ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

EXPEDITION PROGRAMME PS101

Polarstern

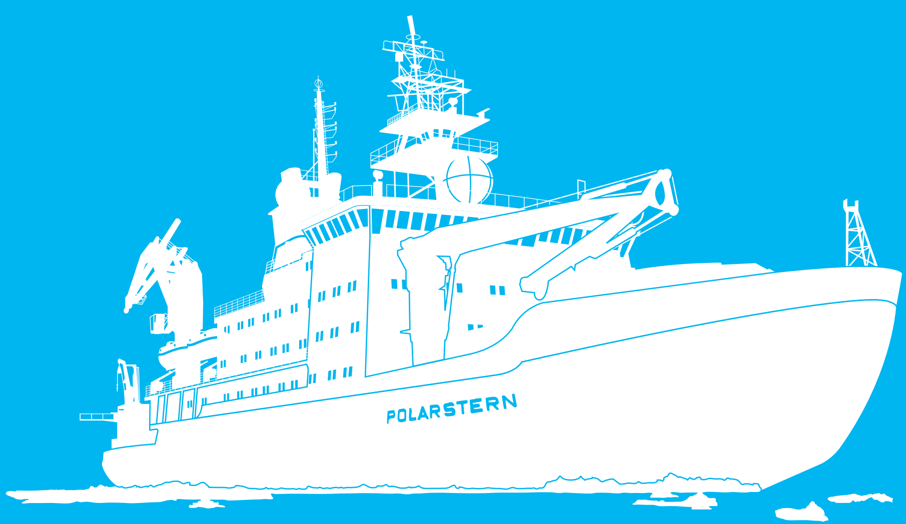
PS101

Tromsø - Bremerhaven

9 September 2016 - 23 October 2016

Coordinator: Rainer Knust

Chief Scientist: Antje Boetius



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Karasik Seamount

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1. ÜBERBLICK UND FAHRTVERLAUF

Das Forschungsschiff *Polarstern* wird am 9. September 2016 von Tromsø aus zur Forschungsreise PS101 auslaufen. Die Expedition ist der Erkundung des Karasik Seebergs am Gakkelrücken gewidmet. Zudem werden Komponenten des FRAM Observatoriums ausgetauscht. Zunächst wird der Kurs mit einem Transit von ca. 7 Tagen nach Nord-Nordost in das Arbeitsgebiet bei ca. 87°N, 61°E führen, dort wird sich die Expedition für ungefähr 21 Tage am Seeberg aufhalten. FS *Polarstern* wird am 22. Oktober 2016 in den Heimathafen Bremerhaven einlaufen. Die grobe Fahrtroute ist in Abbildung 1.1 dargestellt, wird aber in Abhängigkeit von der Eisbedeckung angepasst.

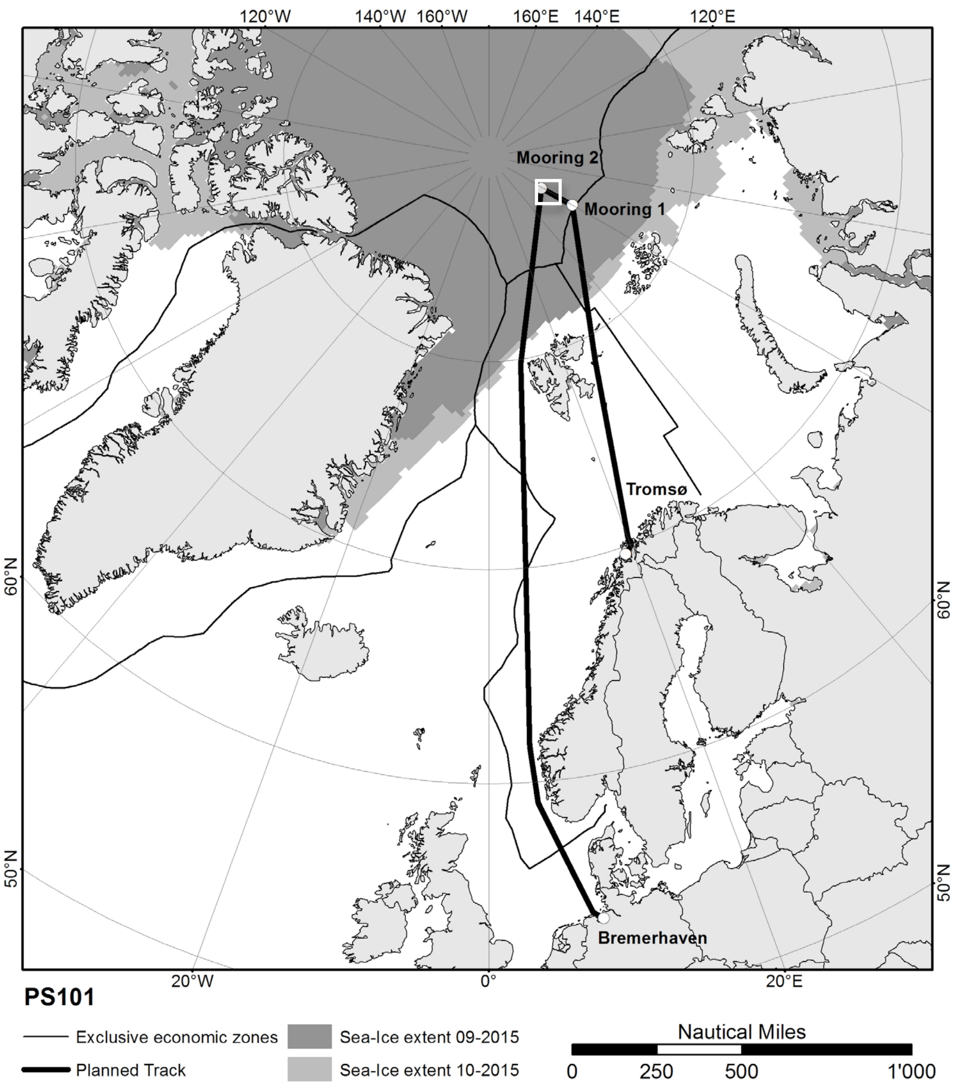

Fig. 1.1 Lage des Untersuchungsgebietes und geplante Fahrtroute. Die Hauptarbeiten finden in internationalen Gewässern am 'Karasik'-Seeberg des Gakkel-Rückens bei ca. 87°N 61°E statt, des weiteren werden Komponenten des FRAM Observatoriums ausgetauscht („Mooring 1+2").

Fig. 1.1 Position of survey area and planned route. The main station work will be conducted at the Karasik Seamount of Gakkel Ridge near 87°N 61°E. The mission will replace components of the FRAM observatory („Mooring 1+2").

Das vorgeschlagene Arbeitsprogramm beruht auf einer engen Zusammenarbeit von Ozeanographen, Geologen, Biogeochemikern, Ökologen und Biodiversitätsforschern. und trägt zur integrativen internationalen Seeberg-Forschung bei. Seeberge sind besondere geobiologische Systeme, die aufgrund ihrer Morphologie und Interaktion mit Meeresströmungen durch erhöhte Produktivität, Biomasse und Biodiversität ausgezeichnet sind. In der zentralen Arktis sind bisher keine Seeberge systematisch erkundet. Der Karasik Seeberg (87°N, 61°E) ist der größte Seeberg der Arktis und 60 km lang, über 4500 m hoch. Er ist ein Teil des hydrothermal aktiven Gakkelrückens, der isolierten, ultralangsamen mittelozeanischen Spreizungsachse der zentralen Arktis mit einer Spreizungsrate von unter 13 mm pro Jahr. Eine zentrale Fragestellung ist das Vorkommen und die Verteilung hydrothermaler Aktivität, sowie der Beziehung zwischen Morphologie des Seeberges, und hydrographischer, geologischer, chemischer und biologischer Prozesse. Während früherer *Polarstern* Expeditionen in 2001, 2011 und 2015 wurden auf der Kuppe des Seeberges riesige lebende Schwämme und Spuren von chemosynthetischen Lebensgemeinschaften entdeckt, sowie im Trog des Gakkelrücken Temperaturanomalien, die im Rahmen der Expedition PS101 weiter untersucht werden sollen. Es sollen dabei neue Technologien der Unterwasserrobotik für die Erkundung der extremen Lebensräume unter Eis eingesetzt werden, einschließlich von Untersuchungen der Meereisbedeckung und Produktivität im arktischen Herbst. Dabei werden auch verschiedene Komponenten der FRAM Infrastruktur erprobt. Der vorliegende Fahrtvorschlag zielt dabei insgesamt auf die systematische integrative Untersuchung des Ökosystems Karasik Seamount, auch um eine Basislinie vor den schnell fortschreitenden Änderungen der Meeresumwelt wie durch Meereisrückgang, Erwärmung oder künftigen Schiffsverkehr in dieser Region aufzunehmen.

SUMMARY AND ITINERARY

RV Polarstern will depart for research cruise PS101 from Tromsø on 9 Sept., 2016 and will reach the survey area, the Karasik Seamount, at 87°N and 61°E after a 7-day transit. The expedition is dedicated to a systematic study of this giant seamount at Gakkel Ridge north of Franz-Joseph-Land, and to the implementation of some FRAM infrastructure. RV *Polarstern* will work for around 21 days at the seamount, and will return to Bremerhaven on 22 October, 2016. The itinerary is shown in Fig. 1.1.

With spreading rates of less than 13 mm/y, the Gakkel Ridge is considered the slowest spreading mid-ocean ridge on earth. Due to its remoteness and ice-cover it has been poorly explored, and very few direct observations at the potential vent locations have been made.

The proposed working programme will focus on the Karasik seamount, and combine interdisciplinary work of oceanography, geology, biogeochemistry, ecology and biodiversity research. Seamounts are biological and biogeochemical hot spots, which attract abundant life due to their specific morphology, which influences currents and productivity. This seamount named after Arkandy Moiseyevich Karasik, is located 86°N, 61°E, and peaks at 566 m water depth, rising for 4,500 m above the rift valley and stretching out for 60 km. Previous *Polarstern* missions in 2001, 2011, 2015 have detected sponge gardens, remnants of chemosynthetic fauna and also nearby temperature anomalies in the rift valley suggesting active hydrothermalism. A key focus of the expedition is to locate hydrothermal vents, and to record their influence on fauna, biogeochemical processes and the seafloor ecosystem. To budget the vent heat and chemical flow, the expelled fluids and produced hydrothermal plumes will be sampled and analyzed for various marker compounds including helium concentrations and isotopic compositions, methane, hydrogen and sulfide. We will use state-of-the-art underwater technologies to study this extreme environment, and will also assess state of the sea ice and pelagic productivity in the Arctic autumn. This will involve further testing and implementation of FRAM infrastructure. This expedition aims at a integrative analysis of the seamount system, to determine its baseline status before further ice-melt and human access will affect this region.

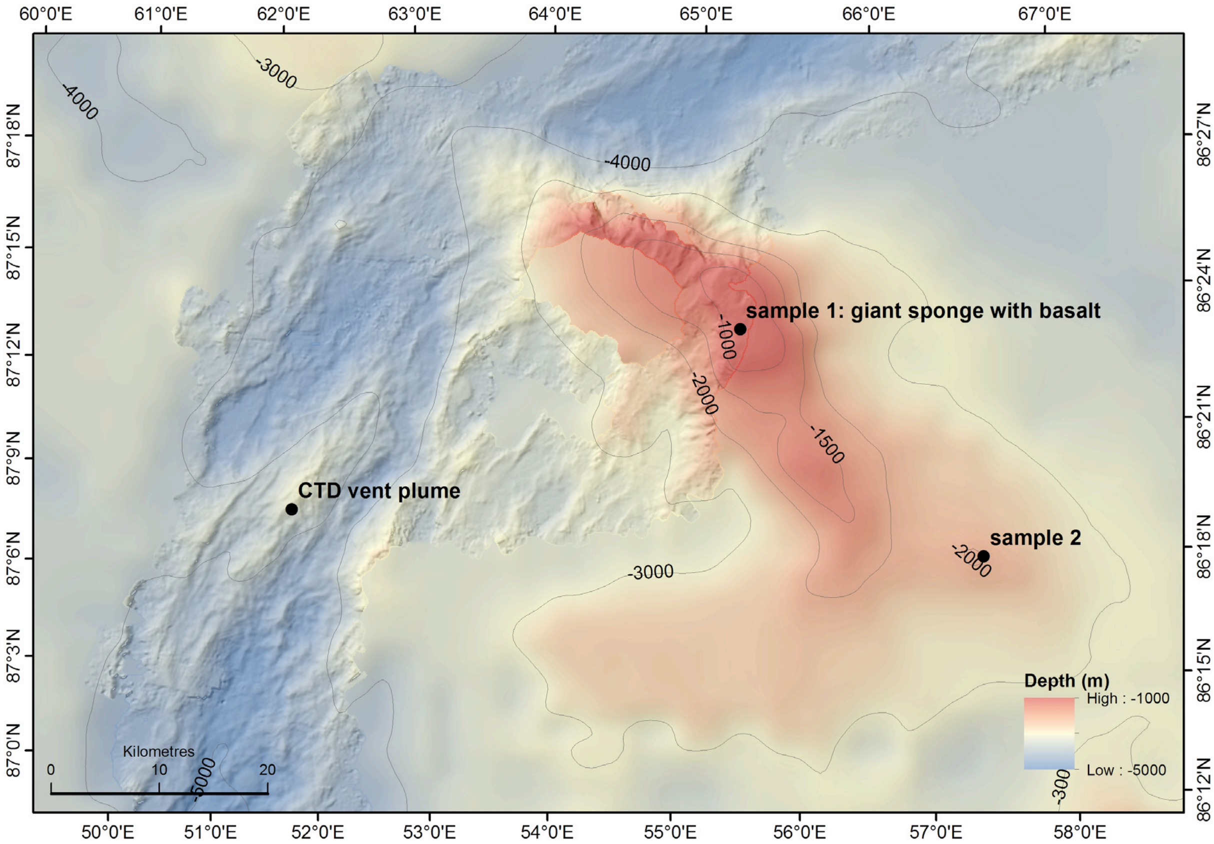

Fig. 1.2 Bathymetrie des Karasik Seeberges und erste Beprobungen während ARK27-3 und PS94 (Quelle: AWI Bathymetrie)

Fig. 1.2 Bathymetry of the Karasik seamount and first samplings during ARK27-3 and PS94 (Source: AWI Bathymetry)

2. BATHYMETRY AND HABITAT MAPPING OF KARASIK SEAMOUNT AND GAKKEL RIDGE

A. Boetius, S. Dreutter, L. Hehemann, A. Purser (AWI); H. Biebow (iSiTEC); J. Pliet, S. Roessler (FIELAX); not on board: B. Dorschel, (AWI) Y Marcon (AWI/MARUM)

Objectives

Bathymetry, hence geo-morphology, is a basic parameter for the understanding of the general geological setting of an area and many geological processes such as for example erosion and deposition. Even information on tectonic processes can be inferred from the bathymetry. Furthermore, bathymetry and bathymetry-derived products are basic key information for the characterisation of habitats and can be complemented by videographic data for habitat mapping and high-resolution sub-bottom data add the 3rd dimension to the bathymetric maps.

In many places, the seafloor of the Arctic Ocean is still a white spot on the map with only sparse direct bathymetric and sub-bottom measurements. Most existing bathymetry is modelled from satellite altimetry with according low resolution. Satellite altimetry derived bathymetry therefore lack the resolution necessary to resolve small- to meso-scale geo-morphological features (e.g. erosional escarpments, small seamounts or the detailed structures of larger seamounts). Ship-borne multibeam data provide bathymetry information in a resolution sufficient to resolve those features. This is of particular importance for the investigation of seamounts that generally show highly variable geo-morphologies. In combination with sub-bottom information, these data can be used to optimise the on-site sampling strategy and support the survey planning for towed equipment.Several recent *Polarstern* expeditions (e.g. Schauer 2011; Boetius 2015) confirmed the presence of active hydrothermal vent fields along the ultraslow spreading Gakkel Ridge in the Arctic Ocean, as described earlier (Thiede 2002; Edmonds et al., 2003). The central part of the Gakkel Ridge with the Karasik seamount at 87°N, 61°E is of particular interest as it is the largest structure on the Ridge, which seems to be volcanically active (Thiede 2002; Edmonds et al. 2003). One primary objective of our mission will be to enhance our knowledge of the morphology and structure of the seamount (Fig. 1.2). Therefore ship- and OFOS based microbathymetric analyses of seafloor will be performed using the ship's hydroacoustic instruments, as well as multibeam and sonar systems deployed with the NUI ROV and the OFOS. Typically for seamounts, also Karasik Seamount is characterised by steep and complex terrain. Accurate sampling and the operation towed equipment in such terrains requires detailed bathymetric site information. Furthermore, these data provide information on the adjacent and regional context of the samples collected and the high resolution data recorded. The detailed maps of Karasik seamount and the connected Gakkel Ridge will be the basis for all further investigations of this and the other groups.

Work at sea

The bathymetry and habitat mapping group will be involved in:

1. Mapping the bathymetry of Karasik Seamount and the nearby seafloor structures of Gakkel Ridge. The *Polarstern* multibeam and parasound system will be used for mapping of the mount and the surrounding deep Gakkel Ridge structure and for seafloor terrain analyses. Microbathymetric analyses of seafloor will be performed with OFOS and NUI HROV ultra-high resolution multibeam system and sonars. Bathymetric and sub-bottom profiler surveys will be run using the Atlas Hydrosweep DS3 and Atlas PARASOUND P70

systems in the study area and during transit. The raw bathymetric data will be corrected for sound velocity changes in the water column and further processed and cleaned for erroneous soundings and artefacts on board. Detailed seabed maps derived from the bathymetric data will provide information on the general and local topographic setting of the Karasik Seamount. Simultaneously, acoustic sub-bottom profiler data will be recorded. High resolution seabed and sub-bottom data recorded during the surveys will promptly be made available for site selection, cruise planning and track-planning for towed equipment. The acoustic surveys will be carried out by three operators in a 24/7 shift mode.

2. High-resolution video mapping of the Karasik seamount will be carried out with the Ocean Floor Observation System (OFOS) and with NUI. Fauna and features will be coarsely logged throughout each dive in real-time. Megafauna abundances, substrate characteristics etc. will be analyzed on board using the new PAPARA(ZZ)I software application (Marcon and Purser, 2016). Megafauna analysis will be further used in conjunction with the high precision local and shipborne regional scale mapping data to investigate whether particular terrain variables (such as rugosity, slope, aspect or curvature) correlate with faunal abundances. Furthermore photo and video material from the HROV NUI (see chapter below) will be analyzed in comparison to OFOS.

Preliminary (expected) results

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, along the Gakkel Ridge and from Karasik Seamount. Expected outcomes aim towards a better understanding of the geological and sedimentological processes in the research area. On board we will provide high-resolution maps of seafloor structures as basis for all further work using the ship-based sonars, the OFOS multibeam and sidescan sonar and the NUI ROV bathymetry. Utilizing GIS applications, the hypothesis that observed abundances of sponges and other megafauna on and surrounding the Karasik seamount are related to distance from any located active vents will be tested. The observed Karasik megafauna will be compared with off-seamount seafloor images collected during the cruise, as well as with the megafauna communities observed on ridges elsewhere in the world ocean, particularly with those observed previously at Loki's castle at 73°30 N (Petersen et al., 2010).

Data management

The raw multibeam echosounder data collected during the expedition and the data from sediment cores will be stored in the PANGAEA data repository at the AWI. Processed hydroacoustic data are stored at the AWI and can be requested at infobathy@awi.de. Bathymetric data sets will be provided to mapping projects and included in regional data compilations, such as the International Bathymetric Chart of the Arctic Ocean (IBCAO) and the General Bathymetric Chart of the Ocean (GEBCO).

All OFOS photographic data will be stored in PANGAEA and will be open to taxonomists and other researchers for further study and further image analysis via BIIGLE. Video data will be uploaded to the AWI-MARUM Video Library (MARVIDLIB) system for public dissemination and to allow online access to further researchers. Tracks of video and photography surveys will be stored in PANGAEA.

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Thiede, J 2002. *Polarstern* ARKTIS XVII/2 Cruise Report: AMORE 2001. Reports on Polar and Marine Research 421

3. GEOLOGY AND HARD ROCK GEOLOGY OF KARASIK SEAMOUNT

A. Diehl, E. Albers, S. Sopke (MARUM/UHB-GEO); not on board: W. Bach (MARUM)

Objectives

A key aim is to investigate the geological processes shaping the Gakkel Ridge and its seamounts and hydrothermal systems. So far only few rock samples primarily altered diabase at the flanks (Michael et al., 2003) and some fresh basalts from the top of the mount (TransArc expedition ARK26-3, 2011) have been sampled. One perspective of the rock-sampling programme enabled by ROV and/or dredging is to collect basement rocks to identify the type of volcanic rock (i.e. tholeiitic vs. alkaline basalt). We will also determine the Nd-Pb isotopic fingerprints of the Karasik Seamount volcanism to see whether they belong to the Eastern Volcanic Zone or stem form a distinct mantle domain. Mapping and sampling of rocks will show if Karasik seamount is indeed an entirely volcanic edifice. Its position in the inside corner of the spreading center and its general appearance could also be interpreted as core complex. We will hence look for possible exposures of plutonic and mantle-derived rocks on the seamount. 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 are the relations to active venting?

We furthermore hope to collect hydrothermal precipitates from the vent sites using the nUI-HROV NUI. 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. In addition, sediment gravity coring and multiple coring are further sampling methods for retrieving archives of hydrothermal sediments, both fall-out and debris-flow deposits.

Work at sea

The bathymetry and geology groups will be involved in the following activities at sea:

(1) Mapping the Karasik Seamount and other seafloor structures. The *Polarstern* multibeam system will be used for high-resolution mapping of the complete mount and the deep Gakkel Ridge structure. Microbathymetric analyses of seafloor will be performed with OFOS based ultra-high resolution multibeam system and NUI HROV. The produced details maps will be the basis for all further investigations of this and the other groups.

(2) Collection of basement rocks and hydrothermal precipitate using box coring and the NUI-HROV, and - depending on ice condition - also a rock dredge. We will cut the samples using a rock saw and carry out systematic and detailed petrographic descriptions of the samples. Samples will be photographed and archived before they are packed for shipping to the home laboratories.

(3) Collection of water samples from the CTD/water sampler rosette and analyses of methane with a GC-FID, 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*. Additionally we will collect methane samples for **$\delta^{13}C$**

∂13C measurements in the home laboratory to identify the source of the methane.

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

Preliminary (expected) results

On-board results will 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, as well as Sr-Nd-Pb isotopic analyses by TIMS. Moreover, metal concentrations of the water samples will be measured in our home labs by ICP-MS, and methane isotopy will be measured at AWI.

Data management

All samples and data retrieved onboard will be listed in the cruise report. Data and core descriptions 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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4. SEAFLOOR HEATFLOW AT THE ULTRASLOW SPREADING GAKKEL RIDGE

M. Doll (UHB-GEO), P. Müller (UHB-GEO), not on board: N. Kaul (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 show 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 still should be 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 another ultraslow spreading ridge, the South West Indian Ridge (SWIR) during *Polarstern* cruise ANT XXIX/8 in November-December 2013 showed rather low heat-flow rates. In contrast, from the cruises AMORE (2003) and AURORA (2014) we know that the likewise ultra-slow spreading Gakkel Ridge contains sites of high heat flow (> 1,000 mW/m²; Baker et al., 2004; Aurora expedition PS86 report, 2014). During *Polarstern* cruise PS101 in 2016 extended heat flow investigations will be carried out, thereby focusing on the Karasik seamount with its expectedly very young crust. We attempt to detect advective processes with fluid flow recharge and discharge sites and very high heat flow rates in this area. We expect to contribute to the understanding of hydrothermal activity and distribution in the Gakkel Ridge area and thus to the fueling of microorganisms and macro fauna.

Work at sea

Our heat flow programme will contain profiles across and along the Karasik. Additionally, we will try to extend the heat flow profiles to the Amundsen and Nansen Basins on both sides of Gakkel Ridge, to enhance our knowledge about the age dependent heat flow distribution.

To measure seabed temperature we will use miniaturized temperature data loggers (MTLs), which will be mounted on the outside wall of a strength member or gravity corer. This tool is ideal for the rough and poorly charted terrain and under severe ice conditions. The thermal conductivity will be measured on recovered core material. Preliminary data evaluation is done on board to support search strategies of other disciplines.

Data management

Original data will be stored in the PANGAEA database. Processed date 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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5. PHYSICAL OCEANOGRAPHY AND BIOGEOCHEMISTRY OF HYDROTHERMAL PLUMES

M. Walter, J. Köhler (UHB-IUP); M. Horn, B. Steinmacher (UHB–IUP), M. Molari, G. Wegener, (MPI); A. Diehl, E. Albers, S. Sopke (MARUM/UHB-GEO); J. Baeger (AWI), C. German, J. Seewald, (WHOI); not on board: C. Mertens, J. Sültenfuß (UHB-IUP), M. Hoppmann, E. Damm (AWI); W. Bach (MARUM)

Objectives

The main objective of the oceanography group will be to study the dispersal of hydrothermal plumes from the vent field of the ultraslow spreading ridge Gakkel Ridge around the Karasik seamount. We aim to determine the heat and mass fluxes of the field, and to estimate vertical mixing of the water above the ridge and in the axial valley. The first objective is to identify the hydrothermal plumes in the water column, which will also help to locate the vent areas on the seafloor. A hydrothermal plume signal can be identified either by anomalies in temperature and/or an increase in turbidity and drop of oxygen reduction potential (Eh). Hence, measurements of temperature, salinity, turbidity, redox and velocity will be conducted to study the plume dispersal. We will also sample the CTD water for microbial community composition measurements (cell counts and *in-situ* hybridization). Furthermore we will use *in-situ* pumping to retrieve larger amounts of microbial biomass and mineral precipitates for further analyses. Another aspect of our work is to characterize the mineral composition of 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). We plan to analyze methane concentrations in the water column sampled by CTD/Niskin water sampler rosette along tow-yo transects. We will also sample for post-cruise measurements of dissolved metals (specifically Fe and Mn) in these samples. From methane, metal, heat, and turbidity data collected in these surveys, inferences can be made about the nature of the vent (Edmonds et al. 2003; German et al., 2010).

The water column of the plumes and reference depths will be sampled with high vertical resolution using the CTD sampling rosette. On board samples will be analyzed for hydrogen, methane and sulfide concentrations, and in addition nutrients such as silicate. Helium and neon isotopes will be measured in the noble gas laboratory (University of Bremen). The hydrothermal plumes are highly enriched in Helium (Isotopes: ^{3}He and ^{4}He) leading to He/Ne ratios, which are 5-8 times higher than outside the plumes. The helium isotopic composition is an important tracer for the distribution of vent fluids in the water column, since the inert gas helium is 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 seamount area and along valley.

The expected large amounts of reduced components in the plumes such as metals (Fe^{2+}, Mn^{2+}), sulfide, methane, hydrogen or carbon monoxide provide a potential energy source for microorganisms. On-board hydrogen and carbon monoxide concentrations will be assessed, to set up rate measurements for microbial consumption of these potential energy sources. Together with the oceanographical and biogeochemical data, we will be able to assess potential energy sources in the plume. The metabolic activity close to the vents and the seamount may lead to changes in microbial community compositions, which might be displayed in the genomic fingerprints (i.e. 16S rRNA, genomic and transcriptomic signatures of the water column biota enriched by *in-situ* filtration). These analyses will be accompanied by cell enumeration techniques, including *in-situ* hybridization using on-board filtered seawater.

Work at sea

Main tools for the exploration surveys will be the CTD-Rosette equipped with biogeochemical sensors, as well as the NUI surveys with CTD and sensors mounted. Both will be geo-referenced by POSIDONIA transponders, allowing the characterization of bottom near environmental parameters, as well as a connection to the visual analysis of habitats and megafauna. CTD work will consist mainly of tow-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 added to sample background profiles. The tow-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 NUI dives. Repeated profiles of density stratification allow determining mixing intensities and vertical property fluxes. The 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 analyzed after the cruise in the Bremen Mass Spectrometer Laboratory. For hydrogen measurements water samples are taken from the CTD rosette, samples in butyl rubber sealed vials. A defined headspace with hydrogen-free air is added. Samples are rapidly agitated and the headspace is measured for hydrogen using a high performance gas chromatograph with RCP (reducing component photometer) detection (Peak Laboratories). Furthermore we take CTD water samples in 250 ml bottles basified with NaOH to analyze methane carbon isotopic composition. To determine cell abundances and CTD water will be filtered on 0.2 µm filters using a newly developed in-line peristaltic tube-pumping system. To retrieve large amounts of plume microfauna and solid particles *in-situ* pumps will be mounted on selected CTD casts. Based on CTD data (i.e. Eh, turbidity, temperature) the pumps will be adjusted in the plume, and *in-situ* pumping for 1-3 hours will collect fractions> 0.2 µm on polycarbonate filters. Samples for nucleic acid analysis will be preserved in liquid nitrogen.

Preliminary (expected) results

During the AMORE expedition (2001) evidence for multiple hydrothermal plumes along the Gakkel Ridge was found. The Karasik Seamount is the so far shallowest part of the ridge. So evidence for vent activity relied on a few camera tows and dredging that recovered vent fauna. With the combination of turbidity, Eh, helium, methane and hydrogen measurements as well as plume minerals we expect to characterize the plume properties and to estimate the vent fluxes and composition of end member vent fluids. The sampling by *in-situ* pumps will allow us retrieve plume material for different analyses, and finally to quantify the current extend of seepage and the influence of seepage on water column microbial life.

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. Genomic data will be published via INSDC, the international public database collaboration (DDBJ, EMBL-EBI and NCBI).

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6. PLANKTON OF KARASIK SEAMOUNT

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Objectives

The Arctic Ocean is strongly affected by climate change, which in turn will have large impact on the carbon cycle and sequestering in the pelagic ecosystems. Long-term observations of all plankton size classes, from pico- to large zooplankton, as well as experiments with key species are thus required to understand and predict future ecosystem functioning.

Phytoplankton

Since the nineties, ecological investigations of unicellular phyto- and protozooplankton biomass, species composition, productivity, sedimentation and biochemical parameters (i.e. chlorophyll a, particulate organic carbon & nitrogen, carbonate and biogenic silica) have been carried out in Arctic waters of the central Arctic Ocean (CAO) during 8 cruises between 1993 and 2015 with *Polarstern*. Phytoplankton biomass, chlorophyll a (integrated values 0 - 100 m), stayed more or less constant in the CAO with the exception of 2015 exhibiting less biomass during late summer. POC distribution patterns for the summertime show slightly different results with a slightly increasing trend other than chlorophyll a. Data from autumn (late September/October) are rare, hence a main objective is the study of plankton distribution and activity under freeze-up situations.

Our work on planktonic protists and biogeochemical fluxes will thus focus on monitoring species and biomass distribution, on biogeochemical parameters and on the vertical particle flux of organic matter in relation to season, sea ice cover, nutrient distribution and water circulation patterns. Specific hypotheses we intend to test are:

1. Less sea ice in summer will promote higher production followed by higher sedimentation in regions that have been totally ice covered before.
2. Shifts in species compositions on different trophic levels will change trophic interactions and change fluxes and export of organic matter.
3. Changes in the circulation like the stronger influence of Atlantic water masses may also alter the pelagic system and export fluxes.

A main focus is on *Melosira arctica*, a filamentous sea ice diatom populating the sub-ice habitat of the Arctic Ocean. It was proposed that this diatom is responsible for a large amount of the sub-sea ice productivity, and also plays a significant role for the carbon export to the deep sea in ice-covered Arctic basins (Boetius *et al*. 2013). *Melosira arctica* forms large mats consisting of algal filaments embedded in an extracellular polysaccharide matrix, which is densely populated by bacteria. First analyses of associated bacterial communities show unique profiles different from the surrounding sea-ice and seawater bacterial communities (Rapp et al. in prep). During the last years, we collected and isolated different *Melosira* strains during two central Arctic Ocean cruises of *Polarstern* (PS86 and PS93.1). Based on these cultures, it is possible to conduct laboratory experiments to investigate the potential of the species to cope with changing abiotic parameters (i.e. temperature, light, and nutrient availability) on a physiological but also on a genetic level. Furthermore, it is possible to sequence the genomes of different *Melosira* strains from a large geographic area and from different water masses. Comparison of these genomes to a reference genome will unravel whether *M. arctica*, like *Emiliania huxleyi* (Read et al. 2013), possesses a large pan genome or uses a different strategy.

The main objectives in this regard are:

1. **Cultures**: We plan to sample as many different *Melosira arctica* mats as possible to isolate uni-algal cultures from different locations. The isolation procedure will start directly on the ship.
2. ***In-situ* experiments**: We plan to immediately conduct on-board experiments with *Melosira* mats under controlled conditions at 0°C. We will test how the photosynthetic efficiency of the mats will change at high light levels and accompanied nutrient limitation. Afterwards, the mats will be frozen and used for RNA extraction to sequence transcriptomes. These experiments will be counterparts to experiments with uni-algal *Melosira* cultures conducted at the AWI Bremerhaven. With this, we hope to complement our understanding of the ability of this diatom to cope with changing conditions in the light of climate change.
3. **Genetics**: The sampled mats will also be used for molecular approaches to reveal the total (based on rDNA) and the active (based on rRNA) part of the eukaryotic community. Furthermore, samples for 16S biodiversity investigations based on the mat communities will be taken to complement the knowledge about the community. Based on these approaches we will get a detailed overview on which species are associated to *Melosira* in the field. Additionally, subsamples of the sampled mats will be used for further DNA and RNA isolation to retrieve metagenomes and metatranscriptomes from whole *Melosira* mats. Based on available genome data we could identify *Melosira arctica* genes in the metatranscriptomes and from comparison to reference transcriptomes the status of *Melosira* in the field. This will allow the comparison of transcriptomic responses under controlled conditions in the lab versus the transcriptomic activity in the field.

Zooplankton

Since the 1990s, ecological investigations of phyto- and zooplankton have been carried out in the central Arctic Ocean with *Polarstern* in order to document basic characteristics of plankton ecosystems, relate them to environmental parameters and processes and understand how they are influenced by ongoing and projected climate change. These studies demonstrated that species composition, community structure and distribution patterns of zooplankton in the Arctic Ocean are strongly affected at regional and even basin scales by water circulation patterns, ice conditions and primary productivity (Hirche & Mumm 1992, Mumm 1993, Kosobokova & Hirche 2000, 2009).

In addition to standard investigations of the zooplankton communities of the epipelagic water layers, since 1995 zooplankton sampling has been carried out down to the bottom at most visited locations, including the deepest ones in the Arctic deep basins with bottom depths of >3,000 and >4,000 m. The aim of these studies was to document the poorly known and unique deep-water fauna of the Arctic Ocean to better understand its origin, distribution and role in pelagic trophodynamics. The efforts of the 20 years campaign allowed achieving base-line information on the species composition of mesozooplankton, patterns of the vertical community structure and assessment of zooplankton stock (biomass and abundance) at bathy- and abyssopelagic depths of the Arctic Ocean. The studies carried out in the vicinity of underwater ridges, and the Lomonosov Ridge in particular, indicated that the ridge areas are characterized by peculiar fauna and enriched plankton life (Kosobokova & Hirche 2000, 2009). However, the knowledge on diversity and productivity of pelagic organisms and the effects of underwater ridges and mountains on zooplankton distribution is still very limited. In particular, the information on plankton communities associated with seamounts and hydrothermal vents is completely missing.

The main research questions to be answered during this mission are therefore:

1) **Patterns:** What is the zooplankton composition in the of the Karasik seamount area, what is their diversity and spatial distribution? Are there vent-specific zooplankton species and what are their distribution patterns?

Our goal is to relate the composition, abundance, biomass and spatial distribution of zooplankton to water circulation patterns and specific local bathymetric conditions of the study area. Our sampling protocol will follow standard procedures as applied during previous *Polarstern* cruises (1993-2015). We will carry out deep casts up the flanks of the seamount (5000-500 m water depth) and shallow ones on the top of the mount, with some focused stations once we have the location of the vents mapped. In parallel to net sampling, we will use the zooplankton imaging and analyzing system LOKI (= Lightframe On-sight Key species Investigation) to determine the small-scale distribution of these organisms. LOKI is equipped with a high-resolution digital camera and sensors measuring temperature, salinity, depth, oxygen and fluorescence as a proxy for algal abundance. This approach can directly relate distribution patterns of the zooplankton to hydrographic information.

2) **Rates:** The cruise will take place after termination of the primary productive season, which gives us an opportunity to investigate the pre-winter state of the entire zooplankton community and, in particular, populations of predominantly herbivorous zooplankton filter-feeders (i.e. the copepods *Calanus hyperboreus* and *C. glacialis*), which are key-players in the Arctic pelagic ecosystem. We will collect *Calanus* spp. for incubation with natural sea water at 0 °C to assess their feeding activity and use frozen material for measuring *in-situ* grazing rates and gut fullness.

3) **Genetics:** We will continue building the DNA sequence library needed for molecular approaches to assess community structure and identifying regional and basin-scale population patterns within the Arctic using molecular markers.

Work at sea

Phytoplankton sampling

Water samples of the ocean surface will be regularly taken by en route filtration and CTD-Rosette casts for the analysis of pigment concentrations and other planktological variables, as well as for the microscopic study of phytoplankton composition in the pelagial. We will sample seawater with a CTD/rosette sampler at 5-10 depths. Additionally we will sample

Arctic seawater using a newly developed automated filtration (AUTOFIM) device that is coupled to the ships pump. All samples except those for phytoplankton & protozooplankton counts will be 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, particulate organic carbon (POC), particulate biogenic silica (PbSi), phytoplankton & protozooplankton abundance (traditional microscopy, molecular-biological assessments of protist communities).

Melosira sampling

The sampling of *Melosira* will highly depend on presence of diatoms during in the study area. *Melosira* mats will be sampled by manual pumping/catching below the ice. Ideally, the exact location of the mats can be explored by collaborating with the sea ice physics team to optimize the sampling procedure. All samples collected for genetic analyses will be immediately frozen in liquid nitrogen and stored at -20°C (DNA) or in a dry shipper filled with liquid nitrogen (RNA) until further analyses.

Zooplankton sampling

- Quantitative sampling of zooplankton will be carried out with a Multinet Type Maxi (0.5 m^2 mouth opening, 150 µm mesh size). Our sampling protocol will follow standard procedures as applied during previous *Polarstern* cruises (1993-2015). The entire water column (0 m - bottom) will be sampled with the following sampling intervals: bottom-2000-1000-500-300-200-100-50-0 m or bottom-4000-3000-2000-1000-500-200-100-50-0 m at the deepest locations.
- The LOKI will be deployed at the stations of Multinet sampling. The system will be towed vertically from 1,000 m depth to the surface, while continuously taking pictures for zooplankton analyses and measuring temperature, salinity, depth, oxygen and fluorescence.
- The material for gut content fluorescence measurements and biochemical analyses will be collected with Bongo net hauls (100 or 200 and 500 µm mesh size) or a “side net” attached to the multinet. We will sort out life copepods from life catches and freeze them at -20°C for further measuring the gut fluorescence at home laboratories. The biochemical material will be used for the analyses of stable isotope signatures, lipid content and development of molecular-based identification systems based on DNA-barcoding of rare zooplankton species.
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Preliminary (expected) results

We expect to improve our knowledge on the zoo- and phytoplankton as well as on the *Melosira* mat diversity and distribution patterns in the areas of seamounts and adjoining deep troughs after termination of the productive season in the Arctic Ocean. 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 within about two years after the cruise. We plan that the full data set will be available at latest about three years after the cruise. Most of species samples and samples which will not be 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 many comparisons will be made, long-term study 2 to 5 years after the cruise). Zooplankton samples for species composition and biomass assessments as well as molecular genetics analyses and gut fluorescence measurements will be processed at the P.P. Shirshov Institute of Oceanology RAS, Moscow, under long-term cooperation with the AWI. The data gained during this cruise will also be made available to the public via PANGAEA.

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7. BENTHOS OF KARASIK SEAMOUNT

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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). Distinct biogeographic provinces have been recognized in the distribution of currently known vents and taxonomic affinities between provinces were observed that demonstrated the existence of an evolutionary link across the communities that inhabit the vents (Van Dover et al., 2002, Bachraty et al., 2009; Petersen et al. 2010). 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 connected the Atlantic and Pacific oceans, and once 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 North Atlantic continuation the North Atlantic mid ocean 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, Edmonds et al., 2003). 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. Currently, the fauna and in particular the invertebrate-bacteria symbioses of the Karasik Seamount vents is only known from anecdotal sampling. Tubeworms and dense mats of sponges were detected in this area. The study of this area will significantly contribute to our understanding of the migration pathways and evolution of hydrothermal symbioses and seamount fauna on a global scale. Furthermore, the Karasik seamount system could be a hotspot of biodiversity and productivity within the Arctic deep-sea plains (e.g., Henrich et al. 1992).

A main objective of our cruise is to test what relationships exist between the Arctic vent and seamount communities, and those occurring elsewhere, for example at the Northern most vents investigated so far, the Loki and Aurora vents. 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). Vent ecosystems are typically dominated by benthic invertebrates that host symbiotic, chemoautotrophic microorganisms (van Dover 2014). Therefore, benthic production and biomass is very high at vents, while species richness is comparably low. However, nothing is known about the benthos of Arctic vent fields and seamounts. Hence, the Gakkel Ridge expedition provides an opportunity to examine the influence of spreading rate and water depth on the biogeography of vent fauna. The former Census of Marine Life programme 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).

Our objectives are to (a) analyze the faunal distribution, diversity and production along a depth gradient from seamount base to top, (b) evaluate potential species endemism within the seamount fauna and (c) compare the fauna of chemosynthetic and non-chemosynthetic habitats around vent fields. The expected findings will serve as a base to characterize and potentially map different habitats of micro-, meio- and macrofauna at the seamount. We will combine environmental information including seafloor and bottom water biogeochemistry and microbiological activity, to assess the faunal ecology of the Karasik Seamount.

Work at sea

The Functional Ecology group will investigate Makrozoobenthos. Particular in deep waters this organism group is a good indicator for environmental change, as it is relatively stationary and long-lived and reflect changes in environmental conditions in the oceans (e.g., organic flux to the seabed) at integrated scales (Gage & Tyler 1991, Piepenburg 2005). Yet, compared to other deep-sea areas, the benthos of central Arctic basins is poorly studied (Bluhm et al. 2011). The few existing studies provided evidence on strong gradients in faunal abundance, biomass and production from slopes to basins (Cusson & Bourget 2005, Bluhm et al. 2011), caused by low surface-water production, small flux of particulate organic matter to the seafloor and, hence, general food limitation of the benthos (Wassmann et al. 2010, Degen et al. 2015).

The Senckenberg am Meer Meiofauna Group will study the meiofaunal communities at both the seamount's summit and the surrounding deep sea, focusing especially on three meiobenthic major groups: Copepoda, Gastrotricha, and Tardigrada, covering taxonomic, faunistic and biogeographical aspects. Main topics are the comparison of the meiobenthic seamount communities with (i) anchialine cave fauna (Huys 1996, George & Martínez Arbizu 2005), (ii) with associations of other Atlantic seamounts (George 2013), and (iii) with the vent fauna of Atlantic and Pacific hydrothermal fields (Gollner et al. 2011).

The GEOMAR Kiel Marine Microbiology group will investigate the microbial diversity and microbial gene activity of a selected number of arctic deep-sea sponges by metagenomic and metatranscriptomic sequencing as well as amplicon sequencing of the V4 region of the 16S rRNA gene (following the EMP protocols, http://www.earthmicrobiome.org/). Microscopy (electron microscopy and otherwise) will be performed alongside to visualize the presence and abundance of microbial consortia within the sponge extracellular matrix. Further effort will be placed on understanding the functional role of sponges in the Karasik seamount ecosystem in collaboration with University Bergen's experts on Northern vents and their sponge ecology.

AWI's Biogeoscience department will analyze the benthic foraminiferal fauna and potential endosymbiosis with bacteria using Cell Tracker Green, transmission electron microscope (TEM), stable isotope and trace metal analyses.

AWI and MPI's deep sea ecology group will carry out microbiological studies, including the sampling of rocks, sediments, with their microbiota to assess the composition and distribution of hydrothermal vent and seamount microbial communities, their main activities in carbon and nutrient cycling and their key energy supplies. Porewater as archive for chemical alteration by vent fluids will be sampled by Rhizon technology directly on board and preserved for different analyses (dissolved metals, salts, sulfide, sulfate inorganic carbon content). Sediments are sampled for geochemical analyses including TOC content and microbiological analyses together with the other working groups.

To collect the fauna of all the different size classes described, will deploy box corer and multiple corer systems (TV-MUC) as well as the Van Veen grab, depending on the ice conditions and on the seafloor features. Animals from active vents will be collected using NUI and processed on board for photography, molecular and isotopic analyses in the home laboratories.

Sample and data management

Specimens for morphological phylogenetic analyses will be fixed and sent and analyzed by cruise participants and other taxonomic experts. 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 stored at the Arctic Benthos-Database at AWI, the Pan-Arctic

Inventory and the OBIS database. Microbiological sequence data will be archived in GenBank.

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8. USE OF HROV NUI FOR UNDER ICE EXTREME ENVIRONMENT EXPLORATION (PSTAR&ROBEX)

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Objectives

Our field campaign will focus on use of the novel NUI vehicle in a range from fully autonomous to real-time human-directed modes for survey and sampling missions at the seafloor, throughout the water column, and at the underside of the overlying ice. Complementary ice-station operations will allow us to collect a continuous sample suite from the deep ocean floor all the way to the surface of the ice-shell.Our programme will explore for and characterize (geochemically and microbiologically) new sites of hydrothermal venting at the Karasik Massif which rises from 4,700 m to 566 m deep on the Gakkel Ridge (87°N, 61°E) and hosts chemosynthetic ecosystems at relatively shallow seafloor depths beneath the permanent ice-cover of the northern Arctic. Our programme will seek to identify biosignatures generated by these chemosynthetic ecosystems and to investigate the fate of those biosignatures as they are released upward in hydrothermal plumes into the water column and/or the overlying ice-cover.

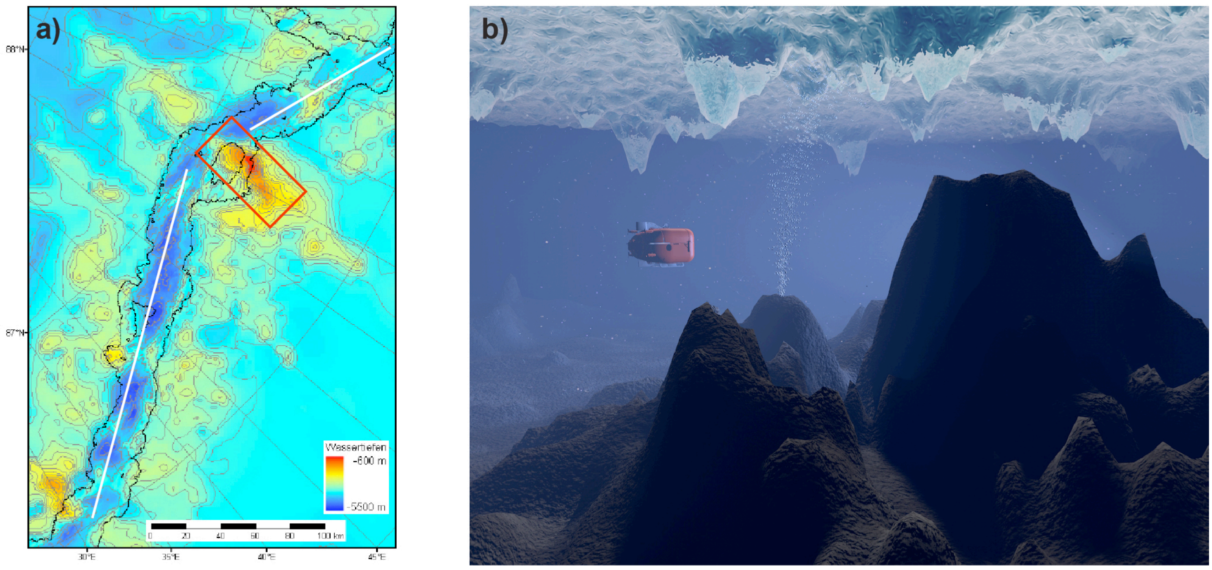

Fig.1 a) Regional map showing the Karasik Massif (red box) at the offset between two adjacent ridge segments (dark blue) on the Gakkel Ridge at (87°N, 61°E); b) Artist's impression of NUI operations at the Karasik Massif.

Work at sea

The NUI vehicle is uniquely suited to conduct the exploration proposed – both as an autonomous underwater vehicle (AUV) and as a remotely operated vehicle (ROV) which employs an unprotected, expendable glass fiber as a communication tether for human-supervised under-ice operations and exploration. Its compact size, low weight and horizontal mobility provide more maneuverability than conventional ROVs while offering the full bandwidth data return unavailable to conventional AUVs. Bi-directional telemetry enables direct control of the vehicle over relatively extended distances (up to 20 km) from a central location (in this project, the RV *Polarstern*). While *Polarstern* will be equipped with a CTD-rosette to conduct water column surveys and prospect for chemical signals indicative of submarine venting, and the OFOS camera systems that can survey the seafloor directly beneath the ship, addition of NUI's freedom to move laterally as well as vertically will add a capability for systematic exploration of the Karasik Massif and precise sampling, independent of the ship's track. NUI will be employed at the seafloor, in overlying hydrothermal plumes, and at the ice-ocean interface. During 24 days on-station we plan for complete 3 dives in AUV mode to prospect for and locate sites of venting across the summit of the massif, followed by 6 dives in ROV mode, to conduct directed sampling in pursuit of our research objectives.

We will first use NUI to (i) survey the water column above Karasik for physico-chemical signatures indicative of venting; (ii) map the summit of the massif in high resolution while continuing to prospect for water column signals; and (iii) image the seafloor at the *lamellibrachia* site and any new targets we identify. Because the summit of the massif is small, we will be able to survey the entire overlying water column for hydrothermal plume signals in one ~15 h dive (5 km x 3.5 km; 500 m line-spacing at 1.5 kts). During that dive we will both detect hydrothermal anomalies using our standard sensors (CTD, optical back-scatter, Eh) *and* search for acoustic signatures indicative of any rising bubble-plumes using the vehicle's forward looking sonar. On the next dive we will map the seafloor at high resolution using NUI's Delta-T multibeam sonar. A 10h survey of this type, at 50 m altitude and following 80 m spaced lines (25 % overlap between adjacent data-swaths), would already suffice to capture the entire ~2 km x 1km summit area at Karasik. If evidence for multiple fluid-flow sources are detected during Dive 1, however, up to 15h of Dive 2 mapping could be broken out into multiple discrete blocks, up to a cumulative survey area of ~3 km^2 (e.g. 3 blocks of ~1 km^2 each). From interception of rising plume signals, we would also be able to locate any new sites of fluid flow to within ≤80 m by the end of this dive. AUV Dive 3 will conduct down-looking imaging over one or more areas of interest, following lines spaced at ≥5 m. By flying at a constant altitude of ~5 m above the seabed, at a survey speed of 0.5 m/sec to ensure overlap between consecutive photographs, we will be able to survey up to three discrete 200 m x 200 m areas, during that dive.

From our AUV surveys of Karasik Massif we expect to locate, precisely, at least one active chemosynthetic ecosystem at the seafloor. Our immediate scientific priority will then be to sample both the fluids emitted from that site and any associated microbial communities. We will achieve this over a series of 2-3 dives (dependent upon the number and variety of sites identified) using NUI in ROV mode, equipped with a payload that includes specially designed gas-tight fluid samplers for organic and inorganic geochemical analyses and a multi-chamber *in-situ* suction sampler, for microbiological sampling. Insulated boxes will also be employed to recover rock/sulfide samples, ± any attached micro-organisms, at *in-situ* temperatures.

To trace the transport of potential bio-signatures from sea-floor venting up through the water column, we will conduct routine sampling from the mid-water in parallel with our ROV operations, using the ship's CTD rosette and a large-volume *in-situ* filtration device. To complement that research, we will also be able to conduct more targeted mid-water sampling from NUI, but with the added advantage that NUI's real-time video and acoustic sonar data will allow us to search for and confirm that we are within the influence of any rising and/or bubble-laden hydrothermal plumes. Rather than devote dedicated ROV dives to these operations, we will ideally conduct such sampling in parallel with seafloor sampling dives, during the ascent back toward the research vessel – i.e. the vehicle will rise up, following and sampling the plumes rising above each vent-site that we sample. What will also be unique about our use of NUI for this project will be our ability to conduct ROV-based sampling directly at the ice-ocean interface. There, using real-time video for guidance, we will be able to "land" the ROV on the underside of the ice and collect fluid and ice-bound geochemical and microbiological samples directly from the ice-water interface using the same manipulator and sampling devices to be employed for our seafloor sampling dives. We will plan to dedicate 2-3 ROV dives to this effort which, ideally, will include sampling at locations where we are able to trace plumes, both visually and acoustically, from the seafloor up to the ice-water interface. An important final part of our larger field-programme will be that we will also occupy ice- stations that are both spatially and temporally coincident with the ROV under-ice dives. We have already demonstrated this concept, using NUI for such combined on- and under-ice studies to great effect during our earlier "proving" campaign in July 2014 (Katlein et al., 2015).

Preliminary (expected) results

- We will use NUI under direct human control to sample for fluid geochemistry and microbiology at the seafloor and upward as far as the overlying ice-water interface.
- We will use complementary ice-stations to core through to the base of the ice and, hence, obtain contiguous sample sets, from venting at the seafloor to the Arctic's outer ice-shell.
- We will characterize the geochemical nature of hydrothermal fluids at Karasik with particular emphases on (i) abiotic organic synthesis, and (ii) distinguishing biotic *vs*. abiotic chemical processes that may influence the generation of life-related biogeochemical signatures.
- We will develop thermodynamic models, based on fluid compositions observed at Karasik, to assess the chemical energy available to support life in vent ecosystems at Karasik.
- We will characterize the spectral properties of samples throughout our sample suite.

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 the Sentry AUV and Jason ROV, both of which are part of the US National Deep Submergence Facility. Standard data products from this cruise will include: navigation data, bathymetric and sidescan data, time-stamped *in-situ* (physical and biogeochemical) water-column data and HD video and still imagery of the seafloor, the water column and the sea-ice interface.

These data-types will be readily manageable by following the same standard protocols already established by the NDSF at WHOI for Sentry and Jason. 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 to the Cruise data portal for archiving at Pangaea and for banking in the Data Library and Archive at WHOI, where they can be accessed readily by any interested parties.

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9. FRAM INFRASTRUCTURE: SEA ICE, OCEAN PHYSICS AND BIOGEOCHEMISTRY

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9.1 Oceanography

Objectives

FRAM oceanographic infrastructure tasks include the exchange of two FRAM moorings, the autonomous surveying of surface water conditions from *Polarstern*, and in addition to background CTD Rosette casts, the AWI time series survey at 60°E. Around 50 additional hydrographic profiles, ranging from the surface up to ,1100 m depth, will be obtained by an expendable CTD (XCTD) system from the moving ship and from ice floes accessible by helicopter. In the presence of sea ice, XCTD profiles will be interspersed to enhance resolution in currents near ridges or the continental slope, and additional sections perpendicular to the track of *Polarstern* will resolve the horizontal gradients in that direction. To extend the observational range of the ship survey in space and time FRAM operates bottom-moored observatories. Two FRAM moorings from PS94 will be recovered and redeployed during PS101 in the Nansen Basin and at Gakkel Ridge (Fig. 1).

Work at sea

We will recover and redeploy two moorings: one in the Nansen Basin south of the Karasik Seamount and another in the deep trench of the Gakkel Ridge. The moorings have been recording temperature, salinity and currents in the whole water column while simultaneously collecting water and particulate material from the upper water column at regular intervals since late summer 2015. Together with previous flux studies this will yield in a time series studying sedimentation events in the Arctic Ocean. Long- and short-term trap deployments in the Arctic Ocean will also be carried out in cooperation with scientists from other nations, e.g. Canada.

A mobile CTD-system, using a custom-made winch and an SBE16+ CTD, and capable of measuring full-depth profiles, will be used from ice floes with helicopter assistance. This system will be used to obtain additional profiles, branching off the route of *Polarstern*. If no sea ice is present, an underway CTD (UCTD) system will be used from the ship in a similar way as the XCTD system to obtain profiles from the surface to about 400 m depth.

A turbulence profiler (MSS90L, Sea & Sun Technology) will be repeatedly operated during ice stations to obtain profiles of fine-scale motion by measuring temperature, salinity, pressure, and current shear. The profiler is free-falling with a 400 m long data cable attached to an electrical winch.

Data management

All oceanography data will be deposited in the PANGAEA data base and in other international data bases. The data recorded by the moored instrumentation will be processed after the cruise at AWI and submitted to the PANGAEA database.

9.2 Sea ice physics

Objectives

The characterization of the state of the sea ice cover is of great importance for the evaluation of the polar climate system. Sea ice thickness data sets are sparse and rarely combine high-resolution thickness information and high spatial coverage. Furthermore instrument design and processing techniques are usually based on a simple 1D representation of the sea ice layer and the ice cover is interpreted as level ice. This mostly affects thickness measurements of sea ice pressure ridges, whose thickness can be underestimated by as much as 50 percent. 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. Visual observations the expeditions into the Arctic create large datasets on seasonal ice coverage. Such datasets are important to validate remote sensing data.

Work at sea

To further develop of EM sea ice thickness measurements, high-resolution thickness information using multi-frequency device (GEM-2) will be used during this expedition. GEM-2 surveys planned for PS101 are a continuation of measurements made during earlier campaigns in the central Arctic. Using different sounding depths will allow us to resolve sea-ice structures, small-scale sea ice thickness and condition. In addition, snow and sea ice thickness will be measured to resolve the thickness distributions on individual floes.

Transects 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. Surface temperature will be measured along and across the *Polarstern* track with a KT-15 radiometer mounted on an Octocopter and on the bridge. The multicopter will also be used to track sea ice drift. Together with information about incoming short- and longwave radiation, albedo, air and ocean temperature, measurements can be used to derive ice thickness of up to 0.5 m. Measurements will be used to validate different remote sensing products such as thin ice thickness information obtained from SMOS and lead ice thickness derived from satellites working in the optical range such as AVHRR or MODIS. While the ship is moving, hourly observations of sea ice conditions by trained observers from the bridge will allow a continuous picture of the sea ice conditions.

Data management

Processed and quality-controlled data from EM instruments, Magnaprobe and KT-15 will be made available in PANGAEA within one year after the cruise. Visual sea ice observation data will be distributed via the standardized database of the International Arctic Research Center, University of Alaska, Fairbanks, and additionally published via PANGAEA within 3 months after the expedition.

9.3 FRAM remotely operated vehicle

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 freeze-up. These data shall lead to a better understanding of the seasonal evolution of Arctic sea ice, in particular during fall, when the icescape refreezes causing a sudden change in the physical properties of the ice pack. 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. The geometry of sea ice also 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.

Work at sea

Spectral light transmission through snow and sea ice will be measured employing the new FRAM - ROV. In addition, the ROV will also acquire ice geometry using a multi-beam sonar and measure oceanographic and biological properties of the underlying water column. Ice and snow thickness will be measured along selected survey lines

In close collaboration with the WHOI group, several dives of the NUI vehicle close to the sea ice will be performed, furthering the capabilities of AUVs in the interaction with drifting sea-ice.

Data management

All data from the radiation measurements and the FRAM ROV require post-processing after the cruise. The data from AWI sensors will be made publically available in the PANGAEA database within one year.

9.4 FRAM buoy network

Objectives

Recent evaluations of trends in Arctic sea ice extent observed by passive microwave satellite missions show a downward trend of total annual average sea ice cover by -3.8 % per decade, whereas multi-year ice coverage is effected the most (-11.5 %per decade) (Comiso et al., 2014). While these are annually averaged values, the spread in the seasonal cycle is most pronounced during the summer minimum, where the three lowest observed ice extents occurred between 2007 and 2012. The reduction of summer sea ice cover and its shift to a dominant seasonal ice type has implications on the energy balance in form as the ice-albedo feedback, but also increased absorption of solar radiation in ice covered waters (Nicolaus et al., 2012) and its function as a habitat (Boetius et al., 2012).

Although the Arctic Ocean has been studied extensively during recent decades, observational data are relatively sparse due to its remoteness and harsh environmental conditions. Except passive microwave estimations of sea-ice concentration and satellite retrieval algorithms of melt pond concentrations, most *in-situ* observations of the sea-ice mass balance rely on airborne and ship-borne campaigns, which are mostly limited to summer and the following freeze-up period. One important tool to fill the observational gaps of *in-situ* data has become more and more feasible during the last years: autonomous, ice-based observation platforms, which are able to record data throughout the winter, and which extend the investigation area of manned expeditions.

One aim of the FRAM (FRontiers in Arctic marine Monitoring) infrastructure programme is to establish and maintain a network of multi-disciplinary measurement platform across the Arctic Ocean. As part of this network, several buoys will be deployed in open water and on sea ice during PS101. In addition to the already established platforms, several new developments will be field-tested. These are part of FRAM's efforts to provide multi-disciplinary observations, and the data are expected to contribute to a better understanding of the linkages between the atmosphere, sea ice and upper ocean in the polar regions, and their interaction with the ecosystem.

Work at sea

A number of autonomous measurement platforms will be deployed in open water or installed on sea ice floes along the cruise track of PS101. Most buoys will be installed on sea ice during ice stations, while the ship is anchored to a floe, or alternatively by mummy chair or helicopter. Contributors include the Finnish Meteorological Institute, ICE-ARC - EU FP7 project, and Eumetnet.

Types of buoys range from snow-depth and thermistor string ice mass-balance buoys (IMBs) for monitoring ice growth and snow accumulation, over radiation and atmospheric measurements for energy budget estimations, to complex bio-optical platforms to determine the seasonality of algal blooms within and below the ice. Surface Velocity Profilers equipped with barometric pressure sensors will be deployed in collaboration with Eumetnet, contributing to fill the gap of barometric pressure measurements in the polar oceans. Several lightweight GPS buoys will be deployed via an Unmanned Aerial Vehicle (UAV) to support the prediction of small and medium scale sea ice drift. In addition to standard SRSL IMBs, we will deploy a number of newly developed IMBs in collaboration with the ICE-ARC - EU FP7 project (Ice, Climate, Economics - Arctic Research on Change). These will be equipped with cameras and additional sensors, to provide for example spectral radiation, PAR, and several bio-optical parameters. They will be co-deployed with enhanced snow height beacons, which also provide atmospheric measurements. Finally, we intend to perform first field tests of a more complex prototype system, comprising a suite of bio-optical sensors within and below the ice, such as Chl-a and CDOM fluorescence, and different oxygen optodes.

Data management

All buoys transmit their data via the Iridium network in regular intervals (mostly hourly). The data will be available through the FRAM data portal in near-real time, as well as on www.meereisportal.de on a daily basis. The raw data will be stored in PANGAEA weeks after a buoy ceases transmitting. Processed data will be archived in PANGAEA once the quality checks have been applied. Most buoy types also report their data into the Global Telecommunication System.

9.5 Biogeochemistry

Objectives

Due to human activities, atmospheric CO_2 has increased from pre-industrial concentrations of 280 ppm to currently 400 ppm. Since the atmosphere and the ocean are in a permanent gas exchange, oceanic CO_2 concentrations increase with rising atmospheric CO_2 levels. The capacity of the ocean to take up and store large amounts of CO_2 is bases on the buffering capacities of total alkalinity (Zeebe & Wolf-Gladrow, 2001). Nevertheless increased CO2 in the atmosphere leads to ocean acidification. Moreover, the observed rapid decline in summer sea ice extent has led to surface water freshening, thus exacerbating the temperature-dependent stratification and potentially reducing the supply of nutrients from deeper waters (Yamamoto-Kawai et al. 2009, Denman et al. 2011, Shadwick et al. 2013). The reduction in ice cover also allows for more light penetration and longer growing seasons, potentially stimulating primary production (Arrigo et al. 2008). Based on these alterations, one could expect the Arctic Ocean to move from a predominantly light-controlled (ice-covered) to a more nutrient-controlled (open water) system (Carmack & Wassmann 2006).

To monitor the changing Arctic ocean chemistry we aim to monitor at high resolution along the ship's track the carbonate chemistry, nutrient concentrations and their dynamics in the melt-ponds and water column. This will also include sampling for calibration and filtering for particulate materials. Other FRAM objectives with regard to phyto and zooplankton are described in the previous chapters.

Work at sea

Our new *Contros alkalinity flow through system* will be tested and compared with traditional analysis methods. Being able to install this system onboard *Polarstern* for a whole season and to take discrete samples (measured with a VINDTA system) to validate results will provide a unique opportunity to assess the reliability and sensitivity of this new instrument. Being able to determine pH and other parameters of the carbonate system in high resolution has been a key goal for many years, and with the new alkalinity flow through instrument, together with the *General Oceanographic* *pCO_2 system*, we will be able to finally achieve this goal.

In order to monitor nutrient concentrations, a *MicroMac system* from HZG will measure SiO_2, PO_4, NO_2 and NO_3 in Arctic surface waters on an hourly basis. Additionally, two *in-situ NO_3 sensors* will be used to measure profiles down to max 500m. Based on discrete samples (measured with a *QuAAtro 39*) from the CTD/rosette, the *in-situ* data will be validated. This experiment will give us information about the sensor performance and data reliability when deployed in the harsh Artic environment.

We will also employ a high resolution, underway sampling system to measure the surface water gas concentrations using real-time *Membrane-Inlet Mass Spectrometry* (MIMS). More specifically, we will measure the biological oxygen saturation ($\Delta O_2/Ar$) alongside with CO_2 partial pressures (pCO_2) to derive estimates on the net community production (NCP) and sea-air CO_2 fluxes, respectively. These data will be interpreted in the context of other continuous measurements, providing insights how the balance of autotrophy vs heterotrophy in polar ecosystems is affected by different environmental forcings, and how this may change in the future.

Data management

The gas and nutrient data will be available for all scientists onboard, while the *MIMS* data requires post cruise processing. Both data sets will be stored in the PANGAEA database after being checked and analyzed by the person in charge.

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11. FAHRTTEILNEHMER / CRUISE PARTICIPANTS

	Last Name; Nachname	Given name, Vorname	Institute; Institut	Profession; Beruf
1	Boetius	Antje	AWI	Chief scientist
2	Albers	Elmar	MARUM	PhD student, Geology
3	Baeger	Jana	AWI	Technician, Geomicrobiology
4	Bailey	James	WHOI	Engineer, nUI ROV
5	Barz	Jakob	AWI	Technician, Geomicrobiology
6	Biebow	Harald	AWI	Engineer, OFOS
7	Branch	Andrew	WHOI	Engineer, nUI ROV
8	Dannheim	Jenny	AWI	Scientist, Fauna
9	Diehl	Alexander	MARUM	Group leader, PhD student, Geology
10	Doll	Mechthild	UHB-GEO	Group leader, Student, Heat-flow
11	Dreutter	Simon	AWI	Scientist, seafloor observation
12	George	Kai Horst	Senckenberg	Group leader, Fauna
13	German	Chris	WHOI	Group leader, nUI ROV
14	Hand	Kevin	NASA JPL	Scientist, nUI ROV
15	Hehemann	Laura	AWI	Scientist, seafloor observation
16	Hildebrandt	Nicole	AWI	Group leader, Zooplankton
17	Horn	Myriel	AWI	PhD Student, FRAM Oceanography
18	Jacobs	Mirta	AWI	PhD Student, Plankton
19	Jakuba	Mike	WHOI	Engineer, nUI ROV
20	Katlein	Christian	AWI	Scientist, FRAM Sea-ice physics
21	Kieneke	Alexander	Senckenberg	Scientist, Fauna
22	Kinsey	James	WHOI	Engineer, nUI ROV
23	Kosobokova	Ksenia	IORAS	Scientist, Zooplankton
24	Köhler	Janna	UHB-IUP	Scientist, Oceanography
25	Krumpen	Thomas	AWI	Scientist, Sea-ice physics
26	Machado	Casey	WHOI	Engineer, nUI ROV
27	Molari	Massimiliano	AWI	Scientist, Geomicrobiology
28	Müller	Paulina	UHB-GEO	Student, Heat-flow
29	Nicolaus	Marcel	AWI	Group leader, Sea-ice physics
30	Nordhausen	Axel	MPI	Technician, Coring
31	Pliet	Johannes	FIELAX	GIS, Data management
32	Purser	Autun	AWI	Groupleader Seafloor obs.
33	Rössler	Sebastian	FIELAX	GIS, Data management
34	Schiller	Martin	AWI	Engineer, Sea-ice physics
35	Schmidtmann	Linn	AWI	Student, Fauna (Foraminifera)

	Last Name; Nachname	Given name, Vorname	Institute; Institut	Profession; Beruf
36	Scholz	Daniel	AWI	Engineer, FRAM chemistry
37	Schramm	Fabian	MPI/MARUM	Technician, Coring and OFOS
38	Seewald	Jeff	WHOI	Scientist, Vent chemistry
39	Slaby	Beate	GEOMAR	PhD student, Macrofauna
40	Sopke	Stefan	MARUM	Technician, Geology
41	Stecher	Anique	AWI	Group leader, Plankton
42	Steinmacher	Bermann	UHB-IUP	Student, FRAM Oceanography
43	Suman	Stefano	WHOI	Engineer, nUI ROV
44	Vonnahme	Tobias	AWI	Student, Geomicrobiology
45	Walter	Maren	UHB-IUP	Group leader, Oceanography
46	Wegener	Gunter	AWI	Group leader, Geomicrobiology
47	Wischnewsky	Laura	AWI	Technician, FRAM chemistry
48	NN			Helicopter
49	NN			Helicopter
50	NN			Helicopter
51	NN			Helicopter
52	NN			DWD
53	NN			DWD

11. SCHIFFSBESATZUNG / SHIP'S CREW

	Name	Rank
01.	Schwarze, Stefan	Master
02.	Grundmann,	1.Offc.
03.	Farysch, Bernd	Ch. Eng.
04.	Janik, Michael	2. Offc.
05.	Hering, Igor	2.Offc.
06.	Fallei, Holger	2.Offc.
07.	Scholl, Thomas	Doctor
08.	Fröb, Martin	Comm.Offc.
09.	Grafe, Jens	2.Eng.
10.	Krinfeld, Oleksandr	2.Eng.
11.	Holst, Wolfgang	3. Eng.
12.	Redmer, Jens	Elec.Tech.
13.	Christian, Boris	Electron.
14.	Hüttebr.ucker, Olaf	Electron.
15.	Lehnert, Lars	Electron.
16.	Himmel,Frank	Electron
17.	Loidl, Reiner	Boatsw.
18.	Reise, Lutz	Carpenter
19.	Hagemann, Manfred	A.B.
20.	Winkler, Michael	A.B.
21.	Scheel, Sebastian	A.B.
22.	Bäcker, Andreas	A.B.
23.	Brück, Sebastian	A.B.
24.	Wende, Uwe	A.B.
25.	Völker, Frank Rainer	A.B.
26.	Leisner, Karl-Heinz Bert	A.B.
27.	Schröder, Christoph	A.B.
28.	Preußner, Jörg	Storek.
29.	Teichert, Uwe	Mot-man
30.	Rhau, Lars-Peter	Mot-man
31.	Lamm, Gerd Mot-man	
32.	Schünemann, Mario	Mot-man
33.	Pinske, Lutz	Mot-man
34.	Redmer, Klaus-Peter	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.	Grigull, Elke	2.Steward
42.	Arendt, Rene	2.Steward
43.	Sun, Yong Shen	2.Steward
44.	Yu, Kwok Yuen	Laundrym.