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

EXPEDITION PROGRAMME PS109

Polarstern

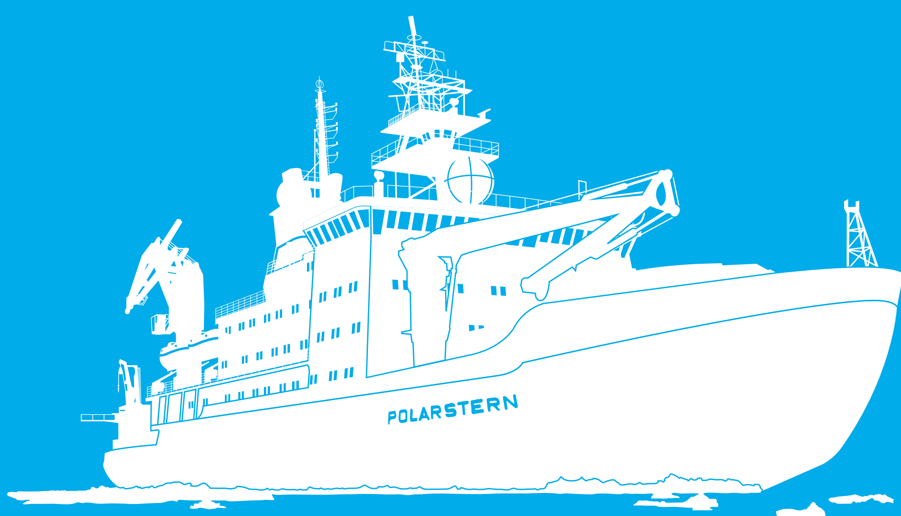
PS109

Tromsø – Bremerhaven

12 September 2017 – 14 October 2017

Coordinator: Rainer Knust

Chief Scientist: Torsten Kanzow



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Alfred-Wegener-Institut
Helmholtz-Zentrum
für Polar- und Meeresforschung
Am Handelshafen 12
D-27570 Bremerhaven

Telefon: ++49 471 4831- 0
Telefax: ++49 471 4831 – 1149
E-Mail: info@awi.de
Website: http://www.awi.de

Email Coordinator: rainer.knust@awi.de
Email Chief Scientist: torsten.kanzow@awi.de

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1. ÜBERBLICK UND FAHRTVERLAUF

Torsten Kanzow (AWI)

Die Expedition "Greenland ice sheet/ocean interaction" (GRIFF) zielt auf die Erforschung der ozeanischen Transportprozesse zwischen der Framstraße, dem grönländischen Eisschild und dem europäischen Nordmeer ab. Der starke Temperaturanstieg der arktischen Atmosphäre und des Ozeans sowie erhebliche Veränderungen des arktischen Süßwasserhaushalts in den letzten Jahren sind in komplexer Wechselwirkung mit dem Rückzug des grönländischen Eisschildes als auch dem Wandel der Ozeanzirkulation verbunden.

Während die Expedition PS100 im Sommer 2016 Untersuchungen im regionalen System Framstraße – Europäisches Nordmeer – nordostgrönländischer Schelf vornahm, wird sich diese Expedition spezifisch auf die Wechselwirkungen zwischen dem Ozean und dem Eisschild konzentrieren. Der NEGIS (North East Greenland Ice Stream) mündet auf dem Schelf der westlichen Framstraße, wo sein Auslassgletscher, der 79°-Nord-Gletscher, in direktem Kontakt mit warmem, in die Framstraße rezirkulierendem Atlantikwasser kommt.

Die Studie ist zeitgemäß, denn das Atlantikwasser in der Framstraße und am Schelf hat sich in den letzten Jahrzehnten beträchtlich erwärmt, während gleichzeitig auch der 79°-Nord-Gletscher Anzeichen eines Rückzugs seiner schwimmenden Gletscherzunge zeigt.

Zur Erforschung dieses komplexen Systems wird die geplante Reise Arbeiten aus den Bereichen Ozeanzirkulation, Geochemie, Glaziologie, Geodäsie, Geologie, Geophysik, Atmosphärenphysik, Meereis Fernerkundung, Biologie und Biochemie kombinieren.

Die Studie der physikalischen Ozeanographie zielt auf zwei Aspekte ab: die Zirkulation des Atlantikwassers unterhalb der Oberfläche und der Oberflächenströmung (Polarwasser und Gletscherschmelzwasser) zwischen dem Ostgrönlandstrom, der sich an der Schelfkante befindet, und dem inneren Schelf, wo das Meerwasser und die marinen Auslassgletscher (79°-Nord-Gletscher und Zachariae Gletscher) aufeinander einwirken. Wir werden Zirkulationspfade und -stärken studieren, Eigenschaften der Wassermassen und deren Zusammensetzung (z. B. Gletscherschmelzwassergehalte), diapyknische Vermischung von Warm- und Süßwasserzweigen auf dem Schelf (zwischen Ozean und Gletscher), sowie Schelf-Beckenaustausch von Atlantikwasser.

Die Untersuchungen werden auf der Bergung und Auslegung von ozeanographischen Verankerungen sowie hydrographischen Vermessungen (LADCP und Dissipationsmessungen) basieren. Wir werden Schmelzwasser identifizieren und Schmelzraten beziffern. Letzteres wird durch Beobachtungen von einerseits stabilen Edelgasisotopen und andererseits transienten Tracern belegt werden. Um die kleinskaligen, turbulenten Austauschprozesse zwischen dem Gletscher und dem Gewässer am inneren, mittleren und äußeren Schelf zu erforschen, werden autonome Unterwasserfahrzeuge eingesetzt.

Außerdem werden per Meereis Fernerkundung die physikalischen Charakteristika von verschiedenen Eisoberflächen (Eisschollen, reines Eis, Schnee) mit Hilfe von Helikoptervermessung erkundet. Atmosphärische Untersuchungen, unterstützt von einem unbemannten Fluggerät (UAV), werden sich auf die Struktur der atmosphärischen Grenzschicht konzentrieren. Das beinhaltet Studien der Transportprozesse des Methans vom Ozean bzw. Meereis in die Atmosphäre.

Die Expedition wird außerdem Messungen der glazialen und der terrestrischen Dynamik bewerkstelligen. Geräte für gletscherbezogene, geodätische und seismologische Beobachtungen werden entlang der Küste Nordost Grönlands und auf dem 79°-Nord-Gletscher installiert werden. Das glaziologische Programm wird die Schmelzraten und Bewegungen des Eisflusses erfassen. Dieses wird durch Wiederholmessungen mittels Phasen-sensitiven Radarsystemen und die Bergung von GPS-Observatorien auf der Eiszunge des 79°-Nord-Gletschers bewerkstelligt. Das geodätische Programm konzentriert sich auf die wiederholte Einmessung von Langzeitbeobachtungspunkten, um Deformationsgeschwindigkeiten der Erdkruste zu bestimmen, welche Informationen über die postglaziale isostatische Anpassung liefern wird. Eine seismologische Messanordnung wird Hinweise auf die glazialen und tektonischen Ursprünge der ungewöhnlich großen Häufigkeit von seismologischen Ereignissen (Beben) in der Nähe des 79°-Nord-Gletschers liefern.

Um die modernen Beobachtungen nahe Grönland in einen größeren Kontext zu stellen, wird das Geologieprogramm die Geschichte der nordostgrönländischen Eiströme nach dem Höhepunkt der letzten Eiszeit studieren. Ein ganz besonderes Ziel ist es, die Eisstrom- und die Eisschelfausdehnungen und Mächtigkeiten zu quantifizieren, um daraus ein Maß des Gletscherrückzugs und Vortriebs mit Hilfe von Sedimentbohrungen und akustischen Meeresbodenuntersuchungen an Schlüsselpunkten des nordostgrönländischen Kontinentalschelfs zu bestimmen. Die Zyklen des Eisschildrückzugs werden dann im Kontext von ozeanischen und atmosphärischen Bedingungen sowie von Meeresspiegelveränderungen interpretiert.

Die physikalischen Arbeiten werden von biogeochemischen und biologischen Programmen ergänzt. Die benthischen Studien werden sich darauf konzentrieren, wie der Schmelzwassereintrag die benthisch-biogeochemischen Prozesse und Community-Zusammensetzung beeinflussen. Diese Arbeiten werden eine Quantifizierung der Mineralisierung von organischer Materie im Verhältnis zum Schmelzwassereinfluss, der Faunavielfalt (Mikro bis Makro) und dem Gesamtvorkommen beinhalten. Dieses Experiment basiert auf benthischen Landermessungen sowie Kamera-gesteuerten Multicorer Probennahmen.

Meereis ist ein wichtiger Lebensraum für zahlreiche Organismen des polaren Ökosystems. Das Team der Meereisbiologie wird seinen Fokus auf I. Meereisflora und Fauna, II. mit den Schmelztümpeln verbundenen Lebensgemeinschaften, III. aus dem Meereis stammender Kohlenstoff in pelagischen Nahrungsnetzen, IV. die Vielfalt von Meereisfauna, V. genetischen Verbindungen von Polardorschlarven und VI. den Methanzyklus zwischen Meerwasser, Meereis und der Atmosphäre richten. Es werden hierzu Proben vom Meereis, Meerwasser, in Schmelzablagerungen und aus der Luft genommen.

Ferner wird eine geophysikalische Studie vom Prozess der Meeresbodenspreizung an einer sich extrem langsam spaltenden Kante durchgeführt. Wir wollen erforschen, wie die Gesteinsschmelze es schafft, durch die starke, kalte Gesteinsrinde zum Meeresboden an den vulkanischen Zentren zu gelangen. Dafür werden wir Logachev Seamount mit seismischer Tomographie durch Verwendung von 4 Meeresboden Seismometern (OBS) rund um Logachev Seamount abbilden.

Polarstern wird am 12. September von Tromsø auslaufen. Auf dem Weg zu den Hauptarbeitsgebieten am nordostgrönländischen Schelf werden wir die Seismologen Station südlich der Framstraße bei Logachev Seamount bedienen (Fig. 1.1). Danach sollten wir beginnen, die Forschungsprogramme durchzuführen.

Hier sollen die 2016 während der Expedition PS 100 an der Schelfkante, dem mittleren Schelf und in unmittelbarer Nachbarschaft zum 79°-Nord-Gletscher ausgelegten Verankerungen wieder geborgen werden. Die Aufgabe wird außerdem Auslegungen von Verankerungen an der Schelfkante und dem inneren Schelf beinhalten, sowie zielorientierte

Hydrographie / Tracer und meereisbiologische Forschungen, als auch Lander- basierende Benthosbiologie und Sedimentbohrungsprogramme entlang des Norsketrogs und des Westwindtrog Systems.

Gleichzeitig werden Helikopter-gestützte Arbeiten durchgeführt, um sowohl die geodätischen als auch seismologischen Stationen an der Küste, den glaziologischen Forschungen am 79°-Nord-Gletscher, der Ozeanographie, der Meereisphysik und Meereis Biologie Forschungen am Schelf abzudecken. Diese werden vollendet durch Arbeiten, die auf AUV (Ozeanographie) und UAV (atmosphärischen Grenzschicht) basieren.

Nach Beendigung des Programms wird es einen direkten Transit zurück nach Bremerhaven geben, wo die Expedition am 14. Oktober 2017 enden wird.

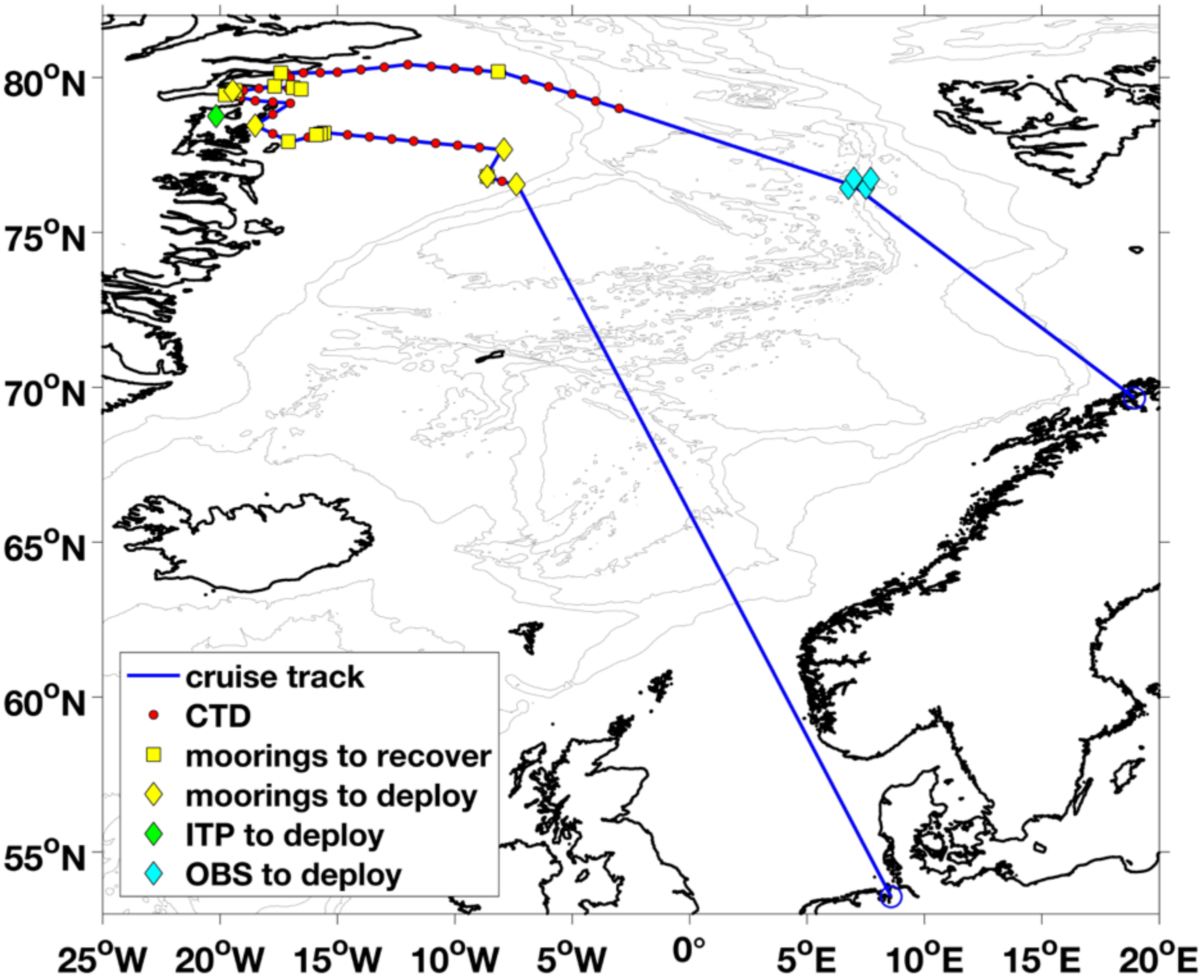

Abb. 1.1: Vorläufige Fahrtroute der Polarstern Expedition PS109, die am 12. September in Tromsö beginnen und am 6. Oktober in Bremerhaven enden wird. Während der Expedition werden Forschungstätigkeiten auf dem Schelf von Nordostgrönland stattfinden sowie an der Logachevkuppe südlich der Framstraße.

Fig. 1.1: Preliminary track of R/V Polarstern cruise PS109 starting in Tromsö on 12 September, and returning to Bremerhaven on 14 October. The main work area is the shelf of Northeast Greenland.

SUMMERY AND ITINERARY

The cruise "Greenland ice sheet/ocean interaction" (GRIFF) targets investigations of the oceanic fluxes between Fram Strait, the Greenland ice sheet and the Nordic Seas. Strong temperature increase of the Arctic atmosphere and ocean and considerable changes of the Arctic fresh water budget during the past years, and during the same time the retreat of the Greenland ice sheet as well as changes in the ocean circulation are linked via complex interactions. Whereas expedition PS100 in summer 2016 carried out investigations on the wider Fram Strait - Nordic Seas – Northeast Greenland shelf system, this expedition will focus specifically on the ocean – ice sheet interaction. The NEGIS (North East Greenland Ice Stream), drains into the shelf in western Fram Strait where its outlet glacier, the 79° North Glacier, is in direct contact with warm Atlantic water recirculating in Fram Strait. The study is timely, as the Atlantic water in Fram Strait and on the shelf has been warming considerably during the last decades while at the same time the 79° North Glacier has been showing indications of retreating and thinning of its floating ice tongue. The proposed cruise will combine work on **ocean circulation**, **geochemistry**, **glaciology**, **geodesy**, **geology**, **geophysics**, **atmospheric sciences**, **sea ice remote sensing**, **biology** and **biochemistry** of this complex system.

The physical oceanography study targets both the subsurface Atlantic water circulation and the surface flow (Polar Water and glacial melt water) between the East Greenland Current residing at the shelf edge and the inner shelf, where the seawater interacts with the marine terminating glaciers (79° North Glacier and Zachariæ Isstrøm). We will study circulation pathways and strength, water mass properties and composition (e.g. glacial meltwater fraction), diapycnal mixing on the shelf, heat- and freshwater fluxes (between ocean and glaciers) and shelf – basin exchange of Atlantic Water. The study will be based on the recovery and redeployment of oceanographic moorings, hydrographic surveys (including LADCP and dissipation measurements). We will also identify melt water and quantify rates. The latter will be constrained by observations of both stable noble gas isotopes and transient tracers. For the study of small–scale turbulent exchange processes between the glacier and the waters on the inner, mid- and outer shelf an autonomous underwater vehicle will be used.

In addition, sea ice remote sensing techniques will target the physical characterization of different ice surfaces (ice floes, pure ice, snow) based on helicopter surveys. Atmospheric investigations based on an unmanned aerial vehicle will focus on the structure of the atmospheric boundary layer. This includes studies of transport processes of methane from the ocean / sea ice into the atmosphere.

The cruise will further support measurements of the glacial / terrestrial dynamics. Devices for glaciological and geodetic and seismological observations will be installed along the coast of Northeast Greenland and on the 79° North Glacier. The glaciological programme will capture the melt rates and dynamics of the ice flow. This will be accomplished by reoccupation of phase-sensitive radar sites and recovery of GPS observatories on the ice tongue of the 79° North Glacier The geodetic programme focuses on a re-occupation of a long-term sites to capture deformation rates of the earth crust, which will provide information of the glacial isostatic adjustment. The seismological array to be deployed will investigate the glacial and tectonic origins of the unusually large frequency of seismologic events (quakes) in the area of the 79° North Glacier.

In order to put the modern observations near Greenland into a long-term perspective, the geology programme will study the history of Northeast Greenland Ice Stream after the last glacial maximum. A particular aim is to constrain both the ice stream and ice shelf extents and thicknesses in order to determine rates of retreats and re-advances by sediment coring and acoustic seafloor surveys at key locations on the Northeast Greenland continental shelf.

The ice sheet retreat cycles will then be interpreted in the context of oceanic and atmospheric conditions as well as sea level change.

The physical work will be complemented by biogeochemical and biological programmes. The benthic biogechemical studies will focus on how increased melt water input effects benthic biogeochemical processes and community composition. They will include a quantification of organic matter mineralization in relation to melt water influence and fauna (Micro- to macrofauna) diversity and abundance. The experiments will be based on Benthic Lander measurements and TV-guided Multicorer samples.

Sea ice is an important habitat and feeding ground for various organisms of the polar ecosystem. The sea ice biology team aim will focus on I. sea ice biota, II. melt pond associated communities, III. sea ice-derived carbon in pelagic food webs, IV. abundance of sea-ice fauna, V. genetic connectivity of larval polar cod, and VI. the methane cycle between sea water, sea ice and the atmosphere. The environmental sample will be collected of sea ice, under ice water, in meltponds and from the air.

In addition, a geophysical study of spreading processes at an ultraslow spreading ridge will be conducted. We want to study how melts manage to travel through the thick cold lithosphere to the seafloor at the volcanic centres. We will therefore image Logachev Seamount with seismic tomography by deployment of 4 ocean bottom seismometers (OBS) around Logachev Seamount.

Polarstern will depart Tromsø on September 12. On the way to the main work areas on the shelf of Northeast Greenland we will cover the seismology stations south of Fram Strait at Logachev Seamount (Fig. 1.1). We shall then begin to conduct the research programmes. Here moorings deployed in 2016 during expedition PS100 at the shelf edge, the mid shelf and in close vicinity to the 79° North Glacier are intended to be recovered. This work will further involve re-deployments of moorings at the shelf edge and the inner shelf, and targeted hydrography / tracer and sea ice biology studies, as well as lander-based benthic biology and sediment coring programmes along the Norske Trough / Westwind Trough system. At the same time, helicopter-based operations will be conducted in order to cover both the geodetic and seismologic stations on the coast, the glaciological survey on the 79° North Glacier and the oceanographic, sea ice physics and sea ice biology studies on the shelf. This will be complemented by operations based and the AUV (oceanography) and UAV (atmospheric boundary layer). Upon completion of the programmes there will be a direct transit back to Bremerhaven, where the expedition will end on October 14.

2. PHYSICAL OCEANOGRAPHY

J. Schaffer (AWI), T. Kanzow (AWI), Z. Hofmann (Geomar), L. von Albedyll (Uni Bremen), A. Behrendt (AWI), R. Graupner (AWI), N. Hutter (AWI), A. Muenchow (UDEL), P. Washam (UDEL), C. Engicht (AWI), N. Beird (WHOI)

Background and objectives

Mass loss from the Greenland Ice Sheet presently accounts for a third to a quarter of sea-level rise (Milne et al. 2009) and the rate of mass loss is increasing (Velicogna 2009). The dominant mechanism is increased mass discharge along the marine margins where numerous major outlet glaciers have undergone a nearly simultaneous retreat, acceleration and thinning (Rignot and Kanagaratnam 2006; Howat et al. 2008; Stearns and Hamilton

2007; Dietrich et al. 2007). Both data and models indicate that this acceleration was triggered by a change at the tidewater margins of these glaciers (Thomas 2004; Nick et al. 2009; Pritchard et al. 2009), suggesting that the ocean plays a key role in modulating the ice sheet's mass balance (Vieli and Nick 2011; Straneo et al. 2012).

The proposed oceanic trigger is supported by recent studies showing that warm Atlantic waters are present and circulating in Greenland's glacial fjords (Holland et al. 2008; Straneo et al. 2010; Murray et al. 2010; Straneo et al. 2011) and by the observation that these waters were warming and accumulating in the subpolar North Atlantic at the same time as the glaciers started to retreat (e.g. Bersch et al. 2007).

Greenland's glacier acceleration has been concentrated along the southeastern and western margins terminating in the subpolar North Atlantic. Only recently, Helm et al. (2014) observed a general reduction in ice sheet elevation near the margins in the northeast of Greenland. Here, mainly two glaciers Nioghalvfjerdsfjorden Glacier (also referred to as 79° North Glacier) and Zachariæ Isstrøm drain the Northeast Greenland Ice Stream (NEGIS) whose drainage basin contains more than 15 % of the Greenland Ice Sheet area (Rignot and Kanagaratnam 2006). Zachariæ Isstrøm lost about 5 Gt/yr of its mass since 2003 and was observed to retreat at an accelerated rate since fall 2012, whereas no mass loss but an increased bottom melting was found at 79° North Glacier (Mouginot et al. 2015). Khan et al. (2014) observed an acceleration of the ice flow of 79° North Glacier and a sustained dynamic thinning of NEGIS which they linked to a regional warming. The fact that a warming and thickening of the Atlantic layer has recently been observed in the Nordic Seas (e.g. in Fram Strait; Beszczynska-Möller et al. 2012) raises the question whether the ocean changes may have triggered the fast retreat of Zachariæ Isstrøm (as suggested by Mouginot et al. 2015) and will trigger unstable behavior of 79° North Glacier.

Warm Atlantic water is carried to the North by the North Atlantic Current - Norwegian Atlantic Current - West Spitsbergen Current system (Fig. 2.1). In Fram Strait a sizable fraction of the Atlantic water recirculates to the south on the East Greenland continental slope. Studies on the eastern Greenland shelf in the 1980s and 1990s found this recirculating Atlantic water (RAW) to penetrate through sea bed troughs onto the Northeast Greenland continental shelf (e.g. Bourke et al. 1987) below the fresh and cold polar waters (PW).

The Atlantic water mass found on the continental shelf was described by Bourke et al. (1987) as Atlantic Intermediate Water (AIW) with temperatures ranging between 0°C and 3°C and salinities between 34.5 and 34.9. Budeus et al. (1997) found two distinct types of Atlantic waters in the trough system. They found 1°C warm Atlantic waters with salinities of 34.9 to be present throughout the southern Norske Trough, which cooled and freshened towards 79° North Glacier, and 0.5°C warm Atlantic waters with salinities of 34.8 in the northern Westwind Trough. An anticyclonic surface circulation on the continental shelf following the trough axis was found based on hydrographic observations (Bourke et al. 1987, Schneider and Budeus 1995), moored (Topp and Johnson 1997) and ship based (Johnson and Niebauer 1995) velocity measurements. In addition, Topp and Johnson (1997) proposed an anticyclonic subsurface circulation from moored measurements in Westwind Trough, in contrast to Budeus et al. (1997), who proposed that there is no one-directional flushing of the trough system. In the trough area east of the outlet glaciers, i.e. between Westwind and Norske Trough, Budeus and Schneider (1995) suggested a sill depth of 250 m causing the differences in water properties. This part of the continental shelf has rarely been studied due to a perennially fast sea ice cover (e.g. Schneider and Budeus 1995; Schneider and Budeus 1997), but is of strong interest when studying warm water pathways towards the outlet glaciers.

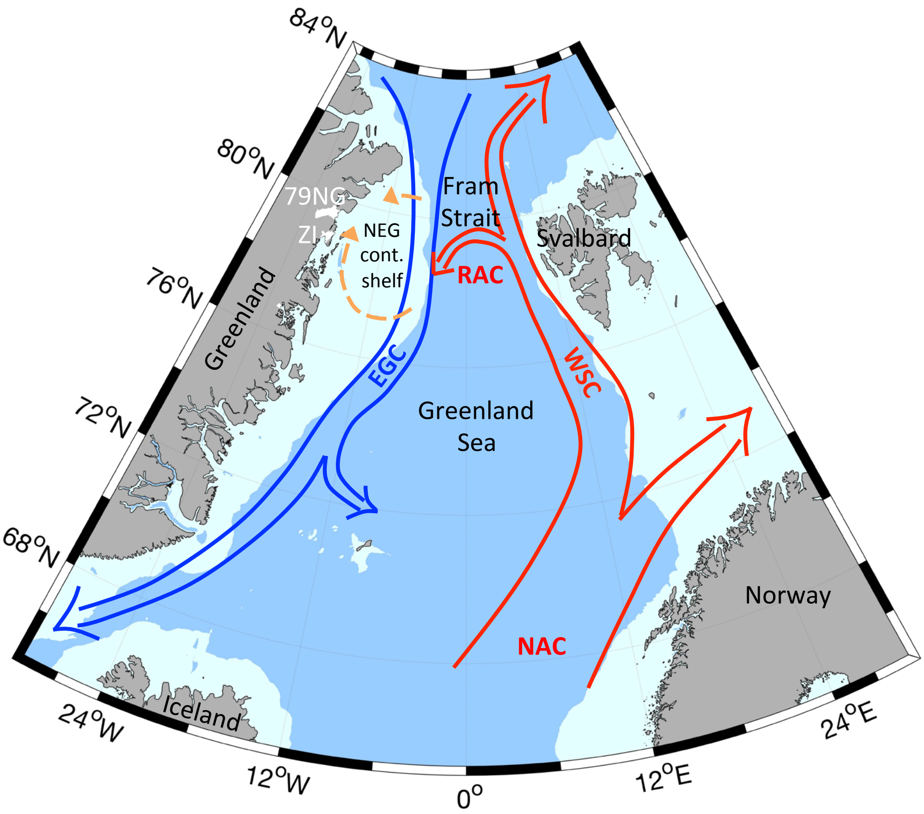

Fig. 2.1: Schematic of the circulation in the Nordic Seas. Red arrows represent the flow of warm Atlantic Water with the Norwegian Atlantic Current (NAC) and West Spitsbergen Current (WSC) towards the Arctic Ocean with a large fraction of this water recirculation in Fram Strait (Return Atlantic Current, RAC). The East Greenland Current (EGC) transports Atlantic Water modified in the Arctic Ocean and RAC southwards flowing along the continental shelf break. Parts of the Atlantic Water are transported on the Northeast Greenland continental shelf (NEG cont. shelf) where they are spreading towards the 79° North Glacier (79NG) and Zachariæ Isstrøm (ZI).

A survey of the 79° North Glacier in the mid-1990s led to very high estimates of submarine melt rates (about 40 m/yr locally, with a mean basal melt rate of 8 m/yr), which account for the bulk of the ice shelf mass loss (Mayer et al. 2000). The melting was attributed to the presence of AIW in the 600 m to 800 m deep subglacial cavity as observed in several conductivity, temperature and depth (CTD) profiles collected at the glacier's margins (Thomsen et al. 1997; Mayer et al. 2000). A more recent survey conducted in the summer of 2009 (Straneo et al. 2012) confirmed that the AIW found under the floating ice tongue still contains large amounts of heat to drive melting. Based on three CTD sections taken north of the main glacier calving front, Wilson and Straneo (2015) discussed that warm AIW cannot enter the cavity through Dijmphna Sund due to a sill of 170m depth but needs to pass the main 79° North Glacier calving front. First results from *Polarstern* cruise PS100 carried out in summer 2016 in the vicinity of the main 79° North Glacier calving front imply that the bathymetry triggers a descending gravity plume of warm AIW flowing into the subglacial cavity below the 79° North Glacier. This hydraulic controlled flow is accompanied by turbulent mixing. However, more velocity and turbulence measurements are needed to support this concept.

During the *Polarstern* cruise PS109 we aim to achieve the following objectives:

- Analyse circulation pathways and strength of Atlantic Water on the Northeast Greenland continental shelf
- Study the water mass properties and composition of glacial meltwater fraction focussing on the region close to the calving fronts of the 79° North Glacier and Zachariæ Isstrøm
- Measure diapycnal mixing on the continental shelf and in front of the 79° North Glacier where first results from few stations carried out in summer 2016 imply strong turbulent mixing
- Determine heat and freshwater fluxes between the subglacial cavity and the continental shelf
- Analyse the exchange of Atlantic Water across the continental shelf break

Work at sea

Moorings were deployed on the East Greenland shelf by the Alfred Wegener Institute in summer 2016 (PS100). It is planned that the 14 moorings currently still in the water (Fig. 2.2) shall be recovered on PS109. The moorings on the Northeast Greenland continental shelf belong to the physical oceanography section of AWI with the exception of five of the moorings, which belong to the University of Delaware. Apart from the mooring recoveries the physical oceanography group will deploy 5 moorings (Fig. 2.3).

In addition, an ITP (Ice Tethered Profiler) will be deployed near the calving front of Zachariæ Isstrøm near 78°45'N 20°10'W. This is an area that is covered by sea-ice. Equipment will be moved there by helicopter. The ITP consists of a surface float, a 500 m long cable, an instrument package (i.e. a profiler which measures temperature, salinity and turbidity profiling up and down the water column), and an anchor. Gear needed to deploy this system includes a winch, a tripod, sleds to move gear and a generator.

The measurements will be undertaken with a range of instruments, from the ship as well as from the ice. Conductivity-Temperature-Depth (CTD) measurements are carried out with the ship-board SBE 9/11+ CTD system, which is combined with a SBE 32 Carousel Water Sampler (Seabird). The CTD carousel (rosette) will also be equipped with a TRDI Lowered Acoustic Doppler Current Profiler system (LADCP) for recording velocity during the CTD casts. Velocity in the upper water column (200-300 m) is additionally recorded by the vessel mounted 150 kHz ADCP (Teledyne - RDI). Supplementary to CTD measurements we will use an CTD (RBR) attached to a fishing rod and a mobile echosounder (50 kHz) launched from the sea ice that can be reached by the helicopter only (i.e. supposedly close to calving front of Zachariæ Isstrøm). Fine-scale temperature and shear needed to infer turbulence, mixing, and heat or nutrient fluxes, will be measured with a MSS90D microstructure profiler (Sea & Sun Technology and ISW Wassermesstechnik), which is equipped with shear- and fast response CTD sensors.

The LADCP on the CTD rosette will concurrently record vertical velocity profiles throughout the water column. The horizontal scales of currents in high latitudes are small (~1-10 km) and, hence, for capturing typical boundary current features, a fine station resolution is required. In addition, current measurements of the upper ~200 m along each transect will be collected with the vessel mounted ADCP.

During times when *Polarstern* has to stay in or near one location for at least one day, we will establish small ice camps to measure microstructure. *Polarstern's* vessel-mounted ADCP can record velocity data below 25 m. These data will complement the MSS casts, which will be repeatedly carried out at the beginning of each hour throughout the long-term stations.

These sampling methods will generate short (1-2 days) time series of currents and vertical fluxes, and hence valuable physical insights, relevant for biogeochemical processes and for the role of currents and turbulence to oceanic heat fluxes to sea ice as well as between glacial meltwater and Atlantic Water and the mixing of the two water masses.

CTD, velocity and microstructure profiles will be measured in as many locations as possible. In particular, there will be a focus on measuring the flow in the trough system on the Northeast Greenland continental shelf towards the 79° North Glacier and Zachariæ Isstrøm, and into/out of the subglacial cavity beneath the 79° North Glacier. The measurement strategy will be based on analyses of the data measured in 2016 during *Polarstern* cruise PS100.

Preliminary (expected) results

It is expected that the moorings to be recovered in Norske Trough, Westwind Trough and along the calving front of 79° North Glacier will provide insights into the along-trough circulation of Atlantic Water and into the flow of Atlantic Water into the subglacial cavity beneath 79° North Glacier. The CTDs and microstructure measurements will improve the understanding of the interaction of Atlantic Water, Polar Water, and glacial modified waters. In addition, the moored, CTDs and LADCP measurements will give more insights into the transport of Atlantic Water flowing into and glacially modified waters flowing out off the subglacial cavity. CTD, depth, and ITP measurements close to Zachariæ Isstrøm will provide information on the seafloor structure and potential Atlantic Water pathways towards the calving front of Zachariæ Isstrøm. Here, five temperature profiles launched from the sea ice in 2016 provided the first measurements ever taken in this remote area.

The data from the deployed moorings will not be available until 2018, but then it will allow for the first assessment ever made of the dynamics transporting Atlantic Water onto the Northeast Greenland continental shelf.

Data management

The data recorded by the moored instruments that will be recovered on PS109 will be processed after the cruise at AWI and submitted to the PANGAEA data publisher. The moorings that will be deployed on PS109 will be recovered in 2018. The data recorded on those instruments will accordingly be processed after recovery and submitted to the PANGAEA data publisher at that time. Likewise, the data collected during PS109 from the different CTDs, the LADCP, and the microstructure profiler will be processed at AWI and afterwards submitted to the PANGAEA data publisher.

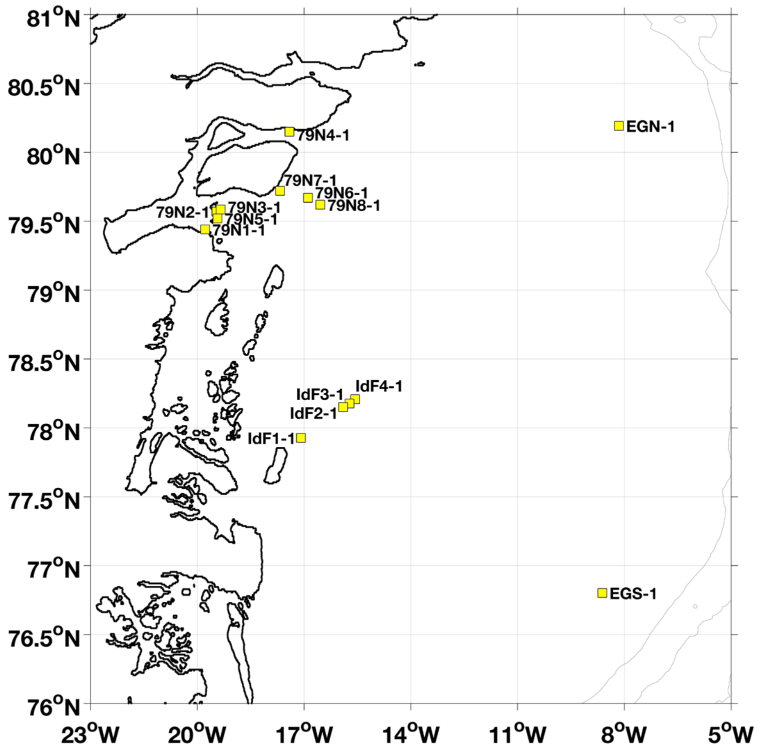

Fig. 2.2: Positions of the moorings to be recovered on the Northeast Greenland continental shelf

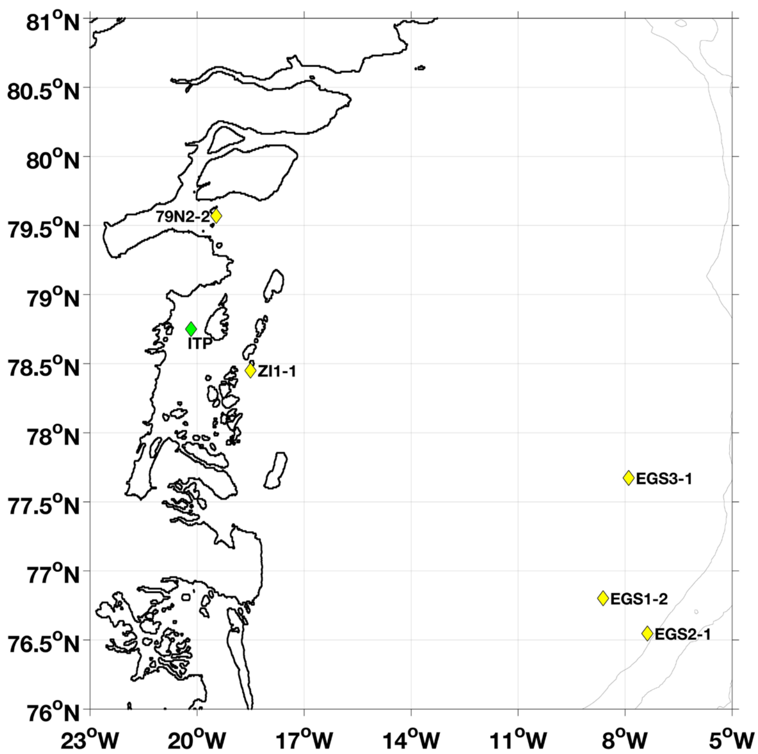

Fig. 2.3: Positions of the moorings and the ITP to be deployed on the Northeast Greenland continental shelf. The ITP and the mooring ZI1-1 may be moved slightly depending on the local ice conditions during deployment

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3. INVESTIGATING PHYSICAL AND ECOLOGICAL PROCESSES IN THE OUTFLOW AREA OF THE 79° NORTH GLACIER USING AN AUTONOMOUS UNDERWATER VEHICLE AND UNMANNED AERIAL VEHICLES

T. Wulff (AWI), S. Lehmenhecker (AWI), S.Tippenhauer (AWI), N.N.

Objectives

The 79° North Glacier, located in northeast Greenland, is one of two fast moving glaciers of the North East Greenland Ice Stream (NEGIS) draining ice into the Fram Strait. Its two floating tongues and associated outflow areas are separated by the Hovgaard Island. The southern outflow area has been mapped by *Polarstern* in summer 2016 for the first time.

As encountered by many glaciers around the world, and especially by glaciers at the edge of Greenland´s ice sheet, the 79° North Glacier faces substantial loss of ice and its calving front retreats rapidly. It is one of the expedition´s PS 109 basic questions whether the particularly high melting rates are due to the increasing temperatures of the sea water below the floating tongues. To better understand the interaction between the ocean and the glacier, deployments of AWI´s Autonomous Underwater Vehicle (AUV) "*PAUL*" will provide high resolution measurements of the hydrography and ecological conditions in the glacier´s outflow area.

Physical parameters in the outflow area will be observed by the AUV with a set of sensors such as a conductivity, temperature and depth probe (CTD), an acoustic doppler current profiler (ADCP), a microstructure probe (MSP) and an upward looking irradiance sensor. With these instruments, we will be able to distinguish different water bodies, determine small scale mixing processes at their interfaces, estimate fluxes, measure the water column´s stability and gather data on the underwater light field. These physical parameters are essential to understand the ecological response. To observe the respective biological activity, the AUV is equipped with a chlorophyll *a* fluorometer, a fluorometer for colored dissolved organic matter (CDOM) and a nitrate sensor to determine the water column´s nutrient inventory. As an optional sensor, a turbidity sensor can be integrated on short notice to observe sediments released by the glacier. A water sample collector which is able to collect 22 samples with an overall volume of 4.8 liters is used to calibrate the nitrate as well as the chlorophyll *a* sensor, to measure mineral micronutrients such as iron and to study the composition of plankton communities.

Prior to *PAUL*´s deployments, Unmanned Aerial Vehicles (UAVs) will set up a network of tracking devices on the ice. These ice trackers will stay on the ice for the duration of the expedition. They will constantly determine their own position via GPS and transmit the position via Iridium. Deploying these tracking devices, the dimensions of the ice-free area off the glacier´s tongue can be observed permanently.

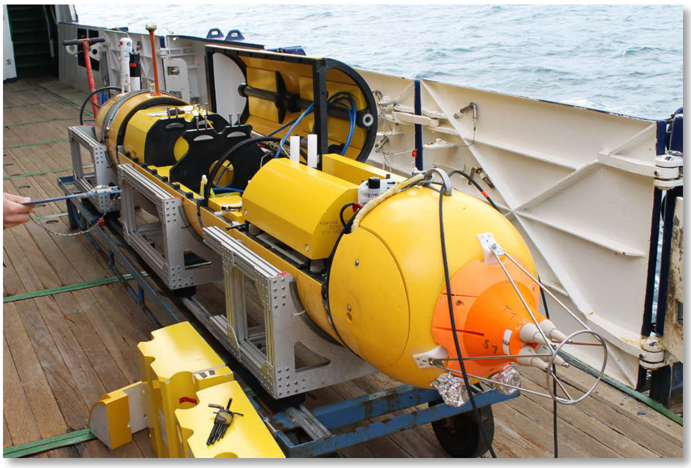

Fig. 3.1: PAUL prior to a deplyoment during PS99 in summer 2016

Fig. 3.2: One of AWI´s UAVs during a flight off the coast of Svalbard in 2016.

Work at sea

In order to prepare *PAUL*'s missions, the ice edge will be monitored several days in advance using satellite imagery. Special attention will be paid to sea ice in the outflow area as fast moving ice floes pose the greatest risk to *PAUL*. After reaching the outflow area, *Polarstern*´s ADCP will be used to measure water currents in different water depths to further minimize the risk for the AUV. The UAVs will take off from *Polarstern* to set up the tracking network on the ice. Deploying the trackers will be executed by a human pilot controlling the vehicle via a camera providing a first person view (FPV). For long range video transmission, a high gain antenna will automatically track the vehicle and permanently align itself to point towards the location of the vehicle.

For the very first deployment, *PAUL* will remain attached to one of the cranes of *Polarstern*. This first deployment is necessary to check the vehicle´s trim as the glacier releases large amounts of melt water – ultimately changing the sea water density and affecting the buoyancy distribution over the vehicle.

For the scientific missions, *PAUL* will be deployed in save distance to the ice. The missions will be planned such that they will cross two channels, which have been discovered by *Polarstern* in 2016, lengthwise and crosswise. Missions will either be executed at constant depths or in a "follow-terrain" mode. The vehicle will also cover overlying transects to provide scientists with a high resolution cross section of the channels´ hydrography. Special attention will be given to two sills which partly block the underwater channels.

During the missions, which will last approx. 8 hours each, *PAUL* will operate several kilometers away from *Polarstern*. Up to a distance of 2.5 km, the AUV can be tracked using an Ultra Short Baseline (USBL) System. Missions that go beyond that range ("unattended" missions) will only be executed in open water. Due to their high risk, missions in the proximity of ice will remain within the GAPS range. After completing a mission, *PAUL* will guide itself to the pre-programmed recovery location. Water samples will then be processed in a cold room and stored deep frozen. Biological, chemical and physical data will be checked aboard to avoid unperceived sensor malfunction. Post-processing will be conducted when back at AWI.

Preliminary (expected) results

From the deployments of the AUV, we expect to collect hydrographic data with a much higher resolution than can be provided by any other method. Eventually, this will hopefully lead to a much better understanding of the glacier´s interaction with the surrounding ocean. In addition to that, biological data will illustrate the effects of the glacier, which represents a large fresh water source, on the marine ecosystem.

Data management

Completely corrected navigation data and preliminary biogeochemical and physical (CTD) data will be stored on *Polarstern*´s servers. In order to support further expedition planning, preliminary overview maps showing salinity and temperature data will be made available on the ship within 24 hours.

As sample processing will be carried out at AWI, time periods for data provision will vary from two to four months depending on the parameter. The ADCP and MP data processing is still under review and thus no time period can be given at this point. The finally processed data will be submitted to the PANGAEA data library. Final results will be published in international journals.

4. STABLE NOBLE-GAS ISOTOPES (^{3}HE, ^{4}HE, NE) AND ANTHROPOGENIC TRANSIENT TRACERS (CHLOROFLUOROCARBONS, CFCS; SULPHUR HEXAFLUORIDE, SF_6) TO INVESTIGATE BASAL GLACIAL MELTING AND WATER MASS CIRCULATION AT 79N

O. Huhn (UHB-IUP), T. Breckenfeldt (UHB-IUP), J. Brünjes (UHB-IUP), M. Rhein (UHB-IUP) (not on board)

Objectives

Greenland Ice Sheet (GrIS) basal melting is one of the major contributors to GrIS ice mass loss and thus sea level rise, and accelerating melt rates are caused by intrusions of warm Atlantic water into the glacier terminating fjords. However, estimates of submarine melt rates are usually based on indirect methods (difference between total mass loss from remote sensing methods and surface mass balance or estimated from measurements of ice velocities and ice thickness changes) and are, thus, still highly uncertain. Model results depend strongly for instance on the models ability to simulate the small-scale fjord dynamics and other parameterizations. Large uncertainties also still exist in the processes in the fjords and how the glacial melt is transformed before released into the Greenland boundary current and subsequently into the interior of the adjacent ocean basins. These uncertainties might cause erroneous projections of GrIS mass loss rates and thus sea level for the next centuries. So far, there are no sufficient data available that might allow to trace and quantify the glacial melt water in the ocean.

Here we will use the distributions of measured helium and neon isotopes and transient tracers (CFC and SF_6) in ocean water in the vicinity of one of the major outlet glaciers in northeastern Greenland (79° North Glacier) to estimate the basal melt water fraction and inventory in the near- and the far field of the 79° North Glacier and how much of the glacial melt water is transported into the Greenland boundary current. From this new data and the data derived during PS100 in 2016 and additional historic data we will estimate how much of the glacial melt water of the GrIS is transferred into Fram Strait and further downstream and quantify whether the fractions of glacial melt has increased. We can also provide data to validate high resolution ice-ocean model to analyse how and where and to what amount subsurface melt water is transferred from the Greenland Ice Shelf and the Greenland boundary current into the interior of the adjacent ocean basins, and how an increase in the melt rate changes the regional sea level and by which mechanisms (mass increase, changes in the 3-D thermohaline structure and thus dynamic topography, changes in the large-scale circulation and associated changes in freshwater and heat distribution).

Oceanic measurement of low-solubility and stable noble-gases helium (^3He, ^4He) and neon (Ne) provide a useful tool to identify and to quantify basal glacial melt water. Atmospheric air with a constant composition of these noble gases is trapped in the ice matrix during formation of the meteoric ice. Due to the enhanced hydrostatic pressure at the base of the floating ice, these gases are completely dissolved, when the ice is melting from below. This leads to an excess of helium and neon in pure glacial melt water (He=1260 %, Ne=890 %). Frontal or surface melt water would equilibrate quickly and not lead to any noble gas excess in the ocean water. With an accuracy of <0.5 % for He and Ne measurements performed at the IUP Bremen, basal glacial melt water fractions of <0.05 % are detectable. Helium has a additional oceanic source (primordial helium from hydrothermal vents with a distinct higher $^3He/^4He$ isotope ratio), which neon does not have.

The transient trace gases chlorofluorocarbons (CFC-11 and CFC-12) and sulfur hexafluoride (SF_6) are completely anthropogenic and enter the ocean by gas exchange with the atmosphere. Since the evolution of these transient tracers in the ocean interior is determined on first order by their temporal evolution in the atmosphere and subsequently by advection and dispersion in the ocean interior, they allow estimating the time scales of the renewal and ventilation of inner oceanic deep and bottom water masses. This is often referred to as a "age" of a water mass, i.e. the time elapsed since the water has left the surface.

The combination of the transient tracer based "ages" and the noble gas based melt water inventories allow estimate basal glacial melt rates.

Work at sea

We intend to obtain about 500 water samples for noble gas isotopes from the ship deployed full depth profiling CTD and water sample system. Additionally we plan about 500 water samples for CFCs and SF_6 in total, i.e. about 200 water samples of for CFC-12 and SF_6 and further 300 water samples for CFC-12 and CFC-11.

The oceanic water samples for helium isotopes and neon will be stored from the CTD and water bottle system into 50 ml gas tight copper tubes, which will be clamped of at both sides. The noble gas samples are to be analyzed later in the IUP Bremen noble gas mass spectrometry lab. The copper tube water samples will be processed in a first step with an ultra high vacuum gas extraction system. Sample gases are transferred via water vapour into a glass ampoule kept at liquid nitrogen temperature. For analysis of the noble gas isotopes the glass ampoules are connected to a ultra high vacuum mass spectrometric system equipped with a two-stage cryogenic trap system. The system is regularly calibrated with atmospheric air standards (reproducibility better ±0.2%). Also measurement of blanks and linearity are done.

Water samples for CFC and SF_6 measurements will be stored from the ship deployed water samplers into 200 ml glass ampoules (CFC-12 and SF6) or 100 ml glass ampoules (CFC-12 and CFC-11) and will be sealed off after a CFC and SF_6 free headspace of pure nitrogen has been applied. The samples will be later analyzed in the CFC-laboratory at the IUP Bremen. The determination of CFC and SF_6 concentration is accomplished by purge and trap sample pre-treatment followed by gas chromatographic (GC) separation on a capillary column and electron capture detection (ECD). The amount of CFC and SF_6 degassing into the headspace is accounted for during the measurement procedure in the lab. The system is calibrated by analyzing several different volumes of a known standard gas. Additionally the blank of the system are analyzed regularly.

Expected results

The new noble-gas and CFC measurements near the 79° North Glacier will close gaps and extend the 2016 data set (PS100; Fram Strait, 79° North Glacier and vicinity) and provide data to assess the glacial melt water inventory released from the 79° North Glacier directly into the ocean. The noble-gas data will allow to estimate the basal melt water fraction and inventory in the near- and the far field of the 79° North Glacier and how much of the glacial melt water is transported into the Greenland boundary current. They will allow estimating the actual melt rate of the 79° North Glacier. We will be able to analyze how and where and to what amount subsurface melt water is transferred from the 79° North Glacier and the Greenland boundary current into the interior of the adjacent ocean basins.

Data management

Due to shipping home, the extensive treatment of the samples in the IUP home labs, and an accurate quality control, the results of the measurements are expected for the end of 2016. The data will be made available to our colleagues as soon as possible. Once published, we will store them in the PANGEA data base.

5. BASAL MELT RATES OF THE FLOATING PART OF 79° NORTH GLACIER

A. Humbert (AWI, UHB), D. Steinhage (AWI), (both not on board), C. Lüttig (AWI),
J. Eis (UHB)

Objectives

The 79° North Glacier is one of three outlet glaciers of the only large ice stream in Greenland, the NEGIS (North-East Greenland Ice Stream). In contrast to other glaciers in Greenland, which are typically tidewater glaciers, the 79° North Glacier forms a floating tongue and is rather comparable to an ice shelf (Fig. 5.1). As the NEGIS drains about 8 % of the ice sheet, the question whether its contribution to sea level change is increasing is coming more into focus. The floating tongue is pinned by ice rises along the ice front, which keeps its lateral extent at the moment stable, however, the ice flow velocities at its grounding line are slightly increasing (Joughin, pers. comm.) and the upstream ice surface elevation has started to decrease in the past few years (Helm et al., 2014). Warm water masses were also already detected to drain underneath the floating tongue and hence the question arises if the warm water increases the basal melt of the floating tongue, causing grounding line retreat and weakening of the tongue itself.

Thus we aim to measure the seasonal variation of basal melt rates of the 79° North Glacier at about 25 locations on its floating tongue. The melt rates at the ice-ocean transition are measured using a phase sensitive radar (Corr et al., 2002; Jenkins et al., 2006), which measures the change of the distance between internal layers of the glacier. This method can separate the ice thickness change due to stretching of the glacier from the thickness change due to basal melt. As the basal melt over a short period of time is too small to be detected by the amplitude of the radar signal, the phase of the radar signal is used for this purpose. The radar is a multi-frequency radar that sends a burst of radar signals with defined repetition times and hence gives a change of the phase and therefore the basal melt rate over time. By using this method it is possible to detect the penetration of warm water masses underneath the tongue that causes the change of the melt rates.

During the land-based iGRIFF campaign in June-July 2017 Daniel Steinhage and Angelika Humbert will be installing autonomous pRES stations and will also do a survey of about 50 locations which require then a revisit, retrieving a second dataset allowing to estimate the amount of melt during that period. During PS109 a first revisit of a subset of the 50 locations will be carried out, so that beside an annual mean melt rate also a melt rate over about three months' time, late summer, can be estimated.

In addition to the melt rates, we aim to understand the tidal forcing on the ice dynamics, hence flow velocities. For this purpose during the land-based iGRIFF campaign in June-July 2017, we plan to deploy GPS stations some of which will be operating from July until they will be recovered by PS109 somewhen in September. This will enlarge the dataset to about two full tidal cycles. Other GPS stations are deployed as autonomous stations and will be recovered only in 2018 by the second land-based campaign.

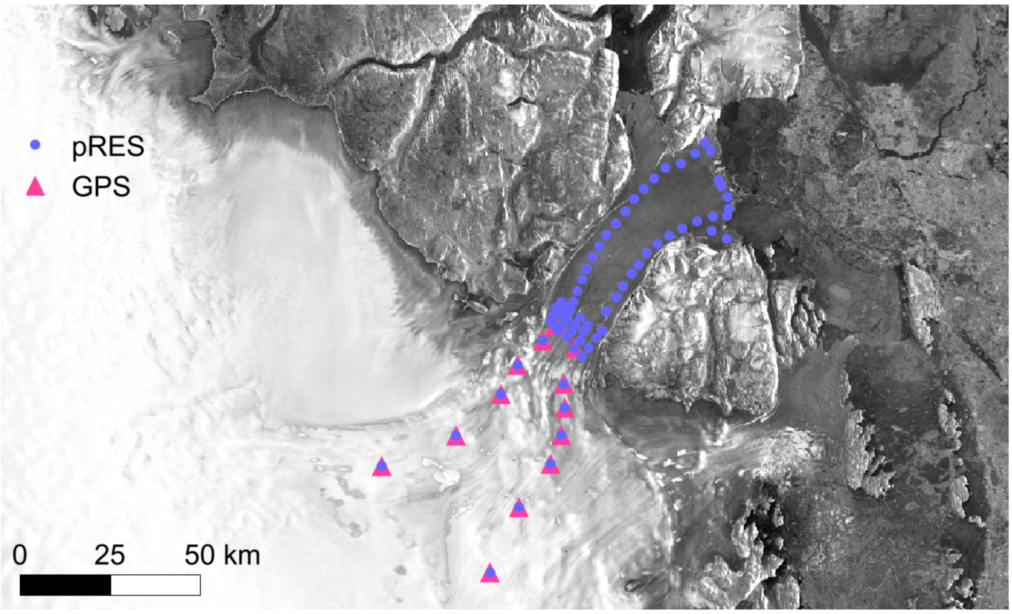

Fig. 5.1: Overview of the 79° North Glacier in the vicinity of the calving front showing potential ApRES sites

Work at sea

Using the helicopter a group of 2 scientists plus ranger will be flown to the glacier and repeat the measurements of the phase sensitive radar at about 25 locations. In case this is very time efficient one could aim for the full 50 locations. The work is expected to take 15 min for each of the stations. In addition to that about 6 GPS stations need to be recovered. Expected time for each station is about 30-45 min. Each station has a weight of about 50 kg and a volume of one 60x60x80 cm^3 Zarges box plus glacio poles.

Preliminary (expected) results

Distribution of late summer melt rates across the floating tongue and tidal displacement of the glacier.

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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6. NEGIS: UNDERSTANDING THE MECHANISMS CONTROLLING THE LONG TERM ICE STREAM/SHELF STABILITY OF THE NORTHEAST GREENLAND ICE STREAM.

J.M. Lloyd (Durham); C. ÓCofaigh (Durham); L. Callard (Durham); D.H. Roberts (Durham, not on board); J.A. Smith (British Antarctic Survey, not on board); M. Kappelsberger (TU München); M. Meier (AWI); B. Dorschel (AWI, not on board); B. Rea (Aberdeen, not on board); M. Bentley (Durham, not on board); S. Jamieson (Durham, not on board)

Background and Objectives

The NEGIS project is supported through the Alfred Wegener Institute (Project N405) via the GRIFF I project through the *Polarstern* Cruise PS100, the GRISO project through *Polarstern* Cruise PS109, as well as through UK Natural Environment Research Council (NERC Grant NE/N011228/1).

The incursion of warm Atlantic Water (AW) over the last 15 years to many Greenland glacier margins, as well as increased air temperatures and sea-ice loss, have all been linked to rapid ice margin instability (Straneo et al., 2013; Carr et al., 2013; Khan et al., 2015). However, despite our improved understanding of the forcing mechanisms that have driven recent glacier change, the limited time-span of our observations provide only a short time series with which to understand the complex and non-linear response of ice streams to ocean and atmospheric forcing (Nick et al., 2010). This hinders our ability to understand and forecast how ice sheets will change over longer timescales (Seroussi et al., 2014). What we fundamentally lack is decadal to millennial scale input data with which to calibrate, validate and test the sensitivity of predictive models. One solution to this issue is to distinguish patterns of former rapid ice margin change during periods of warmer climate when the key forcing mechanisms that influence ice sheet stability can be simultaneously reconstructed so their relative importance can be determined.

This project will investigate the dynamics of the Northeast Greenland Ice Stream (NEGIS); the main artery for ice discharge from the NE sector of the Greenland Ice Sheet (GrIS) to the North Atlantic. Unlike other sectors of the GrIS, NEGIS and the ice shelves that front it, have exhibited little response to increased atmospheric and oceanic warming over the last 20 yrs. However, very recent ice shelf loss and grounding line retreat (~ 4 km) post 2010 suggest that this sector of the GrIS, and NEGIS in particular, is starting to respond to recent atmospheric/oceanic change (Khan et al., 2014, 2015; Mouginot et al., 2015). Model projections suggest that ocean warming will double by 2100 (Yin et al., 2011) and air temperature will increase significantly in northeast Greenland (AMAP, 2011), so the future evolution of the NEGIS catchment is important not only for understanding changing dynamics in this sector of the GrIS, but also for predicting sea-level rise.

The NEGIS catchment as a whole holds a significant sea-level equivalent (SLE) of 1.1 to 1.4 m, but it is the marine-terminating end of the NEGIS system that is particularly vulnerable to marine ice sheet instability because it sits series of interconnected, over-deepened, subglacial troughs; those troughs harbour a SLE of 0.12 - 0.35 m. A rapid retreat of this system would therefore have significant consequences for global sea-level rise. Furthermore, the triggering of surface mass balance (SMB) feedback, through dynamic ice loss at the coast and concomitant surface lowering inland (cf. Rignot et al., 2014), could push the entire NEGIS catchment beyond a sustainable SMB threshold (e.g. 0.9 to 2.8°C; Robinson et al. 2012) potentially making a more significant contribution to future sea-level rise.

A critical component of this project is the knowledge that one of the NEGIS ice shelves (known as '79N') retreated (possibly collapsed) over 100 km during the mid-Holocene Thermal Maximum (HTM; 8.0 – 5.0 ka BP). 79N is the only large scale ice stream/shelf outlet system in Greenland that has a partially constrained Holocene retreat and re-advance history (Bennike and Weidick, 2001). The HTM was a period when radiative forcing and summer temperatures were up to 2°C higher than presently, and analogous to those predicted for the next 100 yrs and beyond (Carlson and Winsor, 2012). Hence, increased air temperature could have played a role in ice stream fluctuation and ice shelf collapse, but we presently lack the data to assess the role of different forcing mechanisms (e.g. ocean warming) on ice stream fluctuation which limits our ability to predict the response of NEGIS to future change.

The overall aim of this project is to reconstruct the ice sheet/stream history of the NEGIS from the end of the LGM and through the Holocene. Working both onshore and offshore the project will generate a series of tie points to reconstruct ice sheet thickness, grounding line position, and ice shelf presence/absence. It will also generate a time series of forcing data on ocean and atmospheric temperatures. These datasets will be used to test and model the sensitivity of the ice stream to different forcing mechanisms at 100 - 1000 yr timescales.

The project has three main objectives:

Objective 1: To constrain ice stream/shelf extent/thickness in order to determine rates of retreat/re-advance between 15 – 0 ka BP.

Objective 2: To constrain oceanographic/atmospheric conditions and sea-level change adjacent to NEGIS between 15 – 0 ka BP.

Objective 3: To apply the 3D BISCICLES ice sheet model to test the sensitivity of NEGIS to atmospheric/oceanic /sea-level forcing and to explore feedbacks over 1000 yr timescales.

Work at sea

Objective 1: Our onshore and offshore work programme in 2016 and 2017 (GRIFF I + GRISO) aims to reconstruct the geometry (vertical and horizontal) of NEGIS from the end of the LGM through the Holocene. Using the *Polarstern* cruise in 2016 geophysical data was collected from the Norske and Westwind troughs, in front of the 79° North Glacier and the Belgica Bank (Fig. 1). In addition sediment cores were collected from areas of the Norske Trough and close to 79° North Glacier (Fig. 6.1). Exploring the troughs is a critical part of our research strategy as they played a dual role in routing ice offshore and enabling AW incursion on to the shelf at the beginning of the Holocene (Evans et al., 2009; Winklemann et al., 2010). Following the PS100 cruise there are several additional key target areas for PS109 (Fig. 6.1; sub-areas 1-5). Areas 2 and 3 in particular will be critical for constraining ice stream configuration and timing of retreat from the LGM maximum in Westwind Trough. Area 1 will provide a constraint on the timing of ice stream retreat from the continental shelf edge in Norske Trough, while areas 4 and 5 will also be important for constraining ice steam configuration in the inner trough and providing chronological control on ice stream evolution through the Holocene (both of which are crucial for model spin-up).

Swath bathymetric and sub-bottom profiler data (Atlas Hydrosweep DS-2 and Parasound) will be collected to capture seafloor geomorphology and sub-bottom stratigraphic architecture to reconstruct ice stream dynamics and grounding line retreat from the continental shelf edge to the present NEGIS margin (*e.g.* Dowdeswell et al. 2014). Previous work and data collected during PS100 clearly shows submarine moraines, mega-scale glacial lineations and grounding zone wedges occur on the NE Greenland shelf (Evans et al., 2009; Winklemann et al., 2010; Arndt et al., 2015). Additional data from PS109 will complement and extend data collected during PS100, particularly through inner Westwind Trough.

The key areas for collection of gravity and box core transects will be from target areas 2 and 3 along the Westwind Trough, and also additionally target areas 1, 4 and 5 to fill in gaps from PS100. Subglacial to open-marine conditions will be reconstructed on the basis of sedimentology (shear-strength, grain-size, x-radiographs, multi-sensor core logger data) and combined with geomorphological mapping to determine the nature and style of retreat. ^{14}C dating of the contact between subglacial and postglacial sediments at core sites along each transect will allow us to determine the timing and rate of ice retreat (*e.g.* Ó Cofaigh et al., 2013). Work across the continental shelf (e.g. Belgica Bank) is also essential to establish the configuration of NEGIS at the start of the Holocene and to generate Holocene ocean temperature data.

In order to complement our offshore work the project will work onshore in 2017 and identify/map ice marginal geomorphology (e.g. lateral moraines; ice shelf moraines; deltas; raised beaches) to constrain ice stream thickness and ice shelf extent (*e.g.* Glasser et al., 2006; Roberts et al., 2013). Work in the 1990s has shown abundant moraines and uplifted marine sediments which mark Holocene thinning, retreat & re-advance of the 79N ice shelf (Bennike and Weidick, 2001). A chronology for ice surface thinning, ice margin retreat, ice shelf collapse and sea-level change will be developed using radiocarbon dating (^{14}C - organic material) and cosmogenic exposure surface dating (^{10}Be). Our aim is to sample ice marginal landforms along a series of vertical transects ('dipsticks') to constrain ice stream and shelf geometry through the Holocene along the 79N, and possibly Zachariæ Isstrøm, ice shelves (e.g. Roberts et al., 2013). Additional cosmogenic samples will be collected from *Polarstern* during PS109 using the helicopter support from regions close to the ice shelf of 79° North Glacier (Fig. 6.1) to support the onshore campaign.

Objective 2: The sediment cores collected using the *Polarstern* from the continental shelf edge to the current ice shelf margin will provide a record of oceanic conditions from the LGM to the present day. We will use the *Polarstern* gravity and box coring systems to recover glacial to modern seafloor sediments and retrieve multiple proxies for quantitative reconstruction of palaeooceanographic & palaeoglaciological conditions (e.g. diatoms, forams, dinocysts & molluscs; Evans et al., 2002; Spielhagen et al., 2011; Muller et al., 2012). Sea surface, shallow surface and bottom water temperatures will be based on proxy datasets (forams, diatoms and dinocysts) and quantified using transfer functions (Ran et al., 2011; Spielhagen et al., 2011). Planktic and benthic foraminiferal stable isotope analyses and sediment geochemistry (total organic carbon (TOC), total nitrogen (TN), C/N) will also be used to support the temperature reconstructions and yield information on water mass characteristics, productivity, sea-ice cover and input of glacier melt water (Lloyd et al. 2007, 2011; Smith et al., 2007; Jennings et al. 2014). Ice-rafted debris will be used to investigate periods of increased iceberg calving linked to episodes of ice margin instability (Andreasen et al., 2011). Contemporary temperature/salinity data collected by the GRIFF and GRISO projects and analysis of the diatoms and stable-isotopes from core tops/surface sediments will also be utilised to aid in the interpretation of down-core (palaeo) sedimentological data. Preliminary results from PS100 cores demonstrates the presence and abundance of both planktic and benthic foramininfera in recent and palaeo-samples.

While working onshore in 2017 we will also recover sediment cores from epishelf lakes along the margin of 79N. These will provide a detailed record of grounding line and ice shelf retreat/advance during the Holocene. Epishelf lakes have been shown to harbour detailed records of ice shelf history (presence/retreat), anatomy of collapse (processes and duration) as well as forcing mechanisms (ocean and atmosphere) (Smith et al. 2006; 2007).

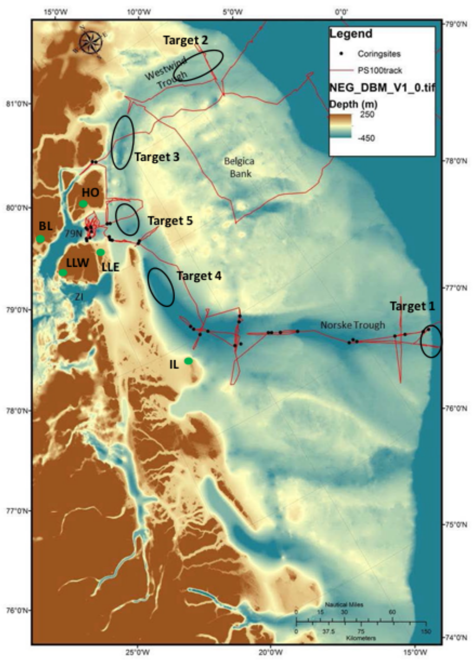

Fig 6.1: The NE Greenland continental shelf showing cruise track (red) and sediment cores (black dots) collected during PS100. Target areas for the NEGIS project during PS109 are indicated (areas 1 to 5). Additional land-based cosmogenic radionuclide samples close to the 79N ice shelf are also shown (green circles). The NEGIS drains the NE sector of the Greenland ice sheet and reaches the ocean via two ice shelves; 79N and ZI. Fig. derived from Arndt et al., (2015).

Expected results

Our overall goal is to combine the epishelf cores with the offshore and onshore geomorphologic and sedimentological data to provide a record of grounding line and ice shelf thickening, thinning and migration over a >300 km transect from the opening of the Holocene through to present.

Data management

Sediment cores will be logged and described sedimentologically on broad the Polarstern. They will also be sampled for forams and molluscs. Stable isotope analyses and sediment geochemistry (total organic carbon (TOC), total nitrogen (TN), C/N) can be conducted at Durham, as can multi-sensor MSCL core log measurements (*Bulk density, porosity, grain size, P-wave velocities and water content*), XRF and XCT 3D X-ray analysis. Cores will be archived at AWI post analysis. Sample processing for radiocarbon dates (^{14}C) and cosmogenic exposure surface dating (^{10}Be) will be carried out at the NERC Radiocarbon Lab and NERC CIAF, UK. 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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7. SEISMOLOGY

V. Schlindwein (AWI, not on board), M. Meier (AWI)

Objectives

Polarstern cruise PS109 will cross Knipovich Ridge on its way from Tromsø to Northeast Greenland. Knipovich Ridge is an ultraslowly opening mid-ocean ridge that we instrumented during *Polarstern* cruise PS100 with 23 ocean bottom seismometers to study the active spreading processes of a mid-ocean ridge at segment-scale. Our network extends over more than 160 km and covers two major volcanic centres where magmatic accretion of new ocean lithosphere takes place. Apart from the passive recording of thousands of small earthquakes that accompany spreading and give information on the deformation mode and the thermal structure of the lithosphere, we want to study in detail how melts manage to travel through the thick cold lithosphere to the seafloor at the volcanic centres. We will therefore image Logachev Seamount with seismic tomography using rays that are generated by earthquakes and artificially. The seismic refraction profiles will be acquired by cruise MSM67 of *Maria S. Merian* in early October. For this experiment, we will drop 4 ocean bottom seismometers (OBS) around Logachev Seamount during PS109 that will complement long-term stations that will have run out of power by early October. Cruise MSM68 of *Maria S. Merian* will subsequently recover all OBS in October 2017.

The area around the 79° North Glacier shows unusually many seismic events for a stable craton, presumably along the northern edge of the 79° North Glacier and near the mouth of the glacier. However, due to the sparse station cover the seismicity is in parts very poorly located. We suspect that it may be partly of cryogenic origin, but local seismic networks are needed to resolve in more detail the provenance and source mechanisms of these seismic events. The 79° North Glacier itself creates hundreds of small icequakes potentially by fracturing near the grounding line. We want to study where these events come from, how they relate to tides or flow speed of the glacier and how the seasons affect their occurrence. We therefore want to take the opportunity of *Polarstern* cruise PS109 and the subsequent land campaign iGRIFF18 in summer 2018 to deploy temporary seismic land stations and leave them for one year in place giving us a rare chance to acquire several months of seismicity data in a poorly accessible region. Furthermore, simultaneous geodetic measurements will provide crucial additional information on glacier motion and tides.

Work at sea

Shortly after leaving Tromsö, we will deploy four OBS around Logachev Seamount. The instruments will be assembled in port and can readily be slipped at the planned positions.

The seismic network at the 79° North Glacier can be installed in two helicopter flights, each carrying three stations. A small network consisting of three stations at a distance of about 700 m will be deployed on a hard rock outcrop at the northern end of the grounding line. Mounting the seismometer at a suitable site and covering cables and seismometer protection with rocks takes about 30 min. The other three stations will most likely be installed at distances of about 15 – 20 km along the northern and southern edge of the 79° North Glacier to capture regional seismic events. All stations will remain in place until summer 2018.

Preliminary (expected) results

Based on a reconnaissance survey during *Polarstern* cruise PS100, we expect to record hundreds of icequakes with the small array near the grounding line. Most of these icequakes result from fracturing near the grounding line and their occurrence is tidally modulated. Our previous survey covered only few days. We now expect to see changes in seismicity not only on a diurnal but also on a seasonal basis that will help to constrain the source processes of the icequakes.

The seismic stations will run out of power in late autumn and should recover once sufficient daylight has recharged the batteries. We expect about 6 months of data. This more extended data set should include several regional seismic events that occur in the wider region of the 79° North Glacier and are strong enough to be recorded by the entire network. We hope that we can determine focal depths and resolve the focal mechanisms of these earthquakes to understand their origin.

Data management

Continuous seismic data will be made available approximately three years after recovery through seismological data portals that allow automatic data retrieval.

8. GPS OBSERVATIONS IN NORTH-EAST GREENLAND TO DETERMINE VERTICAL AND HORIZONTAL DEFORMATIONS OF THE EARTH'S CRUST

M. Scheinert (TU Dresden, not on board), C. Knöfel (TU Dresden), S. Lunz (TU Dresden)

Objectives

The Greenland Ice Sheet (GIS) is the second largest continental ice sheets after the Antarctic one. It contains only 10 % of the global fresh-water storage in comparison to the Antarctic Ice Sheet. However, it reacts in a sensitive way to changes of the environmental and climate conditions due to its location at high and subpolar latitudes. Therefore, it plays an important role for global climate. It has been subject to intensive geophysical and glaciological investigations for almost one century.

Changes of the ice sheet are visible indirectly at deformations of the surface of the Earth. Ice mass changes can be regarded as changing surface loads, which cause – due to the rheological properties of the upper layers of the Earth – long-term visco-elastic and immediate elastic reactions. Hence, in the observable vertical deformation of the Earth's crust we can find the integral effect of all ice-mass changes during glacial history and in present times.

North-East Greenland is characterized by a high variability of the ice edge with regard to its location and mass change as well as of a visco-elastic signal due to glacial history, that – according to model predictions – reaches maximum values for entire Greenland. Additionally, deformations of tectonic origin cannot be excluded, which will be tested analysing the horizontal components.

Satellite-based positioning by means of GPS allows a precise geodetic determination of coordinates and, with repeated observations, the determination of changes for the horizontal as well as for the vertical components with an accuracy in the sub-centimetre level. In order to ensure a high accuracy of repeated measurements, a stable base for the GPS marker has to be chosen. Therefore, the stations are to be set-up at ice-free bedrock locations.

This project is a continuation of research work done during *Polarstern* cruises ARK-XXIII/1+2 (2008), ARK-XXIV/3 (2009) and PS100 (2016).

Work at sea

During the expeditions in 2008 and 2009, 22 locations at bedrock were surveyed, where GPS stations were successfully set up and most of them observed for the first time. The geodetic network configuration realized in this way includes a west-east component (stations at the ice edge and at the coast), and covers a north-south extension from about 74°N to 81.5°N. During *Polarstern* cruise PS100, 9 of 10 stations between 78°N and 81°N could successfully occupied again in order to carry out a first re-observation by geodetic GPS positioning. Now, during the planned expedition PS109, we plan to re-occupy five locations (see Table 8.1 and Fig. 8.1). All these locations will be reached by helicopter. The GPS equipment will be set up and remain at each location to observe permanently for 3 days at least.

Furtheron, one location at the floating part of the Nioghalvfjerdsbræ will be visited, where a continuous GPS station is planned to be set-up during field work in July 2017. This visit should be used to check the installation and to download data.

Preliminary (expected) results

The GNSS observations will be processed at the home institution (so-called post-processing using the Bernese GNSS Software). In the analyses latest standards have to be incorporated used in geodesy (e.g. consistent and precise realization of the reference frame). From the analysis of the repeated GPS observations we will come up with coordinate change rates (especially for the vertical deformation), that serve as an independent source of information for the validation and improvement of models on the glacial history and on the recent ice mass balance of North-East Greenland. While testing the significance of horizontal deformations we will contribute to an improved analysis of the tectonic regime in the working area.

The observations at Nioghalvfjerdsbræ will be analysed in a so-called kinematic mode in order to investigate the tidal dynamics of the floating glacier.

Data management

The geodetic GPS data will be archived in a similar database like the SCAR GNSS Database that is maintained at TU Dresden. The long-term preservation of the data will be maintained also through the close cooperation within the SCAR Scientific Programme SERCE (Solid Earth Responses and Influences on Cryosphere Evolution). A common structure of the data holdings is ensured through the application of the same scientific software package utilized to analyse geodetic GNSS measurements at TU Dresden (i.e., the Bernese GPS Software). Further products and resulting models will be archived in the PANGEA database at AWI.

Tab 8.1: List of GPS stations installed and observed in 2008, 2009 and 2016, resp., and to be re-observed during cruise PS109

ID	Longitude	Latitude	Geographical Region
HOLM	-16.4315	80.2730	Holm Land SE
MUSK	-22.7228	79.9795	Skallingen (Kronprins Christian Land SW)
HOVG	-18.2306	79.7002	Hovgaard Ø
FRAN	-18.6273	78.5784	Franske Øer
BILD	-23.5033	78.1164	Bildsøe Nunatakker
NIOG	tbd.	tbd.	Nioghalvfjerdsbræ

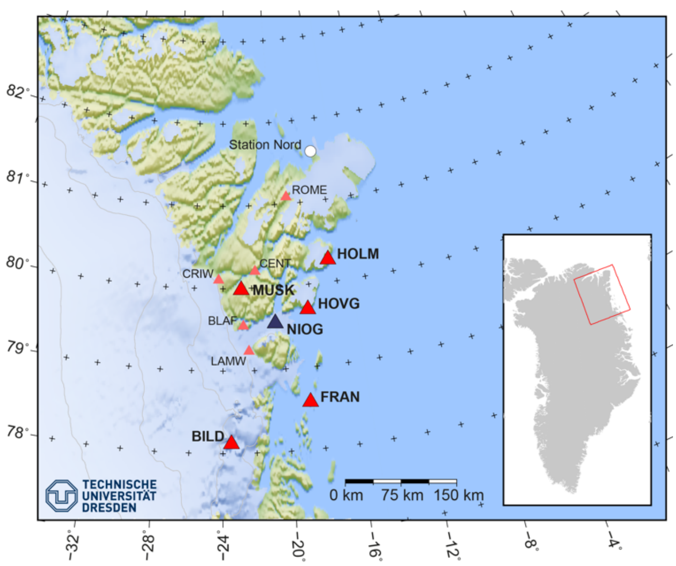

Fig. 8.1: Overview of the working area with the planned GPS stations (large red triangles) that shall be re-observed during cruise PS109. The site NIOG will be visited to check the installation.

9. BENTHIC BIOGEOCHEMICAL PROCESSES

J. Felden (Uni Bremen/Marum), U. Braeckman (UniGent), V. Asendorf (MPIMM), NN, F. Wenzhöfer (AWI, not on board)

Objectives and scientific programme

During *Polarstern* expedition PS109, benthic lander measurements and TV-guided Multicorer samples will be used to investigate how increased melt water input effects benthic biogeochemical processes and community composition.

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). Arctic shelf sediments reveal high fauna abundance and biomass and show high benthic microbial activities. Changes in sea ice extent and thickness, precipitation and river discharge, as well as melt water input alter the light and nutrient availability in the shelf zone and are expected to affect productivity. However, how benthic communities respond on climate induced environmental shifts, as increased melt water input, is not known.

Work at sea

Benthic carbon mineralization, biogeochemical processes and benthic communities will be studied in situ at five sites in front of the glacier. 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. The benthic lander systems (Fig. 9.1) 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 turn over rates.

Multicorer samples will be used to measure onboard gradients and fluxes, and to retrieve sediment samples for fauna and microbial community analysis as well as various biogenic compounds and nutrients. 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.

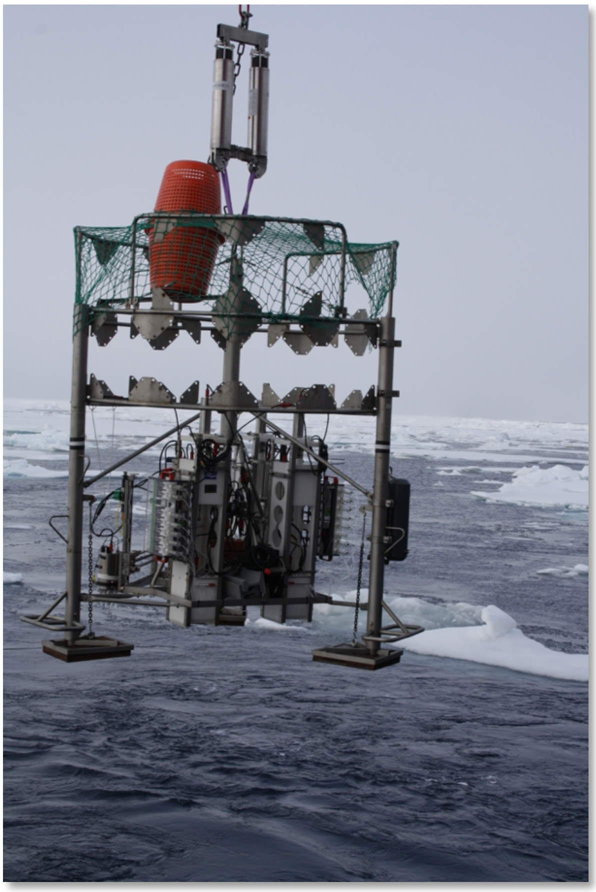

Fig. 9.1: Benthic Lander System with transecting microprofiler and 3 benthic chambers

Data management and samples

Sample processing will be carried out at AWI, MPIMM and Uni Gent. Data acquisition from the several types of investigation will be differently time-consuming. The time period 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 from PANGAEA will depend on the required time and effort for acquisition of individual datasets and its status of scientific publication.

10. SEA ICE BIOLOGY AND BIOGEOCHEMISTRY IN RELATION TO ATMOSPHERIC EMISSIONS

Peeken (AWI, not on board, coordinator), F. Pätzold (TUB, group leader), J. Ehrlich (AWI, UHH), T. Krüger (TUB); A. Lampert (TUB, not on board), E. Damm (AWI, not on board), H. Flores (AWI, UHH, not on board), S. Maes (AWI), J. Verdugo (AWI),

Objectives

Sea ice is of major importance in the polar oceans since it affects the solar radiation fluxes due to its reflective properties and it 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 Arctic.

Due to the decrease of the sea ice thickness, new evolving habitats for sea ice algae have been observed in surface melt ponds (Fernández-Méndez et al. 2014) and under the ice (Assmy et al. 2013). This new evolving ice aggregates in Arctic melt ponds and under the ice might have consequences for the carbon budget, leading to major implications for the cryo-benthic and cryo-pelagic coupling of the Arctic Ocean.

Sea ice also offers an attractive substrate for sea-ice-associated species known as sea-ice fauna. Sea-ice fauna refers predominantly to heterotrophic protists and ectotherm metazoans living either inside channels or cavities of sea ice or using the ice-water interface as a temporarily habitat. It is anticipated that the decline of the sea ice will alter the composition and biodiversity of the sea-ice fauna and flora. Recent studies show a reduction od biodiversity from multi to first year ice (Hardge et al. 2017). Biodiversity in turn plays a vital role for the stability of ecosystem processes, and is positively coupled with the efficiency of important ecosystem functions like fluxes of energy, nutrients and organic matter through an environment. Thus understanding the relationship of the biodiversity of sea-ice fauna and flora with ecosystem functions is important for predicting consequences of climate change in an Arctic ecosystem.

On the East Greenland side, detailed studies on the sea ice and adjacent ecosystems are only restricted to the subarctic region in the Young Sound at 74 degrees N. Little is known about land fast sea ice biology north of 74°N and preliminary results from the recent *Polarstern* PS 87 cruise indicate also very low standing stocks of sea ice algae in this region. The current expedition will therefore allow detailed biological studies in an under-sampled area.

Polar cod Boreogadus saida is the most abundant fish species in the high Arctic and the staple food of numerous Arctic seabirds and seals and also strongly depends on the sea ice algae derived carbon (Kohlbach et al. 2016). On the broad shelves inhabited by the spawning populations, a part of the first-year population associates with the under-ice habitat at the end of summer. Recent studies showed that juvenile polar cod residing in the ice-water interface layer are practically ubiquitous in the Eurasian Basin, and probably throughout the Arctic Ocean. Satellite-based sea-ice back-tracking enabled to identify the potential areas on the Siberian shelf from where juvenile polar cod associated with sea-ice possibly followed the Transpolar Drift across the central Arctic Ocean, potentially reaching spawning populations in northern Greenland (David et al. 2016). Hence, the Transpolar Drift may act as a vector enabling genetic exchange between coastal populations, and contributing to their recruitment. Further decline in extent and duration of sea ice may thus compromise genetic exchange, juvenile survival and recruitment of shelf populations. To assess the importance of the connectivity of Siberian and Greenland populations, the genetic relationship between potential Siberian spawning populations and stocks on the Greenland shelf must be elucidated.

The changes in sea ice also influence the atmospheric boundary layer, by an increase of sensible and latent heat fluxes above open water and thinner ice. The small-scale vertical structure of the boundary layer, especially the profiles of temperature and humidity, and therefore of atmospheric stability, is altered. Particular summer sea ice retreat alters water mass formation and convection, which may have profound effect on natural biogeochemical cycles between sea ice, seawater and atmosphere. Especially feedback effects to pathways of climatically relevant trace gases will loom large in the equation of change. Increasing water stratification during sea ice melting is likely to limit nutrient availability in near-surface water, which in turn limits the phytoplankton growth. A characteristic feature of the Arctic Ocean is the distinct post-bloom nutrient limitation found in the Atlantic-dominated and Pacific-dominated sectors. Nutrient limitation may be also a possible regulator of methane (CH_4) production in surface water. Methanogens form CH_4 via various pathways commonly classified with respect to the type of carbon precursor utilized, e.g. the methylothrophic pathway indicates the intact conversion of a methyl group to CH_4. The contribution of methylated substrates is potentially large in sea ice, and methylothrophic methanogenis may be a principal pathway from which the greenhouse gas CH_4 is readily formed by microbial activity. However, the direct evidence of this role of methylated substrates in sea ice is still lacking. In this context, the degradation of dimethylsulfoniopropionate (DMSP), an abundant methylated substrate in surface water and sea ice becomes pivotal. DMSP is produced by marine phytoplankton and sea ice algae. Cleavage of DMSP can be carried out by bacteria or by phytoplankton, and leads to formation of DMS (dimethylsulfide) or methanethiol. DMS, an important climate-cooling gas, partly escapes to the atmosphere where it is oxidized to sulphuric acid and methanesulfonic acid. Methanethiol is a key reactive intermediate utilized as sulphur and carbon sources for biosynthesis or energy generation. In anaerobic environments methanethiol act also as precursor for greenhouse gas CH_4 production. In the ocean, processes producing N_2O are mainly being controlled by organic matter and dissolved oxygen. This trace gas is mainly produced by nitrification or nitrifier denitrification under oxic and also microaerophilic conditions. Conversely, partial denitrification can produce N_2O under suboxic conditions, whereas the complete reduction is the only reaction able to consume N_2O under suboxic/anoxic conditions. The assimilative reduction of N_2O to NH_4^+ (N_2O fixation) may be responsible for a certain amount of consumption, but not much is known so far.

During PS109 we aim to achieve the following objectives:

- 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
- Using molecular and isotopic biomarkers to trace sea ice-derived carbon in pelagic food webs
- Analyse the abundance, biodiversity and community structure of sea-ice fauna and quantifying ecosystem functions and their relationships with biodiversity in an Arctic ecosystem
- Sample larval polar cod on the shelf to investigate the genetic connectivity of the Greenland populations with other Arctic populations
- Investigate the small-scale atmospheric structure and stability for different ice conditions, and the interaction with methane emissions from the sea ice and ocean
- Determine the isotopic signature of CH_4 in the atmosphere, and compare to the signature in ice and water
- Identify the main triggering processes for climate-relevant compounds (CH_4, N_2O and DMS) in sea-ice and in the underlying water column and to quantify the fluxes across the sea-air interface following the melting cycles in the Arctic Ocean.

Work at sea

General sea ice work

Sea ice cores will be taken for biological, chemical and biogeochemical analyses during individual ice stations reached by helicopter or with the zodiac. We will further sample sack holes, the water under the ice and 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 measure environmental parameters as sea ice temperature, snow depth, free board and ice thickness.

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 and algae biomass and composition, which will be determined by size-fractionated chlorophyll, marker pigments, DNA and cell counts (microscopy). Also biogenic silicate, particulate organic carbon and nitrogen (POC, PON) and the isotopic composition of POC and PON ($\delta^{13}C$ POC and $\delta^{15}N$ PON) will be determined. Additional biomarker analysis and in-ice and meiofauna communities will be collected. All samples will be stored and measured at the AWI.

Polar cod

To sample larval and post-larval polar cod, we will conduct oblique hauls with a bongo net in the surface layer (0-50 m) of the outer shelf region. Fish will be extracted from the samples and frozen individually for subsequent analyses of trophic biomarkers, genetics and otolith chemistry.

Trace gases

Dissolved gases (CH_4 and N_2O), DMS, DMSP and δ13C-CH_4 values will be measured in sea ice, surface and deep sea waters. Water samples will be collected in Niskin bottles mounted on a rosette sampler at discrete depths throughout the water column up to 200 m and deeper, depending on the logistic plans of the cruise. The number of sampling depths depends of the fluorescence signal and the O_2- sensor signal. We will sample one-year and multi-year sea ice and brine by taking cores with a standard corer. Sea ice cores will be sectioned and melted at 4°C. Methane concentration will be measured on board by gas chromatography (GC) equipped with a flame ionization detector (FID). Gas samples will be stored for analyses of the $\delta^{13}C$ values of methane by mass spectrometry in the home laboratory. DMS and DMSP concentrations will be measured on board by GC equipped with a pulsed flame photometer (PFPD) and by GC equipped by a flame photometer (FPD), respectively. N_2O will be measured either on board or in the home laboratory by GC. In addition, underway continuous measurements of greenhouse gases, will be performed with an instrument from Los Gatos Research.

Atmospheric measurements

The vertical structure of the atmosphere (temperature, humidity) will be determined by quadrocopter measurements up to an altitude of 1,000 m. During the descent, air samples will be taken at various altitudes above the boundary layer, and within the boundary layer for isotopic analyses of methane. The samples will be partly analysed on board, partly later with the mass spectrometer at the AWI laboratory.

Preliminary (expected) results

The aim of this study is to understand the variability and biodiversity 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 from the shelf to the deep sea basin and on land fast ice.

Linking the various components of the food webs to a joint ice-related ecopath model will improve to access the role of climate change on the carbon cycle of the Arctic Ocean.

Our work on polar cod will help to assess whether the Transpolar Drift is important for the genetic exchange and the recruitment of populations around the Arctic Ocean, and study the implications of sea ice decline for the resilience of an Arctic ecological key species to climate change.

Our goal is to achieve high data resolution by continuous measurements of greenhouse gases fluxes across sea-air interface along the late summer. We will be able to know the budget of relevant- climate compounds in compartments, sea ice and sea water, influenced by physical and/or biogeochemical processes.

The quadcopter measurements provide the link to the atmosphere: The meteorological profiles help to determine the mixing processes in the atmospheric boundary layer, and therefore the vertical transport of methane from the ocean / sea ice into the atmosphere. The methane isotopic analyses serve to identify the origin of the atmospheric methane, and provide the missing link to the methane in the ocean and sea ice.

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 and the CTD 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.

The meteorological data obtained with the quadrocopter will be submitted to PANGAEA. The isotopic analyses of the air samples will be performed at AWI Bremerhaven. The isotopic data will be submitted together with the isotopic data of ocean and sea ice.

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11. DETERMINATION OF SEA ICE PARAMETERS BY MEANS OF MULTI-FREQUENCY MICROWAVE SCATTEROMETER MEASUREMENTS (ICESCAT)

M. Fischer (UHH), T. Schlick (UHH), D. Stammer (UHH, not on board)

Objectives, work on sea and expected results

Measurements of sea ice parameters will be taken by means of a newly developed microwave scatterometer which operates on 5 frequencies and three polarizations. The scatterrometer was constructed and built by the University of Hamburg and will be taken on board of a helicopter during the *Polarstern* cruise to sample microwave backscatter measurements from various different sea ice types. The analysis of those measurements will serve to identify algorithms by which sea ice characteristics and snow on sea ice can be identified through microwave back scatter remote sensing measurements. In the long term those new insights are required to help in the planning and development process of new satellite missions for cold regions, including sea ice. The measurement campaign during the *Polarstern* cruise will serve as a first test of the newly developed technology. This will be done in preparation of larger experiments, which will be performed jointly with the AWI sea ice group in 2019 and beyond.

Work on board of *Polarstern* will be concerned with various aspects of instrument testing and improvements. Most importantly, it will serve to collect a so fare unique data set of radar backscatter measurements that will be analyzed together with simultaneous visible and infrared measurements for a first analysis of sea ice and snow parameter. With the help of the scientific analysis the goal is to demonstrate the value of the new unique instrument for future sea ice studies. To this end several flight campaigns lasting up to one hour are being planned during which the instrument will be mounted on board of the *Polarstern* helicopter. Goal is to sample measurements from various sea ice types under different physical conditions, including different antenna incident angles. Flights will be performed in the vicinity of the research vessel within 20 km in diameter. Results will serve to improve a sea ice classification, which previously has been started with an older degraded version of the instrument (Brath et al., 2013). Work can be considered to be part of the AWI sea ice strategy and will be essential for the planning of future joint sea ice field campaigns in which the scaterometer will be one element in a suit of measurements. All experiences gained during this first application will also benefit the AWI sea ice group

Data management

Datea will be made available through the ICDC data portal http://icdc.cen.uni-hamburg.de/1.html

Reference

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12. MEASUREMENT OF THE ATMOSPHERIC BOUNDARY LAYER USING A WIND LIDAR

A. Preußer (Uni Trier), G. Heinemann (not on board, Uni Trier)

Objectives

The representation of the atmospheric boundary layer (ABL) in the Arctic is a major challenge for numerical weather forecast models 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 for the verification of a regional climate model (COSMO-CLM, Gutjahr et al. 2016) and for process studies.

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 15 kHz and is eye-safe (class 1M). Values are typically averaged for 1 second. The used lidar is 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 or over leads. Radiosondes launched from *Polarstern* will be used for comparisons of the wind profiles (Heinemann and Zentek 2016).

Preliminary (expected) results

The measurements during the *Polarstern* cruise shall yield a data set of continuous and high-resolution vertical profiles of wind and aerosol backscatter. Continuous sampling of vertical profiles will be performed during the cruise. For special observation periods (SOPs), RHI and horizontal scans will be performed yielding cross-sections of the ABL. The data will be used in a BMBF project for the verification of simulations using a high-resolution regional climate model.

Data management

All lidar data obtained during the cruise will be stored on a laptop and USB disks of the participants.

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13. TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTIONS

	Address
AWI	Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung Postfach 120161 27515 Bremerhaven Germany
DUR	Department of Geography Science Laboratories Durham University South Rd Durham DH1 3LE, United Kingdom
DWD	Deutscher Wetterdienst Geschäftsbereich Wettervorhersage Seeschifffahrtsberatung Bernhard Nocht Str. 76 20359 Hamburg, Germany
GEOMAR	Helmholtz-Zentrum für Ozeanforschung (GEOMAR) Wischhofstr. 1-3 24148 Kiel, Germany
GEUS	Geological Survey of Denmark and Greenland Øster Voldgade 10 DK-1350 Copenhagen K, Denmark
Ghent Uni	Ghent University Campus Ufo, Rectorate Sint-Pietersnieuwstraat 25 B-9000 Ghent Belgium
KU Leuven	Catholic University of Leuven Laboratory of Biodiversity and Evolutionary Genomics Charles Deberiotstraat 32 bus 2439 B-3000 Leuven Belgium
Marum	Zentrum für Marine Umweltwissenschaften Universität Bremen Leobener Str. 8 28359 Bremen Germany

	Address
TUB	Technische Universität Braunschweig Institute of Flight Guidance Hermann-Blenk-Str. 27 38108 Braunschweig Germany
TUD	Technische Universität Dresden Institut für Planetare Geodäsie Helmholtzstr. 10 01069 Dresden Germany
TUM	Technische Universität München Arcisstr. 21 80333 München Germany
UDEL	University of Delaware 111 Robinson Hall Newark, DE 19716 USA
UHB-IUP	University of Bremen Institute of Environmental Physics (IUP) – Oceanography Otto-Hahn-Allee 28359 Bremen Germany
UHH	Universität Hamburg Mittelweg 177 20148 Hamburg Germany
Uni HB	Universität Bremen Marine Zoologie (FB 02) Postfach 330 440 D-28334 Bremen Germany
Uni Trier	University Trier Universitätsring 15 54296 Trier Germany
WHOI	Woods Hole Oceanographic Institution 266 Woods Hole Road Woods Hole, MA 02543-1050 USA

14. FAHRTTEILNEHMER / CRUISE PARTICIPANTS

Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession	Scientific Field
Abledyll, von	Luisa	UHB	Student	Oceanography
Asendorf	Volker	Marum	Technician	Deep Sea
Beaird	Nicolas L.	WHOI	Scientist	Oceanography
Behrendt	Axel	AWI	Scientist	Oceanography
Braeckman	Ulrike	Ghent University	Scientist	Deep Sea
Breckenfelder	Tilia	UHB-IUP	Student	Tracer
Brünjes	Jonas	UHB-IUP	Student	Tracer
Callard	Sarah Louise	DUR	Scientist	Geology
Codling	Peter	DUR	Scientist	Geology
Ehrlich	Julia	AWI	PhD Student	Sea Ice Biology
Els	Julia	UHB-IUP	Student	Glaciology
Engicht	Carina	AWI	Technician	Oceanography
Felden	Janine	UHB	Scientist	Deep Sea
Fischer	Mayk	UHH	Technician	Sea Ice Remote Sensing
Graupner	Rainer	AWI	Technician	Oceanography
Gruebner	Lars	AWI	Media Designer	Communication & Media
Hoffmann	Zerlina	Geomar	Student	Oceanography
Huhn	Oliver	UHB-IUP	Scientist	Tracer
Hutter	Nils	AWI	PhD Student	Oceanography
Kanzow	Torsten	AWI	Scientist	Oceanography
Kappelsberger	Maria	TUM	PhD Student	Geology/Bathymetry
Knöfel	Christoph	TUD	Scientist	Geodesy
Krüger	Thomas	TUB	Engineer	Sea Ice Biology
Lehmenhecker	Sascha	AWI	Technician	AUV
Lloyd	Jerry M.	DUR	Scientist	Geology
Lunz	Susanne	TUD	Student	Geodesy
Lüttig	Christine	AWI	Student	Glaciology
Maes	Sarah	KU Leuven	Student	Sea Ice Biology
Meyer	Michaela	AWI	PhD Student	Geology/Bathymetry
Münchow	Andreas	UDEL	Scientist	Oceanography
NN		AWI		AUV
NN				Geology
NN				Geology
NN				Deep Sea

Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession	Scientific Field
O'Cofaigh	Colm	DUR	Scientist	Geology
Pätzold	Falk	TUB	Scientist	Sea Ice Biology
Preusser	Andreas	Uni Trier	Scientist	Meteorology
Schaffer	Janin	AWI	Scientist	Oceanography
Schlick	Thomas	UHH	Scientist	Sea Ice Remote Sensing
Streuff	Katharina	DUR	PhD Student	Geology
Tippenhauer	Sandra	AWI	Scientist	AUV
Verdugo	Josefina	AWI	PhD Student	Sea Ice Biology
Vermassen	Flor	GEUS	PhD Student	Geology
Washam	Peter	UDEL	Scientist	Oceanography
Wulff	Thorben	AWI	Engineer	AUV

15. SCHIFFSBESATZUNG / SHIP'S CREW

No.	Name	Rank
01.	Wunderlich, Thomas	Master
02.	Lauber, Felix	1.Offc.
03.	Westphal, Henning	Ch.Eng.
04.	Spielke, Steffen	1.Offc.Lad.
05.	Kentges, Felix	2.Offc.
06.	Peine, Lutz	2.Offc.
07.	Scholl, Thomas	Doctor
08.	Hofmann, Jörg	Comm.Offc.
09.	Schnürch, Helmut	2.Eng.
10.	Buch, Erik-Torsten	2.Eng.
11.	Rusch, Torben	2.Eng.
12.	Brehme, Andreas	Elec.Tech.
13.	Ganter, Armin	Electron.
14.	Markert, Winfried	Electron.
15.	Winter, Andreas	Electron.
16.	Feiertag, Thomas	Electron.
17.	Schröter, Rene	Boatsw.
18.	Neisner,Winfried	Carpenter
19.	Clasen, Nils	A.B.
20.	Schröder, Norbert	A.B.
21.	Burzan, Gerd-Ekkehard	A.B.
22.	Hartwig-Labahn, Andreas	A.B.
23.	Fölster, Michael	A.B.
24.	Müller, Steffen	A.B.
25.	Brickmann, Peter	A.B.
26.	Sedlak, Andreas	A.B.
27.	Schröder, Christoph	A.B.
28.	Beth, Detlef	Storekeep.
29.	Plehn, Markus	Mot-man
30.	Klein, Gert	Mot-man
31.	Krösche, Eckard	Mot-man
32.	Dinse, Horst	Mot-man
33.	Watzel, Bernhard	Mot-man
34.	Meißner, Jörg	Cook
35.	Tupy,Mario	Cooksmate
36.	Möller, Wolfgang	Cooksmate
37.	Wartenberg, Irina	1.Stwdess

No.	Name	Rank
38.	Schwitzky-Schwarz, Carmen	Stwdss/KS
39.	Hischke, Peggy	2.Stwdess
40.	NN	2.Stwdess
41.	Krause, Tomasz	2.Steward
42.	NN	2.Steward
43.	Chen, Quan Lun	2.Steward
44.	Ruan, Hui Guang	Laundrym.