EXPEDITIONSPROGRAMM NR. 93

RV POLARSTERN

PS84 (ARK-XXVIII/1)
15 May 2014 - 5 June 2014
Bremerhaven - Longyearbyen

PS85 (ARK-XXVIII/2)
6 June 2014 - 29 June 2014
Longyearbyen - Tromsø

PS86 (ARK-XXVIII/3)
1 July 2014 - 30 July 2014
Tromsø - Tromsø

PS87 (ARK-XXVIII/4)
2 August 2014 - 6 October 2014
Tromsø - Bremerhaven

Coordinator
Rainer Knust

Chief Scientists

PS84: Ingo Schewe
PS85: Benjamin Rabe
PS86: Antje Boetius
PS87: Rüdiger Stein

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PS84 (ARK-XXVIII/1)

15 May 2014 - 5 June 2014

Bremerhaven - Longyearbyen

Chief Scientist
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1.1 ÜBERBLICK UND FAHRTVERLAUF

I. Schewe (AWI)

Die Expedition PS84 (ARK-XXVIII/1) wird am 15. Mai 2014 in Bremerhaven starten und als erstes Ziel den Kontinentalhang vor Ost-Grönland ansteuern. Die hier durchgeführten Arbeiten finden vor allem im Rahmen des durch das BMBF geförderten Projekts TRANSDRIFT statt.

Das bilaterale Projekt widmet sich den folgenden übergeordneten Forschungsthemen:

- die Bedeutung der Meereis- und Ozeandynamik in der Laptewsee für das transpolare Driftsystem
- Veränderungen der arktischen Halokline, der Wassermassenbildung und des Stoff-transportes im transpolaren Driftsystem
- Ökologische Konsequenzen des Klimawandels in Schlüsselregionen der Trans–polar-drift
- Regionale Veränderungen des Systems Atmosphäre/Meereis/Ozean in der Arktis
- Stabilität des arktischen Klimasystems: Geschichte der Transpolardrift.

Vor diesem Hintergrund werden sich die Untersuchungen in dieser End-Region der Transpolardrift vor allem auf Veränderungen im gesamten System konzentrieren, welche in direktem Zusammenhäng mit den Vorgängen in der Laptevsee und im zentralen Arktischen Ozean stehen. Die Studien umfassen Untersuchungen des Meereis Ökosystems, Messungen der Arktischen atmosphärischen Grenzschicht, einem geologischen Programm zur Untersuchung der Vergangenheit der Transpolardrift und Studien der Ökosysteme in der Wassersäule und des Tiefseemeeresbodens am Ostgrönlandhang. Neben pelagischen und benthischen Probenahmen und Parasound Surveys ist auch ein kleines Mooring- und Lander-Programm auf dieser Seiter der Framstrasse geplant. In seiner Gesamtheit stellen viele der Arbeiten vor Ost-Grönland auch eine ersten Schritt dar, um die Langzeitstudien des HAUSGARTEN Observatoriums, welches ursprünglich nur vor West-Spitzbergen lokalisiert war, auch über die Framstrasse auszudehnen und in das neue HGF geförderte FRAM-Observatorium zu überführen.

Sobald die Arbeiten vor Ost-Grönland abschlossen sein werden, wird sich die Expedition nach Osten über die Framstrasse in Richtung Spitzbergen wenden und den Transit dorthin mit einigen Messungen und Probenahmen ergänzen.

Die im Bereich des HAUSGARTENs geplanten Probennahmen und *in-situ* Experimente liefern wichtige Beiträge zu dem ESFRI (European Strategy Forum on Research Infrastructures) Roadmap Projekt SIOS (Svalbard Integrated Arctic Earth Observing System) sowie zu dem EU geförderten Fixed point Open Ocean Observatory Netzwerk (FixO3). Die Arbeiten sind in verschiedenartigste Forschungsaktivitäten eingebettet, welche Studien der Veränderungen im Arktischen Meereis und ihre Auswirkungen auf die davon beeinflussten Ökosysteme und Nahrungsnetze umfassen. Diese Veränderungen werden durch eine Reihe von Untersuchungen beleuchtet, welche Langzeit-Monitoring, Experimente und Modellierungen miteinander verknüpfen. Hierunter fallen Studien zur funktionellen Spezialisierung von ausgesuchten polaren Meeresorganismen, von den Algen bis zu den Säugetieren. Diese Aktivitäten klassifizieren und quantifizieren die Reaktion von Organismen auf die fortschreitenden Veränderungen in funktionellen Schlüssel-Stufen, von molekularer bis Ökosystem Ebene. Die geplanten Arbeiten stellen einen weiteren Beitrag zur

Sicherstellung der Langzeitbeobachtung am HAUSGARTEN dar, in denen der Einfluss von klimatisch induzierten Veränderungen auf ein arktisches Tiefseeökosystem dokumentiert wird. Die im Rahmen des durch die EU und die norwegische Öl-Gesellschaft Statoil/Hydro finanzierten KONGHAU-Projekts (Impact of climate change on Arctic marine community structures and food webs) begonnenen Langzeituntersuchungen, werden durch weitere Probennahmen auf dem Spitzbergen-Schelf und im Bereich des Kongsfjords fortgesetzt. Klimabedingte Veränderungen der Phyto- und Zooplankton-Zusammensetzung in der Framstraße werden durch die am AWI etablierte Arbeitsgruppe PEBCAO (Phytoplankton Ecology and Biogeochemistry in the Changing Arctic Ocean) untersucht.

Die Expedition wird am 05 Juni in Longyearbyen enden.

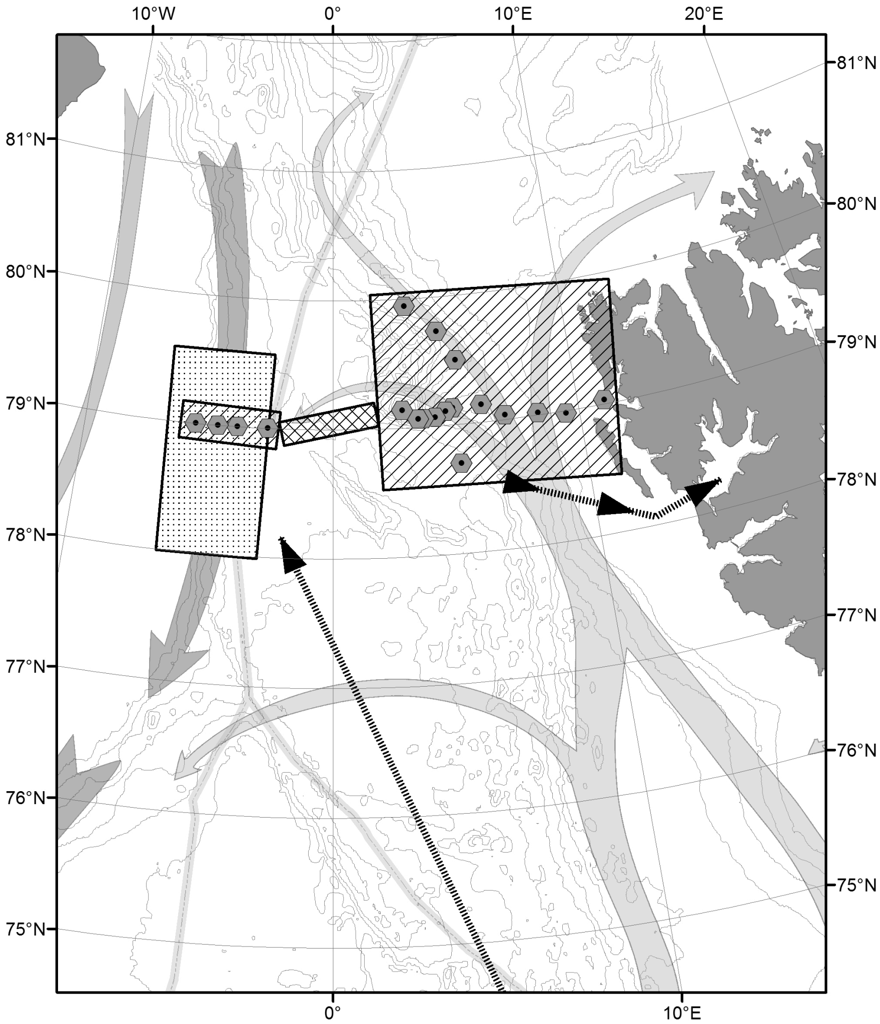

Abb. 1.1: Überblick über den geplanten Arbeitsverlauf und die Arbeitsgebiete (gestrichelte Pfeile: An- und Abfahrtsroute, gepunktete Box: Parasound Surveys, schraffierte Boxen: TRANSPOLAR & FRAM Gebiete, rautierte Box: Transit-Area, graue Sechsecke: benthische und pelagische Probennahmen).

Fig. 1.1: Overview of planned route and research areas (dashed line: access and departure routes, dotted box: parasound surveys, hatched box: TRANSPOLAR & FRAM areas, cross-hatched box: transit area, grey hexagons: benthic and pelagic samplings)

SUMMARY AND ITINERARY

The expedition PS84 (ARK-XXVIII/1) will start on 15 May 2014. The ship will depart from Bremerhaven to conduct research on two key sites within the Fram Strait. First investigations shall take place on the East-Greenland slope. One focus of investigations in this first research area will be dedicated to the BMBF funded TRANSDRIFT project.

Main objectives of the TRANSDRIFT-Project are:

- to assess the influence of sea-ice and ocean dynamics in the Laptev Sea on the transpolar drift;
- to investigate changes in the arctic halocline, water mass formation, and transport mechanisms in the transpolar system;
- to study ecological consequences of changes in key regions of the transpolar drift;
- to investigate regional variations in the atmosphere - sea-ice - ocean system;
- to study the history of the transpolar system.

On this background studies in this end region of the Transpolar Drift will focus on changes within the whole system which are directly related to processes in the Laptev Sea and the Central Arctic. Investigations during this part of the expedition cover sea-ice studies, measurements of the Arctic atmospheric boundary layer, a geological program investigating history of the Transpolar Drift and studies of the pelagic and benthic ecosystems of the East-Greenland Slope. Besides pelagic and benthic samplings and Parasound surveys, also some mooring and lander work is planned. Sea ice investigations will be supported by helicopter operations. All In all, most parts of the East-Greenland scientific program also represents a first step to transfer the HAUSGARTEN program, which was in the past many dedicated to studies in the western Fram Strait, into the new Helmholz funded long term observatory FRAM.

Once the work at the East-Greenland slope has been completed the expedition will head towards Svalbard, crossing the deep Fram Strait with some measurements and samplings in transit.

In the eastern parts of Fram Strait the work will serve various projects and concentrate on the continental margin off Svalbard (Deep-Sea Observatory HAUSGARTEN) and a short transect on the shelf towards Kongfjorden. The work planned for the HAUSGARTEN area will contribute to the ESFRI (European Strategy Forum on Research Infrastructures) Roadmap project SIOS (Svalbard Integrated Arctic Earth Observing System) as well as to the EU funded Fixed point Open Ocean Observatory network (FixO3). The work is embedded in various research activities through studies on changing Arctic sea ice conditions and their impact on ecosystems and food webs. These changes will be addressed through a dedicated combination of long-term observations, experimental work, and modelling. Those include studies on the functional specialization of selected polar marine species, from algae to mammals, on polar climate regimes and associated living conditions. These activities qualify and quantify the responses of model organisms to ongoing warming trends at key functional levels, from molecular to ecosystem. Building on recent progress, they also characterize the physiological and ecological background of species-specific sensitivities as well as the capacity of organisms and ecosystems to acclimate or adapt to change. The research contributes to the time-series studies at HAUSGARTEN, where we investigate the impacts of Climate Change on an Arctic marine deep-sea ecosystem through field studies and models since 1999. Research activities started within the framework of the former KONGHAU project (Impact of climate change on Arctic marine community structures and food webs), co-financed by the EU and the Norwegian oil company Statoil/Hydro, will be continued by taking additional samples on the continental shelf off Svalbard and inside

Kongsfjorden. Climate-induced changes of phyto- and zooplankton communities in Fram Strait will be investigated by the AWI research group PEBCAO (Phytoplankton Ecology and Biogeochemistry in the Changing Arctic Ocean).

The cruise will end on 05 June in Longyearbyen.

1.2 IMPACT OF CLIMATE CHANGE ON ARCTIC MARINE ECOSYSTEMS

E. Bauerfeind, C. Hasemann, U. Hoge, T. Küber, C. Lalande, N. Lochthofen, A. Pappert, B. Sablotny, I. Salter, I. Schewe, J. Taylor (AWI); S. Schütte (AWI/); S. Cordes, S. Rößler (Fielax); H. Lilienthal (Isitec)

Objectives

The marine Arctic has played an essential role in the history of our planet over the past 130 million years and contributes considerably to the present functioning of the Earth and its life. The past decades have seen remarkable changes in key arctic variables, including a decrease in sea-ice extent and sea-ice thickness, changes in temperature and salinity of arctic waters, and associated shifts in nutrient distributions. Since arctic organisms are highly adapted to extreme environmental conditions with strong seasonal forcing, the accelerating rate of recent climate change challenges the resilience of arctic life. The stability of a number of arctic populations and ecosystems is probably not strong enough to withstand the sum of these factors which might lead to a collapse of subsystems.

The Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI) established the deep-sea long-term observatory HAUSGARTEN to detect and track the impact of large-scale environmental changes in the transition zone between the northern North Atlantic and the central Arctic Ocean, and to determine experimentally the factors controlling deep-sea biodiversity. This observatory is the first, and until now the only open-ocean long-term station in a polar region.

The HAUSGARTEN observatory in the eastern Fram Strait includes 16 permanent sampling sites along a depth transect (1,000 - 5,500 m) and along a latitudinal transect following the 2,500 m isobath crossing the central HAUSGARTEN station. Multidisciplinary research activities at HAUSGARTEN cover almost all compartments of the marine ecosystem from the pelagic zone to the benthic realm, with some focus on benthic processes. Regular sampling as well as the deployment of moorings and different free-falling systems (bottom-lander) which act as local observation platforms, have taken place since the observatory was established in summer 1999. Frequent visual observations with towed photo/video systems allow the assessment of large-scale epifauna distribution patterns as well as their temporal development.

In addition to the time-series work at the HAUSGARTEN observatory, our work during PS84 (ARK-XXVIII/1) include the sampling at additional stations from ~1,000m depth on to the shelf off Svalbard, thereby continuing time-series work started within the former international project KONGHAU ("Impact of climate change on Arctic marine community structures and food webs"), co-financed by the EU Integrated Project HERMES ("Hotspot Ecosystem Research on the Margins of European Seas") and the Norwegian oil company Statoil/Hydro. The KONGHAU project combined data collected over the past 10 years from time-series work at Kongsfjord and HAUSGARTEN observatory.

Within the frame of the BMBF project TRANSDRIFT ("System Laptewsee"), the work currently performed in the HAUSGARTEN area should be extended by 4 additional stations in the western part of the Fram Strait from ~2,500m depth to the 1,000m isobath at the Greenland slope. Here sediment samples should be taken by multiple corer and box corer to record benthic organisms of different size classes.

To investigate the impact of a changed primary production on meiobenthic organisms, which is likely to happen in the future, a long-term enrichment experiment of sediments should be installed at 2,500 m water depth.

Work at sea

During the cruise hydrographic data will be assessed at all stations using a cabled CTD-rosette system. Long-term measurements of the vertical particle flux at HAUSGARTEN are conducted since the establishment of the observatory in 2000. By means of these measurements we are able to quantify the export of organic matter from the sea surface to the deep sea, and trace changes in these fluxes over time. The organic material which is produced in the upper water layers or which is introduced from land is the main food source for deep-sea organisms. Measurements of organic matter fluxes are conducted by bottom tethered moorings carrying sediment traps at a ~200 m, 1,000 m below sea-surface, and about 180 m above the seafloor. Besides sediment traps the moorings are also equipped with Aanderaa current meters (RCM 11) and self-recording CTD's (Seabird MicroCats). During PS84 (ARK-XXVIII/1), we will exchange moorings and instruments that were deployed at ~2,500 m water depth at the central HAUSGARTEN site (79°00'N/04°20'E), and at a position in the northern HAUSGARTEN area (79°43'N/04°30'E) during the cruise MSM29 in 2013.

At the central HAUSGARTEN station we will also deploy a mooring equipped with a prototype of a profiling winch system carrying a sensor package. This device has been developed within the BMBF project "ICOS-D" and shall conduct measurements within the upper 200 m of the water column at regular preprogramed intervals. At present the sensor package consist of instruments for measuring carbon dioxide, oxygen, conductivity, temperature, pressure (CTD) and chlorophyll fluorescence.

Additional to the moorings at HAUSGARTEN a long-term mooring equipped with sediment traps shall be deployed in western Fram Strait at ~2,500 m water depth (~79°N,3°W) within the project TRANSDRIFT ("System Laptewsee").

At all stations where moorings are deployed, we will conduct CTD-rosette casts from the surface close to the seafloor. Water samples will be taken for the analyses of chlorophyll a, particulate organic carbon and nitrogen (POC/N), biogenic particulate silica (bPSi, total particulate matter (seston), calcium carbonate ($CaCO_3$), and stable isotopes ($\delta^{15}N/\delta^{1}3C$) content in the particulate matter. This work as well as the sampling at the other HAUSGARTEN stations will be conducted in close cooperation with the PEBCAO group. For further details regarding the work in the water column see the contribution of the PEBCAO group (Chapter 1.6).

A free-falling device supporting a current meter, optical oxygen sensors (optodes), and a smaller sediment trap at 2.5 m above ground will be replaced. Another bottom-lander carrying colonisation-cores with azoic, organically-enriched artificial sediments will be deployed to study the attraction of "plain" sediments to meiofauna organisms, focussing on nematode communities.

Virtually undisturbed sediment samples are taken using a video-guided multiple corer (MUC). Various biogenic compounds from these sediments are analysed to estimate activities (e.g. bacterial exoenzymatic activity) and the total biomass of the smallest sediment-inhabiting organisms. Results will help to describe ecosystem changes in the benthal of the Arctic

Ocean. Sediments retrieved by the MUC will also be analysed for the quantitative and qualitative assessment of the small benthic biota.

During the cruise PS84 (ARK-XXVIII/1) the study on inter-annual dynamics of megafaunal organisms using our towed photo/video system OFOS (Ocean Floor Observation System) we will be continued. The OFOS will be towed along established tracks at HAUSGARTEN stations of the latitudinal transect (N3, N5, HG-IV, S3). The new footage will extend our image time series that started in 2002. Additionally to the sections described above we will also perform a video transect in the western Fram Strait.

Particle-attached and free-living bacterial communities

The E-W transect from Svalbard to Greenland traverses distinct hydrographic regions. This year the transect will be extended westwards to incorporate several stations in the core of the East Greenland Current (EGC). The EGC is the main conduit for waters exiting the Arctic Ocean. In addition to low-salinity Polar water and sea ice, the East Greenland Current transports deep and intermediate waters exiting the Arctic Ocean and Atlantic Water re-circulating in the Fram Strait. It is possible that EGC waters contain a terrestrial particulate organic carbon signatures originating from the Arctic shelves and sea-ice and transported out of the Arctic through the FRAM strait. The objectives of this pilot study are two-fold:

(1) Examine the horizontal and vertical scales in phylogenetic composition of particle attached and free-living communities across the Fram Strait.

(2) Characterize the source and composition of POM in surface waters across the FRAM strait and relate this to particle-attached bacterial communities.

Water column sampling

Objective A

Water samples will be collected from Niskin bottles of the CTD rosette casts. Optimally samples will be taken from each station if possible. The minimum requirement for horizontal sampling requirement would be two stations in the East Greenland Current, two stations in the West Spitzbergen Current, and two stations at the central Hausgarten site. One litre water samples will filtered with a peristaltic pump fitted with an inline filtration system to separate bacterial communities associated with particles >5µm.

Objective B

Water samples will be collected from Niskin bottles of the CTD rosette casts. These samples will be treated as described above in Objective A. The vertical resolution of these samples will be restricted to one depth. In addition to collecting samples for bacterial community structure, 10 - 20 litres of water will be collected onto GF/F filters to measure lipid biomarkers. The goal will be to use the lipid biomarkers of particulate material to assign POC source and combined with bacterial community structures to assess whether carbon with specific terriginous signatures are associated with specific bacterial communtities. Where possible these samples will be coordinated with those collected for particulate analyses of amino acids and carbohydrates. Combining this information will facilitate a preliminary assessment on the link between organic composition of particulate substrates and particle-attached bacterial communities.

Pilot deployment of Aquamontior discrete water sampler

One important challenge for ecosystem observations is to establish new technologies that can remotely sense or sample specific properties of water masses. Although this is an important goal in all observation based programmes it is particularly relevant in the Fram strait where access to a particular site can be severely restricted by seasonal access to sampling. The objective of this deployment is to test the use of the aquamonitor to collect and store water samples over a time period of one year to analyse macronutrient concentrations. The long-term objective of this activity would be to integrate these types of autonomous sampling systems onto moorings to monitor changes in nutrient concentrations over an annual cycle. For PS84 (ARK-XXVIII/1) this system will be deployed with a custom built benthic lander to make these measurements at one of the central Hausgarten sites. This study is a proof of concept for autonomous water samplers that may eventually be configured to conduct incubation studies at *in-situ* temperature and pressure conditions.

Data management

Sample processing will be carried out at AWI and cooperating institutions. Data acquisition from the several types of investigation will be differently time-consuming. The time periods from post processing to data provision will vary from one year maximum for sensor data, to several years for organism related datasets. Until then preliminary data will be available to the cruise participants and external users after request to the senior scientist. The finally processed data will be submitted to the PANGAEA data library. The unrestricted availability fro PANGAEA will depend on the required time and effort for acquisition of individual datasets and its status of scientific publication.

1.3 BENTHIC MICROBIOLOGY

C. Bienhold, K. Hoffmann, J. Rapp, S. Becker (AWI/MPI)

Objectives

Even though the deep-sea floor covers more than half of the Earth's surface, it remains one of the least understood ecosystems. Bacteria can make up to 90 % of benthic biomass in the deep sea, and therefore play a central role in carbon and nutrient cycles at the seafloor (Jørgensen & Boetius 2007). Yet, key bacterial players and their specific functions, e.g. in organic matter remineralization, in deep-sea surface sediments remain largely unknown. Also, the effects of pressure/depressurization on environmental microbial communities from the deep sea are still not well understood. We will address these questions using environmental samples from HAUSGARTEN, both for direct analyses of bacterial diversity and activity, as well as for experimental set-ups, including incubations of deep-sea sediments at *in-situ* pressure. Samples from HAUSGARTEN stations will also contribute to the continuation of time-series analyses of bacterial diversity at this site (Jacob et al. 2013, Jacob et al. unpublished). With experimental set-ups and the analysis of dissolved organic matter (DOM) in sediment porewaters, we want to develop a better understanding of the dynamics of organic matter degradation by environmental bacterial communities. In addition to benthic work, we plan to include sampling of the deep water column (CTD rosette), as well as subsampling of sediment trap material, in order to investigate links between the pelagic and benthic environments in terms of bacterial diversity (e.g., Kellogg and Deming 2009). The work will be carried out in the framework of the European Research Council Advanced Investigator grant ABYSS (A. Boetius).

Work at sea

Sediment samples

A video-guided multiple corer (TV-MUC) will be deployed to retrieve undisturbed sediment samples from the seafloor. Samples will be fixed for the determination of microbial cell numbers and for microbial DNA/RNA extractions. The respective analyses will be performed in the home laboratory.The upper sediment layers will also be sampled for a characterization of the geochemical environment, e.g. chlorophyll pigment concentrations, total organic carbon content (see also Chapter 1.2).

Live sediments obtained from TV-MUC cores will be used to initiate feeding experiments with chitin and algal material (partly using ^{13}C stable isotope labeled substrates) at *in-situ* temperature and at both atmospheric and *in-situ* pressure directly on board. Subsamples will be taken for the determination of prokaryotic cell numbers, microbial diversity, dissolved inorganic carbon, and potential extracellular enzyme activity. Additional live sediments will be stored at 0°C for further analyses and experiments in the home laboratory.

Furthermore, benthic chambers of lander deployments (see Chapter 1.4) will be sampled for microbiological analyses, including microbial cell numbers and diversity.

Dissolved organic matter

Porewater samples for experimental set-ups and the analysis of dissolved organic matter will be retrieved from modified MUC cores (with pre-drilled holes) using rhizones (http://www.rhizosphere.com/rhizons). Ultra high-resolution mass spectrometry (i.e. Fourier Transform Ion Cyclotron Resonance Mass Spectrometry) will be performed in the home laboratory (with P. Rossel, AWI/MPI and T. Dittmar, ICBM Oldenburg/MPI).

Water samples

Deep-water samples will be retrieved from the CTD rosette. Water samples will be fixed for the determination of prokaryotic cell counts, and will be filtered (0.22 µm) and stored frozen for the determination of microbial diversity.

Data management

Post-cruise data archival will be mainly hosted by the information system PANGAEA at the World Data Center for Marine Environmental Sciences (WDC-MARE), which is operated on a long-term base by the Alfred Wegener Institute, Helmholz Centre for Polar and Marine Research, Bremerhaven and the MARUM, Bremen. Scientific data retrieved from observations, measurements and home-based data analyses will be submitted to PANGAEA either upon publication, or with password protection as soon as the data are available and quality-assessed. This includes also biological data, for most of which parameters are already defined in PANGAEA. Molecular data will be deposited in globally accessible databases such as GenBank. Microbiological samples will be stored deep frozen or fixed at the Max Planck Institute in Bremen.

References

Jørgensen BB, Boetius A (2007) Feast and famine - microbial life in the deep-sea bed. Nat Rev Microbiol 5: 770-781.

Jacob M, Soltwedel T, Boetius A, Ramette A (2013) Biogeography of Deep-Sea Benthic Bacteria at Regional Scale (LTER HAUSGARTEN, Fram Strait, Arctic). PLoS ONE 8: e72779.

Kellogg CTE, Deming JW (2009) Comparison of free-living, suspended particle, and aggregate-associated bacterial and archaeal communities in the Laptev Sea. Aquat Microb Ecol 57: 1-18.

1.4 BIOGEOCHEMISTRY OF DEEP-SEA BENTHIC COMMUNITIES

U. Braeckman (MPI/UGent), R. Hoffmann (AWI), V. Asendorf (MPI),
F. Wenzhöfer (not on board)

Objectives

Deep-sea benthic communities are strictly dependent on carbon supply through the water column which is determined by temporal and spatial variations in the vertical export flux from the euphotic zone but also lateral supply from shelf areas. Most organic carbon is recycled in the pelagic, but a significant fraction of the organic material ultimately reaches the seafloor, where it is either re-mineralized or retained in the sediment record. Benthic oxygen fluxes provide the best and integrated measurement of the metabolic activity of surface sediments. They quantify benthic carbon mineralization rates and thus can be used to evaluate the efficiency of the biological pump (export of organic carbon from the photic zone).

Work at sea

Benthic carbon mineralization will be studied *in-situ* at three sites (HAUSGARTEN HG-IV, East Greenland EG-IV and Konghau KH-2), as well as *ex-situ* along two depth gradients (East Greenland transect from 2,500m to 1,000m and Konghau transect from 1,300m to 290 m). The benthic O_2 uptake is a commonly used measure for the total benthic mineralization rate. We plan to measure benthic oxygen consumption rates at different spatial and temporal scales. A benthic lander will be equipped with different instruments to investigate the oxygen penetration and distribution as well as the oxygen uptake of the arctic sediments: (1) Microprofiler, for high-resolution pore water profiles (O_2, T, resistivity) and (2) Benthic chamber, to measure the total oxygen consumption and nutrient exchange of the sediment. The overall benthic reaction is followed by measurement of sediment community oxygen consumption to calculate carbon turnover rates. In addition, we will take sediment samples for ^{210}Pb depth profiles (measure for bioturbation and/or sediment accumulation) and add a bromide tracer to the *ex-situ* experiments (to quantify bio-irrigation).

Multicorer samples will be used to measure onboard gradients and fluxes, and to retrieve sediment samples for fauna and microbial community analysis. From the sediments recovered from the benthic chambers and MUC cores, we will take subsamples to quantify microbial and meiofauna biomass and sieve out the larger macrofauna. We will further identify these organisms and try to relate their functional biodiversity (how they bioturbate) to the fluxes observed.

Data management

Post-cruise data archival will be mainly hosted by the information system PANGAEA at the World Data Center for Marine Environmental Sciences (WDC-MARE), which is operated on a long-term base by the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven and the MARUM, Bremen. Scientific data retrieved from observations, measurements and home-based data analyses will be submitted to PANGAEA either upon publication, or with password protection as soon as the data are available and quality-assessed. This includes also biological data, for most of which parameters are already defined in PANGAEA. Microbiological samples will be stored deep frozen or fixed at the Max Planck Institute in Bremen.

1.5 AWI-ARCTICNET COLLABORATION ON ARCTIC MARINE OBSERVATORIES

L. Fortier, C. Aubry S. Meredyk (ArcticNet)

Objectives

The participation of ArcticNet to the 2014 HAUSGARTEN expedition in Fram Strait is a first step towards the development of a Canadian-German collaboration on Arctic marine observatories. The ultimate objective of this collaboration is the joint implementation of a Canadian observatory in Baffin Bay that would be coordinated with and would complement the HAUSGARTEN observatory in the study of the outflows of the Arctic Ocean and the changing balance of freshwater inputs around Greenland.

Work at sea

During this expedition, ArcticNet will deploy 2 McLane Moored Profilers (MMP) in Fram Strait. The MMP is an autonomous time-series instrument that profiles the water column by travelling along a fixed wire carrying an array of sensors (Fig. 1.5.1). Sensors measure conductivity, temperature, and depth (Seabird 52), dissolved oxygen (Seabird 43f), and chlorophyll a (Seapoint). The MMPs will profile between 90 and 300 m depth every 13 hours for a 1-year deployment period, with sensors reading every 2 seconds.

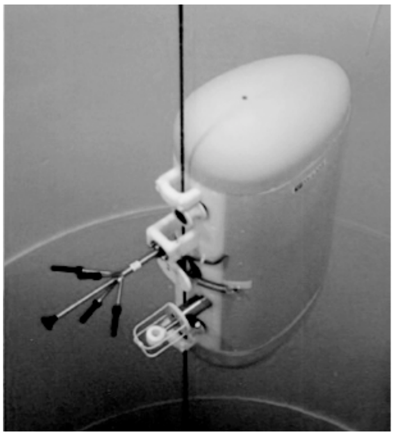

Fig. 1.5.1: McLane Moored Profiler (MMP)

The first MMP will be deployed adjacent to the sediment trap mooring deployed as part of the TRANSDRIFT project near the Greenland shelf and influenced by the East Greenland Current flowing out of the Arctic Ocean. The second MMP will be deployed adjacent to the sediment trap mooring deployed at the HAUSGARTEN central station and influenced by the warm West Spitsbergen Current flowing into the Arctic Ocean.

The overarching objective of this first joint operation is for the Canadian team to study the HAUSGARTEN observatory and assess the costs and timeframe for the implementation of a similar observatory in Baffin Bay in the Canadian Arctic.

Data management

Preprocessing of data acquired in the frame of this ArcticNet-FRAM cooperation will take place at the Université Laval in Quebec, Canada. Final data will be made public available in due time in the PANGAEA library or any comparable open access database.

1.6 PLANKTON ECOLOGY AND BIOGEOCHEMISTRY IN THE CHANGING ARCTIC OCEAN (PEBCAO-GROUP)

B. Niehoff, R. Gonçalves Araujo, N. Hildebrandt, S. Micheller, S. Murawski, C. Otten, I. Peeken, H. Tonkes, M. Winkler (AWI); S. Bold (GEOMAR), J. Piontek (GEOMAR) ;

A. Bracher, S. Gäbler-Schwarz, K. Metfies, E.-M. Nöthig (AWI, not on board); A. Engel (GEOMAR, not on board)

Objectives

The Arctic Ocean has gained increasing attention over the past years because of the drastic decrease in sea ice and increase in temperature, which is about twice as fast as the global mean rate. In addition, the chemical equilibrium and the elemental cycling in the surface ocean will alter due to ocean acidification. These environmental changes will have consequences for the biogeochemistry and ecology of the Arctic pelagic system. The effects of changes in the environmental conditions on the polar plankton community can only be detected through long-term observation of the species and processes. Our studies on plankton ecology have thus recently been established as part of the AWI time-series studies at the Deep-Sea Observatory HAUSGARTEN.

Climate induced changes will impact the biodiversity in pelagic ecosystems. A shift in species composition is expected to occur in all phytoplankton size classes. Smallest algae may thrive the phytoplankton in the future Arctic Ocean while large species may occur less frequently. Thus, small algae will gain more importance in mediating element and matter turnover as well as energy fluxes in Arctic pelagic systems. Also other algae such as Phaeocystis pouchetii, which has a wide size range from small flagellates to large gelatinous colonies and can play a key role in the carbon and sulphur cycle, increases in abundance in the Arctic. However, little is known about its diversity, distribution and physiology in Arctic pelagic regions.

Molecular methods are well suited to provide refined information on the composition and biogeographical differences of arctic phytoplankton communities, including the smallest fractions. The characterization of phytoplankton communities with molecular methods is independent of cell-size and distinct morphological features. The assessment of the biodiversity and biogeography of Arctic phytoplankton will be based on the analysis of ribosomal genes, taking advantage next generation sequencing technology, Automated Ribosomal Intragenic Sequence Analysis (ARISA), and quantitative PCR.

Based on the awareness, that global change increasingly affects marine ecosystems, we also examine the ‘present day’ state of pelagic microbial biogeochemistry in the Arctic Ocean, with emphasis on production and turnover of organic matter. For this purpose, rate measurements on phytoplankton and bacterial production and abundance will be carried out. Concentrations of organic carbon and nitrogen as well as of specific compounds like amino acids and sugars will be analysed. Our overarching goal is to improve the mechanistic understanding of biogeochemical and microbiological feedback processes in the Arctic Ocean and to assess the potential for changes in the near future.

Phytoplankton primary production and CDOM photo-oxidation have opposing impacts on carbon fluxes in the ocean. The balance between the two processes may be significantly affected in the near future by climate change. This is especially true for the Arctic Ocean, which is increasingly exposed to light as perennial ice recedes, and which receives increasing amounts of terrigenous dissolved organic matter (tDOM) as the permafrost thaws and river discharges increase. There is a need to assess the amount of loading by terrestrial CDOM versus the contribution from marine CDOM and quantify the influence on phytoplankton. Since the photons by CDOM and phytoplankton pigments absorb different (shorter) wavelengths than the photons are emitted via fluorescence, the fluorescence signal can especially be seen in reflectance data at the Fraunhofer lines, the wavelengths where due to strong absorption by molecules in the photosphere, the solar irradiance is nearly zero. Therefore, there is also a focus on the development of retrievals using high spectrally resolved reflectance data to detect marine and terrestrial coloured dissolved organic matter and phytoplankton pigment composition. At the field sites also hyperspectral irradiance and radiance above the water is measured which are used to calculate the reflectance above those waters. In a later step the effect of inelastic scattering is analysed for each compartment. This research will give a fundamental contribution for further development of hyper- and multispectral ocean colour satellite retrievals focusing on fluorescence and absorption signals.

The zooplankton community composition may shift due to warmer Atlantic water prevailing in the Fram Strait over the last 10 years. In addition, zooplankton organisms are also affected by changes at the base of the food web and may thus alter the transport and modification of organic matter.

During PS84 (ARK-XXVIII/1) the following topics are covered:

- Monitoring plankton species and biomass distribution as well as biogeochemical parameters in the East Greenland Current and in the AWI HAUSGARTEN
- Investigations on selected phyto- and zooplankton and related biogeochemical parameters
- Investigations on nanoplankton with focus on key species Phaeocystis pouchetii
- Production, degradation and composition of organic matter in a changing Arctic Ocean
- Investigation on the amount and composition of CDOM and its interplay with phytoplankton

Work at sea

Biogeochemical & biological parameters from rosette samples

We will sample arctic seawater by CTD/rosette sampler along the oceanographic transect (~79°N) at about 5 - 8 depths. All samples will be partly filtered and preserved or frozen at 20°C and partly at –80°C for further analyses. At the home laboratory at AWI we will determine the following parameters to describe the biogeochemistry and the abundance and distribution of protists:

- Chlorophyll a concentration (total phytoplankton community and picoplankton-fraction)
- HPLC pigments
- CDOM (coloured dissolved organic matter)
- Dissolved organic carbon (DOC)
- Particulate organic carbon (POC)
- Total dissolved nitrogen (TDN)
- Particulate organic nitrogen (PON)
- Particulate biogenic silica (PbSi)
- Transparent exopolymer particles (TEP)
- Coomassie-stainable particles (CSP)
- Combined carbohydrates, amino acids

- Light absorption by phytoplankton and particulate matter
- Light absorption and fluorescence by CDOM
- Alkalinity
- Phytoplankton & protozooplankton abundance
- Sampling for genetic analyses & clonal cultures
- Sampling for molecular-biological assessments of protist communities
- Flow cytometer (bacterial cell numbers and autotrophic pico- and nanoplankton)
- Bacterial biomass production
- Primary production (selected stations)

Culturing phytoplankton

We will isolate phytoplankton species (mainly Phaeocystis pouchetii) from the CTD/rosette sampler and hand-net (Apstein net) hauls along the 79°N transect for establishing clonal cultures. Later at AWI, genetic analyses will be carried out with the isolates.

Zooplankton sampling and experimental work

Mesozooplankton composition and depth distribution will be determined by means of vertical Multi net tows from 1,500m depth to the surface. In addition, optical surveys with the LOKI (light on-sight key species investigations) will be conducted to determine the small-scale distribution of zooplankton in the water column. Bongo net hauls will be taken to collect organisms for biochemical analyses (carbon, nitrogen, protein and lipid content, fatty acid composition), enzyme activity analyses (citrate synthase, digestive enzymes) and molecular analyses of phytoplankton communities in the stomach of zooplankton organisms. We will also sort live animals from these samples for conducting experiments.

In experiments, we will study the response of dominant Arctic copepods to different algal species (Thalassiosira weissflogii, diatom, and Oxhyrris marina, dinoflagellate) by means of incubation experiments. Particularly we will focus on grazing, egestion and egg production rates in relation to food quality, which will all be measured onboard. In addition, we will deep freeze individuals over the course of the experiment to determine changes in body mass and enzyme activities. This will elucidate the extent to which the copepods are dependent on the spring diatom bloom and their flexibility in exploring different food resources.

Optical profiling

The Apparent Optical Properties of water (AOPs) (mostly light attenuation through the water column) will be estimated based on downwelling and upwelling irradiance using radiometers for collecting data *in-situ*. These are calibrated for the incident sunlight with measurements of a radiometer on deck.

Molecular analysis of phytoplankton

The occurrence of selected phytoplankton taxa that regularly significantly contribute to phytoplankton communities in the Fram Strait will be assessed via molecular methods. We will use taxon specific primer sets to screen water samples via quantitative PCR on board-ship for the presence of Phaeocystis sp., different strains of Micromonas pusilla, dinoflagellates, and Chaetoceros sp.

Preliminary (expected) results

We expect similar results including trends like we observed during the other years of our time-series investigations. Results will strongly depend on the physical and chemical environmental settings in the field.

Data management

During our cruises, we sample a large variety of interconnected parameters. Many of the samples (i.e. pigment analyses, particulate matter in the water column, etc.) will be analysed at AWI and at GEOMAR within about a year after the cruise. We plan that the full data set will be available at latest about two years after the cruise. Most of species samples and samples which will not been analyzed immediately will be stored at the AWI at least for another 10 years and will be available for other colleagues. Data will be made available to the public via PANGAEA after publishing (depending on how many comparisons will be made, long-term study 2 to 5 years after the cruise).

1.7 SEA ICE STUDIES – ECOLOGICAL CONSEQUENCES OF CLIMATE CHANGE IN THE FRAM STRAIT, A KEY REGION OF THE TRANSPOLAR DRIFT (PEBCAO-GROUP)

I. Peeken (AWI), L. C. Lund-Hansen, B. Sorrell and B. Ziersen (UA), M. Nicolaus, R. Ricker (AWI, not on board)

Objectives

Sea ice is of major importance in the polar oceans since it affects the solar radiation fluxes due to its reflective properties and is a habitat and feeding ground for various organisms of the polar ecosystem. The Arctic Ocean is now in a state of rapid transition that is best exemplified by the marked reduction in age, thickness and extent of the sea ice cover, at least in summer. The European Arctic margin is largely influenced by drift ice formed on the Siberian shelves and carried to the Fram Strait via the Transpolar Drift. Sea ice thickness for the various regions of the Transpolar Drift between 1991 and 2007 showed a reduction in modal ice thickness from 2.5 m towards 0.9 m. A long-term trend towards thinner sea ice has profound implications for the timing and position of the Seasonal Ice Zone and the anticipated ice free summers in the future will have major implication for the entire ecosystem and thus alter current biogeochemical cycles in the Artic.

Due to the generally low solar elevation light is considered to be the key factor for primary production in the ice covered oceans. Light penetration in the Arctic is generally reduced by the sea ice cover and additionally snow greatly reduces light transmission through the ice. In the framework of climate warming, the atmospheric moisture budget in the Arctic is forecast to change, resulting in an increasing snow cover and thus reducing the light for primary production. However, the reduction from MYI to seasonal ice and additional increase of melt ponds on FYI will substantially increase light transmission through ice.

Due to the extreme low light intensities caused by the albedo and the strong attenuation of the ice itself and snow, primary production of ice algae is generally thought to be low compared to large ice edge phytoplankton blooms. However, low light penetration and the increasing attenuation towards longer wavelengths in the ice can be compensated for by the algae by modifying their accessory photosynthetic pigments, and thus these organisms are well-adapted to the very low light conditions in early spring. Once blooming, the brown ice algae assemblages at the bottom of the ice cores can have a major impact on the optical properties of the sea ice. Sudden changes in the light field can result in a dramatic loss of algae biomass and production, which can only be compensated for by other parts of the marine community. Currently ice algae are very well adapted to their low light environment and, despite their moderate production, early in the season are the only food source for the pelagic fauna. In particular, in spring the sea-ice algae blooms are essential for the development stages of copepods which fuel higher trophic levels in the Arctic.

Due to the decrease of the sea ice thickness, evolving habitats for sea ice algae have been observed in surface melt ponds. These new evolving ecosystems in Arctic melt ponds might have consequences for the carbon budget, leading to major implications for the cryo-benthic and cryo-pelagic coupling of the Arctic Ocean. Changes in sea ice habitat structure and ice algal production will affect the trophic transfer of sea ice-derived carbon through the under-ice community into pelagic food webs, with unknown consequences for biodiversity, ecosystem functioning and resource availability.

During PS84 (ARK-XXVIII/1) we aim to study the following topics:

- Investigate sea ice biota at the end of the Transpolar Drift and compare with historic data
- Reveal the role of melt pond associated communities for the ecosystem
- Improve estimates of spatial variability of sea ice algae
- Determine the snow cover in spring for the validation of satellite data
- Access the photosynthetic performance of sea ice algae in late spring
- Study adaptation to various light intensities
- Estimate the spectral light and absorption under the ice under various natural conditions

Work at sea

Biological, Physical &, Chemical Biogeochemical parameters of sea ice

Helicopter flights for sea-ice stations will be performed along the cruise track as often as weather conditions allow. Observations of sea-ice, snow, melt-pond, and weather conditions will be performed along the track from the bridge of *Polarstern* in cooperation with other groups. These observations may be supported by automated observations through cameras, recording ice conditions continuously from a point above the bridge.

During the ice stations we will take ice cores for biological, chemical and biogeochemical analyses. We will further sample the water under the ice and if present, melt pond water. The depth of the sampling under the ice will be based on the profiles of the CTD and fluorescence probe which will be conducted prior to the water sampling. We will estimate measure environmental parameters as sea ice temperature, snow depth, free board, ice thickness, water flow velocity below the ice, and directly on the ice floe. We will further run grids of snow depth (Snow Hydro Magna Probe) on the ice station for the validation of satellite data. A hyperspectral radiometer will be used to measure the spectral composition of the light under the ice for distinguishing the ice-algae biomass. Point measurements with this type of sensor will be carried out in drill holes for a direct validation of the hyperspectral estimates of ice-algae concentrations with pigment measurements from ice cores and further optical properties as particle absorption and CDOM from entire sea ice cores. Measurements of light will be carried out under and above the ice. Photosynthetic performance of sea ice algae will be directly determined on the ice floe by using a Waltz Imaging-PAM fluorometer.

The water and ice core samples will be transported back to the ship. A regular sea ice sampling involves the collection of melted ice-core sections, under-ice water and melts pond water. In general we aim to collect the following variables: salinity, nutrients, coloured dissolved organic matter (CDOM), dissolved inorganic carbon (DIC), and filters for particulate N, P and C. Additionally, algae biomass and composition will be determined by size-fractionated chlorophyll, marker pigments, molecular markers and cell counts (microscopy and flow cytometer). Also biogenic silicate, particulate organic carbon and nitrogen (POC, PON) and the isotopic composition of POC and PON (δ^{13}CPOC and δ^{15}NPON) will be determined.

Flow cytometer measurements of the pico- and nanoplankton from all habitats including the entire water column will be directly counted on board. All other samples will be stored and measured at the AWI/Arhus for determination of all other variables.

Preliminary (expected) results

The aim of this study is to understand the variability of the sea ice-associated biomass with respect to the sea ice conditions and nutrient availability, to access the role of sea-ice biota for the cryo-pelagic, cryo-benthic coupling under different environmental scenarios. Special emphasis will be given to understand the role of melt ponds in the carbon cycling of the Arctic Ocean. These data can be used for modelling approaches to access the role of climate change on the carbon cycle of the Arctic Ocean.

Data management

Samples

Except for the microscopic samples, all other variables taken during the cruise will be processed during or after the cruise (1 year). Leftovers of the microscopic samples and the DNA will be stored at the Polar Biological Oceanography at the AWI for approximately 10 years.

Data

Data from Ice work will be collected during and after the cruise. The entire data set will be submitted to PANGAEA within 1-2 years. The unrestricted availability from PANGAEA will depend from the progress of a PhD thesis based on the data.

1.8 SEABIRDS AND MAMMALS AT SEA DISTRIBUTION

J. Guyon, C. Houthoofd, B. Van Gelder (PolE);
C. R. Joiris (PolE, not on board)

Objectives

Our long-term study on upper trophic level species (i.e. seabirds and marine mammals) in polar marine ecosystems aims to deepen our understanding of the basic mechanisms influencing their at-sea distribution. It has been shown for decades that water masses and fronts, pack ice and ice edge, and eddies are the main hydrological factors explaining the distribution of seabirds and marine mammals in the ocean. Studies on the distribution at sea of the upper trophic levels often reflect the existence of limited zones with very high aggregations: they allow us to locate areas of high biological production, even in ecosystems characterized by very low biodiversity such as the polar ones, because these predators depend on high local prey availability. Such a high patchiness thus must reflect the patchiness of their prey: this is why a narrow coordination with specialists of zooplankton and small fish distribution was proposed years ago.

Moreover, these data allow us to detect temporal and spatial changes which are likely connected to global changes such as increasing water temperature and reduction in ice coverage.

Work at sea

Seabird and marine mammal transect counts will be carried out on a continuous basis, light and visibility conditions allowing while *Polarstern* is moving. Transect counting method without width limitation is applied from the bridge, lasting half-an-hour each and covering a 90° angle from the bow to one side, the bridge being too broad for allowing simultaneous counting on both sides by one observer. The animals are detected with the naked eye, and observations confirmed and complemented with binoculars (10 X 42). For Brünnich's guillemot, little auk and kittiwake, one has to to make a difference between local birds, both sitting on the water or locally flying without any clear direction and flocks clearly flying in a given direction, probably breeding adults in movement between feeding grounds and colony. Such observations concern a flux and should obviously not expressed as densities. Followers are identified as far as possible and counted as snapshots, once in each count: this includes birds following the ship, circling at some distance, and sometimes flying above the ship (see detail and discussion of the methodology in Joiris 2007, 2011b; Joiris and Falck 2010). When useful, photographic material is also used, especially for rare or difficult to identify species. Results are presented as basic unmodified data, i.e. numbers encountered per half-an-hour transect count. Density can be calculated as well, the surface covered during each count being evaluated on the basis of specific detection distances (Joiris 2007, 2011b; Joiris and Falck 2010) and mean ship's speed in the different zones.

Ice cover is evaluated by us from the bridge and expressed as percent coverage within a range of 500 m around the ship as well as from satellite pictures. Water temperature and salinity are continuously recorded on board *Polarstern* with a thermo-salinometer, as well as a fluorimetric evaluation of chlorophyll pigments, at sub-surface sampling (keel: -10 m). General extent of pack ice, ice edge, main water masses and fronts in the area were illustrated in Joiris and Falck (2010) and Joiris (2011a).

Statistical significance of noted geographical differences is tested by applying the non-parametric Kruskal-Wallis test (all zones), and Mann-Whitney test (paired zones), both with Statistica 7.

Preliminary (expected) results

In comparison with many expeditions in the Fram Strait/ Hausgarten area, we expect to confirm the importance of hydrological structures and to better understand the existence of large aggregations (if any!), including their seasonal existence and dependence to prey availability: zooplankon including krill, nekton and small fish.

Data management

All data will be included in our PolE data set, available by contacting coordinator Claude R. Joiris: crjoiris@gmail.com and later proposed to PANGAEA data library. Publication in international journals is foreseen within one, maximum two years.

Selected references

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1.9 HISTORY OF THE TRANSPOLAR DRIFT: GEOCHEMICAL PROXIES

D. Garbe-Schönberg, A. Wildau (CAU)

Objectives

"TRANSDRIFT: The Transpolar System of the Arctic Ocean" is a multidisciplinary research project recently funded by BMBF in the framework of German-Russia bilateral cooperation. The project aims at understanding processes that govern the transpolar drift from sea ice formation in the Laptev Sea to sea ice melting in the Fram Strait in a world of continued climate change. One work package addresses the history of transpolar drift in the past as a key for predicting future conditions during global warming. Of special interest are periods with climatic conditions comparable to Present (Early Holocene, ~10.000 yrs b.p.) or with even warmer temperature and higher sealevel than today (Eemian, ~130-118.000 yrs b.p.). Key questions to be answered for these time intervals are: Can we identify periods with less sea ice in the Arctic Ocean than today? How about variability of sea ice production and regional changes in important source areas? What is the influence of sea level for fluctuations in sea ice production and coverage? Did the ice drift pattern change during these periods? Has there always been a continued transpolar drift? How did primary productivity and distribution of Atlantic surface water change with variable ice coverage? Sediment cores represent chemical archives for these time intervals from which proxy data for a number of environmental parameters can be extracted. Our sub-project "Geochemical Proxies" focuses on the use of established, and development of new, inorganic geochemical proxies for reconstructing variability of transpolar ice drift from the Laptev Sea towards the Fram Strait over the last 150ka. We will follow a multi-proxy approach combining elemental ratios and trace element abundance in bulk sediment layers with chemical fingerprints of selected mineral grains for reconstructing ice drift. ED-XRF core scanning and laser ablation-ICPMS will be used for *in-situ* elemental analysis, and ICP-OES, ICP-MS, WD-XRF for bulk chemical analysis, also calibrating the generated ED-XRF data.

Major goals for the sampling campaign during expedition PS84 (ARK-XXVIII/1) are the characterisation of mineral assemblages in both sea ice and surficial sediments of the Fram Strait. We are aiming at the identification of tracer minerals that can be used as source (provenance) proxies for surficial sediments in e.g. the Laptev Sea and other Siberian Seas.

This data will be combined with sea ice drift trajectories for testing the proxies in a well-defined Recent system.

Work at sea

Sampling will focus on surficial sediments in the Fram Strait and on the E Greenland shelf where melting of transpolar drift ice is expected to lead to accumulation of ice-transported particles in the sediment. Along a transect across the shelf a series of short sediment cores will be taken by means of the multi corer (MUC) and sub-sampled in high resolution for subsequent mineral separation. In addition, sea ice (and material from sediment traps) will be sampled for mineral particles if possible. Selected minerals and particles will then be chemically fingerprinted by micro-analytical techniques in our on-shore labs.

Data management

Preprocessing of data from samples of PS84 (ARK-XXVIII/1) will take place at Christian Albrechts University, Kiel and GEOMAR. Final data will be made public available in due time in the PANGAEA library or any comparable open access database.

1.10 MEASUREMENTS OF THE ARCTIC ATMOSPHERIC BOUNDARY LAYER USING A WIND LIDAR

O. Gutjahr S. Kohnemann (Univ. Trier);
G. Heinemann (Univ. Trier, not on board)

Objectives

The representation of the atmospheric boundary layer (ABL) in the Arctic is a major challenge for numerical weather forecast model and regional climate models. Reference data sets are rare, particularly over the ocean areas. The group of the University of Trier will perform measurements of vertical and horizontal profiles of wind, turbulence and aerosols in the Fram Strait area. In this area, the knowledge of wind profiles is of great interest, since the coupling of the ocean and sea-ice surface with the ABL (and the free atmosphere above) determines the wind-driven sea-ice export of the Arctic.

Work at sea

We will use a “Halo-Photonics Streamline“ wind lidar, which is a scanner and can operate with a maximum range of 10 km. The operation principle of the lidar is backscattering at aerosol particles and clouds and the use of the Doppler effect. The lidar operates at a wavelength of 1.5 µm with a pulse rate of 20 kHz and is eye-safe. Values are typically averaged for 1 … 30 minute intervals (wind vectors), but also instantaneous values can be measured using 0.1s intervals.

The main advantage of a wind lidar compared to SODAR systems is that they have a longer range and are independent from the presence of turbulence. In addition, a SODAR is sensitive to acoustic noise, which prohibits the operation on ships. The used lidar has a programmable scanner which enables vertical scans as well as range-height indicator (RHI) and horizontal scans. The RHI mode allows for measurements of e.g. convection structure over the ocean or the internal boundary layer at the sea ice edge.

The measurements during the *Polarstern* cruise PS84 (ARK-XXVIII/1) in the Fram Strait shall yield a data set of continuous and high-resolution vertical profiles of wind, aerosols and tubulence. For special observation periods, RHI and horizontal scans will be performed.

Data management

The data will be used in the BMBF project „Transdrift“ for the verification of simulations using a regional weather prediction model. Preprocessing of data will take place at the University of Trier. Final data will be made public available in due time in the PANGAEA library or any comparable open access database.

1.11 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTIONS

	Address
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GEOMAR	GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel Düsternbrooker Weg 20, D-24109 Kiel/Germany
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MPI	Max Planck Institute for Marine Microbiology, Deutschland Celsiusstr. 1, 28359 Bremen/Germany
PolE	Laboratory for Polar Ecology Rue du Fodia 18 B-1367 Ramillies / Belgium
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Uni Kiel	Cristian Albrechts Universität Kiel Institut für Geowissenschaften, 24098 Kiel/Germany
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1.12 FAHRTTEILNEHMER / CRUISE PARTICIPANTS

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1.	Asendorf	Volker	MPI Bremen	Mechatroniker
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23.	Lilienthal	Heiko	Isitec	Ingenieur
24.	Lochthofen	Normen	AWI	Ingenieur
25.	Lund-Hansen	Lars Chresten	Uni Aarhus	Wissenschaftler
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31.	Otten	Caroline	AWI	Technikerin
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36.	Rapp	Josephine	MPI Bremen	Studentin
37.	Richter	Roland	Heli Service Intl.	Prüfer
38.	Rößler	Sebastian	Fielax	Geograph
39.	Sablotny	Burkhard	AWI	Ingenieur
40.	Salter	Ian	AWI	Wissenschaftler
41.	Schewe	Ingo	AWI	Wissenschaftler
42.	Schütte	Svenja	AWI	FÖJlerin
43.	Sonnabend	Hartmut	DWD	Techniker
44.	Sorrell	Brian	Uni Aarhus	Wissenschaftler
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47.	Tonkes	Henrieke	AWI	Studentin
48.	van Gelder	Bart	PolE	Biologe
49.	Vaupel	Lars	Heli Service Intl.	Pilot
50.	Wildau	Antje	Uni Kiel	Geologin
51.	Winkler	Maria	AWI	Studentin
52.	Ziersen	Bibi	Uni Aarhus	Studentin

1.13 SCHIFFSBESATZUNG / SHIP'S CREW

No	NAME	RANK
01.	Wunderlich, Thomas	Master
02.	Spielke, Steffen	1.Offc.
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04.	Lauber, Felix	2.Offc.
05.	Kentges, Felix	2.Offc.
06.	Langhinrichs, Moritz	2.Offc.
07.	Spilok, Norbert	Doctor
08.	Koch, Georg	R.Offc.
09.	Kotnik, Herbert	2.Eng.
10.	Schnürch, Helmut	2.Eng.
11.	Westphal, Henning	2.Eng.
12.	Brehme, Andreas	Elec.Tech.
13.	Hofmann, Jörg	Electron.
14.	Dimmler, Werner	Electron.
15.	Winter, Andreas	Electron.
16.	Feiertag, Thomas	Electron.
17.	Schröter, Rene	Boatsw.
18.	Neisner,Winfried	Carpenter
19.	Clasen, Nils	A.B.
20.	Burzan, Gerd-Ekkehard	A.B.
21.	Schröder, Norbert	A.B.
22.	Moser, Siegfried	A.B.
23.	Hartwig-L., Andreas	A.B.
24.	Kretzschmar, Uwe	A.B.
25.	Kreis, Reinhard	A.B.
26.	Gladow, Lothar	A.B.
27.	Sedlak, Andreas	A.B.
28.	Beth, Detlef	Storekeep.
29.	Plehn, Markus	Mot-man
30.	Fritz, Günter	Mot-man
31.	Krösche, Eckard	Mot-man
32.	Dinse, Horst	Mot-man
33	Watzel, Bernhard	Mot-man
34.	Fischer, Matthias	Cook
35.	Tupy,Mario	Cooksmate
36.	Völske, Thomas	Cooksmate
37.	Luoto, Eija	1.Stwd.
38.	Westphal, Kerstin	Stwdss/KS
39.	Streit, Christina	2.Steward
40.	Hischke, Peggy	2.Stwdess
41.	Wartenberg, Irina	2.Stwdess
42.	Hu, Guo Yong	2.Steward
43	Chen, Quan Lun	2.Steward
44.	Ruan, Hui Guang	Laundrym.

PS85 (ARK-XXVIII/2)

6 June 2014 - 29 June 2014

Longyearbyen - Tromsø

Chief Scientist
Benjamin Rabe

Coordinator
Rainer Knust

2.1 ÜBERBLICK UND FAHRTVERLAUF

Benjamin Rabe (AWI)

Die Expedition PS85 von *Polarstern* wird am 5. Juni 2014 beginnen. Das Schiff wird von Longyearbyen (Svalbard) abfahren, um Forschung im Bereich der nördlichen Framstraße, der Grönlandsee und nördlich von Svalbard zu betreiben. Die geplanten Feldarbeiten sind mit mehreren Projekten assoziiert und werden den langen Schnitt über die Framstraße, von der Schelfkante westlich von Svalbard bis zum Ostgrönlandschelf und der Küste Grönlands zum Fokus haben. Das Ende der Expedition ist mit dem Einlaufen in Tromsø (Norwegen) für den 29. Juni 2014 geplant. Der Fahrtverlauf und die Expeditionsaktivitäten sind in Abbildung 2.1.1 dargestellt.

Die Messungen der physikalischen Ozeanographie stehen im Zusammenhang mit dem EU-Projekt ACOBAR (Acoustic Technology for Observing the Interior of the Arctic Ocean), dem Projekt des Bundesministerium für Bildung und Forschung (BMBF) RACE (Regional Atlantic Circulation and Global Change) und den Forschungsinfrastrukturen der Helmholtz Gemeinschaft HAFOS (Hybrid Arctic / Antarctic Float Observing System) und FRAM (Frontiers in Arctic Marine Monitoring). Das Hauptziel ist die Abschätzung des Volumen-, Wärme und Salzflusses zwischen dem Europäischen Nordmeer und dem Nordpolarmeer durch die Framstraße. Der Fokus liegt hier auf der Erfassung der interannualen bis dekadischen Variabilität des Austausches. Wir werden hydrografische Messungen (Temperatur, Salzgehalt und Sauerstoff) und Wasserbeprobung auf chemische Spurenstoffe ($\delta^{18}O$) an 76 Stationen entlang des zonalen Schnittes bei 78°50'N durchführen, parallel zu Messungen der Ozeanströmungsgeschwindigkeit an den Stationen und während der Fahrt. Das Verankerungsarray beinhaltet Instrumente zur ganzjährigen Messung von Ozean–strömungsgeschwindigkeit, Salzgehalt und Temperatur. Wir werden Instrumente aufnehmen, die in 2012 ausgelegt wurden. Wir werden die 17-jährige Zeitreihe forsetzen, indem wir einen Teil des Arrays, im Westspitsbergenstrom und im Ostgrönlandstrom, wieder auslegen. Neue Verankerungen werden im Belgicagraben auf dem Ostgrönlandschelf ausgelegt, um die warme Atlantikwasserzirkulation zu beobachten, die potentiell einen Einfluss auf den Grönland-Outletgletscher bei 79°30'N hat. Diese Arbeiten sind in Vorbereitung auf die größere Expedition GRIFF (Greenland Ice sheet/ocean Interaction and Fluxes through the Fram Strait), gepant für 2016, welche Teil von GROCE (Greenland Ice sheet/OCean interaction) ist. Des Weiteren wird eine Verankerung nordöstlich von Svalbard, innerhalb des Arktischen Randstroms und stromabwärts des Westspitsbergenstroms, ausgelegt. Seaglider und autonom profilierende Drifter werden auf dem Weg zum Zielhafen in der Grönlandsee ausgebracht, um mehr als eine Dekade von Temperatur- und Salzgehaltsmessungen in der Region fortzuführen und zu erweitern. Zusätzlich ist dies der Anfang einer Prozessstudie über Wirbelflüsse über den Ostgrönlandstrom. Diese Beobachtungen tragen zum ARGO-Programm, dem Deutsche Forschungsgesellschaft (DFG) Projekt Freshwater in the Nordic Seas und dem EU-Projekt GROOM (Gliders for Research, Ocean Oservation and Management) bei.

An einigen Stationen werden die hydrografischen Messungen mit Wasser- und Netzproben für Studien der Biogeochemie und des Planktons kombiniert. Die Forschungsgruppe PEBCAO (Phytoplankton Ecology and Biogeochemistry in a Changing Arctic Ocean) wird diese Studien koordinieren, um den Einfluss des Klimawandels auf Bakterien, Phyto- und Zoo-plankton und pelagische Biogeoschemie abzuschätzen, inklusive etwaiger Konsequenzen für vertikale Partikelflüsse. Weiterer Fokus sind pelagische Änderungen im Zusammenhang mit den Arbeiten der Gruppen Tiefsee und Messende Ozeanographie des AWI.

Die Meereisgruppe innerhalb von PEBCAO wird außerdem Parameter zur Bestimmung der Biogeochemie und der Biodiversität von autotrophen Organismen im Meereis und in

Schmelztümpeln in der Framstraße, stromabwärts der Transpolardrift, beproben und messen. Die Beoabchtungen werden mit historischen Daten verglichen werden. Weiterer Fokus werden die Mechanismen der physiologischen Anpassung von Eisalgen an unterschiedliche Lichtbedingungen sein. Das soll eine bessere Parameterisierung des Einflusses der Meereisdicke auf Primärproduktion im Meereis ermöglichen. Die Arbeiten sind Teil des BMBF-Projekts: TRANSDRIFT, welches die ökologischen Konsequenzen des Klimawandels in der Schlüsselregion der Transpolardrift untersucht.

Bathymetrische Messungen während der Fahrt werden sich auf die Messung der Tiefe des Meeresbodens, unter Verwendung von akustischen Methoden (Hydrosweep) konzentrieren, insbesondere in den Regionen des Ostgrönlandschelfes, wo nur wenige Beobachtungen existieren. Die Analyse von Meeresbodenstrukturen soll zur Bestimmung der glazialen Geschichte des Schelfes und zur Rekonstruktion der maximalen Ausdehnung und Rückgang des grönländischen Eisschildes genutzt werden. Die verbesserten bathymetrischen Daten werden auch der Ozeanographie nützlich sein, sowohl zur Planung der Verankerungspositionen über den Belgicagraben als auch zur Interpretation des Zirkulationsschemas. Außerdem werden die oberen Sedimenschichten im Meeresboden mit dem Sedimentlot (Parasound) untersucht werden.

Die Beprobung von Partikeln und Chemie in Luft, Wasser, Schnee und Meereis wird das Vorkommen von Schadstoffen und Kohlenstoffnanopartikeln in der Arktis messen. Das Ziel ist die Studie von Transporten und dem Austausch dieser Substanzen zwischen dem Meer, der Atmosphäre etc., und aufzuzeigen, wo diese Substanzen in der Umwelt und dem arktischen Ökosystem verbleiben.

Kontinuierliche Beobachtungen und Zählung von Meeresvögeln und marinen Säugetieren wird während der Expedition durchgeführt. Diese Langzeitstudie hat als Ziel, die Verteilung von Meeresvögeln und marinen Säugetieren im Meer in Relation sowohl zur Flächenverteilung von Wassermassen und Fronten im Meer als auch der Konzentration des Packeises und der Position der Eiskante zu quantifizieren.

SUMMARY AND ITINERARY

The expedition PS85 of *Polarstern* will start on 5th June, 2014. The ship will depart from Longyearbyen (Svalbard) to conduct research in the northern part of the Fram Strait, the Greenland Sea and north of Svalbard. The planned fieldwork is associated with several projects and will focus on the long section across the Fram Strait from the shelf edge west of Svalbard to the east Greenland shelf and coast. The expedition is scheduled to end in Tromsø (Norway) on 29th June, 2014. The cruise track and expedition activities are shown in Figure 2.1.1.

The physical oceanographic measurements are associated with the European Union (EU) project ACOBAR (Acoustic Technology for Observing the Interior of the Arctic Ocean), the German Ministry for Education and Science (BMBF) project RACE (Regional Atlantic Circulation and Global Change) and the Helmholtz Association research infrastructures HAFOS (Hybrid Arctic / Antarctic Float Observing System) and FRAM (Frontiers in Arctic marine Monitoring). The main aim is to estimate the volume, heat and salt fluxes between the Nordic Seas and the Arctic Ocean through the Fram Strait. The focus here is to capture the interannual to decadal variability of the exchange. We will conduct hydrographic measurements (temperature, salinity and oxygen) and water sampling for chemical tracers ($\delta^{18}O$) at about 76 stations along the zonal section at 78º50'N, accompanied by ocean current measurements at each station and underway. The moored array has instrumentation to measure ocean currents, salinity and temperature throughout all seasons. We will recover instruments deployed in 2012. We will continue the 17-year timeseries by re-deploying part of the array, in the West Spitsbergen Current and the East Greenland Current. New moored instrumentation will be deployed in the Belgica Trough on the East Greenland Shelf to observe the warm Atlantic circulation, potentially influencing the Greenland outlet glacier at 79º30'N. This is preliminary work for the larger GRIFF (Greenland Ice sheet/ocean Interaction and Fluxes through the Fram Strait) expedition, planned for 2016, which is part of GROCE (Greenland Ice sheet/OCean interaction). Furthermore, one mooring to be deployed northeast of Svalbard will measure within the Arctic Ocean boundary current downstream of the West Spitsbergen Current. Seagliders and autonomous profiling floats will be deployed on the way to the port of arrival in the Greenland Sea to continue and extend more than a decade of temperature and salinity observations in the region. In addition, this will mark the start of a process study of eddy fluxes across the East Greenland Current. These observations will contribute to the ARGO program, the German Science Foundation (DFG) project Freshwater in the Nordic Seas and the EU project GROOM (Gliders for Research, Ocean Oservation and Management).

At selected stations, the hydrographic measurements will be combined with water and net sampling for biogeochemical and plankton studies. The research group PEBCAO (Phytoplankton Ecology and Biogeochemistry in a Changing Arctic Ocean) will lead these studies to estimate the impact of climate change on bacteria, phyto- and zooplankton and pelagic biogeochemistry including arising consequences for vertical particle fluxes. Further focus will lie on pelagic changes in relation to the work of the deep sea and observational oceanography groups at AWI.

Furthermore, the sea ice group within PEBCAO will sample and measure parameters to determine the biogeochemistry and biodiversity of autotroph organisms in sea ice and melt ponds in the Fram Strait, downstream of the Transpolar Drift. The observations will be compared to historical data. Further focus will be on mechanisms for physiological adaptation of ice algae to a variety of light conditions. This will allow to better parameterise the effects of sea ice thickness changes on sea ice primary production. This work is embedded in BMBF project: TRANSDRIFT which studies the Ecological consequences of climate change in the key region of the Transpolar drift.

Underway bathymetric observations will focus on measuring the depth of the seafloor using acoustic methods (Hydrosweep), in particular the regions on the East Greenland Shelf, where only few observations exist. The analysis of seafloor features in this region will be used to determine the glacial history of the shelf and to reconstruct the maximal extent and retreat of the Greenland ice shield. The improved bathymetric data will also assist the oceanography both for deciding where to deploy the moorings across the Belgica Trough as well as for interpretation of the circulation scheme. In addition, the upper sedimentary layers of the seafloor will be studied using the sediment echosounder (Parasound).

Sampling of particles and chemistry of the air, water, snow and sea ice will measure the occurrence of pollutants and carbon nanoparticles in the Arctic. The aim is to study the transport and exchange of these substances between the sea, the atmosphere etc., and to detect where these substances remain in the environment and the Arctic ecosystem.

Continuous observations and counting of seabirds and marine mammals will be carried out during the entire cruise. This long-term study is aimed to quantify at sea distribution of seabirds and marine mammals in relation to the spatial variability of water masses and frontal zones in the ocean, as well as the concentration of pack ice and the location of the sea ice edge.

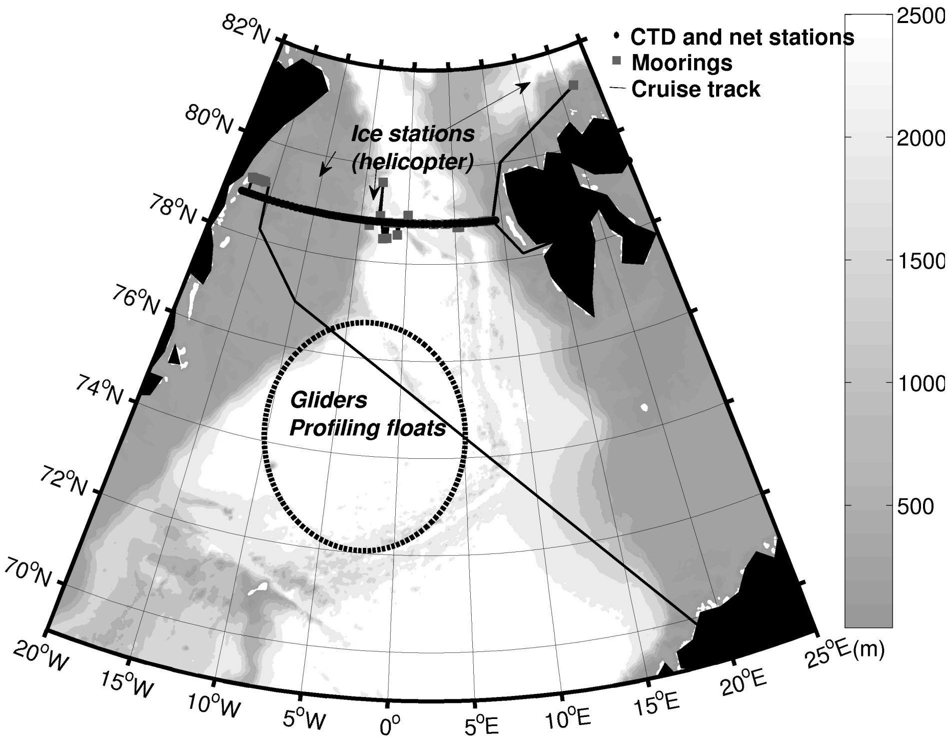

Fig 2.1.1: Summary of expedition cruise track and activities. Shown are the CTD and net stations (black dots), Moorings (gray squares) and the cruise track (continuous black line). The region where ice stations within helicopter reach of the ship will be carried out are marked by arrows. Glider and profiling float deployments will be carried out within the region of the dashed ellipse. Bathymetry is based on IBCAO.

2.2 PHYSICAL OCEANOGRAPHY

W.-J. von Appen, K. Latarius, B. Rabe, O. Strothmann, J. Schaffer, C. Pinheiro Campos (AWI), A. Beszczynska-Möller (IOPAN), A. Muenchow, J. Poole (U Delaware), K. Hoeflich, T. Dippe, A. Roloff (GEOMAR)

Background and objectives

This cruise supports a long-term effort to monitor and quantify the variability of oceanic fluxes through the Fram Strait with a particular emphasis on the physical oceanography.

The Arctic Ocean is a semi-enclosed marginal sea with the Bering Strait, the Canadian Arctic Archipelago, and the Barents Sea being three shallow connections to the world oceans. The Fram Strait is the only deep strait (2,700 m), thereby allowing for the exchange of intermediate and deep waters between the Arctic Ocean and the Nordic Seas, which are in turn a marginal sea of the North Atlantic. Atlantic origin water is cooled throughout the cyclonic boundary current circulation in the Nordic Seas and enters the Arctic through the Barents Sea and the eastern Fram Strait. The temperature and other properties of the inflowing warm and salty Atlantic Water change in response to interannual variability, to large scale-, multi-year climate patterns, such as the North Atlantic Oscillation, and to global climate change. The sum of these effects can be measured in the Fram Strait before it enters the Arctic Ocean, where it participates in the formation of the halocline north of Svalbard and forms a mid-depth cyclonic boundary current. Cooling, freezing, sea-ice melt, mixing with Pacific origin water, and the addition of large amounts of river runoff in the Arctic modifies the inflowing water before it exits through the western Fram Strait. Thus observations of the outflow from the Arctic make it possible to monitor the effects of many processes in the Arctic Ocean.

The complicated topography in the Fram Strait leads to a horizontal splitting of the inflowing branches of Atlantic Water. Additionally, some of the Atlantic Water participates in a westward flow called the recirculation that then turns southward to exit the Fram Strait back to the Nordic Seas. The southward flowing cold and very fresh East Greenland Current is responsible for a large part of the liquid freshwater export from the Arctic and most of the solid freshwater export in the form of sea-ice. This freshwater has the potential to impact convection in the Nordic Seas and the northern North Atlantic and in turn the meridional overturning circulation.

Since 1997, AWI and the Norwegian Polar Institute have maintained a mooring array across the Fram Strait to monitor the fluxes of volume and heat, and, in the western part of the strait, freshwater into and out of the Arctic Ocean through this gateway.

Typical signatures and patterns of geochemical tracers, such as radiogenic neodymium (Nd) isotopes and rare earth element (REE) are introduced into seawater through weathering of different rocks in the source areas of the water masses and can be preserved and transported over large distances. In particular, in the western Fram Strait, these patterns and their distribution in space make it possible to study the pathways of these terrestrial sources.

The western half of the Fram Strait is taken up by the extremely wide East Greenland shelf. A major outlet glacier has its terminus at 79°30'N on the shelf. A complicated trough system dominates the shelf in front of the glacier. Belgica Trough is the trough extending southward from the glacier terminus. This is one of the least accessible areas in the northern hemisphere and many basic things are unknown at this point in time. In particular, the bathymetry of the trough system is largely unsurveyed and it is not established whether warm Atlantic Water circulates in the trough system and potentially reaches the outlet glacier where it might lead to basal melting.

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Next to the dramatic retreat of sea ice, the strongest climatic signal of the Arctic Ocean and the Nordic Seas in the past decade are changes in temperature and salinity. While additional heat and salt are advected northwards from the subpolar North Atlantic into the Nordic Seas, a strong accumulation of fresh water has been observed in the past decades in the Arctic Ocean. The aim of a glider program, starting this summer in the western Nordic Seas, is to observe whether the increasing amount of freshwater reaches the inner basins of the Nordic Seas and thus dampens vertical mixing and intermediate as well as deep water renewal during winter. This might lead to a slow-down of the northern branch of the AMOC.

Work at sea

The cruise will begin with steaming to the north of Svalbard at 20°E, the deployment of a mooring on the upper continental slope there, and steaming back to 78°50'N. Then work on the main line across Fram Strait will commence. This includes a mixture of mooring work during daytime and CTD casts during night. Depending on the conditions at the beginning of the work, this might also be reversed with mooring work at night and CTDs during the day. This would be possible due to constant daylight in June.

The mooring array in the deep Fram Strait will be serviced (Fig. 2.2.1). 12 moorings (AWI moorings F1-F10 and F15/F16) will be recovered between 9°E and 2°W. The top flotation of F9 was damaged (the Argos beacon started sending data while drifting in January 2014) and this mooring will therefore take a significant additional amount of time to recover. Four moorings (F7/F8 and F15/F16) will not be redeployed as it has been decided to focus the array on the West Spitsbergen Current and on the East Greenland Current. Therefore, only eight moorings (F1-F6, F9/F10) will be redeployed in the deep Fram Strait during PS85 (ARK-XXVIII/2) . The locations of the instruments are shown in Figure 2.2.2: microcats will measure temperature and salinity, and either ADCPs or current meters will measure velocity.

A mooring with a winch system and an NGK profiler to sample the top 100 m of the water column up to the surface will be deployed at 78°45'N 5°30'E, just south of the main mooring line, for technological testing. Seven moorings with sound sources were deployed between 5°W and 0° during previous expeditions to the region. We will attempt to recover as many of them as possible, depending on the available time and possible complications in case some of the releasers might not work properly anymore.

A total of 76 CTD stations are planned along 78°50'N (Fig. 2.2.1). Their spacing is narrow (5 - 7 km) in the eastern part of the West Spitsbergen Current and in the East Greenland Current as well as the outer East Greenland shelf. The spacing in the central Fram Strait and on the central East Greenland shelf will be wider (~11 km). An system will be used in combination with an SBE 32 Carousel Water Sampler (Seabird). Water samples will be taken for $\delta^{18}O$. At several stations, additionally large volume (10 - 20 l) samples will be taken for neodymium and rare earth element measurements. A vessel mounted ADCP will measure velocity in the upper water column, both on CTD stations and during transit between stations. A lowered ADCP system will be attached to the CTD rosette to measure velocities below the range of the vessel mounted ADCP.

The physical oceanography group will monitor satellite sea-ice concentration products in the western Fram Strait throughout the cruise. This will aid in the identification of the best locations for surveying Belgica Trough. The bathymetry will be mapped by the bathymetry group along a section perpendicular to the trough and a CTD section along that section will be taken. This will show the vertical and horizontal location of the warm Atlantic water in the trough. If the sea-ice conditions permit mooring operations, two moorings of the AWI and five moorings of the University of Delaware will then be deployed along this line and into the Atlantic Water core. The moorings all contain a microcat and an ADCP looking upward from near the bottom. The precise locations as well as the spacing of the moorings will have to be decided during the cruise in response to the exact bathymetry and the steepness that will be encountered.

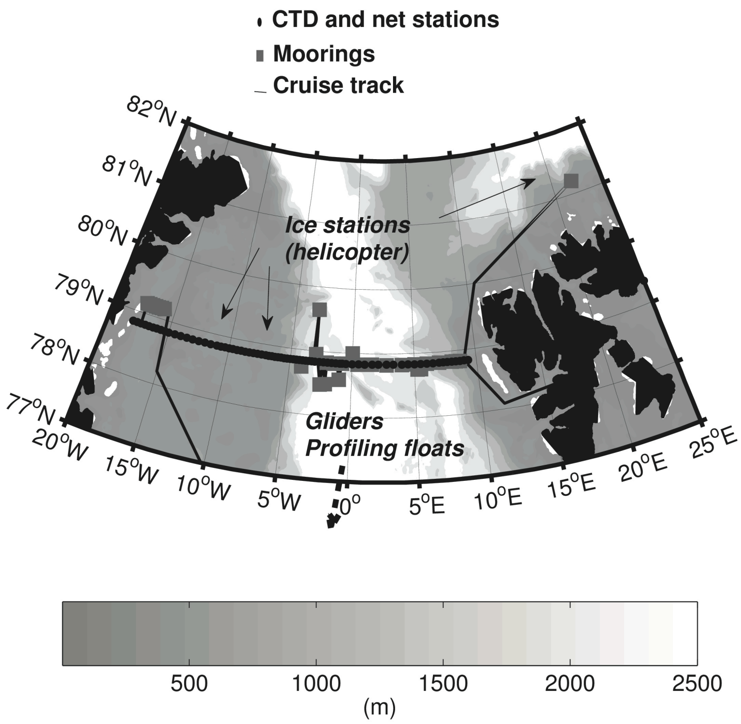

Fig. 2.2.1: Positions of the moorings and CTD stations in the Fram Strait. The region of glider and profiling float deployments is south of the map domain. The remainder is labelled and plotted as in Figure 2.1.1.

At the end of the cruise on the transit back to Tromsø, SeaGliders SG127 and MK558 will be deployed in the Greenland Sea. This requires a small boat operation and monitoring of the gliders during their first short dive to assess whether their buoyancy is sufficient. The gliders will capture hydrographic sections between the inner Greenland Sea Basin and the East Greenland Current. Every 4 km they will dive to 1,000 m depth and thereby record temperature and salinity profiles. These data will be transmitted via Iridium satellites when the gliders return to the ocean surface after each dive. The gliders will be monitored and remotely steered along standard sections by glider pilots at the AWI in Bremerhaven.

Two Argo floats will be deployed in the Greenland Sea and two in the Lofoten Basin. Their purpose is to measure temperature and salinity profiles every ten days as well as velocities at 1,000 m. The measurements contribute to the hydrographic monitoring of the Nordic Seas with Argo floats since 2001.

Data management

CTD data as well as LADCP and VMADCP data collected during PS85 (ARK-XXVIII/2) will be delivered after post-cruise calibration to the PANGAEA Data Publisher for Earth & Environmental Science.database and to the appropriate national data centres. The data recorded by the moored instrumentation will be processed after the cruise at AWI and submitted to the PANGAEA Data Publisher for Earth & Environmental Science.The gliders are piloted from AWI in real time. The uncalibrated data will be provided in near-real time to the Coriolis data centre for use in operational applications. The calibration and final processing will take place after completion of the mission and the data will be delivered to the

PANGAEA Data Publisher for Earth & Environmental Science. The ARGO float data will be provided in near-real time to the Coriolis data centre and replaced by delayed mode quality controlled data afterwards.

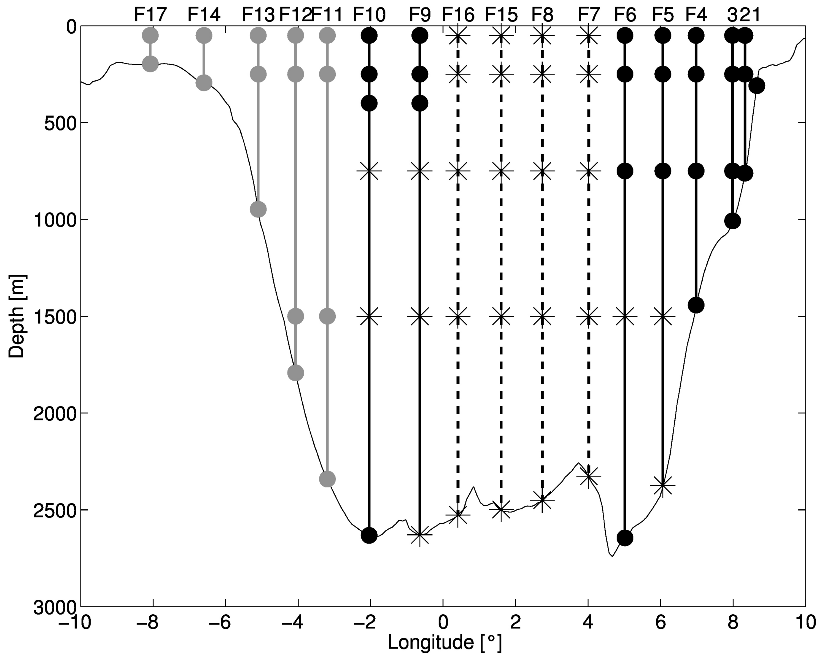

Fig. 2.2: Sideview of the mooring locations in the deep Fram Strait. Solid black lines and dots indicate moorings and instruments that will be recovered and redeployed during PS85 (ARK-XXVIII/2) , while dashed lines and crosses indicate moorings and instruments that will only be recovered. The mooring array is not continued at those locations. Gray moorings are maintained by the Norwegian Polar Institute and will not be serviced during PS85 (ARK-XXVIII/2) .

2.3 PLANKTON ECOLOGY AND BIOGEOCHEMISTRY IN THE CHANGING ARCTIC OCEAN (PEBCAO GROUP)

K. Metfies, R. Gonçalves Araujo, N. Hildebrandt, N. Knüppel, H. Tonkes, M. Winkler I. Peeken (AWI), S. Bold, C. Karthäuser, J. Piontek (GEOMAR),

A. Bracher, B. Niehoff E.-M. Nöthig (AWI, not on board) , A. Engel (GEOMAR, not on board), C. Osburn (NCSU, not on board)

State of the art & objectives

The Arctic Ocean has gained increasing attention over the past years because of the drastic decrease in sea ice and increase in temperature, which is about twice as fast as the global mean rate. In addition, the chemical equilibrium and the elemental cycling in the surface ocean will alter due to ocean acidification. These environmental changes will have consequences for the biogeochemistry and ecology of the Arctic pelagic system. The effects of changes in the environmental conditions on the polar plankton community can only be detected through long-term observation of the species and processes. Our studies on plankton ecology have started in 1991 and sampling has been intensified since 2009 along a Fram Strait transect at ~79°N.

Climate induced changes will impact the biodiversity in pelagic ecosystems. A shift in species composition is expected to occur in all phytoplankton size classes. Smallest algae may thrive the phytoplankton in the future Arctic Ocean while large species may occur less frequently. Thus, small algae will gain more importance in mediating element and matter turnover as well as energy fluxes in Arctic pelagic systems. Also other algae such as *Phaeocystis pouchetii*, which has a wide size range from small flagellates to large gelatinous colonies can play a key role in the carbon and sulphur cycle, increases in abundance in the Arctic.

Molecular methods are well suited to provide refined information on the composition and biogeographical differences of arctic phytoplankton communities, including the smallest fractions. The characterization of phytoplankton communities with molecular methods is independent of cell-size and distinct morphological features. The assessment of the biodiversity and biogeography of Arctic phytoplankton will be based on the analysis of ribosomal genes, taking advantage next generation sequencing technology, Automated Ribosomal Intragenic Sequence Analysis (ARISA), and quantitative PCR.

Based on the awareness that global change increasingly affects marine ecosystems, we also examine the ‘present day’ state of pelagic microbial biogeochemistry in the Arctic Ocean, with emphasis on production and turnover of organic matter. For this purpose, rate measurements on phytoplankton and bacterial production and abundance will be carried out. Concentrations of organic carbon and nitrogen as well as of specific compounds like amino acids and sugars will be analysed. Our overarching goal is to improve the mechanistic understanding of biogeochemical and microbiological feedback processes in the Arctic Ocean and to assess the potential for changes in the near future.

Phytoplankton primary production and CDOM photo-oxidation have opposing impacts on carbon fluxes in the ocean. There is a need to assess the amount of loading by terrestrial CDOM versus the contribution from marine CDOM and quantify the influence on phytoplankton. Since the photons by CDOM and phytoplankton pigments absorb different (shorter) wavelengths than the photons are emitted via fluorescence, the fluorescence signal can especially be seen in reflectance data at the Fraunhofer lines, the wavelengths where, due to strong absorption by molecules in the photosphere, the solar irradiance is nearly zero. At the field sites also hyperspectral irradiance and radiance above the water is measured which are used to calculate the reflectance above those waters. This research will give a fundamental contribution for further development of hyper- and multispectral ocean colour satellite retrievals focusing on fluorescence and absorption signals. Stable carbon isotope ratios of dissolved organic matter (δ^{13}C-DOC) typically range between -28 and -20 ‰, reflective of terrestrial and marine organic matter sources, respectively. The goal of this research is to utilize δ^{13}C-DOC values in Fram Strait to quantify the relative fractions of terrestrial and marine (phytoplankton-derived) DOC in Fram Strait. In addition, δ^{13}C-DOC values will support mass balance modeling of river water contribution to the freshwater export from the Arctic to the North Atlantic Ocean through the Fram Strait.

The zooplankton community composition may shift due to warmer Atlantic water prevailing in the Fram Strait over the last 10 years. In addition, zooplankton organisms are also affected by changes at the base of the food web and may thus alter the transport and modification of organic matter.

During PS85 (ARK-XXVIII/2) the following topics are covered:

- Monitoring plankton species and biomass distribution as well as biogeochemical parameters along the Fram Strait transect
- Investigations on selected phyto- and zooplankton and related biogeochemical parameters
- Production, degradation and composition of organic matter in a changing Arctic Ocean
- Investigations on the amount and composition of the coloured dissolved organic matter (CDOM) and its interplay with phytoplankton
- Fractions of marine and terrestrial DOC for stipulations of carbon export through the Fram Strait

Work at sea

Biogeochemical & biological parameters from rosette samples

We will sample arctic seawater by CTD/rosette sampler along the oceanographic transect (~79°N) at about 5 - 8 depths. All samples will be partly filtered and preserved or frozen at -20°C and partly at – 80° C for further analyses. At the home laboratory at AWI we will determine the following parameters to describe the biogeochemistry and the abundance and distribution of protists:

1. Chlorophyll *a* concentration (total phytoplankton community and picoplankton-fraction)
2. HPLC pigments
3. Dissolved organic carbon (DOC)
4. CDOM (coloured dissolved organic matter)
5. Particulate organic carbon (POC)
6. Total dissolved nitrogen (TDN)
7. Particulate organic nitrogen (PON)
8. Particulate biogenic silica (PbSi)
9. Transparent exopolymer particles (TEP)
10. Coomassie-stainable particles (CSP)
11. Combined carbohydrates, amino acids
12. Hyperspectral irradiance and radiance profiles
13. Light absorption by phytoplankton and particulate matter
14. Light absorption and fluorescence by CDOM
15. $\delta^{13}C$ from DOC
16. Alkalinity
17. Phytoplankton & protozooplankton abundance
    - Sampling for genetic analyses & clonal cultures
    - Sampling for molecular-biological assessments of protist communities
    - Flow cytometer (bacterial cell numbers and autotrophic pico- and nanoplankton)
    - Bacterial biomass production
    - Primary production (selected stations)

Zooplankton sampling

Mesozooplankton composition and depth distribution will be determined by means of vertical Multi net tows from 1,500m depth to the surface. In addition, optical surveys with the LOKI (light on-sight key species investigations) will be conducted to determine the small-scale distribution of zooplankton in the water column. Bongo net hauls will be taken to collect organisms for biochemical analyses (carbon, nitrogen, protein and lipid content, fatty acid composition), enzyme activity analyses (citrate synthase, digestive enzymes) and molecular analyses of phytoplankton communities in the stomach of zooplankton organisms. We will also sort live animals from these samples for conducting experiments.

Experimental work

We will study the response of dominant Arctic copepods to different algal species (*Thalassiosira weissflogii*, diatom, and *Oxhyrris marin*a, dinoflagellate) by means of incubation experiments. Particularly we will focus on grazing, egestion and egg production rates in relation to food quality, which will all be measured onboard. In addition, we will deep freeze individuals over the course of the experiment to determine changes in body mass and enzyme activities. This will elucidate the extent to which the copepods are dependent on the spring diatom bloom and their flexibility in exploring different food resources.

Optical profiling

The Apparent Optical Properties of water (AOPs) (mostly light attenuation through the water column) will be estimated based on downwelling and upwelling irradiance using radiometers for collecting data in situ. These are calibrated for the incident sunlight with measurements of a radiometer on deck.

Molecular analysis of phytoplankton

The occurrence of selected phytoplankton taxa that regularly significantly contribute to phytoplankton communities in the Fram Strait will be assessed via molecular methods. We will use taxon specific primer sets to screen water samples via quantitative PCR on board-ship for the presence of *Phaeocystis sp.*, different strains of *Micromonas pusilla*, Dinoflagellates, and *Chaetoceros sp.*

Preliminary (expected) result

We expect similar results including trends like we observed during the other years of our time-series investigations. Results will strongly depend on the physical and chemical environmental settings in the field.

Data management

During our cruises, we sample a large variety of interconnected parameters. Many of the samples (i.e. pigment analyses, particulate matter in the water column, etc.) will be analysed at AWI and at GEOMAR within about a year after the cruise. We plan that the full data set will be available about two years after the cruise by the latest. Most of species samples and samples which will not been analysed immediately will be stored at the AWI at least for another 10 years and will be available for other colleagues. Data will be made available to the public via PANGAEA after publishing (depending on how much comparisons will be made, long-term study 2 to 5 years after the cruise).

2.4 SEA ICE STUDIES - ECOLOGICAL CONSEQUENCES OF CLIMATE CHANGE IN THE FRAM STRAIT, A KEY REGION OF THE TRANSPOLAR DRIFT (PEBCAO GROUP)

I. Peeken, U. Dierich (AWI), L. C. Lund-Hansen, B. Sorrell and B. Ziersen (UA), L. Weinisch (UKL),

M. Nicolaus, R. Ricker, I. Salter (AWI, not on board)

State of the art & objectives

Sea ice is of major importance in the polar oceans since it affects the solar radiation fluxes due to its reflective properties and is a habitat and feeding ground for various organisms of the polar ecosystem. The Arctic Ocean is now in a state of rapid transition that is best exemplified by the marked reduction in age, thickness and extent of the sea ice cover, at least in summer. The European Arctic margin is largely influenced by drift ice formed on the Siberian shelves and carried to the Fram Strait via the Transpolar Drift. Sea ice thickness for the various regions of the Transpolar Drift between 1991 and 2007 showed a reduction in modal ice thickness from 2.5 m towards 0.9 m. A long-term trend towards thinner sea ice has profound implications for the timing and position of the Seasonal Ice Zone and the anticipated ice free summers in the future will have major implication for the entire ecosystem and thus will alter current biogeochemical cycles in the Artic.

Due to the generally low solar elevation light is considered to be the key factor for primary production in the ice covered oceans. Light penetration in the Arctic is generally reduced by the sea ice cover and additionally snow greatly reduces light transmission through the ice. In the framework of climate warming, the atmospheric moisture budget in the Arctic is forecast to change, resulting in an increasing snow cover and thus reducing the light for primary production. However, the reduction from MYI to seasonal ice and additional increase of melt ponds on FYI will substantially increase light transmission through ice.

Due to the extreme low light intensities caused by the albedo and the strong attenuation of the ice itself and snow, primary production of ice algae is generally thought to be low compared to large ice edge phytoplankton blooms. However, low light penetration and the increasing attenuation towards longer wavelengths in the ice can be compensated for by the algae by modifying their accessory photosynthetic pigments, and thus these organisms are well-adapted to the very low light conditions in early spring. Once blooming, the brown ice algae assemblages at the bottom of the ice cores can have a major impact on the optical properties of the sea ice. Sudden changes in the light field can result in a dramatic loss of algae biomass and production, which can only be compensated for by other parts of the marine community. Currently ice algae are very well adapted to their low light environment and, despite their moderate production, early in the season are the only food source for the pelagic fauna. In particular, in spring the sea-ice algae blooms are essential for the development stages of copepods which fuel higher trophic levels in the Arctic. Once ice algae get detached from the ice during the melting process, they still leave large fraction of carbon compounds in the ice behind which are attributed to extracellular polymeric substances (EPS) produced by the sea ice algae. These processes allow further access of this carbon pools to be used by bacteria. Currently little is known about the biodiversity of TEP associated bacteria.

Due to the decrease of the sea ice thickness, evolving habitats for sea ice algae have been observed in surface melt ponds. These new evolving ecosystems in Arctic melt ponds might have consequences for the carbon budget, leading to major implications for the cryo-benthic and cryo-pelagic coupling of the Arctic Ocean. Changes in sea ice habitat structure and ice algal production will affect the trophic transfer of sea ice-derived carbon through the under-ice community into pelagic food webs, with unknown consequences for biodiversity, ecosystem functioning and resource availability.

During PS84 (ARK-XXVIII/1) we aim to study the following topics:

1. Investigate sea ice biota at the end of the Transpolar drift and compare with historic data
2. Reveal the role of melt pond associated communities for the ecosystem
3. Improve estimates of spatial variability of sea ice algae
4. Determine the role of EPS for the carbon pool in sea ice
5. Identify the the EPS associated bacteria
6. Determine the snow cover in spring for the validation of satellite data
7. Access the photosynthetic performance of sea ice algae in late spring
8. Study adaptation to various light intensities
9. Estimate the spectral light and absorption under the ice under various natural conditions

Work at sea

Biological, Physical &, Chemical Biogeochemical parameters of sea ice

Helicopter flights for sea-ice stations will be performed along the cruise track as often as weather conditions allow. Observations of sea-ice, snow, melt-pond, and weather conditions will be performed along the track from the bridge of *Polarstern* in cooperation with other groups. These observations may be supported by automated observations through cameras, recording ice conditions continuously from a point above the bridge.

During the ice stations we will take ice cores for biological, chemical and biogeochemical analyses. We will further sample the water under the ice and if present, melt pond water. The depth of the sampling under the ice will be based on the profiles of the CTD and fluorescence probe which will be conducted prior to the water sampling. We will estimate measure environmental parameters as sea ice temperature, snow depth, free board, ice thickness, water flow velocity below the ice, and directly on the ice floe. We will further run grids of snow depth (Snow Hydro Magna Probe) on the ice station for the validation of satellite data. A hyperspectral radiometer will be used to measure the spectral composition of the light under the ice for distinguishing the ice-algae biomass. Point measurements with this type of sensor will be carried out in drill holes for a direct validation of the hyperspectral estimates of ice-algae concentrations with pigment measurements from ice cores and further optical properties as particle absorption and CDOM from entire sea ice cores. Measurements of light will be carried out under and above the ice. Photosynthetic performance of sea ice algae will be directly determined on the ice floe by using a Waltz Imaging-PAM fluorometer.

The water and ice core samples will be transported back to the ship. A regular sea ice sampling involves the collection of melted ice-core sections, under-ice water and melts pond water. In general we aim to collect the following variables: salinity, nutrients, coloured dissolved organic matter (CDOM), dissolved inorganic carbon (DIC), and filters for particulate N, P and C. Additionally, algae biomass and composition will be determined by size-fractionated chlorophyll, marker pigments, molecular markers and cell counts (microscopy and flow cytometer). Also biogenic silicate, particulate organic carbon and nitrogen (POC, PON) and the isotopic composition of POC and PON (δ^{13}CPOC and δ^{15}NPON) will be determined.

For the determination of EPS melted sea ice from various stations will be prepared to differentiate between Transparent exopolymer particles (TEP) and Coomassie-stainable particles (CSP). For the estimation of EPS associated bacteria a set of experiments will be carried out with natural sea ice samples and artificial produced EPS from filtered sea ice cores.

Flow cytometer measurements of the pico- and nanoplankton from all habitats including the entire water column will be directly counted on board. All other samples will be stored and measured at the AWI/Arhus for determination of all other variables.

Preliminary (expected) results

The aim of this study is to understand the variability of the sea ice-associated biomass with respect to the sea ice conditions and nutrient availability, to access the role of sea-ice biota for the cryo-pelagic, cryo-benthic coupling under different environmental scenarios. Special emphasis will be given to understand the role of melt ponds in the carbon cycling of the Arctic Ocean. These data can be used for modelling approaches to access the role of climate change on the carbon cycle of the Arctic Ocean.

Data management

Samples

Except for the microscopic samples, all other variables taken during the cruise will be processed during or after the cruise (1 year). Leftovers of the microscopic samples and the DNA will be stored at the Polar Biological Oceanography at the AWI for approximately 10 years.

Data

Data from ice work will be collected during and after the cruise. The entire data set will be submitted to PANGAEA Data Publisher for Earth & Environmental Science within 1-2 years. The unrestricted availability from PANGAEA will depend from the progress of a PhD thesis based on the data.

2.5 MARINE CHEMISTRY

M. Kiel, K.U. Ludwichowski, M. Graeve (AWI)

Nutrients, oxygen and dissolved organic matter

The determinations of nutrients are closely connected with the physical and planktological investigations. The development of phytoplankton blooms is especially dependent on the available nutrients. On the other hand nutrients are well suited as tracers for the identification of water masses. The change in nutrient and oxygen concentrations will be followed in the Fram Strait region and during the Greenland Sea transect, especially across the Greenland shelf and slope. In comparison with similar transects in former years, the seasonal and interannual variability will be determined. In the 1980s and 1990s water masses of Pacific origin occurred usually in the shelf and slope regions of the Fram Strait and further south of the Greenland Sea. The data from 2004, 2008 however, show almost no signal of water of Pacific origin. Especially the nitrate to phosphate ratio, but also silicate are good tracers to follow the outflow of upper halocline Arctic surface water along the Greenland continental shelf and slope. Water masses may be especially rich in silicate compared to Atlantic waters. The data from this expedition will show whether there are further modifications of the water masses exiting the Arctic Ocean.

From water samples taken with the rosette sampler at different depth, the nutrients - nitrate, nitrite, phosphate, silicate and ammonia - are determined immediately on board with an Autoanalyser-system according to standard methods.

In addition, dissolved organic matter (DOC) will be extracted from seawater at representative stations to follow the outflow of water masses transporting terrestrial organic matter from the huge Siberian river towards the Fram Strait. Sampling will be decided from results of the fluorescence profiles and 1-2 l of seawater will be extracted. The chemical characterisation of DOC will be performed in the home labs at Bremerhaven.

After compiling and evaluation of the primary data, a dataset based on the nutrient data will be available after 1 year after the cruise. The data set will be made available for the public in the PANGAEA Data Publisher for Earth & Environmental Science at least 2-3 years after the cruise.

2.6 BATHYMETRY OF THE NORTH-EAST GREENLAND CONTINENTAL SHELF

J. E. Arndt, D. Matahelemual, L. Radig (AWI)

Objectives

The North-East Greenland ice stream reaches about 700 km inland and drains a major part of the Greenland ice sheet via marine terminating glaciers at the western edge of the North-East Greenland Continental Shelf (NEGCS) [Joughin et al., 2000]. Today, the marine terminations of the North-East Greenland ice stream are mostly located in northeast Greenland fjords. During the glacial periods, this glacier however extended as an ice sheet further to the east onto the NEGCS. Based on results from radiocarbon dating, Bennike and Weidick [2001] hypothesized that the Greenland Ice Sheet reached onto the middle shelf or even the shelf edge. An advance to the middle shelf was later proven by Evans [2008]. In addition, multiple terminal moraines have been discovered on the middle shelf in Westwind Trough [Winkelmann et al., 2010]. These moraines indicate that the Greenland ice sheet retreated stepwise on the middle shelf.

The existing studies, however, only provide a fragmented picture of the Greenland ice sheet development with the majority of NEGCS area unmapped. Hence, additional bathymetric surveys are needed to increase the area of multibeam coverage on the NEGCS in order to identify and map seabed features indicative of past ice sheet histories and expenses.

In recent times, the flow of warm and saline water onto the shelf has been observed. This inflow affects the heat exchange from open waters to the floating glacier tongues therefore potentially generate basal melting [Mayer et al., 2000]. For the reconstruction of possible pathways of warm and saline water across the NEGCS and hence the influence on the northeast Greenland glaciers, detailed bathymetric models are of central importance.

The NEGCS is more than 300 km wide. Thus, it is one of the largest shelf areas off the Greenland coast. With only about 6 - 7 % covered by bathymetric soundings and even less with multibeam soundings, for large areas of the NEGCS no high resolution bathymetry exists. Especially in Norske Trough and in front of Nioghalvfjerdsfjorden Gletscher (also referenced to as 79° Glacier) bathymetric data coverage is sparse (Figure 2.6.1).

Work at sea

High resolution bathymetry and sub-bottom profiler data will be constantly recorded during the cruise by three operators working in 24/7 shift mode. Bathymetry will be collected with the hull mounted ATLAS Hydrosweep DS3 system. On board, the raw data will be corrected for sound velocity changes in the water column and, in a first step, cleaned for coarse erroneous measurement and artefacts. Working maps will be made available to other working groups on board for detailed station planning.

Sub-bottom profiler data will be surveyed and collected using ATLAS Parasound P70. The Parasound data will be stored on board in *.ps3 and .sgy formats for later processing on-shore.

Preliminary (expected) results

Expected results are in increased coverage of the NEGCS with high resolution multibeam data and consequently improved bathymetric models for the NEGCS. Furthermore, detailed up-to-date bathymetric maps will support scientific operations during the expedition.

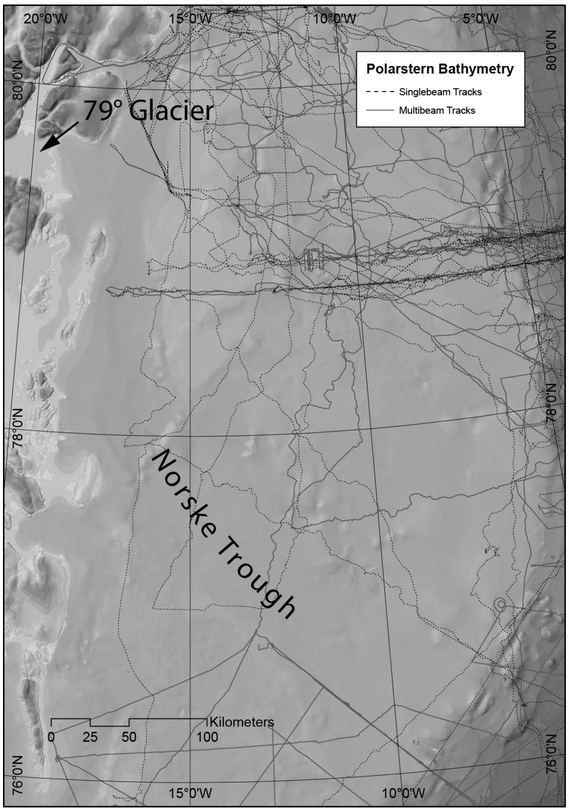

Fig. 2.6.1: Polarstern track plot of the NEGCS showing single- and multibeam data, background data from IBCAO V3.0 [Jakobsson et al., 2012].

Data management

All hydro-acoustic data (swath bathymetry and sub-bottom profiler) collected during the expedition will be stored in the PANGAEA Data Publisher for Earth & Environmental Science at the AWI.

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2.7 INVESTIGATION OF EMERGING PERSISTENT ORGANIC POLLUTANTS AND CARBON NANOPARTICLES IN THE NORTH ATLANTIC AND THE ARCTIC

Z. Xie (HZG), F. Heydebreck (HZG), R. Ebinghaus (not on board)

Objectives

Persistent organic pollutants (POPs) can be transported into the Arctic via atmosphere, ocean current and rivers. Once occurring in the Arctic, the POPs are subject to a variety of processes in the Arctic environment such as degradation, settling, exchange with the atmosphere, adjective transport, water-sediment recycling, bioaccumulation, etc. These processes affect the fate of organic pollutants in the Arctic ecosystem. There are now a few studies for the long-range transport of classic persistent organic pollutants such as PCBs and HCHs from Asia, European and North American continents into the Arctic, while the occurrence and transport pathways of emerging persistent organic pollutants (ePOPs) are still not well understood. Additionally climate change may significantly influence the transport and environment fate of organic pollutants in the Arctic. This project is focused on studies of the distribution and atmospheric transport of emerging organic pollutants such as Per- and polyfluorinated alkyl substances (PFASs) including polyfluorinated alkyl phosphate ester surfactants (PAPs), alternative brominated flame retardants (aBFRs), organophosphorus flame retardants (PFRs), current use pesticides and Carbon nanoparticles in the North Atlantic and the Arctic.

For the 2014 cruise PS85 (ARK-XXVIII/2) , the proposed project is focused on the determination of PFASs, PAPs, alternative BFRs, OPFRs, and Carbon nanoparticles in surface waters and air from the Western Svalbard to Eastern Greenland Sea. The aim of the project is to characterize the distribution of ePOPs in the atmosphere and sea water of the

Arctic Ocean and evaluate the air–sea gas exchange process intervening in the transport of ePOPs into Arctic region. Data from Arctic snowpack, surface seawater and paired air samples will be used to estimate recession and redistribution for ePOPs among different environmental compartments, discover the flow of persistent organic pollutants via air-water or air-snow interaction in the Arctic.

Work on sea

Air samples are collected using a high-volume air sampler operating at a constant flow rate of 500 L min-1. The high volume air sampler consists of a high volume pump, a digital flow meter, a metal filter holder and a PUF/XAD-2 column. A glass fiber filter (GF/F, diameter, 150 mm; pore size, 0.7 mm) is used to collect atmospheric particles. The ship-borne air samples are collected on the upper deck of the research vessel. Field blanks are prepared by spiking surrogate standards in the PUF/XAD-2 column and shortly exposure to the sampling site.

Different sampling procedures for determination of ePOPs in water phase will be applied and compared. High volume water samples are collected using Kiel In-Situ Pump (KISP) equipped with PAD-3 resin column which is optimal for neutral substances. 2-L water samplers are preconcentrated with solid-phase extraction, which is used for determination of PAPs and ionic PFASs. A glass fibre filter (GF/F, diameter, 47 mm; pore size, 0.7 mm) is used to collect suspended particular matters (SPM). Snow sample will be collected with a 1–l barrel and followed with solid-phase extraction on board. Backup of snow samples will be stored in cooling room at -20 °C.

Expected results

By combining integrated atmospheric samples and the collections of reprehensive seawater as well as snow samples across different regions of the Arctic, findings are sought as to determine air-water/snow exchange and setting flux of these organic pollutants. Data and feedback from this project may improve models to predict the environmental progression and assess the effect of climate change on the long-range transport and the fate of the ePOPs in the marine and Arctic ecosystem.

Data management

The finally processed data will be submitted to PANGAEA Data Publisher for Earth & Environmental Science. The open access of data via PANGAEA will be granted after a moratorium in accordance with their scientific publication.

2.8 SEABIRDS AND MARINE MAMMALS AT SEA DISTRIBUTION

Jérémie Guyon, Christophe Houthoofd, Bart Van Gelder (PolE);
Claude R. Joiris (PolE) not on board

Objectives

Our long-term study on upper trophic level species (i.e. seabirds and marine mammals) in polar marine ecosystems aims to deepen our understanding of the basic mechanisms influencing their at-sea distribution. It has been shown for decades that water masses and fronts, pack ice and ice edge, and eddies are the main hydrological factors explaining the distribution of seabirds and marine mammals in the ocean. Studies on the distribution at sea of the upper trophic levels often reflect the existence of limited zones with very high aggregations: they allow us to locate areas of high biological production, even in ecosystems characterized by very low biodiversity such as the polar ones, because these predators depend on high local prey availability. Such a high patchiness thus must reflect the patchiness of their prey: this is why a close coordination with specialists of zooplankton and small fish distribution was proposed years ago.

Moreover, these data allow us to detect temporal and spatial changes which are likely connected to global changes such as increasing water temperature and reduction in ice coverage.

Work at sea

Seabird and marine mammal transect counts will be carried out on a continuous basis, light and visibility conditions allowing while *Polarstern* is moving. Transect counting method without width limitation is applied from the bridge, lasting half-an-hour each and covering a 90° angle from the bow to one side, the bridge being too broad for allowing simultaneous counting on both sides by one observer. The animals are detected with the naked eye, and observations confirmed and complemented with binoculars (10 X 42). For Brünnich's guillemot, little auk and kittiwake, one has to to make a difference between local birds, both sitting on the water or locally flying without any clear direction and flocks clearly flying in a given direction, probably breeding adults in movement between feeding grounds and colony. Such observations concern a flux and should obviously not expressed as densities. Followers are identified as far as possible and counted as snapshots, once in each count: this includes birds following the ship, circling at some distance, and sometimes flying above the ship (see detail and discussion of the methodology in Joiris 2007, 2011b; Joiris and Falck 2010). When useful, photographic material is also used, especially for species that are rare or difficult to identify. Results are presented as basic unmodified data, i.e. numbers encountered per half-an-hour transect count. Density can be calculated as well, the surface covered during each count being evaluated on the basis of specific detection distances (Joiris 2007, 2011b; Joiris and Falck 2010) and mean ship's speed in the different zones.

Ice cover is evaluated by us from the bridge and expressed as percent coverage within a range of 500 m around the ship as well as from satellite pictures. Water temperature and salinity are continuously recorded on board *Polarstern* with a thermo-salinometer, as well as a fluorimetric evaluation of chlorophyll pigments, at sub-surface sampling (keel: -10 m). General extent of pack ice, ice edge, main water masses and fronts in the area were illustrated in Joiris and Falck (2010) and Joiris (2011a).

Statistical significance of noted geographical differences is tested by applying the non-parametric Kruskal-Wallis test (all zones), and Mann-Whitney test (paired zones), both with Statistica 7.

Preliminary (expected) results

In comparison with the outcome of many expeditions in the Fram Strait/ Hausgarten area, we would like to confirm the importance of hydrological structures and to better understand the existence of large aggregations (if any!), including their seasonal existence and dependence on prey availability: zooplankon including krill, nekton and small fish.

Data management

All data will be included in our PolE data set, available by contacting coordinator Claude R. Joiris: crjoiris@gmail.com and later proposed to PANGAEA Data Publisher for Earth & Environmental Science. Publication in international journals is foreseen within one, maximum two years.

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33.	Tonkes	Henrieke	AWI	PhD student, PEBCAO
34.	von Appen	Wilken-Jon	AWI	Scientist, Physical Oceanography
35.	Weinisch	Lea	Univ. Kaiserslautern	PhD student, Sea Ice Biology
36.	Winkler	Maria	AWI	Student, PEBCAO
37.	Xie	Zhiyong	HZG	Scientist, POP
38.	Ziersen	Bibi	Aarhus University	PhD student, Sea Ice Biology
39.	NN		DWD	Technician, Meteorology
40.	NN		DWD	Meteorologist

2.11 SCHIFFSBESATZUNG / SHIP'S CREW

No	NAME	Rank
01.	Wunderlich, Thomas	Master
02.	Spielke, Steffen	1.Offc.
03.	Ziemann, Olaf	Ch.Eng.
04.	Lauber, Felix	2.Offc.
05.	Kentges, Felix	2.Offc.
06.	Hering, Igor	2.Offc.
07.	Spilok, Norbert	Doctor
08.	Koch, Georg	R.Offc.
09.	Heuck, Hinnerk	2.Eng.
10.	Schnürch, Helmut	2.Eng.
11.	Westphal, Henning	2.Eng.
12.	Brehme, Andreas	Elec.Tech.
13.	Ganter, Armin	Electron.
14.	Christian, Boris	Electron.
15.	Dimmler, Werner	Electron.
16.	Winter, Andreas	Electron.
17.	Feiertag, Thomas	Electron.
18.	Schröter, Rene	Boatsw.
19.	Neisner,Winfried	Carpenter
20.	Clasen, Nils	A.B.
21.	Burzan, Gerd-Ekkehard	A.B.
22.	Schröder, Norbert	A.B.
23.	Moser, Siegfried	A.B.
24.	Hartwig-L., Andreas	A.B.
25.	Kretzschmar, Uwe	A.B.
26.	Kreis, Reinhard	A.B.
27.	Gladow, Lothar	A.B.
28.	Sedlak, Andreas	A.B.
29.	Beth, Detlef	Storekeep.
30.	Plehn, Markus	Mot-man
31.	Fritz, Günter	Mot-man
32.	Krösche, Eckard	Mot-man
33.	Dinse, Horst	Mot-man
34	Watzel, Bernhard	Mot-man
35.	Fischer, Matthias	Cook
36.	Tupy,Mario	Cooksmate
37.	Völske, Thomas	Cooksmate
38.	Luoto, Eija	1.Stwd.
39.	Westphal, Kerstin	Stwdss/KS
40.	Streit, Christina	2.Steward
41.	Hischke, Peggy	2.Stwdess
42.	Wartenberg, Irina	2.Stwdess
43.	Hu, Guo Yong	2.Steward
44	Chen, Quan Lun	2.Steward
45 .	Ruan, Hui Guang	Laundrym.

PS86 (ARK-XXVIII/3)

1 July 2014 - 30 July 2014

Tromsø – Tromsø

Chief Scientist
Antje Boetius

Coordinator
Rainer Knust

3.1 ÜBERBLICK UND FAHRTVERLAUF

A. Boetius (AWI)

Am 1. Juli 2014 wird das Forschungsschiff *Polarstern* von Tromsø zur Forschungsreise PS86 (ARK-XXVIII/3) auslaufen, die der Erkundung der 'Aurora' Hydrothermalquellen gewidmet ist. Zunächst wird der Kurs nach Nord-Nordwest führen ins Messgebiet bei ca. 82°53'N und 6°15'W. In dieser Region werden wir uns circa 20 Tage aufhalten, um die Quellen für in 2001 beobachtete Temperaturanomalien aufzuspüren. Nach Ende der Messzeit werden wir direkt nach Tromsø zurückkehren und dort am 30. Juli 2014 einlaufen. Die Fahrtroute ist in Abbildung 1.1 dargestellt.

Weltweit umspannen 60.000 km mittelozeanischer Rücken die Erde. Entlang der Rückensysteme finden sich unzählige Hydrothermal-Quellen, die von fundamentaler Bedeutung für den Transport von Wärme und Stoffen aus dem Erdmantel zur Ozeankruste sind. Neuere Untersuchungen zeigen, dass selbst die ultralangsamen Spreizungszonen der Arktis und des Südwestindischen Rückens aktive Vent-Systeme führen. Die tektonischen, magmatischen und biogeochemischen Prozesse an beiden Rückensystemen sind aber bisher kaum verstanden, da sie in fernen und meteorlogisch schwierigen Arbeitsgebieten liegen. Die Hydrothermal-Quellen der Mittelozeanischen Rücken sind nicht nur Wärmequellen sondern auch Inseln chemosynthetischen Lebens in der Tiefsee. Sie beherbergen besondere, an diesen extremen Lebensraum angepasste Arten, deren Biogeographie noch unzureichend verstanden ist. Der arktische Gakkelrücken ist von allen anderen Rückensystemen weitgehend isoliert und daher ein besonders spannendes Untersuchungsgebiet für Fragen der Evolution und Biogeographie der Hydrothermalquellen-Fauna. Es ist gut möglich, dass der Gakkel-Rücken eine völlig neuartige biogeographische Provinz darstellt mit einem hohen Anteil endemischer Fauna.

Die Expedition ARK28-3 *Aurora* ist der Untersuchung von geophysikalischen, geologischen, geochemischen und biologischen Prozessen an Hydrothermalquellen des Gakkelrückens gewidmet. Zielgebiet ist das Aurora Vent Feld, das in 2001 während der AMORE Expedition entdeckt wurde. Das Aurora-Feld liegt in 4000 m Wassertiefe bei 82°53' N und 6°15' W am südlichen Ende der westlichen vulkanischen Zone. Hier wurden in der Wassersäule mehrere Fahnen von Austritten hydrothermaler Fluide kartiert, ein frischer Schwefel-Schlot gedredgt und interessante Videosequenzen vom Meeresboden erhalten, die auf aktiven Hydrothermalismus sowie auf das Vorkommen von Vent-Ökosystemen hindeuten. Seit 2001 ist dieses vielversprechende Untersuchungsgebiet nicht weiter untersucht worden. Wir möchten ein von WHOI neuentwickeltes ROV/AUV Hybridsystem nutzen für Untereistauchgänge nutzen in Kombination mit neuern chemischen Sensoren und klassischen Untersuchungsmethoden um die hydrothermalen Fluidaustritte des Aurora Feldes aufzuspüren und zu beproben. Das Arbeitsprogramm zielt darauf ab, das geobiologische System des Aurora Feldes zu untersuchen, sowie das komplexe Zusammenspiel zwischen tektonischen, magmatischen und hydrothermalen Prozessen, die die Akkretion neuer ozeanischer Lithosphäre an diesem ultralangsamen Spreizungssystem kontrollieren, und die Nischen für chemosynthetische Ventfauna und assoziierter Gemeinschaften bilden. Ein weiteres Ziel ist die Identifikation dieser bisher unbekannten Fauna und die Untersuchung ihrer Ökologie und Phylogenie im Vergleich zur Ventfauna des Atlantik und Pazifik.

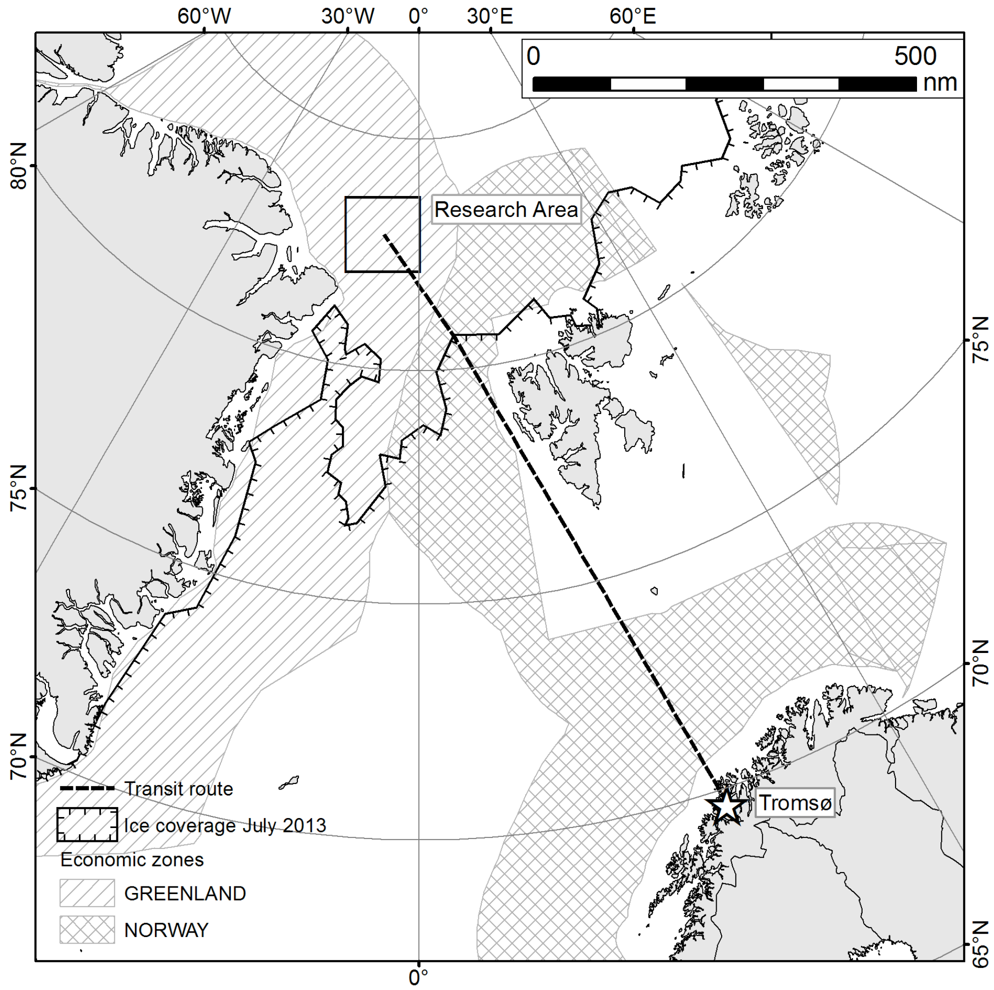

Fig. 3.1.1 Lage des Messgebiets und geplante Fahrtroute. Alle Arbeiten finden im Bereich der 'Aurora' Hydrothermalquellen am Westlichen Gakkel Rücken bei ca. 82°53'N und 6°15'W in ca. 4000 m Wassertiefe statt.

Fig. 3.1.1 Position of survey area and planned itinerary. All station work will be conducted at the 'Aurora' vent site at 4,000 m water depth on the Western Gakkel Ridge near 82°53'N and 6°15'W.

SUMMARY AND ITINERAY

Polarstern will depart for research cruise PS86 (ARK-XXVIII/3) from Tromsø on July 1st, 2014. It will reach the survey area at 82°53'N and 6°15'W after a 5-day transit and stay there for 20 days of survey. In this area, the main aim of PS86 (ARK-XXVIII/3) is to find and study the 'Aurora' vent field on the western Gakkel Ridge. After the end of the survey time, *Polarstern* will return directly to Norway and will arrive in Tromsø on July 30th, 2014. The itinerary is shown in Fig. 3.1.1.

Understanding the distribution of hydrothermal vents along the 60,000 km of mid-ocean ridges that encircle the Earth is of fundamental importance, as these are key to heat and chemical fluxes from the Earth's mantle to its crust. The most isolated and least explored mid-ocean ridge on Earth is the Gakkel Ridge in the Arctic, which is also known to have the slowest spreading rate. The current understanding of ultraslow spreading ridges is that common conceptual models of mid-ocean spreading centres do not apply to these systems. Instead, low melt production and cold lithosphere lead to a thinner overlying crust than at faster spreading ridges. In such system, the magma is believed to be focused towards localized volcanic centres, where the crust is locally thicker. The intervals between those volcanic centres can be large, with little to no crust production, and they may host dominantly mantle-originated rocks.

For these reasons, hydrothermal venting at ultraslow spreading ridges was initially thought to be scarce. Indeed, venting requires both a heat source and pathways for seawater circulation within the rocks. However, surveys in the Arctic and on the Indian Ridge have led to the hypothesis that hydrothermalism is more common than expected, given the abundance of turbidity and temperature plumes as well as chemical anomalies in the water column. In the case of the Gakkel Ridge, vent sites were mostly identified on the volcanic centres. Such distribution is likely controlled by the presence of shallower heat source at those locations. However, because of the remoteness and difficulties of access, the main ultraslow spreading ridges have been so far poorly explored, and very few direct observations at the potential vent locations have been made. Moreover, the large majority of potential vent locations have been neither further investigated nor confirmed with visual observations. Therefore, little is known about the composition and type of the faunal communities that inhabit these high-latitude systems, and their potential linkage with other vent fauna from well-studied vents is entirely unknown.

The main target of research cruise ARKXXVIII/3 is the ‘Aurora’ vent field, located near the western end of the Gakkel Ridge. The Aurora vent is located on a slope near the centre of the axial rift valley. In 2001, dredges in this area recovered sulphide chimneys and camera observations revealed shimmering water as well as abundant fauna. The aim of this cruise is to localize the Aurora vent field, to study the geological processes in the area, and to document and study the associated biological activity. The work will require a cross-disciplinary approach, involving hydroacoustic mapping for bathymetry and sediment cover, search for hydrothermal plume signals in the water column using the CTD/rosette system and the Miniature Autonomous Plume Recorders (MAPR), seafloor visual observations using the high-definition OFOS towed camera system, as well as samplings and identification of the rocks, sediments and faunal communities using dredges, TV-Grab or coring devices. The final sampling program will be planned in more details during the cruise and adjusted depending on the first results as well as on the weather and sea ice conditions. However, the study area is well constrained, which will limit transit times between stations and allow us to rapidly switch surveying or sampling methods. In the meantime, seismometers will be installed on the ice to monitor the seismicity of the vent surroundings, in order to provide better understanding of the ridge system in the part area. Another aim of ARKXXVIII/3 will be to study the sea-ice coverage and thickness using state-of-the-art monitoring techniques such as ROV/AUV under ice mapping and spectral radiometry. Such knowledge is crucial, since variations of ice thickness have a direct impact on the primary production in and below the ice, which in turn, may affect the benthic fauna. The research cruise ARKXVIII/3 is a unique opportunity for a comprehensive insight on a potentially highly active hydrothermal vent system in the Arctic Ocean.

3.2 DEEP-SEA ECOLOGY, BIOGEOCHEMISTRY AND CHEMOSYNTHESIS OF THE GAKKEL RIDGE

A. Boetius, Y. Marcon (AWI); S. Albrecht , J. Pliet (FIELAX); N. Rieper (iSiTEC); C. Borowski , M. Meiners , M. Molari , A. Nordhausen , F. Schramm , R. Stiens, W. Stiens (MPI-Bremen); G. Wegener (MPI-Bremen/MARUM); not on board: N. Dubilier (MPI-Bremen)

Objectives

The distribution of currently known vent systems along the global mid-ocean ridge system is very heterogeneous. Indeed, because of difficulties of access to high latitude areas, most vent observations occurred between 60°S and 60°N, and hydrothermal observations in high latitudes (above 60°) are extremely scarce (Edmonds et al., 2003). Despite this lack, distinct biogeographic provinces have been recognized in the distribution of currently known vents (Van Dover et al., 2002,), and taxonomic affinities between provinces were observed that demonstrated the existence of an evolutionary link across the communities that inhabit the vents (Bachraty et al., 2009). At a global scale, differences between vent biogeographic provinces largely reflect their degree of separation along the ridge system (Tunnicliffe and Fowler, 1996). In this regard, the geographic remoteness and isolation of the Gakkel Ridge in the Arctic Ocean raises questions about the evolution, ecology and dispersal of its biological communities. The Arctic Ocean once connected the Atlantic and Pacific oceans, and may have been used as a pathway for vent fauna to disperse across ocean basins (ChEss Steering Committee 2007). At present there is no ridge-crest connection between the Gakkel Ridge and the rest of the global ridge system. Indeed, the eastern end of the Gakkel Ridge is now a closed end, whereas elevated sections on the western side of the ridge such as Iceland and deep water sills are believed to form natural barriers that isolate the Arctic and Atlantic deep-water masses and to divert deep-water currents. However, the impact of such obstacles onto larval dissemination and community dispersal is currently unknown (Van Dover et al., 2002). Furthermore, observed differences in vent habitats between fast- and slow-spreading ridges suggest that vents at slow spreading ridges may exist for longer periods of time (Van Dover et al., 2002). If we extend this reasoning to ultraslow spreading ridges, the Gakkel Ridge is a good candidate for hosting some of the oldest extant vents on earth.

The recent confirmed discovery of the first hydrothermal vent field on the Gakkel Ridge in the Arctic Ocean (Edmonds et al., 2003) opens up the possibility to answer these questions. Currently, the fauna and in particular the invertebrate-bacteria symbioses of the Aurora vents are still unknown. The knowledge gained by filling this gap will significantly contribute to our understanding of the migration pathways and evolution of hydrothermal symbioses on a global scale. A main objective of our cruise is to test what relationships exist between the Arctic vent communities and the other known vent fauna. Such information is crucial since it will tell us (1) how high the degree of separation between the Gakkel Ridge and the other hydrothermal biogeographic provinces is, and (2) whether the Arctic Ocean provided a gateway for dispersal of vent species between the Atlantic and the Pacific ridge systems in the past. Similar questions equally apply to the non-chemosynthetic deep-sea fauna of the Arctic Ocean, some of which, conversely, have partially been answered. For instance, previous research on non-chemosynthetic deep-sea fauna in the Arctic showed low endemism and high taxonomic affinity to northern Atlantic assemblages (Piepenburg, 2005). Furthermore, some works hypothesized that the Arctic deep ecosystems are young in comparison to other deep ocean ecosystems, because of the low diversity of Arctic species (Paul and Menzies, 1974). This latter point is, however, still under discussion and more data about hard-bottom fauna is required to settle it (Piepenburg, 2005). In any case, the Arctic

Ocean constitutes an ideal laboratory to investigate whether chemosynthetic and non-chemosynthetic Arctic fauna followed similar dispersal and colonization pathways between ocean basins, i.e. to investigate whether the chemosynthetic fauna of the Gakkel Ridge vents also displays a high taxonomic affinity to the current Mid-Atlantic vent assemblages. In addition, the Gakkel Ridge provides an opportunity to examine the influence of spreading rate and water depth on the biogeography of vent fauna. Finally, the former Census of Marine Life program ChEss has identified this ridge segment as a key area to elucidate ecological and phylogenetic relationships between Arctic vent species and Atlantic or Pacific ones, in order to test the hypothesis of a past Arctic Ocean link (ChEss Steering Committee, 2007).

AWI's Deep-sea Ecology and Technology group with collaborators will analyse the distribution of the megafauna at the investigated Aurora vent field, and will combine environmental information including seafloor and bottom water biogeochemistry and microbiological activity, to assess the ecology of deep-sea ecosystems at the Gakkel Ridge. This will include the *in-situ* study of gradients around active vents characterized by redox signals, for example from sulphide emission with the help of sensor modules attached to video-guided instruments. We will also check for gas flares by Parasound-enabled surveys. The assessment of biogeochemical and microbiological signatures in proximity of hydrothermal vents – e.g. redox, sulphide, methane, turbidity plumes and their sources - will be carried out in close collaboration with the oceanography, petrology, and heat flux groups. Members of AWI and FIELAX are responsible to combine all environmental information into geo-referenced maps.

The MPI Bremen Symbiosis Group will investigate the diversity and biogeography of symbioses at hydrothermally active sites. If active Aurora vent field is localized on the seafloor, the diversity, biogeography and function of hydrothermal symbioses will be investigated using taxonomy, molecular methods and isotopic signatures.

Together we will contribute towards several of the main goals of the mission, including

- Localization and characterization of the Aurora hydrothermal vent field and mapping to determine structural controls on the vent location
- Sampling of hydrothermal fluids to determine (a) high-temperature water-rock interactions in the deep root zone of the systems, (b) fluid mixing and cooling processes in the sub-seafloor and potential linkages to microbial activity
- Analyses of vent communities to determine dispersal and colonization pathways along spreading ridges

Work at sea

Main tools for the exploration surveys following the CTD and MAPR transects as well as the Parasound enabled gas flare detection will be the video-guided, winch-operated instruments, which will be geo-referenced by POSIDONIA transponders, allowing both the characterization of bottom near environmental parameters (e.g. via the Microsensor-Profiler and temperature probes mounted to the OFOS and the TV-guided MUC), as well as a visual analysis of habitats and megafauna. High resolution towed camera surveys with photos and videos are a key method to determine the density and distribution of deep-sea megafauna, documenting spatial patterns at a high resolution and showing the organisms *in-situ*, and in association with their immediate habitat. To analyse the photo and video material, we will use a combination of mapping and image analysis tools to extract quantitative information from large amounts of geo-referenced images. The sampling of rocks, sediments, water with their microbiota and fauna from the Gakkel Ridge will fill gaps in the global biogeography of benthic and animal-associated microbial communities, and will help to assess the composition and distribution of hydrothermal vent communities and their key energy supplies. Therefore we will deploy dredges and multiple corer systems as well as the TV grab, depending on the weather and ice conditions and on the seafloor features. Animals from active vents will be collected using the TV grab and processed on board for photography, molecular and isotopic analyses in the home laboratories.

Sample and data management

Care will be taken to deploy the TV grab according to the Code of Conduct for responsible research practices at hydrothermal vents (http://www.interridge.org/IRStatement), i.e. avoid sampling that would cause long-lasting deleterious effects. Specimens for morphological phylogenetic analyses will be fixed and sent to the corresponding taxonomic experts, in collaboration with the Shirshov Institute and Senckenberg Research Institute and Museum. For molecular analyses, we will fix the specimens on board and use multi locus sequencing in the home laboratory for examining the taxonomy and phylogeny of vent biota and their symbiotic microorganisms. All biogeochemical data will be quality checked, stored and made available through PANGAEA. Biological data will be submitted to the OBIS data base. Tracks of video and photography surveys will be stored in PANGAEA; the photographic material will be made available to taxonomists and further image analysis via BIIGLE. Microbiological sequence data will be archived in GenBank.

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3.3 SEISMICITY AND THERMAL STATE OF THE ULTRASLOW SPREADING GAKKEL RIDGE

3.3.1 Seismology

V. Schlindwein, H. Kirk, F. Schmid (AWI)

Objectives

Active spreading processes at mid-ocean ridges are reflected in their earthquake activity. Microearthquakes may image active faults, the motion of magma (e.g. Dziak et al., 1995), the circulation of hydrothermal fluids (e.g. Tolstoy et al., 2008) and the thermal state of the lithosphere (e.g. Schlindwein et al., 2013). Yet, seismicity studies of ultraslow spreading ridges are rare because their main representatives, the Arctic ridge system and the Southwest Indian Ridge, lie in poorly accessible areas. Consequently, their active spreading processes are still not well understood. An analysis of the teleseismic earthquake activity of ultraslow spreading ridges has shown, that these ridges behave differently than faster spreading ridges (Schlindwein, 2012). Especially the isolated volcanic centres of ultraslow spreading ridges are capable of strong and long-lasting seismic activity and vigorous volcanic eruptions (Schlindwein and Riedel, 2010). However, most spreading processes produce small magnitude earthquakes that go undetected by land stations.

In the past, we have therefore started to acquire reconnaissance-style local seismicity data from the Arctic ridge system using passive seismic arrays on drifting ice floes (Schlindwein et al., 2007; Läderach and Schlindwein, 2011). We could demonstrate the feasibility of this method and prove that the rift and its adjacent flanks are seismically active out to a distance of about 30 km. Furthermore, particular events were recorded, that reflected for example ongoing volcanic activity (Schlindwein et al., 2005). The earthquakes can further be used to get an impression of the crustal and lithospheric structure (Korger and Schlindwein, 2014). At 85°E Gakkel Ridge, we managed to obtain a tomographic image of the seismic velocities in the crust and upper mantle during 16 days of recording with 3 seismic arrays that drifted three times over the survey area. We also detected earthquakes with hypocentres as deep as 20 km below seafloor indicating an exceptionally cold lithosphere.

However, the ice-floe based seismic studies are only of very short duration (several days) and the drift paths are unpredictable. Especially, event rates and magnitudes are difficult to compare between surveys. We therefore have recently acquired the first ever long-term seismicity data of an ultraslow spreading ridge instrumenting a magmatic and an amagmatic site of the ultraslow spreading Southwest Indian Ridge with ocean bottom seismometers (*Polarstern* cruises ANT-XXIX/2 and 8). In contrast to the Gakkel Ridge, the Southwest Indian Ridge is tectonically more complex and its structures not as long-lived as on Gakkel Ridge. For a principal understanding of ultraslow spreading ridge processes and for improved knowledge of the structure of the Arctic Ocean basin it is therefore desirable to operate ocean bottom seismometers in ice-covered regions.

During cruise PS86 (ARK-XVIII/3) we will pursue two goals:

We plan to get local seismicity data from the Western Volcanic Zone, preferably surrounding the potential vent site, Aurora. Based on our experience with previous installations, we aim this time for a small network of seismometers on ice-floes rather than 3 single arrays at larger distances. 15 km array spacing proved to be too large to target very small seismic events. We will therefore deploy a network of about 8-10 km diameter instrumented with 5 stations surrounding a central small array. This network will drift over the survey area and will be redeployed whenever it leaves the area of interest. In that way, we will obtain a multitude of small events and a good station coverage through multiple drift paths. We expect that we will be able to see active faults that may serve as pathways for hydrothermal fluids and we may obtain information on crustal and upper mantle structure.

The second purpose of this survey is to conduct a first technical and logistic test with ocean bottom seismometers in dense sea-ice. As *Polarstern* will stay in the survey area for a longer time period, we have the unique chance to perform this essential test. Depending on its outcome, we will be able to determine what technic developments are needed to routinely operate ocean bottom seismometers in ice-covered regions.

Work at sea

Our test of the ocean bottom seismometers will consist of two parts. We will use the winch to lower an OBS with one of the mobile Posidonia transmitters available on *Polarstern* attached to the ocean bottom seismometer. We will follow its path onto the seafloor and wait until it has settled in its position. Depending on battery consumption of the transmitter, we will release this instrument after a short time period and follow its way upward through the Posidonia position. A suitably large area of ice will have to be broken beforehand. We will loose the Posidonia position shortly before the OBS surfaces and can then search a small area for the orange buoys of the instrument, eventually with helicopter's help. Radio beacons are attached to the buoys to further support instrument detection. For the second test, we will use a different Posidonia transmitter that can stay longer at the seafloor. We will let the instrument fall freely onto the seafloor and aim to obtain a longer recording period preferably to allow a comparison with the seismometers on ice floes. Recovery of this ocean bottom seismometer will work in the same manner.

When arriving at the survey area, we will use the first possible opportunity to deploy the network of seismic stations. The network will consist of a central small array of 3 seismic stations deployed in a triangle of about 800 m side length on a single suitably large ice floe. One station will carry an ARGOS transmitter that allows tracking of the station. After that, an additional 5 stations - each with an ARGOS transmitter - will be deployed on a circle of radius 5 km around the central array. The installation of a single station takes about 40 min. 3 stations can be carried in a single helicopter flight. After the deployment, the drift of the seismic stations can be followed through their ARGOS positions. These data will help us to predict the ice drift also for the other experiments. If the stations leave the intended survey area, they will be redeployed "upstream" and drift anew over the survey area. We expect that a redeployment might become necessary after about 5 days depending on wind conditions.

The target area will have to be chosen depending on the plans of the other work groups. It is desirable to aim for the same survey location around the potential vent site, but ship operations may interfere with the seismometer recordings producing noise during ice breaking and helicopter flights, and potentially endangering the seismic stations during repositioning of the ship. A compromise between a suitably close and suitably quiet survey target will have to be found depending on prevailing ice drift directions.

Preliminary (expected) results

We expect to record several hundred microearthquakes during our stay near the Aurora vent field. The seismic events will have to be identified in the continuous seismic records, which will most likely be contaminated by artificial noise from the other research activities. Visual inspection of the data set to identify earthquakes will therefore be necessary. We hope to be able to do this partly on board. Subsequent data processing will involve picking of first and later arrivals before earthquake hypocentres can be located. This, however, will take more time and will be part of the data processing after the cruise. The ocean bottom seismometer test will tell us, how time consuming the recovery of the stations is and what kind of additional measures are necessary to facilitate station retrieval. Subsequently, we plan to equip a number of ocean bottom seismometers with the optimized technology to allow ice operations. We further are interested in tracing the sideward drift of the ocean bottom seismometer during descent and ascent and when lowered on a winch, This will help us to better predict ocean bottom seismometer surfacing positions in future surveys.

Data management

Our seismic data will be archived in a common data repository for all data acquired with the ocean bottom seismometers of the DEPAS instrument pool. This archive is currently being developed and implemented at AWI. After 3 years of restricted access, the data will be made publicly available through the GEOFON seismic data request system.

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3.3.2 Heat Flow

N. Kaul, B. Heesemann, H. Jechlitschek (UHB-GEO)

Objectives

Hydrothermalism can have different expressions. It can be as spectacular as black smokers, it can be visible as shimmering water or it can be below first hand evidence simply as enhanced geothermal heat flow. Even slow spreading ridge systems are known to have a vigorous hydrothermalism. However, ultraslow spreading ridges such as the Gakkel ridge are supposed to be “cold” ridges with minor amounts of melt. Observations of concentrated magmatic activity indicate that there must be a transport of magma and energy in direction of the magmatic centers (Brown and White, 1994, Michael et al., 2003, Standish et al., 2008).

The determination of geothermal heat flow is a valuable tool to characterize the pattern of thermal energy dissipation in the heterogeneous ridge environment. Successful heat flow measurements on the South West Indian Ridge (SWIR) during *Polarstern* cruise ANT-XXIX/8 in November-December 2013 revealed areas of subspectacular fluid flow. Nevertheless these fairly low rates of fluid migration are able to modify the “sea floor climate” in a sense that favours seafloor-bound fauna. Indeed, the global significance of spots with enhanced geothermal heat flow depends on the extent of the area that is affected by elevated heat flow. Such areas of diffuse fluid flow may be large, unlike the more spectacular, but usually small, sites of focused water discharge, and, hence, result in comparable, if not larger, total energy exchange. We expect to contribute to the understanding of hydrothermal activity and distribution in the Gakkel Ridge area and thus to the fuelling of microorganisms and macro fauna.

Work at sea

Heat flow determinations will be carried out using the Bremen heat flow probe. This instrument can penetrate down to 6 m into the seafloor and take temperature measurements through 21 sensors distributed along the probe. It is robust to cope with poorly sedimented areas. Precise measurement locations will be decided on-board based on the preliminary findings from subbottom hydroacoustic mapping surveys and plume search. Temperature gradient and thermal conductivity are going to be calculated on board. Additionally, so called MTLs, miniaturized temperature data loggers will be attached to OFOS and other equipment that is towed near the bottom. MTLs will provide additional information in the search for hydrothermal plumes and vent areas.

Data management

Original data will be stored in the PANGAEA database. Further results will be stored as soon as they are available and after their publication in peer-reviewed papers along with other geophysical results of this cruise. Heat flow data will be freely available after publication.

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3.4 HYDROTHERMAL VENTS AND HARD ROCK PETROLOGY

W. Bach, A. Türke, L. Wagner, A. Diehl, D. Bachmann (MARUM/UHB-GEO)

Objectives

The proposed study area in the transition zone between the ultraslow spreading Gakkel Ridge and the Lena Trough is of considerable petrological interest, because of the large variety of rocks exposed in these settings. Previous work has shown chemical and isotopic heterogeneities of the mantle in the area that were explained by differing extents of partial melting and the presence of continental lithospheric material in the melting zone. The Western Volcanic Zone (WVZ) of the Gakkel Ridge from 6°W to 6°E (Michael et al., 2003) is particularly interesting in this regard because of its peculiar lead isotope composition that is elsewhere found only in the South Atlantic and Indian Ocean (e.g., Goldstein et al., 2008). While the WVZ, despite half-spreading rates <13 km/Myrs, is volcanically robust, the Lean Trough is volcanically starved south of 82.4°N (Snow et al., 2011). Rock dredging and multibeam surveys in the area suggest that predominantly magmatically accreted seafloor north of 82.6°S transitions sharply to the south into a seabed made of mantle peridotite exposed along steeply dipping normal faults bounding both sides of the rift valley (Michael et al., 2003; Snow et al., 2011). Rock sampling through this transition has been spotty, and one perspective of the rock sampling program is to recover more basement sample to help better constrain this intriguing geodynamic boundary. Specific questions we hope to address include: How much did the mantle melt? How deep did melting take place? How deep were crustal magma reservoirs? What were the tectonic-hydrothermal interactions during exhumation (pressure-temperature-mass transfer)? What are the relations to active venting?

Another perspective is to help locate hot vents and characterize the hydrothermal plumes. A reconnaissance study revealed that the Gakkel Ridge shows a higher plume incidence than expected based on the slow rate of spreading and hence low magma budget (Baker et al., 2004). The AMORE expedition found evidence of hydrothermal venting in the 83°N, 6°W area in terms of photo sled visual images of shimmering water and biota as well as dredged sulfide (Edmonds et al., 2003).

The Aurora vent fields appears to be located on a volcanic high in the central graben of the northern end of Lena Trough. The samples consisted main of chimney pieces and chunks of massive sulfide. A miniature autonomous plume recorder mounted on the dredge wire picked up turbility anomalies. We plan on helping locate the vents by analyzing methane concentrations in the water column sampled along tow-yo transects. We also sample water for measurements of dissolved metals (specifically Fe and Mn) in these samples. From methane, metal, heat, and turbidity data collected in these survey, inferences can be made about the nature of the vent (German et al., 2010).

We furthermore wish to collect hydrothermal precipitates from the vent sites by TV-guided grab. These mineral deposits allow insights into the vent fluid temperature and composition as well as near-seafloor mixing and precipitation processes (e.g., Vanko et al., 2004; Craddock and Bach, 2010). Using precipitate samples, we would estimate (1) formation conditions (temperature, fluid composition) of chimneys from paragenetic associations in sulfide samples (2) fluid mixing processes from Sr isotope compositions of sulfate minerals, (3) entrapment temperatures and salinities from microthermometry of fluid inclusions in sulfate minerals, and (4) evolution of hydrothermally altered rocks collected in close proximity to the vents.

Sediment gravity coring is an optional sampling method for retrieving archives of hydrothermal sediments, both fall-out and debris-flow deposits.

Work at sea

The “petrology group” will be involved in the following activities at sea:

(1) Collection of basement rocks and hydrothermal precipitate using dredges and TV-guided grab. We will do systematic and detailed petrographic descriptions of the samples. Samples will be photographed and archived before they are packed for shipping.

(2) Collection of water samples from the CTD/water sampler rosette and analyses of methane with a FID-GC, installed and operated by members of our group. Aliquots of the fluid samples will be filtered (0.45 µ) and acidified with nitric acid to a pH of 1.7 and will then be shipped for onshore analyses of dissolved metal concentrations. If water samples from a buoyant plume are collected, we will filter large quantities to retrieve particles for microscopic and geochemical analyses. Pump-driven filtering devices will be brought aboard *Polarstern*.

(3) Sediment gravity coring, using 5-m long corers. All necessary equipment will be supplied by MARUM. Our group will run the coring program, split the cores, and describe the sediment core before storing them in D-tubes.

These activities will be coordinated with other research groups (cf. sections 2 and 5). Much of the sampling will take place jointly with these other groups.

Preliminary (expected) results

Onboard results that will appear in the cruise report include methane concentrations of the water samples and descriptions of rocks, precipitates, and sediments.

On shore measurements will comprise X-ray scanning of sediments, rock analyses by XRF and ICPMS, mineral analyses by electron microprobe and laser-ablation ICPMS. Moreover, metal concentrations of the water samples will be conducted in the home labs.

Data management

Data will be made available in PANGAEA. Rock and mineral analyses will additionally be submitted to the PetDB petrologically database run out of Columbia University.

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3.5 HELIUM FLUXES AND PLUME DISPERSAL

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not on board: M. Walter (UHB-IUP), F. Fripiat (Friye Universiteit Brüssel)

Objectives

The main objective of the oceanography group will be to study the dispersal of hydrothermal plume material from the Aurora vent field on the ultraslow spreading ridge Gakkel Ridge, to determine the heat and chemical fluxes of the field, and to estimate vertical mixing of the water above the ridge and in the axial valley. This goal will be pursued in close collaboration with the petrology/plume chemistry group (W. Bach), with whom we will jointly run the CTD program and who takes water samples for Mn and CH_4 analysis. A hydrothermal plume signal can be identified either by anomalies in temperature and salinity and/or an increase in turbidity and drop of oxygen reduction potential (Eh). Hence, measurements of temperature, salinity, turbidity, and velocity will be conducted to study the plume dispersal. Water samples with high vertical resolution will be taken to be analysed for helium and neon isotopes later in the noble gas laboratory (University of Bremen). Water in hydrothermal plumes is highly enriched in Helium (Isotopes: ^{3}He and ^{4}He); comparison of the He/Ne ratios with that of water outside the plumes and with air shows 5-8 times higher ratios within the plume. The primordial components of helium isotopes are ideal tracers for the distribution of vent fluids in the water column, since they are non-reactive and detectable over long distances away from the source. Direct current measurements parallel to the CTD casts will be used for the calculation of fine-scale velocity shear to estimate diapycnal mixing above the ridge, and to interpret the dispersal of plume signals in the axial valley. In cooperation with the University of Brussels (F. Fripiat) samples of δ^{18}O and δ^{15}N will be taken to study the nitrogen biogeochemical cycles in the area.

Work at sea

CTD work will consist mainly of yo-yo stations where the instrument package is lowered and heaved repeatedly in a certain depth range, while the ship is drifting slowly with the ice. A number of standard stations at different locations will be made to sample background profiles. The yo-yo stations are used for high resolution mapping of the water column plume; the resulting transect of plume properties will allow to lay the groundwork for the operation of video techniques at the Aurora vent site. Repeated profiles of density stratification allow to determine mixing intensities and vertical property fluxes. A Miniature Autonomous Plume Recorder (MAPR, Baker and Milburn, 1997) that records (offline) temperature, pressure, turbidity, and Eh will be attached to the CTD cable in order to increase the spatial coverage and to capture possible signals in Eh. Turbidity on the CTD will be measured using a custom build Seapoint Turbidity Meters (5x normal gain), the same sensor that is used on the MAPR. Direct current measurements will be carried out using a lowered acoustic Doppler current profiler system (LADCP), where two current profilers are attached to the CTD instrument package. Water samples for helium and neon will be taken in glass ampoules (Roether et al., 2013), where water is drawn into evacuated glass ampoules with subsequent flame sealing. This Ampoule-based Water Sampler (AWS) was developed to minimize the delay between sampling and measurement by combining sample collection and gas extraction in one step. The samples will be analysed after the cruise in the Bremen Mass Spectrometer Laboratory (helis Lab).

Preliminary (expected) results

During the AMORE experiment (2001) evidence for multiple hydrothermal plumes along the Gakkel Ridge were found. The Aurora vent field (82°53'N, 6°15'W) was localized by camera tows and dredging. With the combination of turbidity, Eh, and helium measurements we expect to characterize the plume properties and to estimate the vent fluxes. The mixing will allow us to study the vertical exchange of plume material between rift valley and the Arctic Ocean.

Data management

CTD data will be available for all cruise participants on board and the data will be uploaded to PANGAEA. The trace-gas data will be made public on the PANGAEA database as soon as we have them available (approx. one year after the cruise), carefully quality controlled, and published in a peer reviewed journal.

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3.6 SEA ICE PHYSICS

C. Katlein, S. Arndt (AWI), M. Lensu (FMI), not on board: M. Nicolaus (AWI)

Objectives

The observed shift from thicker multi-year to thinner first-year sea ice in the Arctic has consequences for various physical and biological processes within the sea ice and the upper ocean layer. For example, thin ponded sea ice transmits a significantly higher portion of the incoming solar radiation than snow covered thick ice. Hence, the optical properties of sea ice determine the amount of light (energy) that is transmitted into the ice and further into the upper ocean, contributing to warming and melting of sea ice. In addition, the amount of solar radiation dominates primary production and other biological processes in and below the ice layer. Following up observations during earlier cruises (ARK-XXVI/3 and ARK-XXVII/3), which took place during August / September 2011/2012, we want to quantify the amount of light transmitted through sea ice during early summer. It is expected that the availability and the variability of light in and under different types of sea ice differ compared to later phases in the seasonal cycle. These data shall lead to a better understanding of the seasonal evolution of Arctic sea ice, in particular during July, when the solar surface energy fluxes are large, such that small changes in ice properties have large impacts on the energy budget. In that respect, the thickness and properties of the snow cover are known to be most critical for energy budget estimates. Hence, it is necessary to obtain snow measurements along with the optical measurements.

An additional source of information regarding the state of the Arctic sea ice and its snow cover is visual classification of key sea ice variables by sea ice observers. Though quite subjective, visual observations have the promise of creating large datasets due to the numbers of vessels in the summer Arctic. Such datasets are of high value to record the ice conditions during various observations during the cruise and for validation of remote sensing products.

The geometry of sea ice exhibits large variation in all scales which is mirrored by the variation of energy fluxes. The geometric variation can be described in terms of distributions for key variables: for ice thickness, floe size, leads, and ice ridges. These are needed especially in sub grid scale, the length scale shorter than the resolution of Arctic ice drift models. The geometric variation is inherently related to local scale ice kinematics related to opening, closing and deformation. The local kinematics has strong stochastic features contrasting to the continuous larger scale fields of ice drift models. We seek to quantify the local geometry in 10 km radius around the ship in high temporal and spatial resolution. Such data can also be compared with the visual observations so that rules for estimating errors and correcting systematic biases in the observational data can be formulated.

Work at sea

Spectral light transmission through snow and sea ice will be measured during the dives of the WHOI *nUI* HROV. In close collaboration with the WHOI group, several dives close to the sea ice will be performed, revealing spatial variability of under-ice radiation as a function of sea ice and surface types.

Transects of snow depth on sea ice will be obtained whenever direct access to the sea ice is possible (via gangway or helicopter).

The basic physical properties of different sea ice types will be assessed during regular ice stations.

Continuous observations of the sea ice conditions shall be made while the ship is moving with hourly observations of sea ice conditions by trained observers from the bridge.

The local geometry of ice cover will be monitored by radar techniques and field observations. In addition to the ice and wave radars already on the bridge a radar server storing all radar data from a selected radar, about 1,000 images per hour, is installed. The range is about 10 km and resolution 5-10 m. From the data floe-size, leads, ridges and kinematical parameters are determined with algorithms and distributions are generated. Ice thickness profiles, including ice freeboard, ridge sail profiles and snow thickness, are measured in the field using EM-31 thickness probe and levelling laser.

Data management

All data from the radiation measurements require post-processing after the cruise. The data from AWI sensors will be made publically available in the PANGAEA database within one year. Visual sea ice observation data will be distributed by a standardized database at the International Arctic Research Center, University of Alaska, Fairbanks, and will be made available through PANGAEA.

The kinematic and geometric data determined from radar images are to a large extent generated already during the cruise. Preliminary EM thickness profiles are available after the cruise and more accurate data within one year. The imagery and the data are made available in PANGAEA within one year.

3.7 SEABIRDS AND MARINE MAMMALS

D. D'Hert, M. Watelet (PolE), not on board: C. Joiris (PolE)

Objectives

Our long-term study on upper trophic level species (i.e. seabirds and marine mammals) in polar marine ecosystems aims to deepen our understanding of the basic mechanisms influencing their at-sea distribution. It has been shown for decades that water masses and fronts, pack ice and ice edge, and eddies are the main hydrological factors explaining the distribution of seabirds and marine mammals in the ocean. Studies on the distribution at sea of the upper trophic levels often reflect the existence of limited zones with very high aggregations: they allow us to locate areas of high biological production, even in ecosystems characterized by very low biodiversity such as the polar ones, because these predators depend on high local prey availability. Such a high patchiness thus must reflect the patchiness of their prey: this is why a narrow coordination with specialists of zooplankton and small fish distribution was proposed years ago.

Moreover, these data allow us to detect temporal and spatial changes which are likely connected to global changes such as increasing water temperature and reduction in ice coverage.

Work at sea

Seabird and marine mammal transect counts will be carried out on a continuous basis, light and visibility conditions allowing while *Polarstern* is moving. Transect counting method without width limitation is applied from the bridge, lasting half-an-hour each and covering a 90° angle from the bow to one side, the bridge being too broad for allowing simultaneous counting on both sides by one observer. The animals are detected with the naked eye, and observations confirmed and complemented with binoculars (10 X 42). For Brünnich's guillemot, little auk and kittiwake, one has to to make a difference between local birds, both sitting on the water or locally flying without any clear direction and flocks clearly flying in a given direction, probably breeding adults in movement between feeding grounds and colony. Such observations concern a flux and should obviously not expressed as densities. Followers are identified as far as possible and counted as snapshots, once in each count: this includes birds following the ship, circling at some distance, and sometimes flying above the ship (see detail and discussion of the methodology in Joiris 2007, 2011b; Joiris and Falck 2010). When useful, photographic material is also used, especially for rare or difficult to identify species. Results are presented as basic unmodified data, i.e. numbers encountered per half-an-hour transect count. Density can be calculated as well, the surface covered during each count being evaluated on the basis of specific detection distances (Joiris 2007, 2011b; Joiris and Falck 2010) and mean ship's speed in the different zones.

Ice cover is evaluated by us from the bridge and expressed as percent coverage within a range of 500 m around the ship as well as from satellite pictures. Water temperature and salinity are continuously recorded on board *Polarstern* with a thermo-salinometer, as well as a fluorimetric evaluation of chlorophyll pigments, at sub-surface sampling (keel: -10 m). General extent of pack ice, ice edge, main water masses and fronts in the area were illustrated in Joiris and Falck (2010) and Joiris (2011a).

Statistical significance of noted geographical differences is tested by applying the non-parametric Kruskal-Wallis test (all zones), and Mann-Whitney test (paired zones), both with Statistica 7.

Preliminary (expected) results

We will aim to compare results with many previous expeditions in the Fram Strait/Hausgarten area, to confirm the importance of hydrological structures and to better understand the existence of large aggregations (if any!), including their seasonal existence and dependence to prey availability: zooplankon including krill, nekton and small fish.

Data management

All data will be included in our PolE data set, available by contacting coordinator Claude R. Joiris (crjoiris@gmail.com) and later proposed to PANGAEA data set. Publication in international journals is foreseen within one, maximum two years.

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3.8 TECHNOLOGY DEVELOPMENT: USE OF HROV NUI FOR UNDER ICE RESEARCH

C. German, M. Jakuba, S. Suman, J. Bailey, C. Judge, Stephen Elliot (WHOI);
L. Whitcomb (JHU/WHOI), C. McFarland (JHU),
not on board: James Kinsey, S. Laney (WHOI),

Objectives

We will utilize a newly developed hybrid remotely operated vehicle (HROV) system, *Nereid Under Ice* (*nUI*) to attempt the first detailed *in-situ* characterization of photosynthetically-driven biological communities reliant on the penetration of sunlight through the overlying ice within the uppermost 100 m of the Arctic Ocean including the ice/ocean interface itself. Real-time pilot control, closed-loop semi-autonomous behaviours, along with the sensor suite and sampling paradigm together with a horizontal standoff capability of up to 20 km from *Polarstern* will, we believe, enable us to precisely profile the parameters critical to supporting photosynthetically-based ecosystems in an undisturbed water column, far from the mixed wake of an ice breaker. To date, the standoff distances achieved for similar studies have been limited to a few hundred meters and/or utilized less comprehensive sensor suites. This will be the first research expedition to take advantage of the new *nUI* vehicle, purpose-built for studying the ice-ocean interface under both glacial and sea-ice, thus we are pursuing both engineering and science objectives.

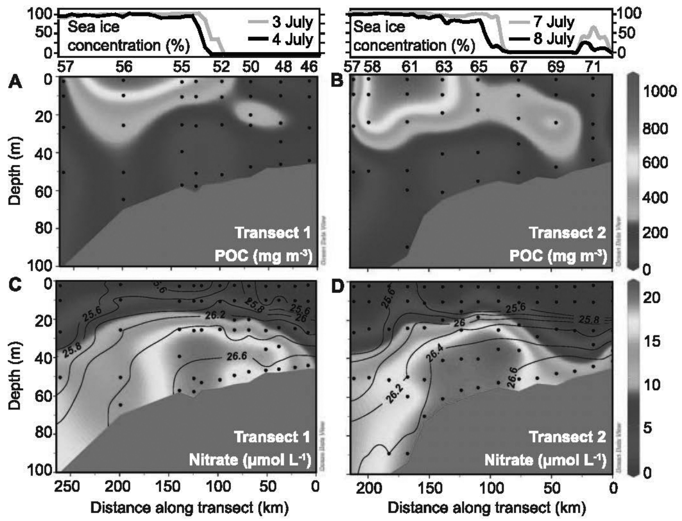

Fig.3.8.1: Under-ice phytoplankton bloom observations from Arrigo et al. (2012). Panels (a) and (b) show high levels of POC (proxy for biomass) while panels (c) and (d) show corresponding panels for dissolved nitrate where the concomitant draw down of nutrient reveal clear evidence that the high biomass observed results from phytoplankton primary productivity.

In July 2011, Arrigo et al. (2012) confounded their own state-of-the-art understanding of primary productivity in the Arctic when they observed a massive phytoplankton bloom that appeared to have developed beneath ~1 m thick first year sea-ice in the Chukchi Sea. Using an ice-breaker to pursue two 250 km transects, spanning from open water to deep within the ice-pack, sampling was conducted to depths of 100 m using a CTD system to investigate for particulate organic carbon (POC) concentrations to measure of biomass as well as dissolved nitrate concentrations as a measure of nutrient uptake (Figure 3.8.1). Depth-integrated concentrations of POC were about fourfold higher beneath the ice-shelf than in the adjacent open ocean and persisted for more than 100 km within ice-pack. These measurements were based on water-column sampling conducted after the icebreaker had cleared sufficient open water to deploy the CTD-rosette. Nutrient depletion was observed to accompany these POC/biomass peaks to depths of 20 m to 30 m, providing evidence that phytoplankton blooms rather than ice algal growth was responsible for the POC enrichments measured. Earlier reports have hinted at similar under-ice phytoplankton blooms in the Barents Sea, Beaufort Sea and Canadian Arctic Archipelago (Strass and Nöthig, 1996; Mundy et al., 2009; Fortier et al., 2002) but until now we have lacked the technology to investigate these processes directly *in-situ*, in unperturbed under-ice settings. Advancing this field is not just timely but urgent if we are to be equipped to understand and predict the impacts of future changes in the Arctic Ocean physical environment.

Fig. 3.8.2: Examples of M. arctica aggregations in Summer 2012 (Boetius et al., 2013). Strands ~20 cm long of Melosira (A) under ice; (B) as recovered in sediment core tops and (C) as imaged in-situ at the seafloor, being grazed upon by the holothurian K. hyaline.

Most recently, Boetius et al. (2013) have considered the case in which thinning of the sea-ice in the Arctic might lead to higher light transmission which, in turn, might lead to higher primary productivity in the 10 m to 30 m thick mixed layer. In their work, studies at the seafloor revealed expansive patches and strands of the ice algae *Melosira arctica* measuring up to 50 cm across covering as much as 10 % of the seafloor in locales at 3,500 m to 4,400 m depth (Figure 3.8.2). These, in turn, were being grazed upon opportunistically by benthic holothurians and ophiuroids, revealing an apparent mechanism by which physical changes at the upper ice-ocean interface could be translated, rapidly, into ecosystem impact at the deep ocean floor. Despite the high organic carbon flux recorded in the 2012 study (Boetius et al., 2013), it was noted that in-faunal burrows and tubes were rare, consistent with an absence of the sediment-dwelling macrofauna that are characteristic of other deep-sea basins (Glover et al., 2010). Similarly, oxygen consumption rates away from the algal falls were very low, similar to conditions found beneath other oligotrophic regions (Fischer et al., 2009). Taken in concert, these observations provide compelling evidence that these ice-algal fluxes are novel and may, indeed, reflect incipent responses to thinning Arctic Ocean ice-cover.

Scientifically, our overall objective is to advance these discoveries with further investigations into the potential for under-ice photosynthesis in the uppermost Arctic Ocean to drive high primary productivity, in ice-algae and/or phytoplankton blooms, and to couple these results with complementary seafloor studies to discern whether Arctic warming and resultant ice-thinning might herald a new era of significant organic Carbon flux in what was previously an oligotrophic basin.

The key technology behind the hybrid ROV *Nereid Under Ice* (*nUI*) is a light-weight (250 µm diameter) communications-only fiber-optic tether technology originally developed for the *Nereus* 11,000 m full-ocean-depth capable vehicle (Bowen et al., 2009). This tether enables operation by a pilot with high-bandwidth real-time streaming of all data feeds including HD video back to the ship, at horizontal stand-off distances up to 20 km from the host ship. Our overarching engineering objective is to demonstrate the viability of the tethering technology and of *nUI*, Figure 3.8.3, in general to conduct operations from an ice breaker through permanent ice cover.

Specific engineering milestones we expect to achieve are:

- Establish the overall usability of *nUI* in conditions likely to occur in Polar regions, including the viability of launch and recovery procedures through sea ice, protocols for minimizing time on deck and mitigating the impacts of sub-zero temperatures on vehicle systems and scientific payloads, adequacy of pilot situational awareness, recovery aids, and tempo of operations.

- Demonstrate the viability of the tethering system for real-time piloted control at a minimum standoff distance of 1 km, and ideally up to 10 km. We do not plan to exercise the ultimate limit of 20 km on this expedition.
- Demonstrate piloted, semi-autonomous, and autonomous „come-home“ behaviors designed to return the vehicle to a location within 100 m of the ship for recovery under a variety of scenarios and (simulated) failure modes, most prominently loss of tether and loss of acoustic communication.
- Demonstrate under-ice navigation, both in ice-relative and geo-referenced coordinate frames, at minimum under a single contiguous floe with *Polarstern* rigidly moored to that floe, and ideally within a field composed of multiple floes in motion relative to one another and the ship.
- Demonstrate the ability of the vehicle to operate as essentially an inverted ROV – in particular to land on the underside of the ice and to hold station relative to overlying ice and execute other motions under closed-loop control.

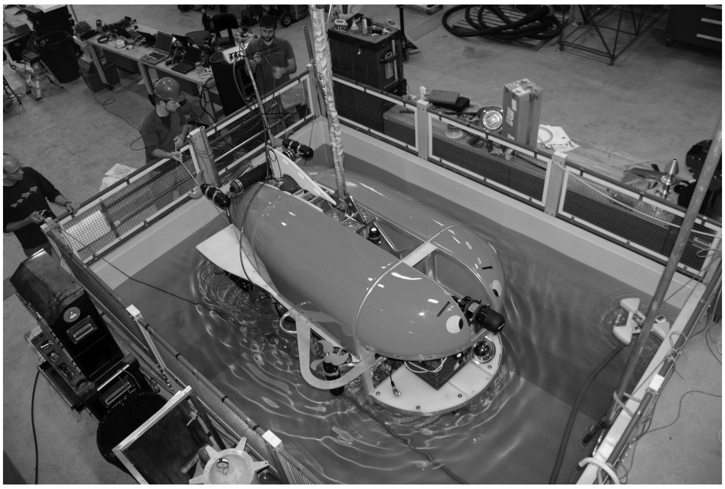

Fig. 3.8.3: The Nereid Under Ice vehicle undergoing tank tests in September 2013

Work at sea

The standard vehicle is equipped with dual up/down 300 kHz ADCP/DVLs, a SeaBird CTD, a WetLabs Chl/NTU fluorometer and an internal pan/tilt/zoom HD video camera capable of looking upward with supporting dedicated lights. For this expedition we are equipping the vehicle with additional sensors including an upward-looking multibeam sonar, radiometers mounted along the dorsal „spine“ of the vehicle to monitor incident radiation penetrating through the ice. A water-sampling snorkel (protruding 1 m to 2 m above the orange flotation visible in Figure 8.3) will pump water to additional *in-situ* sensors in the principal payload space at the front of the vehicle: additional fluorometers, a SUNA *in-situ* nitrate sensor and an FRRF (Fast Repetition Rate Fluorometer). The two TriOS RAMSES spectrophotometers that we will use (1 Radiance ARC and 1 Irradiance ACC Sensor) will measure light penetrating through the sea-ice to determine the energy fluxes available to drive photosynthesis. Measures of the light field will include intensity, color and geometry of the ice-cover. The FRRF, Fluorometers and SUNA will be coupled to a SeaBird25+ unit that will pump water from the snorkel to the sensor package: the FRRF will be used to measure photosynthetic performance and a WetLabs Eco-Triplet fluorometer that combines chlorophyll with backscatter and CDOM measurements to investigate algal, particulate and dissolved organic matter concentrations. By adding a SUNA *in-situ* nitrate sensor to this sample suite we should be able to replicate, *in-situ*, the full suite of measurements reported by Arrigo et al. (2012).

This is important because, in all prior studies, observations in the “under-ice” water column have been achieved by breaking through the ice cover with the research ship and then obtaining samples and sensor data via a CTD-rosette deployed into the open water once the ice has been broken up. By contrast, using *nUI*, we will aim to conduct the first truly unperturbed investigations of such ecosystems. By deploying the *nUI* vehicle through the ice close to our primary work area (we anticipate 10/10 ice cover in the Aurora hydrothermal field area when we are on station in July 2014) we will be able to descend under pilot control to 50 m to 100 m water depths to ensure we are clear of all possible ice-keels and then pilot the vehicle laterally, over distances of at least 1 km and perhaps up to 10 km away from the ship, before ascending toward the ocean-ice interface from beneath under precision closed-loop depth control. The snorkel intake arrangement will limit any perturbations caused by *nUI*’s thrusters by allowing the vehicle to remain beneath the freshwater lens often found in summertime beneath melting Arctic ice. Because we anticipate 24 hr daylight while on station at these high latitudes, the possibility exists that we may be able to conduct all of our operations without using any of the ancillary lighting that the *nUI* vehicle can provide. As such, this study promises to represent the most pristine/unperturbed investigation to date of primary productivity in the sunlit upper reaches of the ice-covered Arctic Ocean.

Preliminary (expected) results

We will operate the vehicle in at least three distinct but complementary modes:

1) Targeted high-resolution vertical profiling, with sites selected based on a combination of real-time video and sensor data. This is the primary modality and will require the snorkel, and likely also some use, probably intermittent, of the vehicle's lights.

2) Constant distance from ice or constant depth survey, primarily for ir/radiance measurements and still camera work. Use of the vehicle's lights is not compatible with the former, and as yet unclear whether necessary for the latter. The pilot will rely primarily on the imaging sonar for these surveys.

3) Ice topology mapping with the multibeam, 40 m distance from the ice being optimal for maximum rate coverage.

A total of 80 km of fiber-optic tether is available for the expedition. The actual number of dives and distances traversed during each dive will depend on the conditions encountered and cruise schedule, *nUI* operations being incompatible with the other planned operations that involve deploying wire (CTD, TV-grab, etc.).

Data management

We anticipate multiple data-types arising from this cruise all of which will be directly analogous to those obtained by other ROVs designed and operated by WHOI including the *Nereus* hybrid ROV/AUV and, more pertinent to this section, *Jason* which is part of the US National Deep Submergence Facility. Standard data products from this cruise will include: navigation data, bathymetric data from the underside of the ice, time-stamped *in-situ* (physical and biogeochemical) water-column data and HD video and still imagery of the sea-ice interface.

Remembering that the *nUI* vehicle is essentially designed, conceptually, as an inverted ROV (which now will be looking upward at the rough topography of the underside of the sea-ice instead of downward at the equally challenging terrain of the seafloor) we anticipate that all of these data-types will be readily manageable by following the same standard protocols already established by the NDSF for the *Jason* ROV and which we also already follow routinely for *Nereus*. Video imagery and digital still camera images are time stamped at source and recorded to hard drive. Likewise, navigation for the *nUI* vehicle is post-processed on a dive-by-dive basis and the final "best navigation" file is then merged with the time-stamped *in-situ* sensor data to generate a standard .txt or .csv file that can readily be ingested into a range of scientists preferred user software (Matlab, Kaleidagraph, etc.). One important distinction is that navigation data from *nUI* will be provided in both ship/ice-relative coordinates and in georeferenced coordinates. At cruise end, duplicate sets of the data will be provided on portable external hard drives to the Project PI (German, WHOI) and to the Cruise PI (Boetius, AWI) while a 3rd archive copy of the data will be retained by the *nUI* team and banked in the Data Library and Archive at WHOI on a like-for-like basis with all NDSF Archive Data-Sets, where they can be accessed readily by any interested parties.

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2.	Albrecht	Sebastian	Fielax	Technician, bathymetry / data management
3.	Arndt	Stefanie	AWI	Scientist, sea ice
4.	Bach	Wolfgang	MARUM/UHB-GEO	Group leader, petrology/fluid chemistry
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27.	Nordhausen	Axel	HGF MPG Group (MPI-Bremen)	Technician, TV grab

	Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession
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45.	NN		Reederei Laeisz	Azubi
46.	NN		HeliService	Helicopter
47.	NN		HeliService	Helicopter
48.	NN		HeliService	Helicopter
49.	NN		HeliService	Helicopter
50.	NN		DWD	Meteorologist
51.	NN		DWD	Meteorologist

3.11 SCHIFFSBESATZUNG / SHIP'S CREW

No	NAME	Rank
01.	Schwarze, Stefan	Master
02.	Grundmann, Uwe	1.Offc.
03.	Heuck, Hinnerk	Ch. Eng.
04.	Fallei, Holger	2. Offc.
05.	Langhinrichs, Moritz	2.Offc.
06.	Stolze, Henrik	2.Offc.
07.	Spilok, Norbert	Doctor
08.	Fröb, Martin	R.Offc.
09.	Grafe, Jens	2.Eng.
10.	Minzlaff, Hans-Ulrich	2.Eng.
11.	Holst, Wolfgang	3. Eng.
12.	Scholz, Manfred	Elec.Tech.
13.	Christian, Boris	Electron.
14.	Hüttebräucker, Olaf	Electron.
15.	Nasis, Ilias	Electron.
16.	Himmel,Frank	Electron
17.	Loidl, Reiner	Boatsw.
18.	Reise, Lutz	Carpenter
19.	Scheel, Sebastian	A.B.
20.	Brickmann, Peter	A.B.
21.	Winkler, Michael	A.B.
22.	Hagemann, Manfred	A.B.
23.	Schmidt, Uwe	A.B.
24.	NN	A.B.
25.	Wende, Uwe	A.B.
26.	Bäcker, Andreas	A.B.
27.	Guse, Hartmut	A.B.
28.	Preußner, Jörg	Storek.
29.	Teichert, Uwe	Mot-man
30.	Schütt, Norbert	Mot-man
31.	Elsner, Klaus	Mot-man
32.	Voy, Bernd	Mot-man
33.	Pinske, Lutz	Mot-man
34.	Müller-Homburg, Ralf-Dieter	Cook
35.	Silinski, Frank	Cooksmate
36.	Martens, Michael	Cooksmate
37.	Czyborra, Bärbel	1.Stwdess
38.	Wöckener, Martina	Stwdss/KS
39.	Dibenau, Torsten	2.Steward
40.	Silinski, Carmen	2.Stwdess
41.	Arendt, Rene	2.Steward
42.	Möller, Wolfgang	2.Steward
43.	Sun, Yong Shen	2.Steward
44.	Yu, Kwok Yuen	Laundrym.
45.	Wittek, Sönke	Appr.
46.	Fachini, Simon	Appr.

PS87 (ARK-XXVIII/4)

02 August 2014 – 06 October 2014

Tromsö - Bremerhaven

Chief Scientist
Ruediger Stein

Coordinator
Rainer Knust

4.1 ÜBERBLICK UND FAHRTVERLAUF

R. Stein (AWI)

Übergeordnete Ziele des marin-geologischen Arbeitsprogramms sind (1) die zeitlich möglichst hochaufgelöste Rekonstruktion der Änderungen von Meereisbedeckung, Paläoproduktivität, paläoozeanischer Zirkulation und Paläoklima im Arktischen Ozean während des Spätquartärs und (2) die Langzeitentwicklung des Paläoklimas im Verlauf des Meso-Känozoikums. Hierzu sollen an gezielt ausgesuchten Lokationen, an denen känozoische/mesozoische Sedimente an der Oberfläche ausstreichen, Sedimentkerne für detaillierte sedimentologische, geochemische und mikropaläontologische Untersuchungen gewonnen werden. Die Kernlokationen (als auch Lokationen für mögliche spätere IODP-Bohrungen) werden mit Hilfe von geophysikalischen Methoden (Seismik und Parasound) ausgewählt. Hierzu ist es erforderlich, möglichst lange seismische Profile über die Becken und Rückenstrukturen zu vermessen, um a) Verbindungsprofile zu existierenden Linien zu erhalten, um deren Altersmodell auf die neuen Profile zu übertragen, und b) um besser zu verstehen, in welchen tektonischen und sedimentären Regimes der vorgeschlagene Bohrpunkt liegt. Ferner liefern die seismischen Daten wichtige Informationen zur sedimentären und tektonischen Geschichte des arktischen Ozeans und der angrenzenden Schelfgebiete. Hauptarbeitsgebiete der geowissen-schaftlichen Forschungen sind der Alpha-Rücken und der südliche Lomonosov-Rücken (Fig. 4.1.1).

Neben dem geowissenschaftlichen Schwerpunktprogramm der Expedition sollen ergänzende Nebenprogramme durchgeführt warden: Messungen der Meereisverbreitung, der Meereis-dicke und der Meereisdrift; Erfassung von Veränderungen in der Wassermassen-zusammensetzung (Temperatur- und Salzgehalt) und der Zirkulation; Verteilung von Vögeln und marinen Säugern in der Hocharktis.

Polarstern wird am 02.08.2014 aus Tromsö nach Norden auslaufen. Auf der Fahrt Richtung Alpha- bzw. Lomonosov-Rücken werden bereits ozeanographische, geologische und bio-logische Messungen bzw. Beobachtungen durchgeführt. Im Arbeitsgebiet 1 liegt dann der Schwerpunkt auf geophysikalischen Vermessungen und geologischer Probennahme. Begleitend werden ozeanographische, meereisphysikalische und biologische Messungen/-Beobachtungen fortgeführt. Im Arbeitsgebiet 2 werden dann schwerpunktmäßig wieder geowissenschaftliche Arbeiten ausgeführt, die bis ca. 22. September laufen sollen. Nach Abschluss der Arbeiten in Gebiet 2 wird *Polarstern* Richtung Vilkitsky Straße dampfen. Die Rückfahrt in der russischen EWZ soll weitgehend entlang der Northern Searoute erfolgen. Während der Rückfahrt durch die russische EWZ sind folgende Forschungsaktivitäten geplant (Arbeitsgebiet 3): Allgemeine meteorologische Messungen, Luftproben, Wasserproben, Beobachtung von Meeressäugern und Wassertiefenmessungen. Alle Messungen finden automatisch und kontinuierlich während der Fahrt statt. Es ist geplant, die russische EWZ etwa bei 30°E spätestens am 30.September 2014 zu verlassen und am 06.10.2014 in Bremerhaven einzulaufen. Die generelle Fahrtroute ist aus der beigefügten Karte zu entnehmen (Fig. 4.1.1).

Sollten die Eisbedingungen es nicht erlauben, das Arbeitsgebiet 1 Mitte August anzufahren, wird eventuell zunächst ins Arbeitsgebiet 2 gefahren werden und dann - nach Abschluss der dort geplanten Untersuchungen – das Schiff ins Arbeitsgebiet 1 dampfen. In diesem Fall wird die Rückfahrt nach Bremerhaven direkt Richtung Fram-Straße erfolgen, Svalbard wird westlich passiert und die Northern Searoute wird nicht befahren werden.

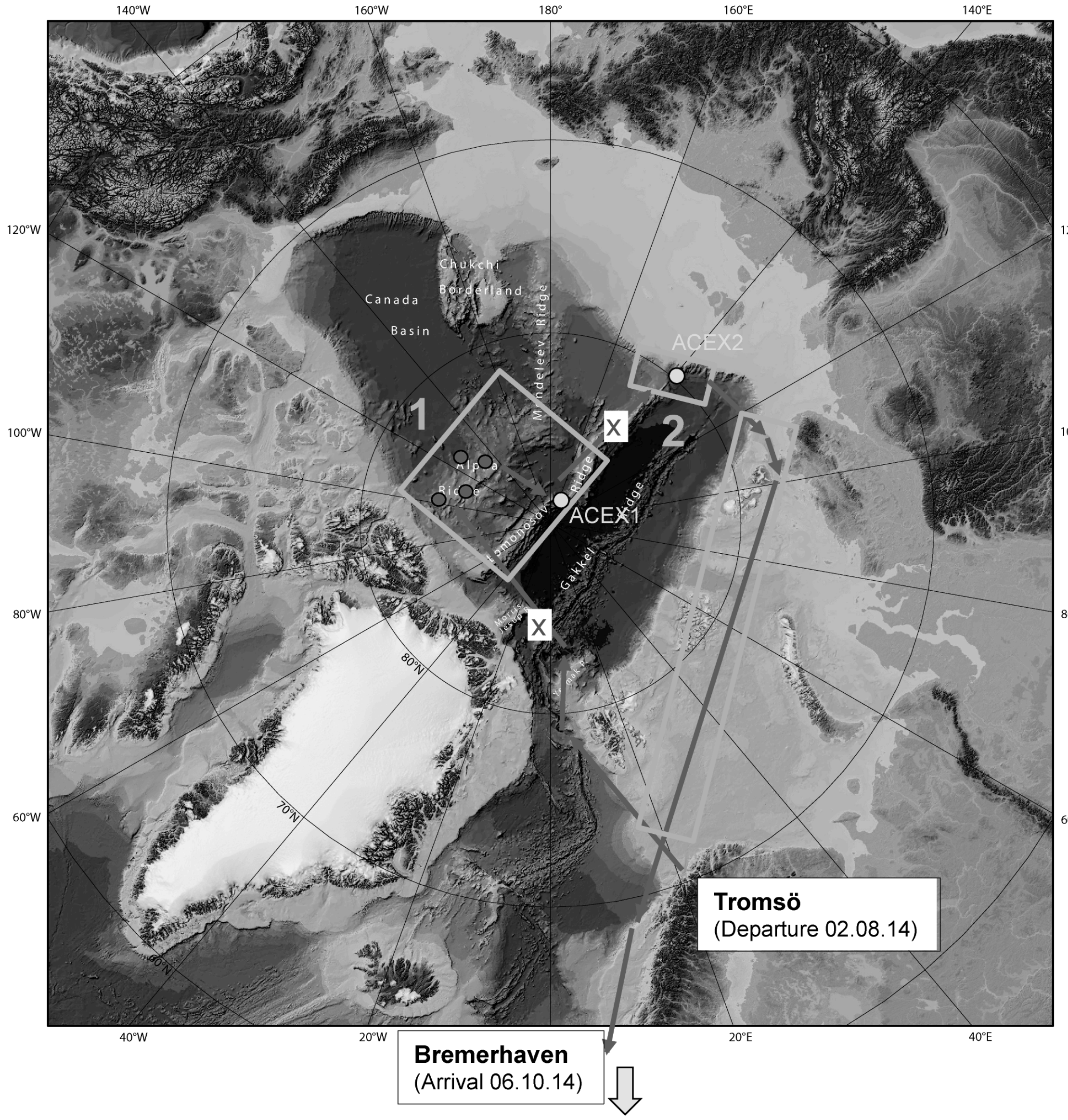


Fig. 4.1.1: Key working areas are the Alpha Ridge and the Lomonosov Ridge (Area 1) and the southern Lomonosov Ridge (Area 2). In these areas, detailed seismic and Parasound/ Hydrosweep profiling surveys as well as a geological sampling program will be carried out. Dark circles indicate locations where older (Mesozoic/early Cenozoic) sediments are cropping out. "x" indicates transit tracks where some additional sediment and sea-ice samples will be taken. Furthermore, xCTD measurements and as well as observations of sea birds and marine mammals will be carried out. In Area 3, only en-route measurements will be carried out (i.e., no station work). In addition, the location of IODP Expedition 302 ("ACEX1") as well as the location of the proposed future IODP drilling "ACEX2" are indicated.

SUMMARY AND ITINERARY

Although major progress in Arctic Ocean research has been made during the last decades, the knowledge of its short- and long-term paleoceanographic and paleoclimatic history as well as its plate-tectonic evolution is much behind that from the other world's oceans. That means - despite the importance of the Arctic in the climate system - the data base we have from this area is still very small, and large parts of the climate history have not been recovered at all in sedimentary sections. This lack of knowledge is mainly caused by the major technological/logistic problems in reaching this permanently ice-covered region such as the Alpha Ridge area with normal research vessels in order to carry out seismic profiling and retrieving long and undisturbed sediment cores. With *Polarstern* Expedition PS87 (ARK-XXVIII/4), we are planning to work in (1) the Alpha Ridge area and (2) the southern Lomonosov Ridge area (Fig. 4.1.1) to carry out seismic profiling and sediment coring, and – by this – fill part of the gap in knowledge.

The overall goals of the marine-geological research program are (1) high-resolution studies of changes in paleoclimate, paleoceanic circulation, paleoproductivity, and sea-ice distribution in the central Arctic Ocean and the adjacent continental margin during Late Quaternary (especially postglacial-Holocene) times, and (2) the long-term history of the Mesozoic and Cenozoic Arctic Ocean and its environmental evolution from a warm (Greenhouse) to an ice-covered polar (Icehouse) ocean. In areas such as the Alpha-Mendeleev-Ridge, pre-Quaternary sediments are cropping out, which could even be cored with coring gears aboard *Polarstern* and which would allow to study the Mesozoic/Tertiary history of the (preglacial) Arctic Ocean. The core locations (as well as potential locations for later IODP-type drilling on Alpha Ridge and Lomonosov Ridge) will be determined by seismic and Parasound profiling. For this it is of great importance to run long seismic profiles across the basin and ridge structures to a) gather tie lines to existing profiles for correlating their age model into the new lines, and b) to better understand the tectonic and sedimentary setting of the proposed drilling location. Furthermore, the seismic data will provide new insights into the tectonic and sedimentary evolution of the Arctic Ocean and the adjacent continental shelves.

The new seismic and geological data to be obtained during the PS87 (ARK-XXVIII/4) Expedition will be the basis for a more precise planning of a future international scientific drilling within the „International Ocean Discovery Program - IODP". That means, we are planning to submit a new proposal for drilling on the Alpha Ridge. Furthermore, the new site-survey data to be obtained on southern Lomonosov Ridge will be used to identify the optimum site location for drilling the ACEX2 program (IODP-Proposal 708; Stein, Jokat et al., 2014).

In addition to the geoscientific program, the major focus of this expedition, several supplementary programs will be carried out:

- XCTD measurements along cruise track (temperature, salinity, density, sonic velocity)
- Measurements of sea-ice distribution, thickness and drift
- Observation of seabirds and marine mammals

The fourth leg of *Polarstern* Expedition PS87 (ARK-XXVIII/4) will start on August 02, 2014, in Tromsø, Norway. Key research areas are the Alpha Ridge and the southern Lomonosov Ridge close to the Laptev Sea continental margin (Fig. 4.1.1). In these areas seismic profiling and geological coring activities will be the main focus. In addition, supplementary oceanographic and sea-ice studies as well as observations of seabirds and marine mammals will be carried out. The expedition will end in Bremerhaven on October 06, 2014.

4.2 MARINE GEOLOGY: RECONSTRUCTION OF PAST ARCTIC CLIMATIC CONDITIONS

R. Stein, J. Matthiessen, F. Niessen, T. Hörner, H. Kolling, N. Lensch, , NN, NN (AWI); L. Castro de la Guardia (UoAE); A. de Vernal (GEOTOP); M. Forwick (UoT); H. Jin (SIOSOA); S. Kaboth (UoU); F. Petersen (UoK), A. Prim (UoM); M. Zwick (UoBr); M. Kaminski (KFU); A. Krylov, (VNIIO); A. Kudryavtseva (UoStP); S. Nam, M. Schreck (KOPRI); R. Spielhagen (GEOMAR)

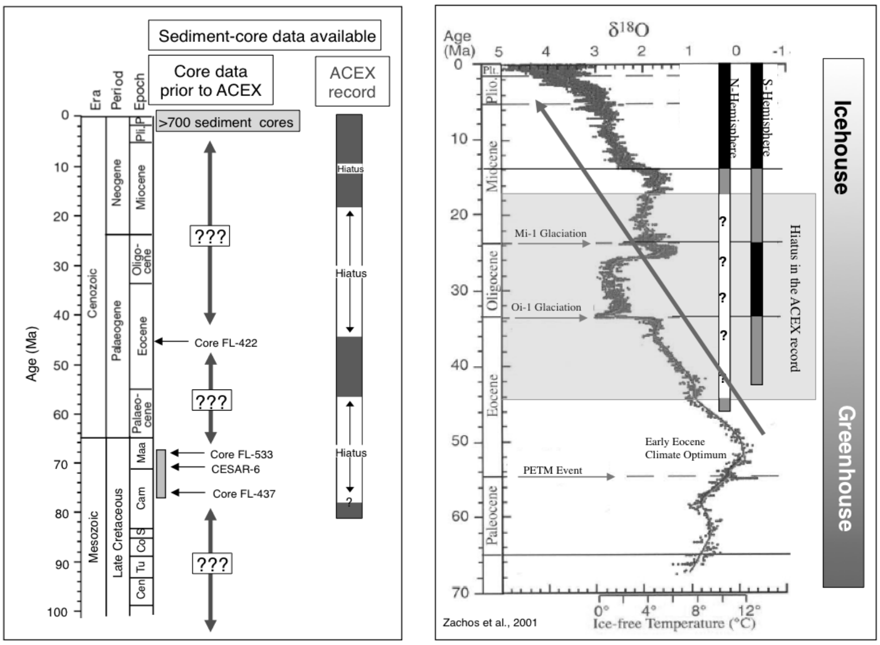
Objectives

Concerning the reconstruction of the long-term Cenozoic Arctic Ocean climate history, a major break-through was the very successful IODP drilling campaign on Lomonosov Ridge, the „Arctic Coring Expedition - ACEX" (e.g., Moran et al., 2006; Stein et al., 2006; Backman, et al., 2008; Figs. 4.1.1 and 4.2.1). For the Alpha-Mendeleev Ridge, however, no long-term paleoclimatic records are available yet. During RV *Polarstern* Expedition ARK-XIV/1a (1998) undisturbed, 4.5 to 7.2 m long sedimentary records were obtained on the Alpha Ridge (Fig. 4.2.2), probably representing the last about 0.5 Ma (Jokat et al. 1999; for an update see Stein, 2008 and references therein). In only four short cores from the Alpha Ridge, older pre-Neogene sediments were recovered (Jackson et al., 1985; Clark et al., 1986; dell'Agnese and Clark, 1994; Firth and Clark, 1998; (Figs. 4.2.1 and 4.2.2):

Core 533:	85° 05.9´N, 98° 17.8´W	Lower Mastrichtian
Core 437:	85° 59.5´N, 129° 58.5´W	Campanian
Core 422:	84° 53.3´N, 124° 32.5´W	Middle Eocene
Core CESAR-6:	85° 49.6´N, 109° 04.9´W	Late Mastrichtian

These sediment cores were retrieved from drifting ice islands, i.e., more or less by accident without any detailed information about the sub-surface structures.

The upper Cretaceous sediments from the Alpha Ridge consist of organic-carbon rich black mud containing a diverse assemblage of acritarchs, prasinophytes and dinoflagellate cysts (Core FL533), and almost pure laminated siliceous oozes with excellently preserved diatoms and silicoflagellates (Cores FL-437 and CESAR-6) (Dell´Agnese and Clark, 1994; Firth and Clark, 1998). In general, these data suggest a warmer (ice-free) Arctic Ocean with strong seasonality and high paleoproductivity, most likely associated with upwelling conditions. Differences in sediment composition between the cores may have been caused by lateral and temporal nutrient conditions, oceanic currents, bottom-water oxygen levels, and basin topography (Firth and Clark, 1998). Detailed reconstructions of the long-term paleo-environmental history during Mesozoic-Cenozoic times from the Alpha-Mendeleev Ridge area, however, are not available yet and the main purpose of the Marine Geology program of expedition PS87 (ARK-XXVIII/4).



(Stein, 2008; based on Miller et al., 1987, 1991; Thiede et al., 1990; Lear et al., 2000; Zachos et al., 2001; Backman, et al., 2006; Backman et al., 2008).

Fig. 4.2.1: Stratigraphic coverage of existing cores in the central Arctic Ocean prior to ACEX (based on Thiede et al., 1990) and the section recovered during the ACEX drilling expedition (Backman, et al., 2006, 2008) (from Stein, 2008), and global climate curve with Greenhouse-Icehouse transition during Cenozoic times (Zachos et al., 2001; supplemented).

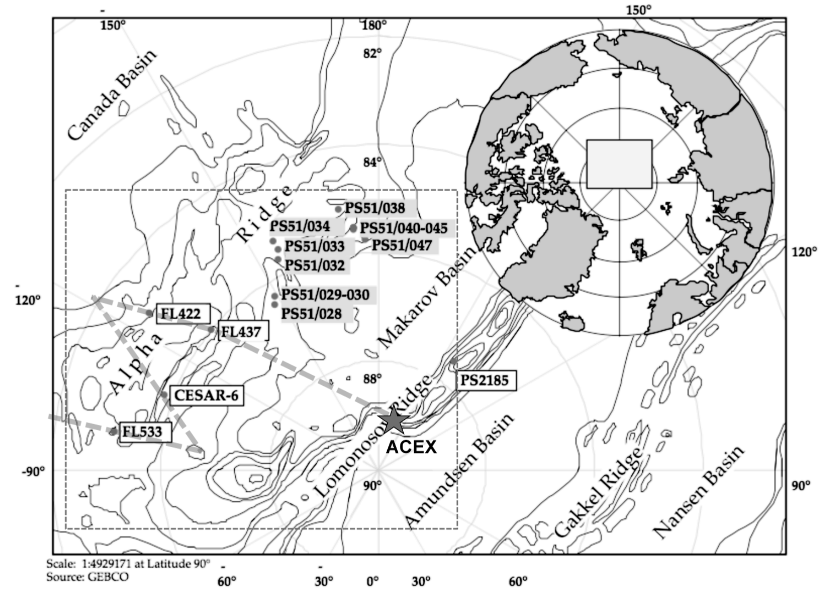


Fig. 4.2.2: Locations of the four sediment cores in which pre-Neogene sediments were recovered on the Alpha Ridge (Jackson et al., 1985; Clark et al., 1986), locations of cores recovered during the Polarstern 1998 Expedition (Jokat et al., 1999), and main working area for geological station work and seismic profiling (stipled box) and proposed key transects during the PS87 (ARK-XXVIII/4) Expedition (stipled bars); details will depend on ice conditions.

Work at sea

Based on a detailed site survey with Parasound (and Hydrosweep), transects of undisturbed sediment cores across the Alpha Ridge and the Lomonosov Ridge will be selected. In the Alpha Ridge area, major focus will be the older pre-Neogene strata cropping out, which may allow to construct a composite Mesozoic/Early Cenozoic sedimentary section. On southern Lomonosov Ridge sediment cores will be recovered in the area of the proposed drilling campaign "ACEX2" (Fig. 4.1.1; Stein, Jokat et al., 2014). The new sediment cores will allow detailed high-resolution reconstruction of late Quaternary paleoenvironmental changes.

Coring gears to be used are Giant Box Corer (GKG), Multicorer (MUC), and Gravity (SL), Kastenlot (KAL) and Piston Corer (PC). In addition, direct sampling of sea ice and sea-ice sediments will be carried out using a helicopter. Furthermore, a hovercraft will be onboard to function as an auxiliary research platform in support of the PS87 (ARK-XXVIII/4) science program. The hovercraft may be used to carry out specific tasks such as instrument deployment/recovery, sediment coring etc.

Expected results and objectives of post-cruise research

- Stratigraphic analyses of the sediment sequences, using a multi-proxy-approach (AMS14C, oxygen and carbon stable isotopes, biostratigraphy, natural radionuclides, physical properties, xrf scanning, cyclostratigraphy, and correlation to other existing Arctic Ocean records).
- Quantification and characterization of terrigenous sediment fraction in order to reconstruct transport processes, oceanic currents, and circum-Arctic ice-sheet history (Proxies/approach: grain size, clay minerals, heavy minerals, major, minor, trace and rare earth elements, organic carbon fractions, and physical properties; analytical techniques: X-ray diffraction (XRD), X-ray fluorescence (XRF), inductivity-coupled plasma mass spectrometry (ICP-MS), and microscopy of coarse fraction as well as MSCL-logging and XRF-scanning.
- Reconstruction of surface-water sub-surface and deep-water characteristics: paleo-sea-ice distribution, surface-water productivity, sea-surface and deep-water temperature, deep-water ventilation, etc., using specific biomarkers (e.g., n-alkanes, sterols, alkenones; U^{k}_{37} Index, TEX_{86} Index, IP_{25} Index), micropaleontological proxies (dinoflagellates, foraminifers, ostracodes, etc.), and inorganic-geochemical proxies (stable isotopes, radiogenic isotopes, etc.). Analytical techniques to be used include LECO ($CaCO_3$, TOC, C/N), Rock-Eval pyrolysis, gas chromatography (GC), gas chromatography/ mass spectrometry (GC/MS), and high-performance liquid chromatography/mass spectrometry (HPLC/MS), XRF, ICP-MS, and microscopy as well as XRF scanning.
- Studies of sea ice and sea-ice sediments (biomarkers, mineralogy, geochemistry, biology, etc.).

Data management

All data will be uploaded to the PANGAEA database. Unrestricted access to the data will be granted after about three years, pending analysis and publication.

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4.3 GEOPHYSICS: TECTONIC EVOLUTION OF THE ARCTIC OCEAN

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Objectives

Geophysical investigation of the past decade concentrated on the sedimentary and tectonic history of the Arctic Ocean. Here, especially the Lomonosov and Alpha-Mendeleev ridges play an important role. While the evolution of the continental Lomonosov Ridge as a consequence of the rifting event along the Barents and Siberian shelves, and subsequent drift history of the Eurasian Basin, is well understood, this is not true for the Alpha Mendeleev Ridge (e.g., Kristoffersen, 1990; Jokat et al., 1995; Jokat, 2004, 2005). In general, this feature is interpreted a large igneous province, which erupted sub-aerial between 100 and 85 Myr during the normal Cretaceous Super Chron with the consequences that no marine magnetic seafloor spreading anomalies can be expected, which provide a definite constraints on the age of the ridge system. The major problems are the missing of basement samples and long sediment cores to understand the evolution and relevance of the ridge system for the geological evolution of the Arctic Ocean.

The geophysical programme has two main scientific targets:

Gather new seismic data on the Alpha Ridge and the Lomonosov Ridge areas to provide a competitive data base for future scientific deep sea drilling. For this a small seismic network with cross lines at the proposed site location as well as shallow geological samples are needed.

Gather additional seismic data at the junction of the Mendeleev Ridge with the East Siberian Sea (alternative working area). Here, we would like to densify the seismic network gathered in the season 2008. Preferably, seismic lines running from the shelf deep into the Makarov Basin as well as lines crossing the Mendeleev Ridge as far north as possible have the absolute priority. The investigation of this area is a fall-back position for the geophysical investigations, if the ice conditions across the central part of the Alpha-Mendeleev Ridge do not allow any seismic activities.

Work at sea

Main work plan of the geophysics group is to gather new seismic data across the Alpha Ridge in its central part and the southern Lomonosov Ridge (Fig. 4.1). Gears to be used onboard within the geophysics program are Airgun Frame (8 x 8 l volume), 600 m and 3,000 m Streamer, KSS 31 Gravimeter, as well as Fluxgate magnetometers.

Concerning the seismic lines across the Alpha Ridge no precise planning can be done, since every activity is strongly depending on the ice conditions. However, here one of the main targets is to map locations were a) a complete Cenozoic/Mesozoic sediment cover is present, and b) where basement rocks of older sediments crop out and/or are easily accessible.

Expected results

The lines gathered in 2008 across the Makarov Basin indicate that approximately 300 m below the seafloor a pronounced velocity jump from 1.8 to 2.9 km/s occurs. Such velocity jump might be an indication for past large-scale mass wastes across a margin. Seismic lines perpendicular to the shelf will provide stratigraphic information on such events. Another shot coming from the 2008 lines is that the interpretation is at some point difficult because of three sediment sources: Lomonosov Ridge, East Siberian Shelf, and Mendeleev Ridge. With the lines across the East Siberian Shelf we will be able to quantify better the significance of each source for the sedimentary history of this area.

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4.4 BATHYMETRY

B. Dorschel, L. Jensen, C. Stolle (AWI)

Objectives

Bathymetric data will be recorded with the hull-mounted multibeam echosound Atlas Hydrtosweep DS3 and sub-bottom data will be recorded with the hull-mounted sediment echosound Atlas Parasound P70. The main task of the bathymetry group is to give advice in planning and to run bathymetric surveys in the survey areas and during transit. The raw bathymetric data will be corrected for sound velocity changes in the water column and will be further processed and cleaned for erroneous soundings and artefacts. Detailed seabed maps derived from the data will provide information on the general and local topographic setting in the area of the expedition. Simultaneously recorded sub-bottom data provide information on the sedimentary architecture of the surveyed area. High-resolution seabed and sub-bottom data recorded during the survey will be made available for site selection and cruise planning. In addition, sediment samples will be collected for ground truthing the acoustic data and to analyse the physical properties of the sediments in the survey area (see Chapter 4.2).

Expected results are high-resolution seabed maps and sub-bottom information along the cruise track and from the target research sites. The bathymetric and sediment acoustic data will be analysed to provide geomorphological information for the seabed in the Arctic Ocean. Expected outcomes aim towards a better understanding of the geological and particularly the sedimentological processes in the research area.

Hydro-acoustic data (multibeam and sediment echosounder) collected during the expedition will be stored in the PANGEA data repository at the AWI. Furthermore, the data will be provided to mapping projects and included in regional data compilations such as IBCAO (International Bathymetric Chart of the Arctic Ocean) and GEBCO (General Bathymetric Chart of the Ocean).

Data management

All data will be uploaded to the PANGAEA database. Unrestricted access to the data will be granted after about three years, pending analysis and publication.

4.5 MEASUREMENTS OF SEA-ICE DISTRIBUTION, THICKNESS AND DRIFT

A. Bublitz, A. O'Brien, C. Haas (YuoT, not on board); M. Nicolaus (AWI, not on board)

Objectives

The 2014 *Polarstern* cruise to the central Arctic Ocean provides a great opportunity to continue long-term observations of sea ice properties and change, particularly of ice thickness. The main objective of this cruise is therefore to gather extensive helicopter electromagnetic ice thickness data in the region along the *Polarstern* cruise track. These data will be used to observe regional sea ice thickness variations and to compare with similar measurements performed in the same region in 1991, 1998, 2001, 2007, 2011, and 2012. As the 2014 cruise will lead into the region of the Alpha-Ridge, for the first time we will also be able to obtain data from older, thicker multiyear ice closer to Canada. This ties up to similar observations we annually perform north of Ellesmere Island in spring, allowing better comparisons between seasonal thickness changes between late spring and late summer. Some of these measurements are performed by the Polar 5 during its PAMARCMIP campaigns. We plan to deploy a number of drifting buoys to track surveyed ice fields in order to possibly re-survey them at later times (e.g. in 2015) when they will have drifted nearer to Ellesmere Island.

Work at sea

A helicopter will be used to operate the EM Bird for ice thickness surveys along the cruise track, i.e. between Svalbard (ice edge at 82N), the North Pole (90N), and the Alpha Ridge (88N), i.e. 10 degrees latitude. We will use York University's EM Bird which is very similar to the AWI birds (AWI bird as spare). Furthermore, a few helicopter flights will allow us to land on the ice to deploy drifting buoys, and to potentially obtain some in-situ ice thickness data for validation. These flights can be performed jointly with other working groups who may want to work in the ice as well.

Data management

All data will be uploaded to the PANGAEA database. Unrestricted access to the data will be granted after about three years, pending analysis and publication.

4.6 PHYSICAL OCEANOGRAPHY

A. Roloff (AWI); not on board: K. Latarius, B. Rabe , U. Schauer , K. Latarius (AWI)

Objectives

Long term heat and fresh water budget of the Greenland Sea: next to the dramatic retreat of sea ice, the strongest climatic signal of the Arctic Ocean and the Nordic Seas are changes in temperature and salinity. While additional heat has been advected northwards from the subpolar North Atlantic, a strong accumulation of fresh water has been observed in the past decades in the Arctic Ocean. Contrary to the central Arctic, the Nordic Seas showed rather increasing salinities in accordance with tendencies in the North Atlantic. This points to a large-scale system change and possibly exhibits a part of a multidecadal oscillation. The glider program aims at supporting long-term observations of the Northern Nordic seas. It is closely related to the AWI glider program in the Greenland sea and enables for the first time a region-wide year-round coverage of the upper ocean in the Greenland Sea. The gliders will capture hydrographic sections through the Greenland Sea. Every 4 km they will dive to 1,000 m depth and thereby record temperature and salinity profiles. These data will be submitted via satellite when the gliders return to the ocean surface after the dive. The gliders will be surveyed and remotely steered along the sections from shore.

Upper ocean observations in the central Arctic Ocean: a positive trend in liquid freshwater of the upper Arctic Ocean basin during the previous two decades raises the question if the freshwater reservoir will continue to increase and if some of this freshwater will be released to the Nordic Seas and the North Atlantic. Temperature and salinity observations in the high Arctic are difficult to obtain and, during summer, rely on ice breaking ships and autonomous platforms. Easy to use expendable systems are an efficient way to obtain temperature and salinity profiles of the upper 1,000 m of the ocean from research vessels while not blocking ship time during an expedition. Several temperature and salinity profiles will be obtained with this method in parts of the Eurasian and Makarov basins during the expedition. This is part of a collaboration between the AWI and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). In addition, a few casts will be carried out with the ship CTD (Conductivity Temperature Depth) rosette.

Work at sea

During transit and in the working areas of the geological and geophysical programs, several Expendable (X)CTD profiles will be carried out from the ship. Some CTD rosette casts will be done depending on the needs of the geophysical and bathymetric groups on board. On the way back to Bremerhaven in the Norwegian Sea, it is planned to deploy four gliders from the University of Washington. Two gliders from AWI might be recovered in the Greenland Sea depending on the route of the ship back to Bremerhaven.

Data management

All (X)CTD and AWI glider data will be uploaded to the PANGAEA database after processing and post-operative calibration. Unrestricted access to the data will be granted within 2-3 years, pending analysis and publication.

4.7 SEA BIRDS AND MARINE MAMMALS

D. Nachtsheim, O. Jamar (PolE), C. R. Joiris (PolE, not on board)

Long-term study on upper trophic level species (*i.e.* seabirds and marine mammals) in polar marine ecosystems aims to deepen our understanding of the basic mechanisms influencing their at-sea distribution. During PS87 (ARK-XXVIII/4), seabird and marine mammal transect counts will be carried out on a continuous basis, light and visibility conditions allowing while *Polarstern* is moving. Further details about background, objectives, work at sea and data management are described under Expedition PS84 (PS84 (ARK-XXVIII/1)) this booklet).

4.8 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTIONS

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4.9 FAHRTTEILNEHMER / CRUISE PARTICIPANTS

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25.	Matthiessen	Jens	AWI	Geology
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27.	Nam	Seung-il	KOPRI	Geology
28.	Niessen	Frank	AWI	Geophysics
29.	Nogi	Yoshi	??	Geophysics
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35.	Rentsch	Harald	DWD	Meteorologist
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37.	Sauermilch	Isabel	AWI	Geophysics

	Name	First name	Institute	Profession
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39.	Sonnabend	Hartmut	DWD	Technician
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46.	NN		AWI	Geophysics
47.	NN		AWI	Geophysics
48.	NN		UoB	Geophysics/Hovercraft
49.	NN		HeliService	
50.	NN		HeliService	
51.	NN		HeliService	
52.	NN		HeliService	

4.10 SCHIFFSBESATZUNG / SHIP'S CREW

No	NAME	
01.	Schwarze, Stefan	Master
02.	Grundmann, Uwe	1.Offc.
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04.	Fallei, Holger	2. Offc.
05.	Langhinrichs, Moritz	2.Offc.
06.	Stolze, Henrik	2.Offc.
07.	Pohl, Klaus	Doctor
08.	Fröb, Martin	R.Offc.
09.	Grafe, Jens	2.Eng.
10.	Minzlaff, Hans-Ulrich	2.Eng.
11.	Holst, Wolfgang	3. Eng.
12.	Scholz, Manfred	Elec.Tech.
13.	Christian, Boris	Electron.
14.	Hüttebräucker, Olaf	Electron.
15.	Nasis, Ilias	Electron.
16.	Himmel,Frank	Electron
17.	Loidl, Reiner	Boatsw.
18.	Reise, Lutz	Carpenter
19.	Scheel, Sebastian	A.B.
20.	Brickmann, Peter	A.B.
21.	Winkler, Michael	A.B.
22.	Hagemann, Manfred	A.B.
23.	Schmidt, Uwe	A.B.
24.	NN	A.B.
25.	Wende, Uwe	A.B.
26.	Bäcker, Andreas	A.B.
27.	Guse, Hartmut	A.B.
28.	Preußner, Jörg	Storek.
29.	Teichert, Uwe	Mot-man
30.	Schütt, Norbert	Mot-man
31.	Lamm, Gerd	Mot-man
32.	Voy, Bernd	Mot-man
33.	Pinske, Lutz	Mot-man
34.	Müller-Homburg, Ralf-Dieter	Cook
35.	Silinski, Frank	Cooksmate
36.	Martens, Michael	Cooksmate
37.	Czyborra, Bärbel	1.Stwdess
38.	Wöckener, Martina	Stwdss/KS
39.	Dibenau, Torsten	2.Steward
40.	Silinski, Carmen	2.Stwdess
41.	Arendt, Rene	2.Steward
42.	Möller, Wolfgang	2.Steward
43.	Sun, Yong Shen	2.Steward
44.	Yu, Kwok Yuen	Laundrym.