedges by volume and are therefore a substantial pool of DOC. Intrasedimental ice (non-massive) like ice lenses and pore ice are another important part of unconsolidated permafrost deposits. DOC concentrations within intrasedimental ice differ in orders of magnitude compared to massive ice and rise up to 1200 mg/L.

Although these numbers might be still small compared to the POC stocks in peat and mineral soils, DOC is chemically labile and may directly enter local food webs of the near-shore zone. Moreover, due to its lability, DOC is quickly mineralized and returned to the atmosphere when released due to permafrost degradation.
Robust estimations of how much organic carbon is potentially released from permafrost are crucial for predicting the strength and timing of carbon-cycle feedback mechanisms in the Arctic. This approach shall lead to an improved understanding of how important permafrost thaw in general and the erosion of permafrost coasts in particular are for the climate development this century and beyond. This is especially important in the Arctic before the background of expected rising air and sea surface temperatures, prolongation of the open-water season, increasing storm frequency and accelerating eustatic sea level rise.

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Effect of submarine groundwater discharge on relict Arctic submarine permafrost and gas hydrate stability

Unique permafrost-associated methane hydrate deposits exist at shallow depths within the sediments of the circum-Arctic continental shelves. Degradation of this shallow water reservoir has the potential to release large quantities of methane, a potent greenhouse gas, directly to the atmosphere. Gas hydrate stability and the permeability of the shelf sediments to gas migration is closely linked with relict submarine permafrost. Submarine permafrost extent depends on several environmental factors, such as the shelf lithology, sea level variations, mean annual air temperature, ocean bottom water temperature, geothermal heat flux, and the salinity of the pore water. The salinity of the pore water is especially relevant because it partially controls the freezing point depression for both ice and gas hydrate. Measurements of deep pore water salinity are few and far between, but show that deep off-shore sediments are remarkably fresh. Deep freshening has been attributed to large-scale topographically-driven submarine groundwater discharge, which introduces fresh terrestrial groundwater into deep marine sediments. Groundwater discharge tends to travel horizontally off-shore beneath the shallowest submarine confining unit (e.g., the impermeable permafrost layer), and a freshwater-saltwater interface is typically located where the groundwater discharge meets the seaward edge of the confining unit. However, in the case of relict submarine permafrost, the extent of the confining unit off-shore is constantly evolving both spatially and temporally, making the location of the brackish mixing zone difficult to predict without numerical techniques.

We investigate the role of terrestrial submarine ground water discharge on the salinity field and its effects on the seaward extent of relict submarine permafrost and gas hydrate stability on the circum-Arctic shelf. We have developed a shelf-scale two dimensional numerical model based on the finite volume method for two-phase flow of pore fluid and methane gas within Arctic shelf sediments. The model tracks the evolution of the temperature, salinity, and pressure fields given imposed boundary conditions, with latent heat of water ice and hydrate formation included. The permeability structure of the sediments is coupled to changes in permafrost. The model can be run over several glacial cycles. Preliminary results show that pore fluid and gas migration is strongly influenced by the permeability variations imposed by the overlying permafrost layer. The seaward permafrost extent is in turn strongly influenced by the salinity field and location of the freshwater-saltwater transition. Our preliminary results suggest that the role of salt transport and its effect on permafrost evolution can provide context for the interpretation of recent methane flux field data in the Arctic.

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Quantification of sediment physical and geothermal properties – Storage capacity for methane hydrates in Arctic continental slope sediments

Along many of the Arctic slopes, there is little published data on geothermal gradients and the relationship between methane hydrate distribution or the presence of gas escape features on the seafloor. During the second leg of SWERUS-C3 expedition to the East Siberian Sea onboard the Swedish icebreaker Oden (running from August 20 to October 4, 2014), we will focus on the quantification of sediment physical and geothermal properties in order to assess the storage capacity for methane hydrates in continental slope sediments. Field measurements will be done using the miniature temperature probes attached to the core barrels, and laboratory measurements will be made to determine in-situ porosity, permeability, thermal conductivity, surface heat flow and geothermal gradients in East Siberian Sea sediments. The presentation will focus on presenting a regional heat flow synthesis of data collected during the SWERUS-C3 expedition and comparison to available data.

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British Geological Survey remotely operated sea bed rockdrills and vibrocorers: new advances to meet the needs of the scientific community

The British Geological Survey (BGS) have developed a number of coring and drilling systems for use in science projects in the UK and internationally. These include 3m and 6m vibrocoring systems; a 5m combined rockdrill and vibrocorer system; an oriented drill designed specifically to recover samples for use in palaeomagnetic studies; and a 55m rockdrill (RockDrill2).

The BGS have developed a 55m rockdrill (RockDrill2), a remotely operated sampling system capable of coring up to 55m below sea floor in water depths up to 4000m. The rockdrill can be operated via its own launch and recovery system and can be outfitted with additional sensors such as gas flow meters, which have been designed by the BGS for assessing volume of gas hydrate, and down-hole logging tools.

The 55m rockdrill has recently been used to sample hydrate-entrained sediments in the Sea of Japan. The maximum coring depth achieved was 32m below sea floor and the system can operate for more than 50 hours on a single deployment. The BGS system will be used in conjunction with the Bremen University (MARUM) MeBo sea-floor rockdrill on future International Ocean Discovery Program (IODP) expeditions.

The BGS have also developed an autonomous, battery-operated vibrocoring system compatible with both the 3m and 6m vibrocorers, which can be used in water depths up to 6000m. Use of a battery system negates the use of an umbilical power cable to operate the vibrocorer, which instead can be deployed using the vessels A-frame and winch. The autonomous battery system comprises six 48V 19Ah batteries connected in series to give a 288V power source, a microprocessor and real-time clock. Data from the sensors are recorded with a time-stamp, giving diagnostic information that can be downloaded once the system is returned to the deck. The vibrocorer is operated via a pre-set program which is set up before deployment.

The new system not only allows vibrocoring in greater water depths, but can also be used on smaller vessels where deck space is limited as a separate winch and umbilical is not required. The autonomous system was used for the first time in June 2014 on-board the R\V Belgica to acquire samples from 20 sites in the Dangeard and Explorer canyon heads, off the southwest of England in 430m water depth.

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A roadmap for the future of permafrost research

At present, no consensus document ("white paper" or "strategy") exists at the international level to identify forward-looking priorities in permafrost research. CliC has partnered with the International Permafrost Association (IPA) to seize the opportunity offered by the upcoming International Conference on Arctic Research Planning III (ICARP III) and the SCAR Horizon Scan to frame a consultative process that will result in the formulation of such permafrost priorities. Provisionally entitled "Permafrost Research Priorities: A Roadmap for the Future", it will focus on all permafrost regions, from the Arctic to the Antarctic and mountain permafrost around the globe in order to accurately represent the level of overlap in scientific challenges in all three domains.
The product stemming from the effort will consist of a high level, but short publication (ca. 2 to 3 pages) in a high-profile journal listing and putting into context permafrost research priorities. The document aims to become the benchmark against which permafrost research should be gauged starting in 2015.
Here we present the first results stemming from this effort and focus on questions relevant to ART. In addition, we introduce selected European efforts envisioned to address these issues in the future.