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The Expeditions PS99.1 and PS99.2 of the Research Vessel POLARSTERN to the Fram Strait in 2016

Edited by
Thomas Soltwedel
with contributions of the participants

HELMHOLTZ GEMEINSCHAFT

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Titel: Der Forschungseisbrecher Polarstern in der westlichen Framstraße (Foto: Josephine Rapp, AWI)

Cover: Research ice-breaker Polarstern in the western Fram Strait (Photo: Josephine Rapp, AWI)

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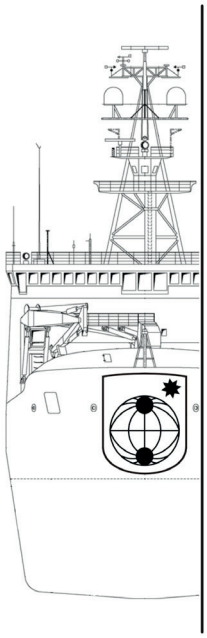
PS99.1

13 June 2016 - 23 June 2016
Bremerhaven - Longyearbyen

PS99.2

24 June 2016 - 16 July 2016
Longyearbyen - Tromsø



PS99

RV POLARSTERN
LTER HAUSGARTEN

Bremerhaven - Tromsø
13.06. - 16.07.2016

Chief Scientist
Thomas Soltwedel

Coordinator
Rainer Knust

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APPENDIX

1. ZUSAMMENFASSUNG UND FAHRTVERLAUF

Thomas Soltwedel
Alfred-Wegener-Institut

Die *Polarstern* Expedition PS99 begann am 13. Juni 2016 in Bremerhaven und führte in Arbeitsgebiete nordwestlich der Bäreninsel, vor der Südspitze Spitzbergens und in der zentralen und östlichen Framstraße.

Auf dem ersten Fahrtabschnitt der Expedition PS99 (Bremerhaven - Longyearbyen) wurden zwei Forschungsprojekte des Europäischen FP7 Infrastrukturprogramms EUROFLEETS2 unterstützt. Im Rahmen des Projekts BURSTER (Bottom currents in a stagnant environment) wurden die geodynamischen und hydrographischen Verhältnisse sowie Gasaustritte am Boden des Kveithola Troughs untersucht, während im Projekt DEFROST (Deep flow regime off Spitsbergen) räumliche und zeitliche Veränderungen in den tiefen Meeresströmungen südwestlich von Spitzbergen im Fokus standen.

Der zweite Fahrtabschnitt der Expedition PS99 (Longyearbyen - Tromsø) wurde genutzt, um Beiträge zu verschiedenen nationalen und internationalen Forschungs- und Infrastruktur-Projekten (ABYSS, ICOS, FixO3, FRAM, ROBEX, SIOS) sowie dem Forschungsprogramm PACES II (Polar regions and coasts in the changing Earth System) des Alfred-Wegener-Instituts Helmholtz-Zentrum für Polar- und Meeresforschung (AWI) zu leisten. Die Forschungsarbeiten stellen einen weiteren Beitrag zur Sicherstellung der Langzeit-Beobachtungen am LTER Observatorium HAUSGARTEN dar, in denen der Einfluss von Umweltveränderungen auf ein arktisches Tiefseeökosystem dokumentiert wird. Diese Arbeiten werden in enger Zusammenarbeit der HGF-MPG Brückengruppe für Tiefsee-Ökologie und -Technologie, der PEBCAO-Gruppe (Phytoplankton Ecology and Biogeochemistry in the Changing Arctic Ocean) des AWI und der Helmholtz-Hochschul-Nachwuchsgruppe SEAPUMP (Seasonal and regional food web interactions with the biological pump) durchgeführt.

Die Expedition wurde darüber hinaus genutzt, um weitere Installationen im Rahmen der HGF Infrastrukturmaßnahme FRAM (Frontiers in Arctic marine Monitoring) vorzunehmen. Das FRAM Ocean Observing System wird kontinuierliche Untersuchungen von der Meeresoberfläche bis in die Tiefsee ermöglichen und zeitnah Daten zur Erdsystem-Dynamik sowie zu Klima- und Ökosystem-Veränderungen liefern. Daten des Observatoriums werden zu einem besseren Verständnis der Veränderungen in der Ozeanzirkulation, den Wassermasseneigenschaften und des Meereisrückgangs sowie deren Auswirkungen auf das arktische, marine Ökosystem beitragen. FRAM führt Sensoren in Observationsplattformen zusammen, die sowohl die Registrierung von Ozeanvariablen, als auch physiko-chemischer und biologischer Prozesse im Ozean erlauben. Experimentelle und Ereignis-gesteuerte Systeme ergänzen diese Beobachtungsplattformen. Produkte der Infrastruktur umfassen hochaufgelöste Langzeitdaten sowie Basisdaten für Modelle und die Fernerkundung.

Die technisch und logistisch sehr aufwendige Expedition PS99, während der neben unbemannten autonomen Fluggeräten (Unmanned Aerial Vehicles, UAV) auch verschiedene autonome, in der Wassersäule und am Tiefseeboden agierende Unterwasserfahrzeuge zum Einsatz gekommen sind, endete am 16. Juli 2016 in Tromsø. Durch die effektive Zusammenarbeit zwischen den wissenschaftlichen Arbeitsgruppen und der Schiffsbesatzung, und begünstigt durch das überwiegend gute Wetter, verlief die Expedition PS99 insgesamt sehr erfolgreich.

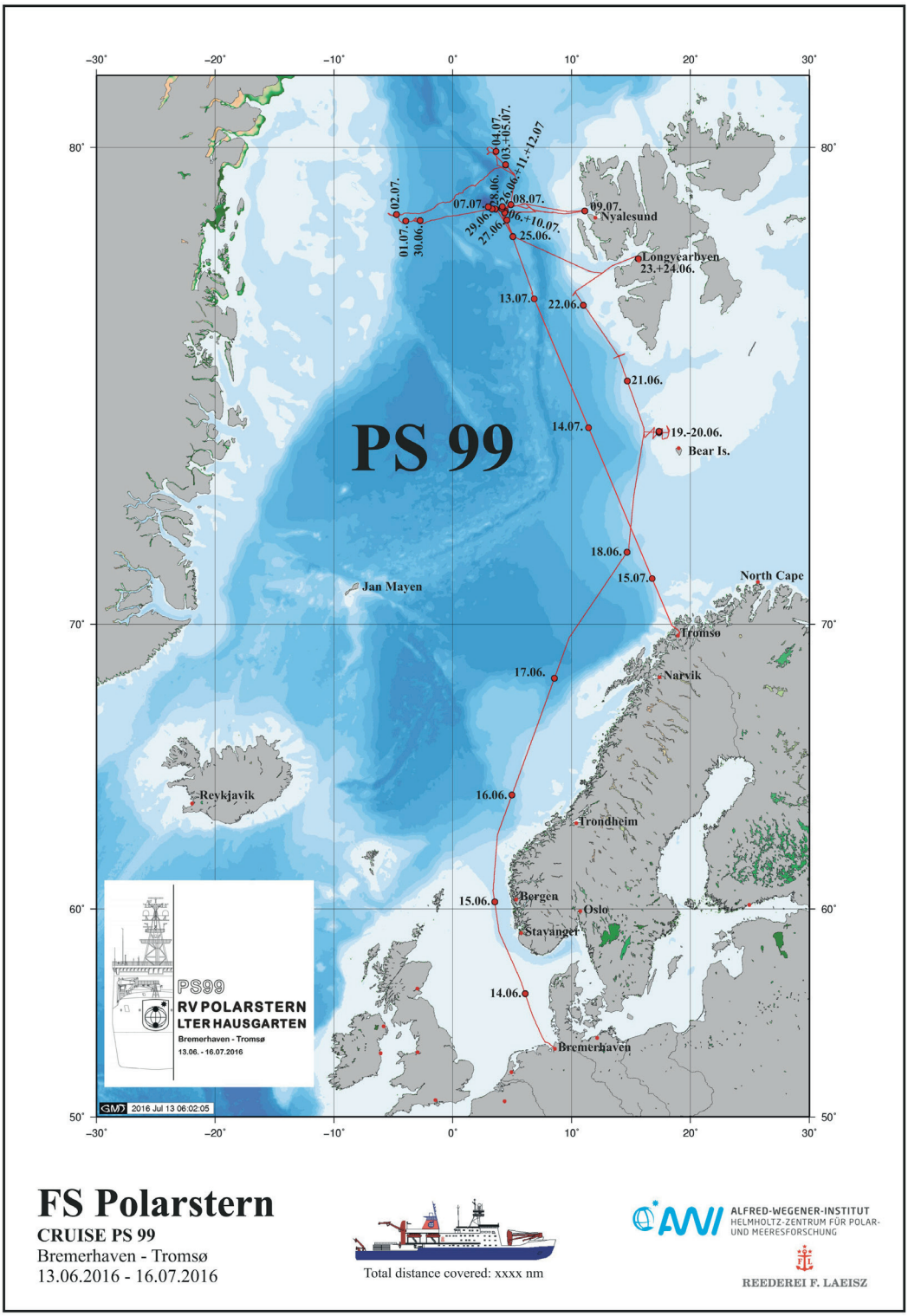

Abb. 1: Kursplot der Polarstern Expedition PS99 (13.06.-16.07.2016)

Fig. 1: Course plot for Polarstern expedition PS99 (13.06.-16.07.2016)

ITINERARY AND SUMMARY

The *Polarstern* expedition PS99 to the Arctic started on June 13 2016 in Bremerhaven to study areas northwest of Bear Island, south of Spitsbergen, and in the central and eastern Fram Strait.

During the first leg of the expedition PS99 (Bremerhaven - Longyearbyen), *Polarstern* supported two scientific projects selected by the European FP7 Research Infrastructure programme EUROFLEETS2. The research project BURSTER (Bottom currents in a stagnant environment) investigated the geodynamic and hydrographic conditions, and the active gas seepage present in the pockmark-field piercing the sediment drift located in the inner part of the Kveithola Trough, whereas temporal and spatial variations of deep currents to the southwest of Svalbard were in focus of the DEFROST (Deep flow regime off Spitsbergen) project.

The second leg of the expedition PS99 (Longyearbyen - Tromsø) contributed to various large national and international research and infrastructure projects (ABYSS, ICOS, FixO3, FRAM, ROBEX, SIOS) as well as to the research programme PACES-II (Polar regions and coasts in the changing Earth System) of the Alfred Wegener Institute Helmholtz Center for Polar and Marine Research (AWI). The scientific work carried out within PACES-II supports the time-series studies at the LTER (Long-Term Ecological Research) observatory HAUSGARTEN, where we document Global Change induced environmental variations on a polar deep-water ecosystem. This work is carried out in close co-operation between the HGF-MPG Joint Research Group on Deep-Sea Ecology and Technology, the PEBCAO Group (Phytoplankton Ecology and Biogeochemistry in the Changing Arctic Ocean) at AWI and the Helmholtz Young Investigators Group SEAPUMP (Seasonal and regional food web interactions with the biological pump), representing a joint effort between the AWI, the MARUM - Center for Marine Environmental Sciences, and the University of Bremen.

The expedition was also used to accomplish installations for the HGF infrastructure project FRAM (Frontiers in Arctic marine Monitoring). The FRAM Ocean Observing System aims at permanent presence at sea, from surface to depth, for the provision of near real-time data on Earth system dynamics, climate variability and ecosystem change. It serves national and international tasks towards a better understanding of the effects of change in ocean circulation, water mass properties and sea-ice retreat on Arctic marine ecosystems and their main functions and services. FRAM implements existing and next-generation sensors and observatory platforms, allowing synchronous observation of relevant ocean variables as well as the study of physical, chemical and biological processes in the ocean. Experimental and event-triggered platforms complement the observational platforms. Products of the infrastructure are continuous long-term data with appropriate resolution in space and time, as well as ground-truthing information for ocean models and remote sensing.

During the technically and logistically very challenging expedition we used not only Unmanned Aerial Vehicles (UAV) but also different autonomous underwater vehicles which operated in the water column and at the deep seafloor. The cruise ended on July 16, 2016 in Tromsø (Norway). The effective cooperation between the scientific party and the ship's crew, in combination with perfect weather conditions during most times of the cruise made this expedition a great success.

2. WEATHER CONDITIONS

Christian Paulmann, Juliane Hempelt DWD

Week 1, 13.06.-19.06.2016

At the beginning of the expedition PS99.1, a complex low pressure system with several centres round British Isles was predominant. *Polarstern* left Bremerhaven with cloudy skies, scattered rain showers, 16°C and 3 wind forces from east-southeast on June 13 at 19:30 pm. Wind rapidly increased up to 5 Bft, however with only 1-1.5 m significant wave height due to the limited wind fetch. The visibility was only moderate. The low over England was weakening again after midweek, while new lows propagated from East-Europe via Scandinavia to the Arctic. At the same time, a very stable high was located between Jan Mayen and the western Norwegian Sea, associated ridges stretched out north- and southward. *Polarstern* came on the high's eastern limb off Mid-Norway from Wednesday evening on (15.06.), accompanied by increasingly strong differences of atmospheric pressure: Until the night to Thursday, winds shifted to northeast and grew up to 7 Bft with gusty 8 Bft. The sea intensified up to 3-4 m. Visibility markedly improved in the inflowing colder air masses. From the night to Saturday (18.06.), wind weakened again below 6 Bft. Work at the first research area BURSTER west of Bear Island could start with 4 to 5 Bft from northwest, 1.5 m wave heights and good visibility on Sunday morning (19.06.).

Week 2, 20.06.- 26.06.2016

During that week, several low pressure areas established off East-Greenland. Milder air masses with higher dew point temperatures were entering the Fram Strait step by step, whereas the lows migrated to northeast. Thus, a transition into a longer foggy period occurred at the end of that week. Already on Monday, wind transitionally shifted to west 5 to 6 and sea reached 1.5 m under the influence of a first low. Around mid-week, a second low caused freshening south-westerly winds and sea states up to 1.5 m over the second research area DEFROST close southwest of Svalbard. There was a change of scientists in Longyearbyen between Thursday morning (23.06.) and Friday afternoon (24.06.), afterwards *Polarstern* headed towards the HAUSGARTEN nearby 78.3°N, 05°E. Shortly after departure inside Isfjorden, south-westerly winds increased up to moderate 4 Bft, drizzle and poor visibility prevailed in the western luff of Svalbard. Subsequently, wind calmed down and first fog patches could establish. On Saturday afternoon, the increasingly moderate wind was forced to more southerly directions on the frontal side of a third approaching low pressure area. Consequently, advection fog developed. Rain, southerly winds 5-6 Bft and 1.5 m wave heights dominated east of the low centre on Sunday (26.06.). But on Sunday evening, fog could dissipate for a while after the passage of a marked cold front together with lulling winds and dropping both temperatures and dew point temperatures.

Week 3, 27.06.-03.07.2016

During the 3rd week of expedition PS99, high pressure areas propagated north from both Jan Mayen and Norwegian Sea to Arctic latitudes between Nowaja Semlja and the Fram Strait. We saw strong near-surface temperature inversions and persistent fog inside a humid atmospheric

boundary layer. At the beginning of the week, light wind backed to southerly directions and increased up to 5 Bft between Wednesday (29.06.) and Friday (01.07.). Simultaneously, inflowing 3° to 4°C mild air upheld the fog over the 0° to -1°C cold water-ice mixture. The research area was shifted to the East-Greenland Current with broken ice cover around 79°N, 02-05°W on Thursday. From Friday on, first training helicopter flights could occur due to momentary dissipating fog. Only from Saturday (02.07.), a change of weather came up: A low 998 hPa developed southwest of Bear Island. That low was deepening, while it moved to southern Svalbard until Sunday evening (03.07.). Meanwhile, the research area was shifted farther to the north to 79-80°N, 03-05°E and the north-north-easterly wind intensified markedly up to 6 Bft with gusty 7 Bft on the low's north-western limb. However, wind induced waves could only increase up to 1 m due to the close pack-ice margin. But the close pack-ice was also the reason for new fog development in the cold and strong off-ice northerly airstream.

Week 4, 04.07.-10.07.2016

During that week, the previously prevented scientific flying could start. But the transition to long lasting good visibility was tenacious: Cold near-gale northerly winds (7 Bft) and gale force gusts (8 Bft) occurred during the night to Monday. Afterwards the Svalbard-low passed to northeast and wind abated down to 5 Bft. But a low-level-jet up to 50 kn generated gravity waves with temporary marked descending cloud bases combined with transitionally deteriorating visibility below 2 km. Aside of sea ice, there were crossed seas with wind induced waves up to 1m from north and swell up to 2 m from east. On Tuesday (05.07.), the research area was shifting south towards 79°N, 04°E again, while an intensifying high pressure area between Jan Mayen and Scoresbysund propagated northeast to the region between Svalbard and Franz-Josef-Land. Wind calmed down and fog developed once more on Tuesday afternoon. Wednesday (06.07.) was the first day without any fog for 12 days due to inflowing dry and mild air. Now the high was pushed north to the region between Northeast-Greenland and Franz-Josef-Land. Till the beginning of next week, *Polarstern* remained between that unusually stable high and marked low pressure activity over Scandinavia. Plenty of sunshine prevailed. Wind freshened up to 5 Bft from northeast on Thursday (07.07.) and up to 6 Bft from Sunday (10.07.) accompanied by significant wave heights up to 2 m. Only on Saturday (09.07.), the research area was temporary shifted to the Kongsfjord (West-Svalbard) with calming winds in the western lee of Svalbard. At the same time, an elongated fog patch established underneath a 6°C temperature inversion over the western Fram Strait. We entered that fog after our return to the HAUSGARTEN temporary on Sunday (10.07.) and during the following night.

Week 5, 11.07.-15.07.2016

From Monday on, the previously stable high north of Svalbard weakened. The weakening and westward moving Scandinavian low could become more and more important for the cruising area. During the night to Tuesday (12.07.), a weak frontal trough passed and temperatures increased up to 8°C. Almost 11°C was measured at 300 m above the ground. Additionally, incoming north-easterly air flow and swell decreased down to 3 Bft respectively 1 m. Dense mid- and high-level cloud sheets came to the Fram Strait, but the lowest tropospheric level remained dry and free of fog. On late Tuesday evening, research activities of expedition PS99 ceased and the 600 nm transit to Tromsø began. Meanwhile, a new low 995 hPa had established over the Scandinavian Kola-Peninsula. We passed an associated frontal system on its western flank during the night to Thursday (14.07.). The north-north-easterly airstream intensified up to 5 Bft, the sea state increased up to 1.5 m, rain came up. On Thursday and Friday, the mentioned low slowly headed towards Bear Island and farther to Svalbard. So we sailed from the low's western limb to the southern limb and the wind shifted via northwest to west-southwest. Especially during the night to Friday and on Friday (15.07.), the wind

temporary increased up to 5-6 Bft. On late Friday during approaching Tromsø, wind veered and calmed again and less humid air prevailed together with increasing atmospheric pressure. We arrived at Tromsø with a gentle breeze on Friday evening.

Weather statistics for the *Polarstern* expedition PS99 are visualized in Fig. 2.1.

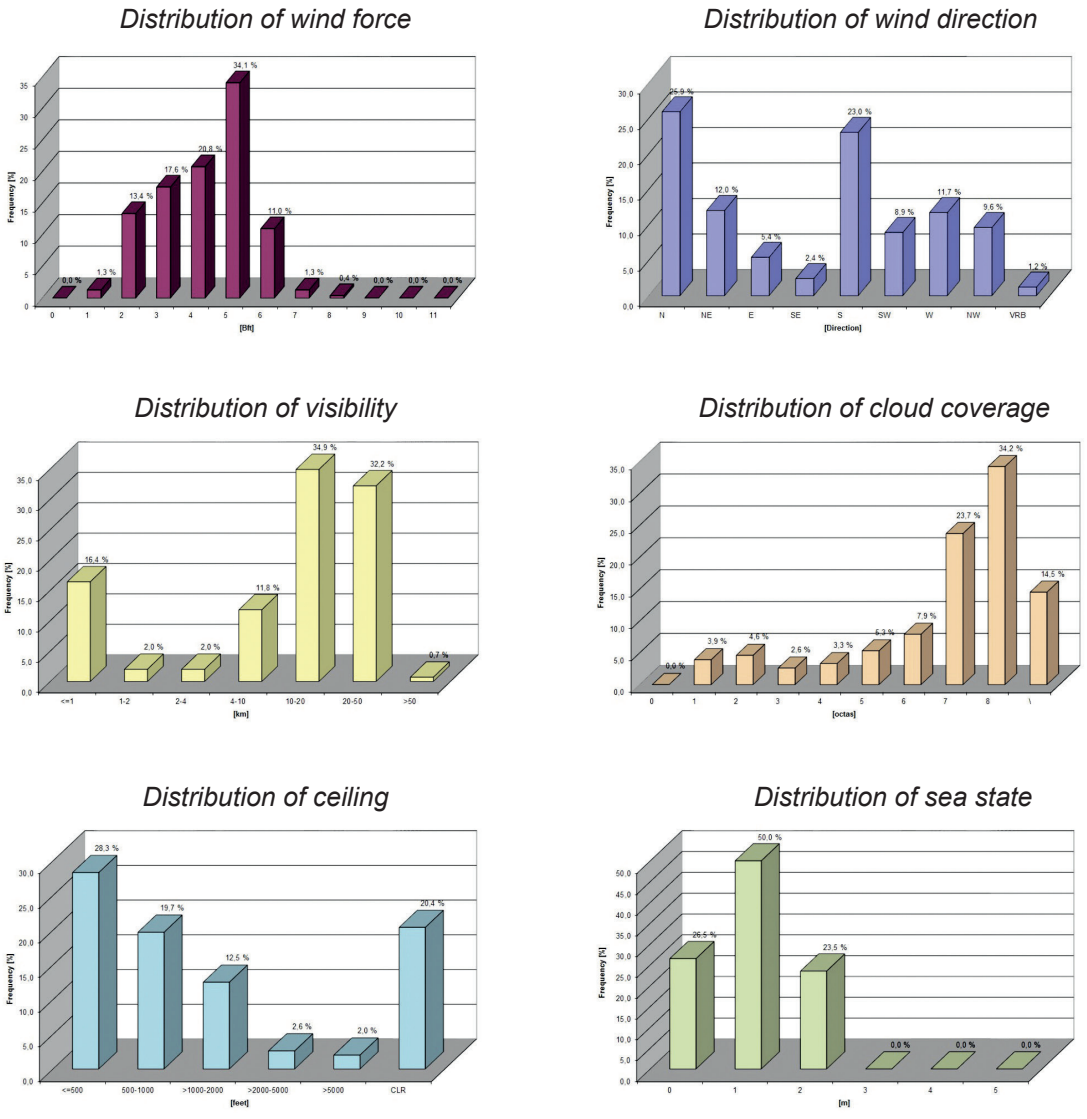

Fig. 2.1: Statistics of various weather parameters

3. BURSTER: BOTTOM CURRENTS IN A STAGNANT ENVIRONMENT

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not on board: Michele Rebesco[1]

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[9] GIFT
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[11] HITACHI
[12] Uni Tromsø
[13] Uni Poznań
[14] IEO Malaga
[15] AWI

Grant No. AWI_PS99_00

Objectives

The Kveithola Trough is an abrupt and narrow (100 km long and 13 km wide) glacigenic sedimentary system located in the NW Barents Sea (Fig. 3.1) that hosted, during last glaciation, ice streams draining ice from the southern Svalbard and from Bear Island, respectively, to the north and south of the Kveithola depositional system (Pedrosa et al., 2011). The bathymetry presents several transversal ridges (Grounding Zone Wedges) revealing a pulsing mode of the glacial retreat after Last Glacial Maximum (LGM, Rebesco et al., 2011). In the inner area, the Kveithola contains two sediment drifts whose bathymetric and stratigraphic characteristics indicate that persistent and vigorous bottom currents were active in the area since the end of LGM (Bjarnadóttir et al., 2013), eroding, transporting, and depositing sediments. Although areas affected by bottom currents are usually characterized by well oxidized sediments with active benthic communities in a nutrients-rich habitat, the inner Kveithola seafloor appears today as a “stagnant”, possibly chemosynthetic, environment with black, organic matter-rich sediments having strong smell of H_2S, abundant black worm tubes and oxygen-depleted infaunal taxa (Hanebuth et al., 2013).

The main objective of EUROFLEETS2 - BURSTER project is to investigate the hydrographic, geo-biochemical, biological, and microbial characteristics of the Kveithola depositional system in order to understand the origin of such an atypical bottom-current related environment, and to understand what can be its local and global impact in terms of carbon cycle and the transfer of chemosynthetic-derived products to the deeper environments as consequence of regional oceanographic patterns. Additionally, the BURSTER project aims to study climate and environmental changes controlling the evolution of living organisms in extreme environments.

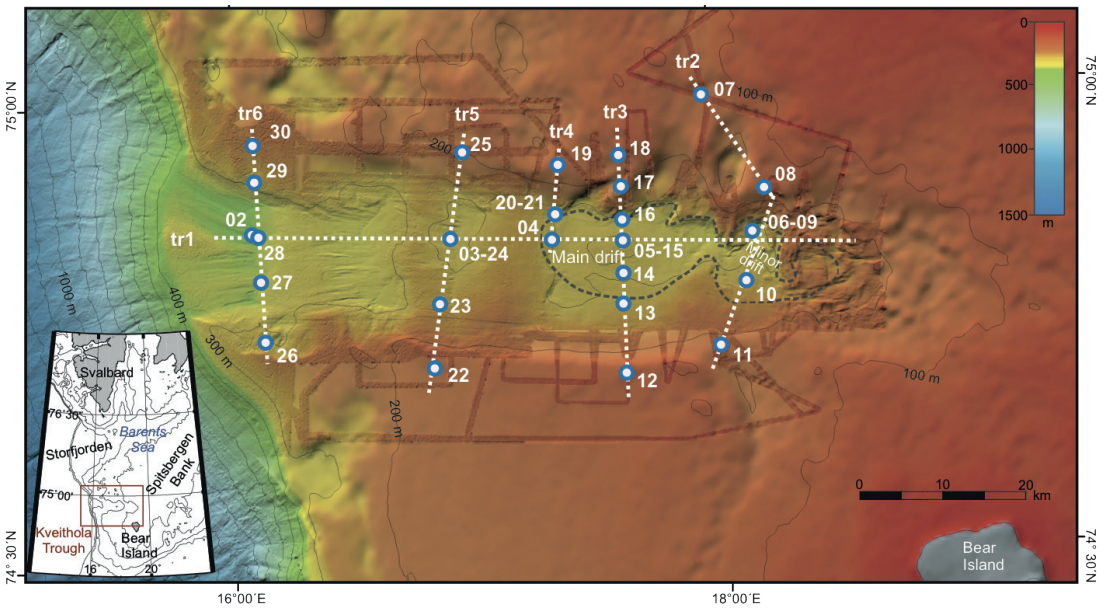

Fig. 3.1: EUROFLEETS2 - BURSTER study area (Kveithola Trough). The inset map indicates the location of the Kveithola Trough in the NW Barents Sea. White/blue dots indicate the studied sites. White dashed lines indicate the location of the six oceanographic transects.

This type of investigation was conceived to be strongly multidisciplinary including physical and biological oceanography, water, sediment and gas geochemistry, micropaleontology, microbiology geophysics, and sedimentology. For this reason, the scientific party of the BURSTER project was formed by scientists coming from 14 different European Institutions having different expertise to fulfil the objectives of the project.

Work at sea

The survey of the Kveithola Trough started on June 19, 2016 at 05:13 UTC with deployment of the CTD/Rosette at site PS99/02 on the outer part of the trough (Fig. 3.1, Table 3.1). The CTD/Rosette Water Sampler, was followed by two consecutive deployments of the TV-MUC and an OFOS survey. All the first day was dedicated to the CTD/Rosette Water Sampler, TV-MUC and OFOS data collection at six selected sites (PS99/02-03-04-05-06-07, Fig. 3.1) located along the E-W oriented axes of the Kveithola (oceanographic transect 1). This first part of the working plan finished at 00:30 UTC of June 20. The water samples and the sediment cores collected at each site were immediately sub-sampled for shore-based analyses. The second day was dedicated to the oceanographic survey along transects 2–6. At 12:00 UTC, along the way to station PS99/20 the echo-sounder and the sub-bottom profiler recorded a possible gas flare. We decide to go back to the point in order to investigate the area (site PS99/21) in detail. The investigations involved firstly a OFOS survey that was followed by a CTD/Rosette Water Sampler with water sampling down to 5 m above seafloor, and three consecutive TV-MUC deployments (the second fail to recover sediments because landed on a rock). The sediment sampling operation at site PS99/21 were complicated by a consistent delay of the MUC TV-camera returning images of about 18 seconds. The investigation of site 21 took approximately 5.5 hours at the end of which the oceanographic survey reprised but with a reduced programme in order to maintain the necessary time for the maintenance/recovery of two moorings on the western side of Svalbard. The Kveithola survey finished at 5:30 UTC of June 21, 2016 for an overall of 24:15 hours of dedicated time, with the recovery of 89 multi-

cores (22.5 m of sediments and 830 sub-samples), 265 water samples, 28 CTD casts along seven transects and 2.57 km of benthic camera survey (OFOS). According to the project work programme, 24 hours were then dedicated to the maintenance/recovery of two moorings that were deployed west of Svalbard during the EUROFLEETS2 - PREPARED project (RV *G.O. Sars*, June 2014). This activity was shared with the scientific party of the Italian PNRA project DEFROST. The transfer from the Kveithola to the first mooring station (*S1*) took nearly 10 hours. Mooring *S1* was recovered during 14:50–16:04 UTC on June 21, 2016 and re-deployed between 2:30–5:14 UTC on June 22, 2016 (new position: Latitude 76°26.265'N; Longitude 13°56.636'E; 1063 m). Mooring *I2* was recovered on the same day between 13:45–14:50 UTC after 8 hours of transfer from station *S1* to station *I2* (see Chapter 4).

Preliminary results

The OFOS survey at site PS99/21 uncovered the presence of meter-large rocks, possibly authigenic carbonates, with irregular or tabular shape that are colonized by Actiniidae and Siboglinidae worms, with shell's debris in the surroundings, and possible presence of bacterial mats (Fig. 3.2). Preliminary analyses indicated the presence of CH_4 in the sediments. Preliminary oceanographic results indicate strong water stratification having very high lateral variation. In particular, cold fresh waters possibly originating from the Barents Sea, move along the northern side of the Kveithola trough, whereas warm and saline North-Atlantic water masses dominate the south-western area.

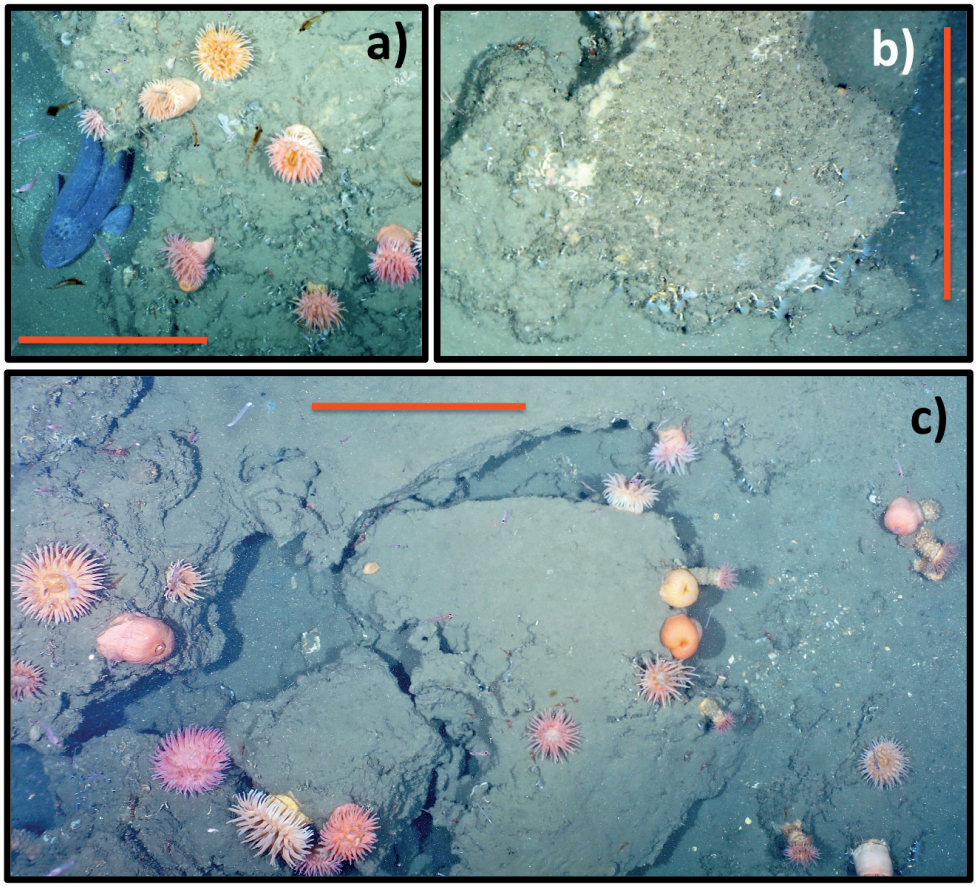

Fig. 3.2: OFOS survey of site PS99/21: a) Carbonate blocks with Actiniidae; d) Carbonate blocks with Siboglinidae worms; e) Tabular carbonate with shell's debris on the seafloor (red line =50 cm)

Table 3.1: Station list

Station	Gear	Date	Time (UTC)	Latitude	Longitude	Depth [m]	Action
PS99/01-1	CTD/RO	17/06/2016	08:51:00	67° 53,75' N	008° 04,19' E	2253.7	CTD-Rosette test
PS99/02-1	CTD/RO	19/06/2016	05:22:00	74° 51,52' N	016° 05,91' E	375.8	
PS99/02-2	TVMUC	19/06/2016	06:13:00	74° 51,49' N	016° 05,84' E	376.1	first deployment
PS99/02-3	TVMUC	19/06/2016	07:10:00	74° 51,53' N	016° 05,93' E	376.0	second deployment
PS99/02-4	OFOS	19/06/2016	08:14:00	74° 51,52' N	016° 06,01' E	376.0	profile start
PS99/02-4	OFOS	19/06/2016	08:51:00	74° 51,34' N	016° 07,18' E	370.4	profile end
PS99/03-1	TVMUC	19/06/2016	10:49:00	74° 51,00' N	016° 54,52' E	317.1	one deployment only
PS99/04-1	TVMUC	19/06/2016	12:11:00	74° 50,75' N	017° 20,86' E	304.7	one deployment only
PS99/05-1	CTD/RO	19/06/2016	13:22:00	74° 50,54' N	017° 38,46' E	295.0	
PS99/05-2	TVMUC	19/06/2016	14:04:00	74° 50,56' N	017° 38,27' E	294.6	first deployment
PS99/05-3	TVMUC	19/06/2016	14:58:00	74° 50,53' N	017° 38,37' E	293.6	second deployment
PS99/05-4	OFOS	19/06/2016	16:00:00	74° 50,51' N	017° 38,32' E	293.0	profile start
PS99/05-4	OFOS	19/06/2016	16:49:00	74° 50,50' N	017° 39,59' E	296.5	profile end
PS99/06-1	OFOS	19/06/2016	18:07:00	74° 50,74' N	018° 10,46' E	334.3	profile start
PS99/06-1	OFOS	19/06/2016	18:49:00	74° 50,59' N	018° 11,61' E	328.8	profile end
PS99/06-2	CTD/RO	19/06/2016	19:22:00	74° 50,72' N	018° 10,57' E	335.5	
PS99/06-3	TVMUC	19/06/2016	20:38:00	74° 50,73' N	018° 10,64' E	335.9	first deployment
PS99/06-4	TVMUC	19/06/2016	21:29:00	74° 50,75' N	018° 10,55' E	335.7	second deployment
PS99/07-1	CTD/RO	19/06/2016	23:01:00	74° 59,72' N	017° 59,61' E	148.0	
PS99/07-2	TVMUC	19/06/2016	23:35:00	74° 59,68' N	017° 59,62' E	159.0	first deployment empty
PS99/07-3	TVMUC	20/06/2016	00:20:00	74° 59,69' N	017° 59,72' E	159.1	second deployment
PS99/08-1	CTD/RO	20/06/2016	01:33:00	74° 53,53' N	018° 14,20' E	152.6	
PS99/09-1	CTD	20/06/2016	02:26:00	74° 50,72' N	018° 10,60' E	336.1	
PS99/10-1	CTD/RO	20/06/2016	03:18:00	74° 47,60' N	018° 08,82' E	287.5	
PS99/11-1	CTD/RO	20/06/2016	04:16:00	74° 43,48' N	018° 01,43' E	178.2	
PS99/12-1	CTD/RO	20/06/2016	05:17:00	74° 41,96' N	017° 38,47' E	108.7	
PS99/13-1	CTD	20/06/2016	06:16:00	74° 46,39' N	017° 37,94' E	288.0	
PS99/14-1	CTD/RO	20/06/2016	07:06:00	74° 48,58' N	017° 38,46' E	303.4	
PS99/15-1	CTD	20/06/2016	08:00:00	74° 50,55' N	017° 38,52' E	294.3	
PS99/16-1	CTD	20/06/2016	08:41:00	74° 51,86' N	017° 38,61' E	318.9	
PS99/17-1	CTD/RO	20/06/2016	09:26:00	74° 54,03' N	017° 38,70' E	186.3	
PS99/18-1	CTD	20/06/2016	10:08:00	74° 56,02' N	017° 38,35' E	133.3	
PS99/19-1	CTD/RO	20/06/2016	11:07:00	74° 55,58' N	017° 22,24' E	167.1	
PS99/20-1	CTD	20/06/2016	11:56:00	74° 52,42' N	017° 21,48' E	306.5	
PS99/21-1	OFOS	20/06/2016	13:22:00	74° 52,41' N	017° 21,66' E	305.7	profile start
PS99/21-1	OFOS	20/06/2016	14:31:00	74° 52,40' N	017° 21,60' E	305.9	profile end
PS99/21-2	CTD/RO	20/06/2016	15:07:00	74° 52,40' N	017° 21,64' E	306.0	
PS99/21-3	TVMUC	20/06/2016	16:19:00	74° 52,40' N	017° 21,57' E	305.7	first deployment
PS99/21-4	TVMUC	20/06/2016	17:29:00	74° 52,40' N	017° 21,62' E	305.6	second deployment
PS99/21-5	TVMUC	20/06/2016	18:15:00	74° 52,40' N	017° 21,60' E	305.4	third deployment
PS99/22-1	CTD	20/06/2016	20:13:00	74° 42,56' N	016° 50,43' E	170.9	
PS99/23-1	CTD	20/06/2016	21:13:00	74° 46,80' N	016° 52,61' E	277.0	
PS99/24-1	CTD	20/06/2016	22:19:00	74° 51,00' N	016° 54,46' E	317.0	
PS99/25-1	CTD/RO	20/06/2016	23:26:00	74° 57,34' N	016° 57,65' E	198.7	
PS99/26-1	CTD	21/06/2016	01:56:00	74° 43,91' N	016° 08,92' E	268.9	
PS99/27-1	CTD	21/06/2016	02:49:00	74° 47,79' N	016° 07,45' E	350.5	
PS99/28-1	CTD	21/06/2016	03:45:00	74° 51,60' N	016° 05,96' E	376.6	
PS99/29-1	CTD	21/06/2016	04:41:00	74° 55,53' N	016° 04,54' E	287.4	
PS99/30-1	CTD	21/06/2016	05:22:00	74° 57,38' N	016° 03,62' E	261.0	

Data management

The water samples collected during the cruise will be stored and processed at the OGS Biological Oceanography laboratory facilities for biochemical analyses (pH, total alkalinity, dissolved oxygen, dissolved inorganic carbon, hydrogen sulphide, dissolved inorganic nutrients, and microzooplankton abundance and diversity), and at the University La Sapienza (Rome) for dissolved gasses analyses (CO_2, CH_4). The samples collected from the MUC cores will be stored and analysed at OGS (sedimentology and compositional analyses), at the University of Pisa (living, recent and fossils foraminiferal microfauna), at the Polytechnic University of Marche (living and recent metazoan meiofauna, and macrofauna), at the University of Oslo (sediments dissolved gases), at the Federal Institute for Geosciences and Natural Resources (sediment-water interface and pore water geochemistry, sediments dissolved gases, microbial communities identification and activity determination), at the University of Barcelona (stable isotope), and at the Adam Mickiewicz University, Poznań, Poland (radiogenic dating).

The data collected during EUROFLEETS2 - BURSTER project will be exclusively on the use of the BURSTER partners for the first three years after cruise collection according to the EUROFLEETS2 policy, although, new collaborations already developed during the cruise with the other scientist of expedition PS99.1. After the first 3-years of moratoria the data will be available to the rest of the scientific community.

References

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Hanebuth TJJ, et al. (2013) CORIBAR – Ice dynamics and meltwater deposits: coring in the Kveithola Trough, NW Barents Sea. Cruise MSM30. 16.07. – 15.08.2013, Tromsø (Norway) – Tromsø (Norway). Berichte, MARUM – Zentrum für Marine Umweltwissenschaften, Fachbereich Geowissenschaften, Universität Bremen, No. 299, 74 pages. Bremen, 2013. ISSN 2195-7894.

Pedrosa MT, et al. (2011) Seabed morphology and shallow sedimentary structure of the Storfjorden and Kveithola trough-mouth fans (North-west Barents Sea). Marine Geology, 286, 65-81.

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4. DEFROST: DEEP FLOW REGIME OFF SPITSBERGEN

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not on board: Michele Rebesco[1], Laura Ursella[1], Stefano Aliani[2], Stefano Miserocchi[2]

[1] OGS
[2] ISMAR

Grant No. AWI_PS99_00

Objectives

The offshore area south-west of the Svalbard Archipelago (Fig. 4.1) is a region where Atlantic waters, considerably warmer than the locally formed dense waters, flow northwards embedded in the so-called West Spitsbergen Current (WSC) through the eastern side of the Fram Strait. These waters keep the region nearly ice-free even during winter season. Cold Arctic waters (East Greenland Current), instead, descend southward on the western side of the Fram Strait contributing to the maintenance of the Greenland ice cap. Additionally, dense waters formed during the winter season through freezing and brine are released in the polynyas of the Barents Sea and particularly in the Storfjorden. After their generation phase, they flow northwards in geostrophic balance following the isobaths of the shelf slope. These ocean processes have strong implications on the climate. Such shelf dense water plumes are also responsible for the formation of contourites (sedimentary structures affected by along slope bottom currents), whose onset coincides with the Early Pleistocene glacial expansion. Contourites are important because their study can provide valuable information on the history of ocean circulation and climate. In particular, two contourite depositional systems were recently discovered in the area, i.e. the Isfjorden and Bellsund contourite drifts (Rebesco et al., 2013).

The main objective of the research project DEFROST (DEep Flow Regime Off SpiTsbergen) is to investigate the temporal and spatial variability of the deep flow in the area of the above mentioned contourites, with emphasis on the near-bottom currents and their associated physical and biogeochemical properties. *In-situ* measurements are conducted mainly by means of moorings, deployed in the layer between 1,000 and 1,500 m water depth. They were equipped with current meters, temperature, salinity, dissolved oxygen sensors, and sediment traps. The choice of using the moorings is motivated by the fact that the most energetic processes, which are able to re-shape the seabed and form contourites, occur in late winter and early spring, when surveys done by means of research vessels are hardly feasible in the region (harsh meteorological conditions). The scientific activities in DEFROST follow up previous international work, such as the EUROFLEETS2 - PREPARED (Present and past flow regime on contourite drifts west of Spitsbergen) cruise carried out in summer 2014 (RV *G.O. Sars*, Norway), and two following cruises carried out in the same region in June and September 2015 on board the RV *Helmer Hansen* (UiT, Norway) and RV *OGS Explora* (OGS, Italy). DEFROST is a project funded by the Italian Ministry of Education, University and Research (MIUR) within the PNRA programme (Italian Antarctic Research Program) and it is linked to the EUROFLEETS2 - BURSTER project (see Chapter 3), which planned the mooring recovery and maintenance as a possible additional activity. The Alfred Wegener Institute for Polar and Marine Research (AWI) is one of the supporting partners of DEFROST and offered ship time during the *Polarstern* cruise PS99.1.

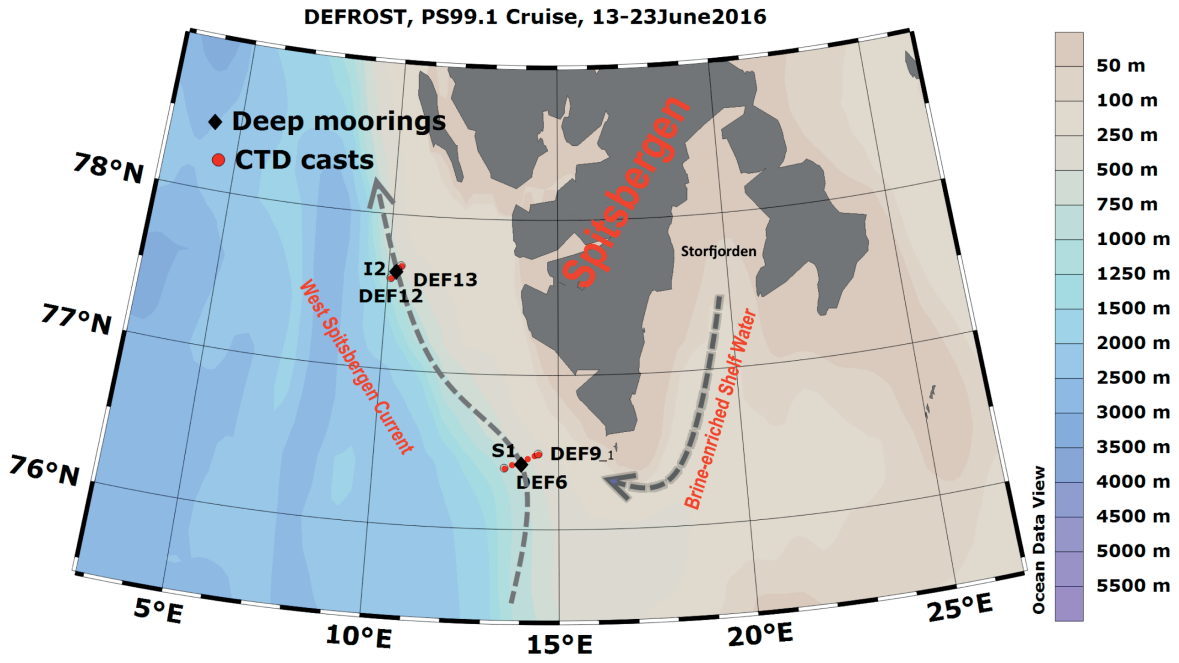

Fig. 4.1: DEFROST study area. Red dots and black diamonds indicate CTD casts and mooring (S1 and I2) positions, respectively

Work at sea

The DEFROST activities have been carried out mainly during June 21-22, 2016, when *Polarstern* approached the SW Svalbard region following the BURSTER activities in the Kveithola Trough (see Chapter 3). Sea and weather conditions were good. On June 21, mooring *S1* (Fig. 4.2) was recovered (operations started at 14:50 UTC and finished at 16:04 UTC), maintained (operations ended at 21:30 UTC), and finally re-deployed on June 22 (operations started at 02:30 UTC and finished at 05:14 UTC). The deployment phase required more time than expected due to the brakeage of a rope, which caused the damage of an acoustic release. The mooring *S1* was deployed in 1,063 m water depth at 76°26.265'N, 13°56.636'E (echo-sounder depth 1,040 m). Its recovery is foreseen during summer 2017. The mooring *I2* (Fig. 4.2) was recovered on June 22 (operations started at 13:45 UTC and finished at 14:50 UTC). After its recovery we proceeded with data download and instruments storage within the container.

Nine CTD casts were performed in the surroundings of the moorings locations down to 5-7 m above the seabed, in order to collect hydrological data throughout the entire water column and detailed information about bottom waters. Water samples were collected from NISKIN bottles to perform some biochemical analyses including pH (by pH-meter and spectro-photometer), total alkalinity (TA), dissolved oxygen (DO), dissolved inorganic carbon (DIC), hydrogen sulphide (H_2S), carbon dioxide (CO_2), methane (CH_4), dissolved inorganic nutrients (NUT), and microzooplankton (MZP) abundance and diversity.

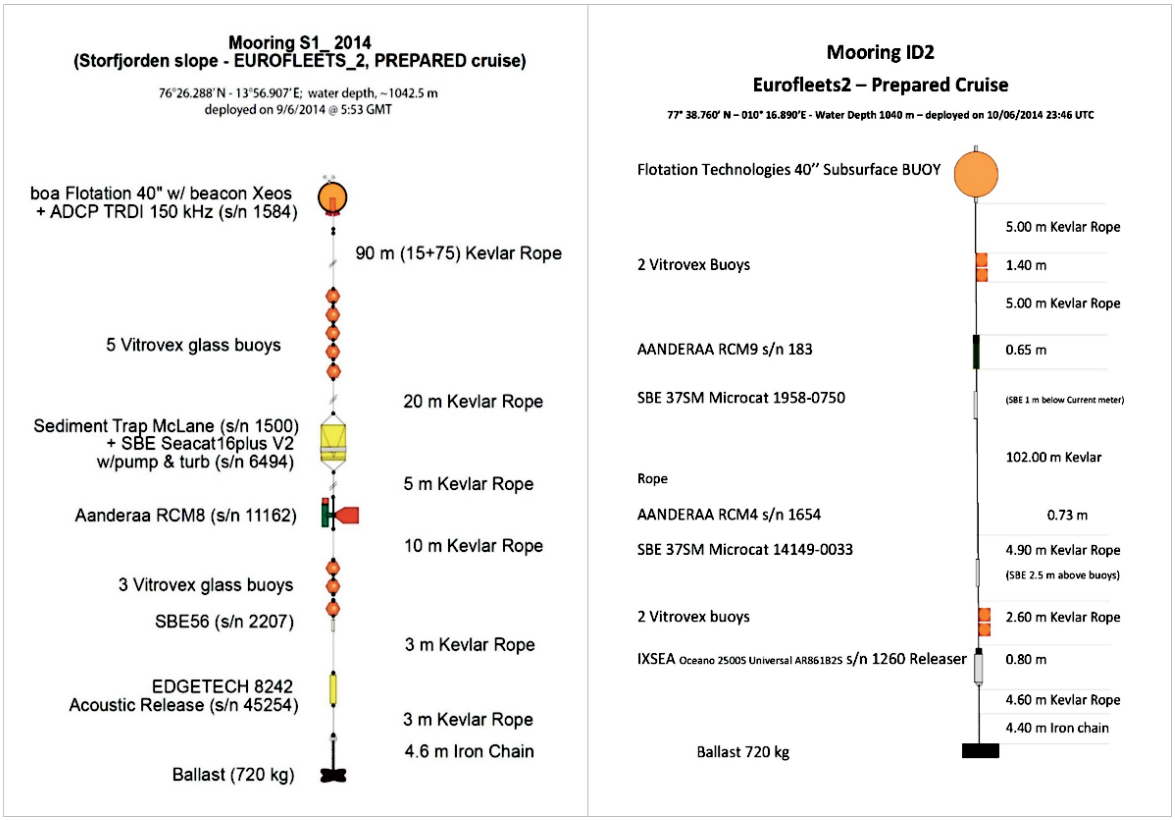

Fig. 4.2: DEFROST moorings S1 (left) and I2 (right)

Preliminary results

Vertical profiles from the CTD casts, time-series from mooring instruments (temperature, salinity, currents), and chemical analyses performed on board (DO and pH) are preliminary results. As an example, we show few plots: the temperature-salinity diagram in Fig. 4.3 a and the vertical distribution of potential temperature, salinity and beam transmission in Figs. 4.3 b and c. A detailed comparison of the DO sensor with the DO Winkler values is still to be performed.

Data management

Data gathered from moorings *S1* and *I2* (temperature, salinity, currents, sediment trap samples etc.) as well as those from multi-parametric CTD casts will be processed by OGS and CNR-ISMAR teams, in order to obtain quality checked time-series. The final format of the datasets will be Ocean Data View compatible. Few biochemical samples were partly analysed on board (DO and pH) and partly stored until the ship's arrival (October 2016), for the successive laboratory analyses. DO and salinity data from water samples will be used for quality check purposes of the CTD sensors. Data and metadata will be treated in accordance with the PNRA restrictions. Finally, they will be uploaded on the OGS NODC (National Oceanographic Data Centre), and made available for DEFROST partners.

Reference

Rebesco M et al. (2013) Quaternary contourite drifts of the Western Spitsbergen margin. Deep-Sea Research I 79, 156-168.

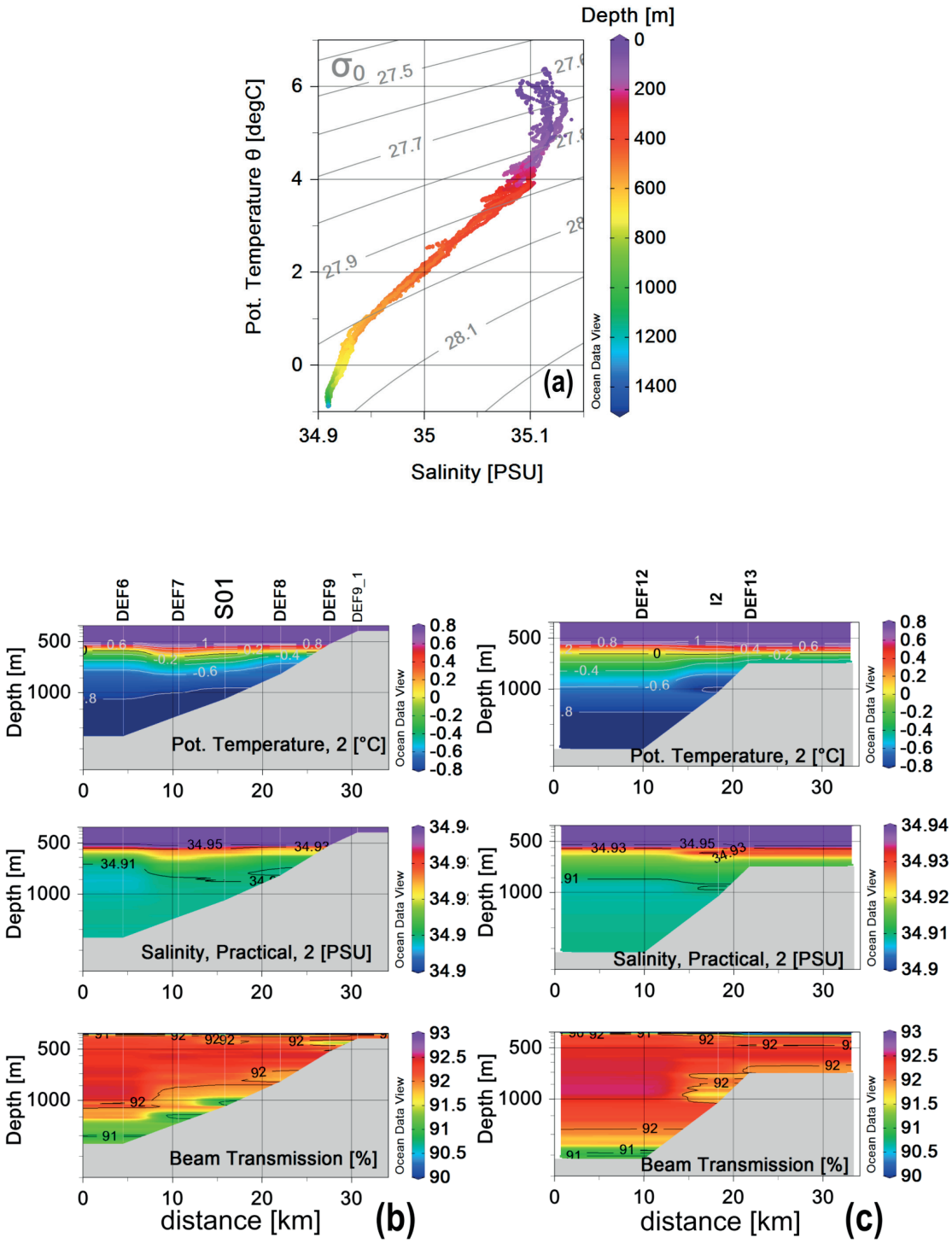

Fig. 4.3: Temperature-salinity diagram from CTD down-casts carried out during PS99.1 (a), vertical distribution of water temperature, salinity and beam transmission along two sections in the moorings areas S1 (b) and I2 (c)

5. ABUNDANCE AND LATITUDINAL DISTRIBUTION OF FLOATING MARINE LITTER AND NATURAL FLOTSAM

Lars Gutow, Claudia Daniel AWI

Grant No. AWI_PS99_00

Objectives

Recent observations indicate that the pollution of Arctic waters by anthropogenic litter has drastically increased. Substantial amounts of litter are found in the deep sea as well as floating at the sea surface in the Fram Straight region (Bergmann & Klages, 2012; Bergmann et al., 2016). Apart from the deleterious effects of plastic litter on marine habitats and organisms the accumulation of artificial flotsam may substantially enhance dispersal opportunities for organisms, which are able to colonise and persist on floating objects. The efficiency of rafting dispersal strongly depends on the availability and the persistence of suitable rafts. Especially plastic objects may facilitate rafting dispersal because of their buoyancy, high persistence and increasing availability in the marine environment. As a first step to understand the biogeographic implications of floating marine litter in Arctic waters it is essential to estimate the amount, distribution and composition of flotsam in that region and in adjacent regions, which may function as supply regions. To estimate the magnitude of change in rafting opportunities, quantities of anthropogenic litter have to be evaluated in comparison to the amount and composition of naturally occurring flotsam. During the transit (PS99.1) of RV *Polarstern* to Longyearbyen we conducted quantitative visual ship-based surveys on floating marine litter and naturally occurring flotsam. This work was continued during the expedition PS99.2.

Work at sea

Floating objects were recorded along the transit from Bremerhaven to Spitsbergen between 55°12'N and 77°06'N. From aboard the moving ship flotsam was quantified along transects parallel to the ship with an estimated width of 10 m. Observations were done by two persons: one major observer and one person responsible for the protocol (Fig. 5.1). For each floating object passing through the transect the position was recorded using a hand-held GPS as well as additional information such as type of object, colour and approximate size. Observation periods lasted between 25 and 61 minutes with breaks of a minimum of 1 h between two consecutive transects. During 31 hours of observation 32 transects were surveyed covering a total area of 5.9 km^2.

Preliminary results

A total of 999 floating objects of both natural and anthropogenic origin were registered. Natural flotsam consisted mainly of buoyant seaweeds (e.g. *Ascophyllum nodosum*, *Fucus* spp.) and bird feathers. Anthropogenic floating objects were very diverse ranging from smallest fragments of formerly larger objects to complete and easily identifiable items such as plastic foils and packaging material (Fig. 5.2). The visually detectable flotsam covered a wide size range from few centimetres up to 1.5 m. Anthropogenic objects were characterised by a broad colour spectrum making them often easily detectable at the sea surface.

Fig. 5.1: Scientists observing floating marine litter and natural flotsam during cruise PS99.1 of RV Polarstern (Photo: C. Le Gall)

Fig. 5.2: Beverage packaging observed floating south of Spitsbergen in June 2016 (Photo: C. Le Gall)

Torn-off seaweeds constituted the largest fraction of floating objects. However, almost 25 % of the flotsam was of anthropogenic origin indicating that floating marine litter may substantially alter the overall composition of flotsam in the northern North Atlantic. Abundance and distribution of floating marine litter did not show a consistent latitudinal gradient whereas the amount of floating seaweeds appeared to increase towards higher latitudes. Floating bird feathers were also common along the entire cruise. However, due to their relatively low persistence at the sea surface, they are expected to be of only minor importance for dispersal of rafting organisms.

Data management

All data collected during this survey will be made fully available through the PANGAEA data repository.

References

Bergmann M, Klages M (2012) Increase of litter at the Arctic deep-sea observatory HAUSGARTEN. Marine Pollution Bulletin 64, 2734–2741.

Bergmann M, Sandhop N, Schewe I, D'Hert D (2016) Observations of floating anthropogenic litter in the Barents Sea and Fram Strait, Arctic. Polar Biology 39, 553-560.

6. PHYSICAL OCEANOGRAPHY IN THE FRAM STRAIT

Sandra Tippenhauer, Florian Krauß AWI

Grant No. AWI_PS99_00

Objectives

The work of the Physical Oceanography group at AWI supported the EUROFLEETS2 projects BURSTER and DEFROST (see Chapters 3 and 4), and the biological and chemical work at the LTER (Long-Term Ecological Research) observatory HAUSGARTEN.

Work at sea

During the cruise a total of 31 conductivity-temperature-depth (CTD) profiles were taken. Measurements were taken using the ship's Seabird 911+ system. The CTD was equipped with twin temperature and conductivity sensors as well as single sensors for pressure and oxygen. Furthermore, a transmissiometer, a fluorometer, an underwater vision profiler (UVP) and a downward looking altimeter (range ~100 m) for bottom detection where attached. Serial Numbers of the Sensors are given in Table 6.1. The UVP was connected to the CTD unit for real-time data uplink. Unfortunately, the uplink was not working. Internal data recording was used instead. CTD-Data was recorded using SeasaveV7 software. The on-board data processing was done using AWI's ManageCTD programme.

Tab. 6.1: CTD system configuration overview during PS99

Device	Model number	Serial number
CTD underwater unit	SBE 9 plus	SN 485
Pressure	Digiquarz with TC	SN 0485
Temperature, primary	SBE 3	SN 2417
Temperature, second	SBE 3	SN 2460
Conductivity, primary	SBE 4C	SN 2054
Conductivity, second	SBE 4C	SN 2055
Oxygen	SBE 43	SN 0880
Fluorometer	WET Labs ECO-AFL/FL	SN 1670
Transmissometer	WET Labs C-Star	SN 946 DR
Underwater vision profiler	Hydroptic	SN 202
Altimeter	Benthos PSA916	SN 1228

For the collection of water samples 24 Niskin bottles (12 litres each) were attached to the CTD (Fig. 6.1). Salinity samples were taken for the calibration of the CTD´s conductivity sensors. The samples were analysed with the on-board Optimare Precision Salinometer (OPS). Water samples were furthermore used for analyses of several chemical and biological parameters (see Chapters 8 through 15). At five stations two casts were performed to cover the high water demand.

Fig. 6.1: Deployment of the CTD/Rosette Water Sampler off Spitsbergen

At six stations *in-situ* pumps were attached to the CTD wire at different depths (see Chapters 14 and 15). At these stations the CTD/Rosette Water Sampler was stopped at a safe distance of at least 20 m above the bottom (depending on the bottom slope up to 100 m) for one hour to allow for sufficient pumping time. The pumps were attached at the stations: PS99/0042-1, PS99/0048-1, PS99/0051-2, PS99/0053-2, PS99/0059-2, and PS99/0065-2.

Data management

The CTD data will be delivered after post-cruise calibration accomplished by the physical oceanography group to the PANGAEA database and to the appropriate national data centres.

7. PHYSICAL AND ECOLOGICAL PROCESSES AT MARINE FRONTAL SYSTEMS

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[2] Uni Oldenburg
[3] Uni Würzburg

Grant No. AWI_PS99_00

Objectives

The Fram Strait is a region featuring a complex hydrography. The northward flowing Atlantic water and the southward flowing Arctic Water form a front of strong gradients in temperature and salinity. Over the year, this front encounters only minor variations in its geographical location, but it shows meanders and eddies. Additionally, ice that is exported from the Arctic through the Fram Strait, melts and introduces meltwater fronts in the upper water column. These frontal systems are suspected to have a large impact on the biological production in the Fram Strait and beyond. However, the transient nature and the small scales of the phenomena make it difficult to conduct *in-situ* observations. To understand these systems, especially in a warming Arctic ocean, we need to understand the physical forcing and the associated biogeochemical response. As the ecologically relevant processes are confined to the upper water column where light is available (roughly above 50 m water depth), these processes cannot be investigated using a research vessel. A vessel would mix the upper water column such that the phenomena of interest become undetectable. Applying AWI's Autonomous Underwater Vehicle (AUV) "PAUL" (Fig. 7.1) the upper water column can be studied introducing only little disturbance to the system.

Using the AUV, the objective was to cover cross-front transects of several kilometres length. On its way, the AUV was supposed to gather high-resolution vertical or zigzag profiles between the surface and 50 m water depth. To get a hint on the along-front structure of temperature, salinity, and chlorophyll *a*, additional observations where conducted from a zodiac in about 400 m distance to the AUV transect.

This year we operated a microstructure package on the AUV for the first time. The microstructure package consists of two velocity shear, and two temperature probes. It was integrated into the AUV in the framework of the FRAM (Frontiers in Arctic Marine Monitoring) infrastructure programme. We aim at observing the distribution of temperature and velocity shear microstructure, to provide information on mixing processes along the frontal interface (detailed list of the operated instruments is given in Table 7.2 at the end of this report).

Along with the Acoustic Doppler Current Profiler (ADCP, WHM 300, Teledyne RD Instruments, SN: 23049), which was integrated within FRAM in 2015, and a Conductivity, Temperature, Depth probe (CTD, SBE 49, Sea Bird Electronics, SN: 4934161-0032), PAUL can map the physical conditions along a front comprehensively.

Biogeochemical sensors, such as a nitrate sensor (Deep SUNA, Satlantic, SN: 180), a chlorophyll *a* fluorometer (C7 c, Turner Designs, SN: 2100733), a dissolved oxygen sensor (SBE 43 f, Sea Bird Electronics, SN: 432056), and a fluorometer for coloured dissolved organic matter (C7 u, Turner Designs, SN: 2101994) can map the distribution of nutrients and phytoplankton biomass. An upward looking radiometer measuring irradiance between 400-700 nm (PAR, PAR-log-s, Satlantic, SN: 217) provides a detailed light profile and the depth of the euphotic zone. Surface PAR data are gathered by a ship mounted radiometer (Ramses, Trios).

The upper water column is strongly influenced by atmospheric forcing. In the vicinity of an ice field, the composition of the field and the drift of the ice represent further important factors affecting the surface water. In addition to satellite products we aim at observing the ice field's composition and its surface texture in our study area.

In the framework of the AUV operations and project ROBEX, Unmanned Aerial Vehicles (UAVs) are developed to autonomously map the ice cover using visual and infrared cameras. Provided by the University of Würzburg, a special infrared camera module was attached to a flying drone (Fig. 7.1) to collect aerial infrared images and to record temperature differences between ice and water. Additionally, UAVs were also used to deploy small GPS / Radio transceivers which provide information on ice drift. As the area, which can be covered by UAVs, is not sufficient at the moment, helicopter based mapping is conducted to support our studies.

Fig. 7.1: (Left) The AUV is being deployed. Note the orange nose cone, which was attached to mount the microstructure probes. (Right) One of the UAVs returns to Polarstern after a survey flight off the coast of Svalbard.

Scientific and technological objectives during expedition PS99.2:

- In the vicinity of frontal systems, record the upper 50 m of the water column by means of biogeochemical and physical parameters. Cover cross-front transects of several kilometres length with the AUV and a Zodiac.
- Successfully operate the microstructure probe from the AUV and gather data of mixing processes.
- Measuring water currents at a melt water front using a vehicle mounted ADCP.
- Determining relevant ice related parameters such as drift velocity, direction of drift and surface topography.
- Collect infrared data of an ice / water surface with an UAV.

Work at sea

During the expedition the AUV conducted four dives with the first dive being a merely technological test dive. Essential dive characteristics are summarized in Table 7.2 at the end of this report.

Dive 1

The first dive was conducted to check main vehicle systems. Running three short transects with a maximum mission depth of 53 m, basic vehicle functions and different ADCP settings were tested. The later scientific mission profile was tested and the vehicle control system´s reaction on the newly designed nose cone was evaluated. Trimming of the vehicle turned out to be insufficient with the AUV “stranding” at the surface as it was almost unable to dive by itself. Weight was added and the wake of the Zodiac was used to push the vehicle below the surface. Eventually these problems led to a shortening of the test dive. After the dive had been accomplished the vehicle was recovered without any problems. Data of the Deep SUNA nitrate sensor indicated a malfunction of the device. The sensor was replaced by an identical instrument (SN: 631).

Dive 2

The second dive was the first scientific dive. It was conducted close to an ice edge. The associated meltwater front was detected prior to the dive by using *Polarstern*’s thermosalinograph which constantly measures temperature and salinity in 5 and 11 m water depth, respectively. The AUV was deployed on the “warm” side of the front (Atlantic Water). During the dive the AUV approached the ice edge. The dive had to be aborted due to a software failure after the vehicle covered about 30 % of the overall mission. During the dive, about 7,700 aerial images of the associated ice field were taken by helicopter.

Dive 3

The third dive was also conducted close to an ice edge, although no clear sign of a meltwater front could be found. Due to the close proximity of the ice, its edge was marked with a GPS / Radio transceiver which was deployed by a remote controlled flying drone. The AUV was supposed to cover a transect of about 10 km length. However, after 5 km, the dive had to be aborted due to a severe ground fault in one of the AUV’s power circuits. During the dive, two helicopter mounted cameras took roughly 10,800 aerial images of the ice field. Simultaneously to the AUV, a total of ten 50 m deep vertical profiles of salinity, temperature and fluorescence were collected from the Zodiac.

Dive 4

The fourth dive was conducted at the polar front, which permanently stretches through the Fram Strait. This front indicates the boundary between Atlantic and Polar water masses and is not necessarily associated to the ice edge. Here, the AUV was deployed on the warmer Atlantic side of the front to cover a transect of 10 km length. The vehicle permanently varied its depth between 53 and 3 m water depth. Roughly every 1,000 m, the vehicle surfaced for 90 seconds to receive a GPS signal to compensate for the drift of its inertia navigation system. At the same time as the AUV, the Zodiac collected 14 vertical profiles of salinity, temperature and fluorescence along a transect parallel to the AUV path.

Preliminary results

In the following paragraphs the preliminary results of the different dives are presented. Only the uncalibrated voltage data of the chlorophyll *a* fluorometer and the nitrate sensor as well as the temperature and the conductivity are shown as all other parameter still need extensive processing.

Dive 2

During dive 2 a cold, low saline water layer of 15 m thickness was observed at the surface (Fig. 7.2: (Upper left) temperature, (Upper right) conductivity, (Lower left) chlorophyll a, and (Lower right) nitrate data of PAUL´s second dive2). Below that layer, fluorescence data illustrate elevated amounts of chlorophyll a to a max. depth of 30 m. At the surface, low nitrate values were detected, although nitrate does not appear to be totally depleted in the upper 20 m.

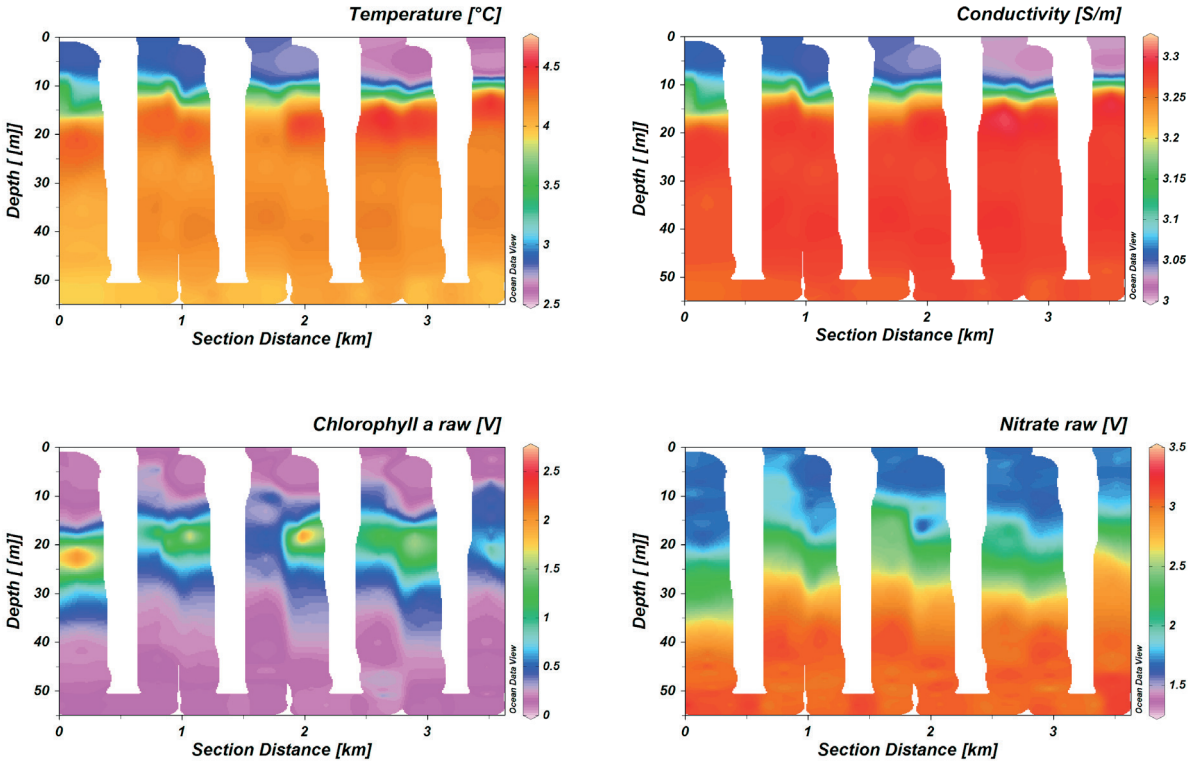

Fig. 7.2: (Upper left) temperature, (Upper right) conductivity, (Lower left) chlorophyll a, and (Lower right) nitrate data of PAUL´s second dive

Dive 3

Using *Polarstern*'s underway system no clear front could be found. Also the AUV observations do not show a clear frontal system (Fig. 7.3: (Upper left) temperature, (Upper right) conductivity, (Lower left) chlorophyll a, and (Lower right) nitrate data of PAUL´s third dive3). The water column consisted of an irregular mixture of cold, low saline and warm, high saline water masses down to a depth of about 25 m. Below 25 m water depth, the structures become more homogenous showing the physical characteristics of Atlantic water masses. Chlorophyll a appears to be concentrated below this boundary line between 30 and 50 m water depth within the Atlantic

water masses. Represented by a steep gradient in the nitrate concentration, a nutricline can be detected in 40 m water depth.

Dive 4

The fourth dive was conducted away from the ice edge at a branch of the Polar front. A section distance of 3 km (Fig. 7.4: (Upper left) temperature, (Upper right) conductivity, (Lower left) chlorophyll a, and (Lower right) nitrate data of PAUL´s fourth dive4) represents the frontal interface between the warm Atlantic side of the front (left) and the cold Polar side (right). The Atlantic side of the front is formed by a water body of 6 to 8°C that reaches from the surface to 50 m water depth. The Polar side consists of a water body of -2 to 0°C that reaches down to 50 m water depth, yet is overlaid by a water body of “intermediate” physical characteristics. This particular water layer of 2°C covers the surface of the Polar side of the front to a maximum depth of 20 m.

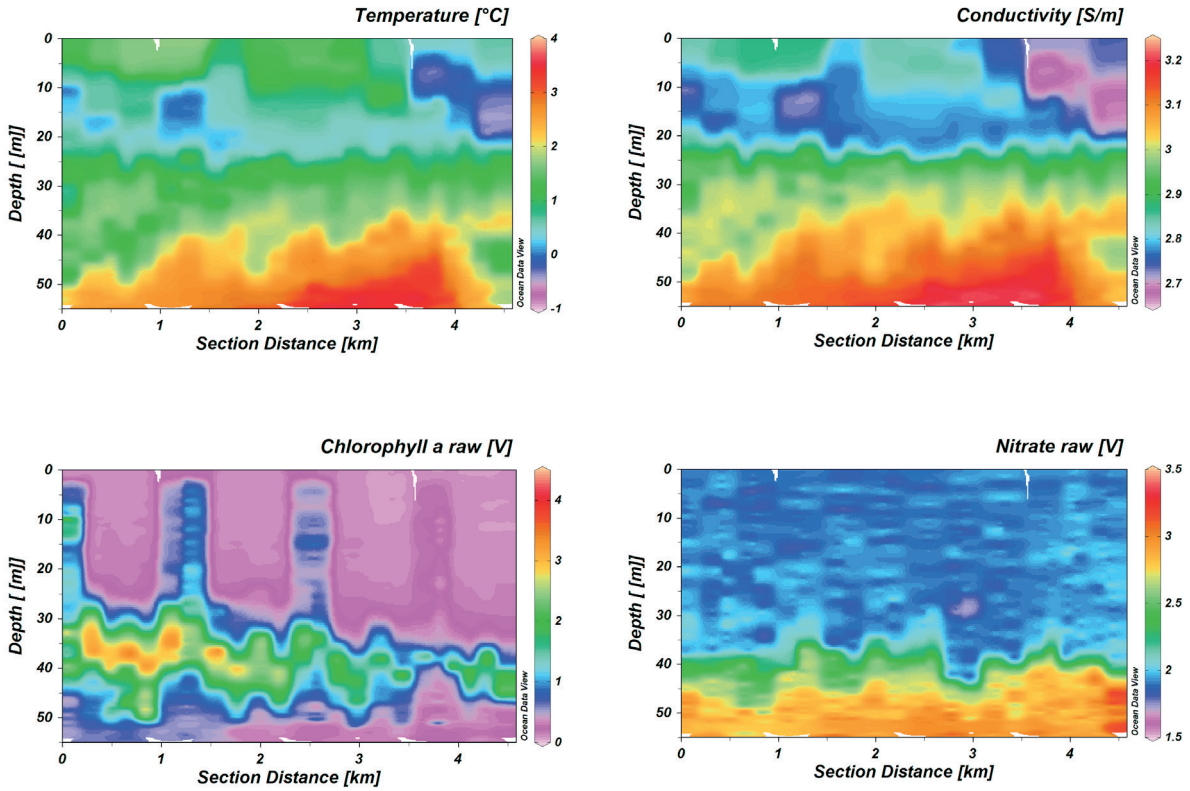

Fig. 7.3: (Upper left) temperature, (Upper right) conductivity, (Lower left) chlorophyll a, and (Lower right) nitrate data of PAUL´s third dive

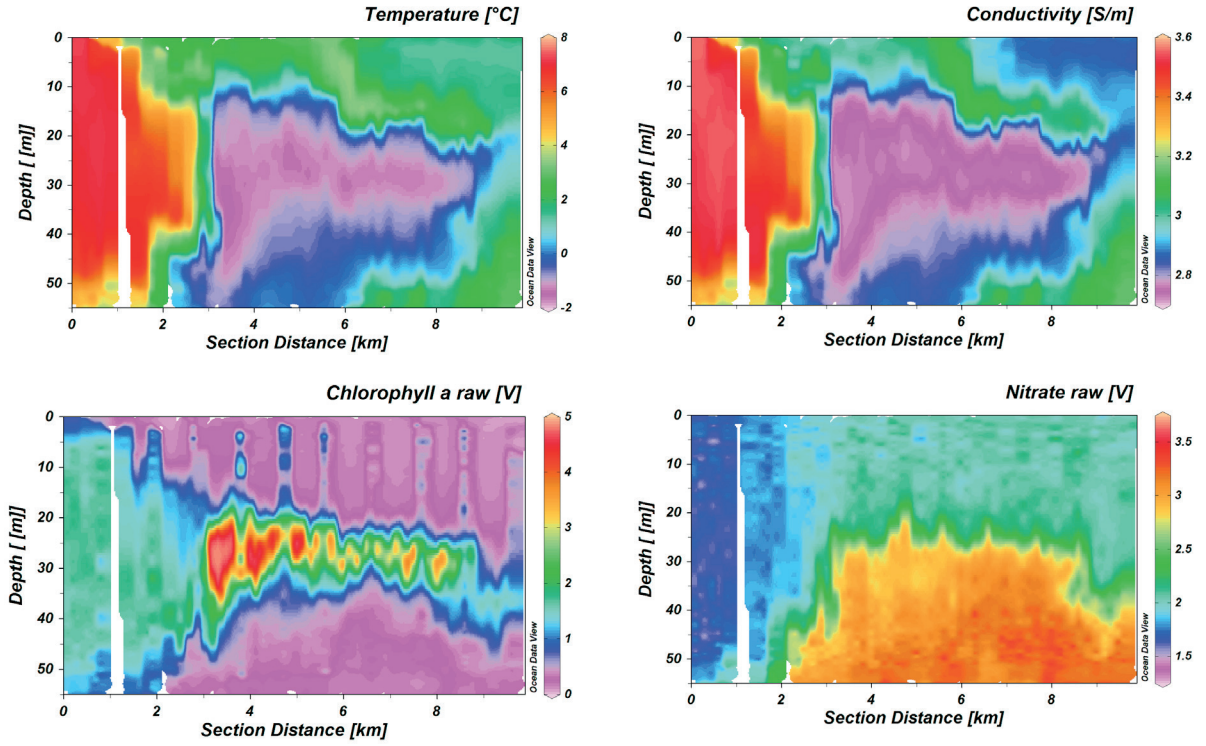

Fig. 7.4: (Upper left) temperature, (Upper right) conductivity, (Lower left) chlorophyll a, and (Lower right) nitrate data of PAUL´s fourth dive

The temperature and conductivity differences are huge, reaching 8 K and 1.8 S m^{-1}, respectively, within just 1 km horizontal distance at the frontal interface. Remarkably, the cold water masses contain the highest amounts of chlorophyll *a* which is concentrated between 20 and 30 m water depth. The Atlantic water masses show lower values, yet chlorophyll *a* appears to be distributed more homogeneously. On the Atlantic side of the front, nutrients appear to be hardly abundant over the entire investigated water column. On the Polar side, however, nitrate concentrations at the surface are comparably high and a clear nutricline can be seen at about 25 m water depth.

Data management

As soon as data are processed completely they will be uploaded on the PANGAEA database. The ADCP and the microstructure processing are still in an experimental stage. Data will be submitted to PANGAEA as soon as the processing is completed.

Table 7.1: Microstructure package operated during PAUL´s deployments during PS 99.2.

Station Number	Dive ID	Serial Numbers Shear Probe 1		Serial Numbers Shear Probe 2		Serial Numbers Temperature Probe 1		Serial Numbers Temperature Probe 2	
		MicroPod S	Shear Sensor	MicroPod S	Shear Sensor	MicroPod T	Temperature Sensor	MicroPod T	Temperature Sensor
PS99/0043-2	30	199	1468	200	1469	195	1209	196	1210
PS99/0053-9	31	201	1470	200	1469	195	1210	196	1212
PS99/0059-5	32	201	1470	200	1469	195	1209	196	1212
PS99/0075-1	33	201	1471	200	1469	195	1209	197	1212

Table 7.2: Basic data on PAUL´s deployments during PS 99.2.

Station number	Dive ID	Launch Date	Launch Time (UTC)	Launch Position	Recovery Time (UTC)	Recovery Position	Duration	Distance [km]	Max. Depth [m]	Samples	Zodiac casts
PS99/0043-2	30	27.06.2016	15:53	78° 36.86' N 005° 02.18' E	18:47	78° 37.19' N 005° 02.52' E	02:54	2.9	53.7	0	2
PS99/0053-9	31	04.07.2016	09:51	79° 55.82' N 003° 40.76' E	13:47	79° 56.01' N 003° 33.23' E	03:56	5.9	54.8	0	0
PS99/0059-5	32	07.07.2016	08:47	79° 07.43' N 002° 48.88' E	13:00	79° 05.41' N 002° 58.15' E	04:13	5.9	57.2	0	10
PS99/0075-1	33	12.07.2016	07:08	79° 02.66' N 004° 31.90' E	13:20	79° 05.76 N 004° 09.66' E	06:12	18.6	100.8	20	14

8. *IN-SITU* SENSORS AND UNDERWAY MEASUREMENTS

Daniel Scholz, Klaus-Uwe Richter, Sebastian Rokitta, Laura Wischnewski; not on board: Maria Nielsdóttir, Björn Rost — AWI

Grant No. AWI_PS99_00

Preface

The observed rapid decline in summer sea ice extent has led to surface water freshening, thus exacerbating the temperature-dependent stratification and potentially reducing the supply of nutrients from deeper waters. The reduction in ice cover also allows for more light penetration and prolonged growing seasons, potentially stimulating primary production. Based on these alterations, one could expect the Arctic Ocean to move from a predominantly light-controlled (ice-covered) to a more nutrient-controlled (open water) system. Due to these rapid changes, knowledge about carbonate chemistry, nutrient concentrations and their dynamics becomes more and more important to understand the biogeochemistry of the Arctic system and potential ecological consequences.

Objectives

An established alternative to manually analysed water samples is the deployment of *in-situ* measuring sensor platforms. Such an approach yields a high-resolution dataset, whereby diffusive fluxes of nutrients across the pycnocline can be more reliably estimated. However, most commercially available *in-situ* sensors are designed and calibrated to operate under a wide range of oceanographic conditions. Deploying such devices in the Arctic Ocean imposes certain challenges. Surface water temperatures are frequently below 0°C and nitrate concentrations may be as low as 0.2 µM. Consequently, the Arctic represents an area characterized by environmental properties that fall outside the range of standard sensor configurations. The quality and reliability of sensor-derived data depends on the sensor's calibration and electrical characteristics, e.g. among others, detection threshold, resolution, accuracy, temperature range and sensor drift. Based on previous results obtained during *Polarstern* expedition PS94, our main objectives were to test the performance of a Satlantic ISUS V3 and SUNA DEEP nitrate sensor as well as a Contros HydroC pCO_2 sensor. Our principal interest was to evaluate the impact of temperature on the sensor's accuracy when values are close to the detection threshold.

To determine biological activity in aquatic systems and to classify biogeochemical processes therein, an innovative, ship-going measurement system, based on Membrane-Inlet Mass Spectrometry (MIMS) was constructed at the AWI. This system can be connected to a flow of water and is able to directly and continuously measure the abundances of the gases argon, oxygen and carbon dioxide. Since the noble-gas argon is non-reactive and equally distributed throughout the oceans, its abundance-relation to oxygen (which is set free by photosynthesis and consumed in respiration) can be used to infer whether aquatic systems are characterized rather by phototrophic or heterotrophic activity. The constructed instrument is also designed

to automatically and regularly conduct self-calibrations using connected reference gases, increasing the reliability and signal confidence. In addition to the MIMS, the performance of two other underway flow-through measuring devices analysing nutrients (NO_3, NO_2, PO_4, Si) and determining Total Alkalinity (TA) was continuously monitored.

Work at sea

The nitrate *in-situ* sensors were configured in a pumped system using a SBE5T underwater pump. The Contros HydroC sensor was deployed with its own pump, since it is calibrated by the manufacturer in this configuration. The sensor's behaviour and data storage was managed by a central micro-controller unit. All sensors and one battery enclosure were combined in a module (Fig. 8.1), deployed on the winch cable, measuring NO_3 and pCO_2 profiles down to about 140 m water depth. To evaluate the sensor's accuracy, discrete water samples were taken from the CTD/Rosette Water Sampler and analysed for nitrate using a Quattro auto analyser.

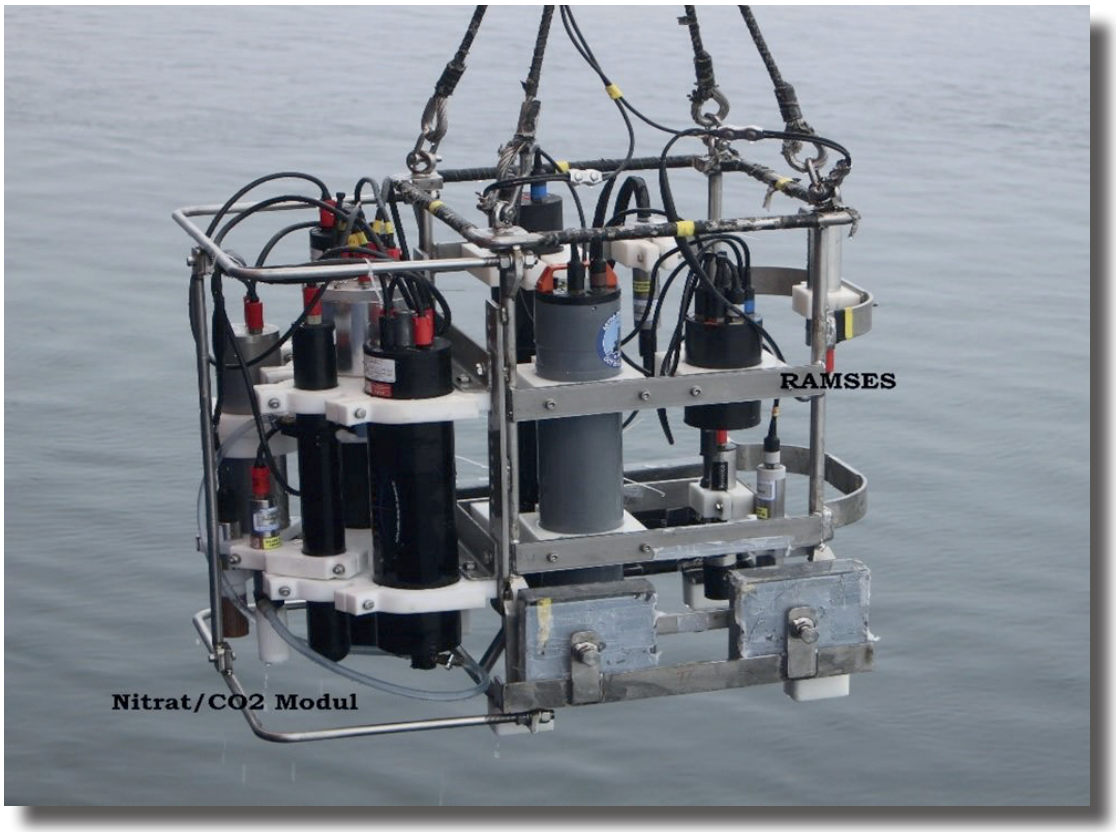

Fig. 8.1: Sensor module attached to RAMSES frame

Furthermore, a MicroMac nutrient analyser, developed by colleagues at the Helmholtz-Zentrum Geesthacht, was installed for a second time during the arctic season, measuring NO_3, NO_2, PO_4, and Si. In addition, a Contros HydroFIA analyser was installed to monitor total alkalinity (TA). The data quality of both flow-through systems will be assessed by discrete samples taken from the seawater supply lines. Although nutrients could be directly measured on board with the Quattro analyser, discrete samples for TA had to be stored for future analysis at AWI using a VINDTA system. The MicroMac nutrient analyser required calibrating with standard solutions on a weekly basis and analytical reagents freshly prepared and loaded into the automated system.

The new ship-going MIMS (Fig. 8.2) was installed in the *Polarstern* wet lab and tested towards its ability to conduct continuous underway measurements of argon, oxygen and carbon dioxide directly from the ship's water stream. The programming of the automated self-calibration routines could be finished on board. Emergency programmes for MS-shutdowns, valve-closures and water flow regulation to avoid damage and harm in case of unattended malfunction were implemented.

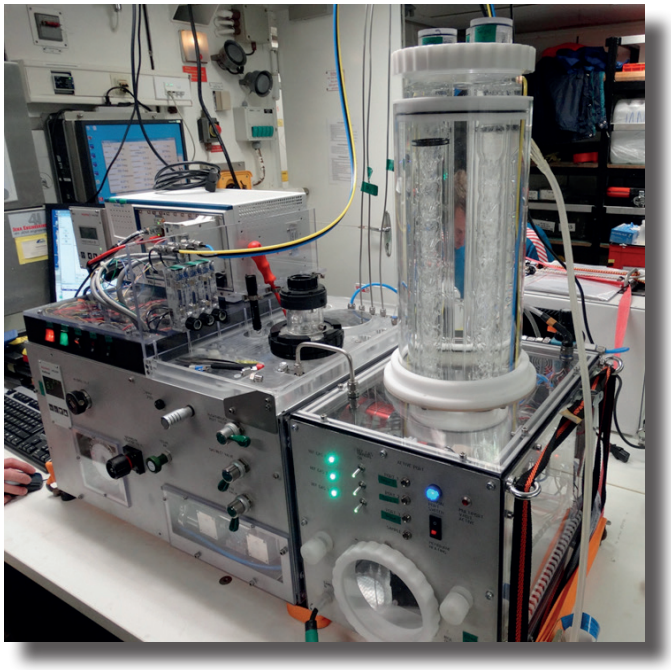

Fig. 8.2: The new Membrane-Inlet Mass Spectrometry (MIMS) on Polarstern

Preliminary results

Protocols and manuals for the installation, connection and operation of the MIMS were developed and written down for later use by other personnel. The automated self-calibration routines were successfully programmed and designed for later modification by the operators. Calibration procedures with reference gases were implemented, tested and largely successful. Emergency programmes were successfully established, protecting the instrument from damage in case of unattended malfunctions. We could monitor the signals of argon, oxygen and carbon dioxide over three days continuously with sufficient signal stability. Further development of the inlet system is required to increase signal dynamic range and precision.

The flow-through systems MicroMac and HydroFIA showed some unexpected technical issues and were only operative at irregular intervals. The influence of this calamity on the overall data quality is yet to determined. Both systems will be maintained and operative during PS101 again.

The data obtained from all *in-situ* sensor deployments and flow-through systems is still in the post processing state. The post processing of the nitrate sensors requires temperature and salinity data obtained with the CTD and the discrete nutrient data. Currently, not all parameters are available. Also, discrete samples to be measured with the VINDTA system at AWI are not available until *Polarstern* returns at the end of October.

Data management

All data will be post processed and quality assured data will be uploaded to PANGAEA.

9. MARINE NITROGEN CYCLING AND MICROBIAL ECOLOGY

Allison Fong; AWI
not on board: Anya Waite

Grant No. AWI_PS99_00

Objectives

The process of biological dinitrogen fixation is the conversion of dinitrogen gas to ammonia. Dinitrogen fixation is an energetically expensive process and iron is required in nitrogenase enzyme complex. Additionally, *in vitro*, the nitrogenase enzyme (*nifH*) is sensitive to inactivation by oxygen. Classically, biological dinitrogen fixation is believed to be limited to subtropical and tropical regions of the worlds' oceans, with waters warmer than 25°C and depleted in inorganic nitrogen, such as nitrate. Recent work has shown a greater geographical extent and more diverse *nifH* phylogeny than previously believed, with low, but measurable rates of dinitrogen fixation and recovery of *nifH* genes from polar regions.

Biological nitrogen fixation in aquatic habitats is limited to organisms possessing the *nif* operon. The *nifH* gene is the most common *nif* gene used to identify and quantify the community and expression of nitrogen-fixing organisms. Additionally, dinitrogen fixation rates can be measured by applying a $^{15}N_2$ tracer technique, in which microbial communities are incubated with $^{15}N_2$-enriched seawater.

We plan to use a combination of experiments and techniques to measure dinitrogen fixation rates, characterize the diazotroph community, and measure *nifH* gene expression. Our aim is to broadly sample multiple arctic environments and link rates of nitrogen fixation to the portion of the microbial assemblages responsible for this process. This work is an extension of a set of experiments conducted on PS92 in summer 2015, so together these rate measurements will provide a more comprehensive understanding of nitrogen cycling processes in the Arctic Ocean.

Work at sea

Discrete water column samples from surface waters, the chlorophyll maximum layer, 50, 75, and 100 meters were subsampled from Niskin bottles attached to the CTD/Rosette Water Sampler. On average, 12-20 litres were subsampled from each depth for nitrogen fixation rate measurements, particulate carbon and nitrogen (PCPN), and collections of microbial DNA and RNA. Incubation experiments with $^{15}N_2$-labeled seawater were performed to measure dinitrogen fixation rates at 11 stations across the Fram Strait. Duplicate nitrogen fixation rate measurement incubations were performed in 4.5 and 2.3 L clear polycarbonate bottles from each depth. Bottles were spiked with ^{15}N-N_2 gas enriched artificial seawater to a final concentration of ~5 atom %, and with ^{13}C-bicarbonate solution to a final concentration of ~100 µmol L^{-1}. All bottles were shaded with neutral density mesh, and incubated in on-deck incubators plumbed with surface seawater for 24 hours. In total, 123 nitrogen fixation rate samples were collected and will potentially provide significant and new observations of both vertical and horizontal spatial distributions of cold-adapted nitrogen-fixing populations and activity.

Additionally, 1-4 litres of seawater were in-line size-fractionated (>10 µm and 0.2 µm) for DNA and RNA collections. Genomic, transcriptomic, and functional gene analysis will be

performed on these samples to assess the active diazotroph community and nitrogen fixation rates. In total, 157 DNA/RNA samples were collected and will be extracted at the AWI onshore laboratory. 16S rRNA bacterial and archaeal gene libraries and *nifH* gene/transcript libraries will be generated via high throughput sequencing technologies to measure prokaryotic community diversity, relative activity, and gene expression.

Additionally, triplicate 2 mL flow cytometry samples were collected from corresponding nitrogen fixation rate measurement depths. Flow cytometry samples were preserved to a final concentration of 0.2 % PFA. In total, 54 unique flow cytometry samples were collected on the cruise.

Expected results

Sampling is expected to result in measurements of the spatial distributions of nitrogen fixation rates, ***nifH*** gene expression patterns, and characterizations of microbial assemblages across the Fram Strait. A majority of samples will be analysed at the AWI onshore laboratory. Rates, expression patterns, and assemblage composition will be analysed in the context of hydrographic and biogeochemical data. Based on previous studies in the Arctic Ocean, we anticipate differences in the relative nitrogen fixation rates between the western and eastern sectors of the Fram Strait due to the influence of source waters.

Data management

Most data will be obtained through laboratory analyses after the cruise. Sample processing times are dependent upon parameter and analysis methods. Sequence data will be uploaded to public open access sequence databases. Data will be available on PANGAEA data repository within one year of the cruise. Data will be published in open access journals. Cruise participants and research partners can obtain data upon request.

10. FREE-LIVING AND PARTICLE ATTACHED PROKARYOTIC COMMUNITY STRUCTURE

Ian Salter, Theresa Hargesheimer AWI
Morten Iversen, Andreas Rogge

Grant No. AWI_PS99_00

Preface

An important goal in microbial oceanography is to link the extensive diversity of marine bacteria to environmental conditions, ecosystem function and climate sensitivity. This is particularly relevant in the Arctic Ocean since microbial communities remain quite poorly characterised in comparison to other oceanic regimes. Furthermore, the Arctic is experiencing rapid changes in environmental conditions, including but not limited to changes in temperature, sea-ice cover and the structure of pelagic ecosystems. Combined spatial sampling regimes of microbial community diversity and oceanographic parameters have emerged as a powerful approach to understand how prokaryotic communities are distributed across ecological niches. However, these types of study are relatively sparse in the Arctic.

Microbes are also known to exhibit differences in phylogenetic structure across different size fractions, which are related to their metabolisms and provides a direct link with their importance in regulating biogeochemical fluxes. In particular, the degradation of substrates on suspended and large marine aggregates may be related to resident microbial communities. A full characterisation of these particle-attached communities and how they relate to physical and chemical particle properties is an important component of our research in the Arctic.

Objectives

The objectives of this work package are primarily to extend the spatial and temporal coverage of bacterioplankton communities integrated with physical and biogeochemical characterisation of the water masses. There are distinct water masses present in the Fram Strait, with northward-flowing Atlantic water that comprises the West Spitsbergen Current characterising the eastern side of the strait, and polar outflow waters comprising the East Greenland Current on the western side. One objective is to characterise the common and novel bacterial lineages that are present in these two water masses. The centre of the Fram Strait is characterised by complex mesoscale variability in water masses. By characterising signature lineages of prokaryotes linked to water masses one can assess the effects of physical mixing on the persistence and loss of certain lineages. Additionally, in order to understand the impacts of environmental change on microbial ecosystem structure and functioning one needs to establish a baseline of observations, to which this sampling contributes. In the first instance, this is related to trying to construct a detailed biogeography of marine bacterioplankton in the Fram Strait and surrounding areas. In addition to the work assessing community structure we also aimed to quantify the respiration of bacterial communities using a proxy that relies on the in vivo reduction of a tetrazolium salt. To complement the information on relative abundance data that is acquired from next generations sequencing of bacterial communities, our objective is to also collect parallel samples for analyses that can determine the absolute abundance of

key phylogenetic groups. Finally, we aim to characterise the bacterial communities associated with aggregates and suspended particles, and in particular how these differ from free-living communities.

Work at sea

Seawater samples were taken at selected stations for various parameters pertaining to the characterisation of prokaryotic community structure and activity (Table 10.1). For water column work all samples were taken from the CTD/Rosette Water Sampler and subsampled in a sterile fashion (UV-irradiated material). For water column work, 2-4 litres of seawater collected from the surface, chlorophyll maximum and below the chlorophyll maximum and were filtered over a 0.2 µm Sterivex cartridges using a low-pressure peristaltic pump. The samples were preserved at -80°C. Parallel samples were taken for FISH and following killing the cells with paraformaldehyde, 50 mL of sample was filtered over 0.2 µm polycarbonate filters. Samples from the chlorophyll maximum only were used for an estimation of prokaryotic respiration from the INT reduction assay as part of a method development project. Samples were partially processed at sea but the final analysis will take place at the home laboratory. In addition, numerous samples for particle-attached bacteria were taken from marine snow catcher deployments. The Marine Snow Catcher (MSC) was deployed at depths ranging from 40-200 m depending on CTD or UVP data documenting maxima in chlorophyll features and/or particle abundance. Upon recovery the marine snow catcher remained on deck for several hours to allow larger and faster sinking aggregates to settle into a bottom chamber whereby they were subsequently removed and filtered over a 0.2 µm Sterivex filters and stored at –80°C. The overlying water was size fractionated using a peristaltic pump and in-line filtration set-up with filter sizes of 10, 3, and 0.2 µm. Samples were stored at -80°C

Tab. 10.1: Summary of the samples taken during PS99; DNA prokaryotes (water column) refers to filtrations of seawater from surface, chlorophyll maximum, and below chlorophyll maximum; DNA prokaryotes (particles) refers to samples taken with the marine snow catcher, aggregates and suspended matter separated over size fractions of 10, 3, and 0.2 µm; FISH prokaryotes (water column) refers to samples taken from surface, chlorophyll maximum and below chlorophyll maximum for Fluorescence In-Situ Hybridisation (FISH); Prokaryotic respiration (INT reduction assay) refers to samples taken from chlorophyll maximum for enzymatic estimates of respiration. Numbers in table refer to the number of samples taken.

Station	DNA Prokaryotes (water column)	DNA Prokaryotes (Particles)	FISH Prokaryotes (water column)	Prokaryotic respiration (INT reduction assay)
HG-I	6		3	
HG-II				
HG-III				
HG-IV	6	9	3	
HG-V	6			

Station	DNA Prokaryotes (water column)	DNA Prokaryotes (Particles)	FISH Prokaryotes (water column)	Prokaryotic respiration (INT reduction assay)
HG-VI				
HG-VII				
HG-VIII				
HG-IX	6		3	8
N5	6	19	3	
N4	6	14	3	8
N3				
EG-I	6	13	3	
EG-II	6		3	
EG-III	6		3	
EG-IV	6	14	3	8
SV-IV	6	14	3	
SV-III	6		3	
SV-II	6	14		
SV-I	6		3	
S3	6		3	8

Preliminary results

All of the samples taken on-board will be analysed at the home laboratory in Bremerhaven. The water column and particle samples obtained from CTD and Marine Snow Catcher deployments, respectively, will be extracted to yield genomic DNA that will be sequenced with primers targeting marine bacteria and archaea.

Data management

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.

11. HAUSGARTEN: LONG-TERM ECOLOGICAL RESEARCH IN THE ARCTIC OCEAN

Deep-Sea Research Group, AWI
Coordination Ingo Schewe

Grant No. AWI_PS99_00

While always fluctuating, the global climate is presently experiencing a period of constantly increasing temperatures, with a warming trend amplified in the Arctic. Results of large-scale simulations of the Earth's future climate by several global climate models predict a continuous increase in air and water temperatures, also leading to further reduction in ice-cover. Since the 1950s, sea ice retreat in the Arctic Ocean has been relatively modest at rates of 3-4 % per decade. However, since the late 1990s, annual-averaged shrinking rates accelerated to 10.7 % per decade, whilst the summer sea ice extent has shrunk even more rapidly. According to the US National Snow and Ice Data Center (NSIDC), arctic sea ice during the 2012 melt season has reached its lowest extent since satellites began measuring sea-ice in 1979, with 44 % ice coverage below the 1981-2010 average, and 16 % ice coverage below the previous minimum extent in 2007.

The shift from an ice-covered and cold ocean to an ice-free and warmer ocean will have severe impacts on the polar marine ecosystem and its functioning. Thinner ice may permit better growth of ice algae, but earlier and faster spring melting may reduce their growing season. Locally, thinner ice floes with a multitude of melt ponds allow enhanced light transmission and may increase phytoplankton growth beneath the ice. Altered algal abundance and composition will affect zooplankton community structure and subsequently the flux of particulate organic matter to the seafloor, where the changing quantity and quality of this matter will impact benthic communities. Changes in the predominance of certain trophic pathways will have cascading effects propagating through the entire marine community. Generally, arctic marine organisms will be compromised by temperature regimes approaching the limits of their thermal capacity. As a consequence, warmer waters in the Arctic will allow a northward expansion of sub-arctic and boreal species. Besides water temperature increase, expanding ocean acidification will pose another threat to pelagic and benthic life in the Arctic Ocean.

To detect and track the impact of large-scale environmental changes on the marine ecosystem in the transition zone between the northern North Atlantic and the central Arctic Ocean, the Alfred Wegener Institute, Helmholtz-Centre for Polar and Marine Research (AWI) established the LTER (Long-Term Ecological Research) observatory HAUSGARTEN in the Fram Strait between NE Greenland and the Svalbard archipelago. Since 1999, repeated sampling in the water column and at the seafloor during yearly expeditions in summer months was complemented by continuous year-round sampling and sensing using autonomous instruments on anchored devices. The central HAUSGARTEN station at about 79°N, 04°E in the eastern Fram Strait (~2,500 m water depth) serves as an experimental area for unique biological experiments at the deep seafloor, simulating various scenarios in changing environmental settings.

The LTER observatory HAUSGARTEN is located in a region which is influenced by the highly productive Marginal Ice Zone (MIZ) in the Fram Strait. Currently, HAUSGARTEN constitutes a network of 21 permanent sampling sites, the majority of which are located along a bathymetric transect between ~250 m and 5,500 m water depth at about 79°N from the Kongsfjorden (Svalbard) in the east, along the Vestnesa Ridge towards the Molloy Hole (i.e. the deepest known depression in the Arctic Ocean) and across the Greenland continental margin (stations in the western Fram Strait were newly established in 2014). Three sampling sites close to the ice edge between 79°30'N and 80°00'N in the north-eastern Fram Strait and a supplementary site in a permanently ice-free area at 78°30'N in the eastern part of the strait complete the network (Fig. 11.1).

Time-series studies at the HAUSGARTEN observatory provide insights into processes and dynamics within an arctic marine ecosystem and act as a baseline for further investigations of ongoing changes in the Fram Strait. Long-term observations at HAUSGARTEN will significantly contribute to the global community's efforts to understand variations in ecosystem structure and functioning on seasonal to decadal time-scales in an overall warming Arctic and will allow for improved future predictions under different climate scenarios.

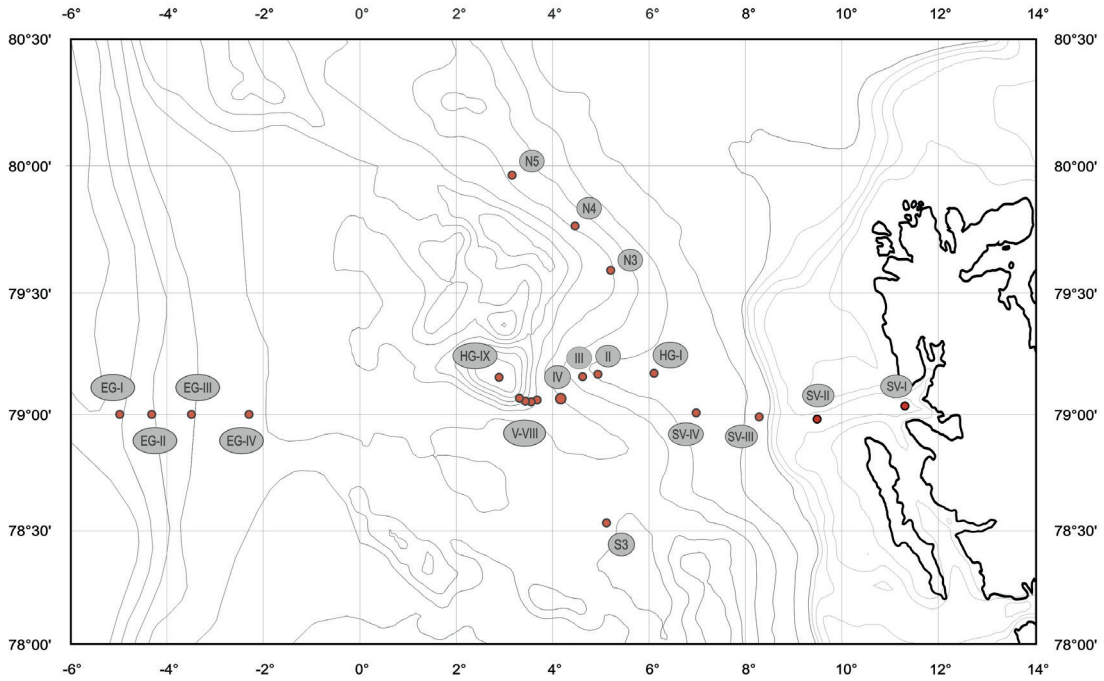

Fig. 11.1: Permanent sampling sites at the LTER observatory HAUSGARTEN

11.1 Fixed-point moorings as autonomous platforms

Ian Salter[1], Eduard Bauerfeind[1], Theresa Hargesheimer[1], Nadine Knüppel[1], Normen Lochthofen[1], Janine Ludszuweit[1], Daniel Scholz[1], Sinhue Torres Valdes[2];
not on board: Eva-Maria Nöthig[1], Maria Nielsdottir[1]

[1] AWI
[2] NOCS

Objectives

Ongoing climate change will impact marine ecosystems in a variety of ways, and polar environments are believed to be particularly sensitive to these changes. Increasing atmospheric CO_2 concentration will lead to a reduction of ocean pH, which is expected to exert a significant impact on marine calcifying organisms. Reductions in sea-ice cover and warming of water masses will modify ocean stratification and restrict the supply of nutrients to the euphotic zone. Taken together with anticipated changes in light conditions, net phytoplankton growth is expected to change with important ramifications for Arctic ecosystem structure and biogeochemical fluxes. In particular, the quantity of photosynthetically produced organic matter exported from the surface ocean is likely to change under these conditions.

These changes have clear implications for the sequestration of atmospheric CO_2 and the structure and function of benthic ecosystems that principally rely on this energy source from the pelagic. Considering the importance of these processes, reliably detecting the effects of climate change and understanding the influence of anthropogenic forcing on Arctic ecosystems is a clear priority. As part of our efforts to observe and detect long-term changes in Arctic Ocean ecosystems we deployed a network of fixed-point moorings in the Fram Strait. On one hand these moorings reflect a continuation of the well-established and long-term efforts of monitoring particle flux in the Fram Strait as part of the LTER Observatory HAUSGARTEN. In addition, to this new mooring arrays were designed to sample biogeochemical and physical properties in the upper water column to link with particle flux observations. These arrays include autonomous water samplers and autonomous particle samplers that are capable of collecting discrete samples with weekly resolution and preserving them for detailed analysis upon recovery. This work is part of the Frontiers in Arctic marine Monitoring (FRAM) infrastructure project.

To determine the transfer of organic matter from the upper productive layer in the water column to the bottom of the ocean, measurements of settling particles are performed by means of year-round moored sediment traps that provide information on the quantity and seasonality of vertical particle flux. The moorings are also equipped with current meters (RCMs) and self-recording CTDs, to gain information on the hydrographic conditions in the study area. Results obtained by these instruments are of major importance for the interpretation of the results derived by the sediment traps, as the settling particles can be transported over long distances before arriving at the seabed.

To determine the seasonal changes in nutrient concentrations in the euphotic zone, water samplers were deployed at approximately 20 and 80 m depth. In total, 24 discrete samples will be taken with weekly to monthly resolution (depending on season) to follow the biological drawdown of nutrients. The moorings are also equipped with a biogeochemical sensor package including SBE37-SMP-ODO (temperature, salinity, oxygen), SAMI pH, SAMI pCO_2, Wetlabs PAR (photosynthetically active radiation), Wetlabs Ecotriplet (Chlorophyll and CDOM fluorescence) and current meters. The combination of these sensors and the water samplers, in combination with the deployment of a profiling winch will facilitate the assessment of seasonal stratification and nutrient concentrations above and below the pycnocline. The nutrient drawdown will enable an estimate of new production. Furthermore, the samples will

be used for DNA sequencing to examine seasonal changes in bacterial community structure. The particle sampler will collect and preserve filters for DNA extraction and sequencing that together with the fluorescence sensors will allow us to track the progression of phytoplankton biomass and community composition over different seasons. These efforts should give us the first year round description of biological and chemical processes in the Fram Strait.

In addition, water samplers were deployed at ~80 m water depth in the anticipated cores of the West Spitsbergen and East Greenland Currents. Together with detailed measurements of physical parameters (temperature and salinity; see Chapter 6), these samples will be used to measure the nutrient composition of water masses flowing into and out of the Arctic Ocean through the Fram Strait.

Work at sea

During the *Polarstern* cruise PS99 several moorings, containing sediment traps and water samplers as well as a benthic lander carrying a sediment trap, were recovered in the eastern and western parts of the Fram Strait (Table 11.1.1). All of the recovered sediment traps functioned satisfactorily with the exception of the 2,341 m sediment trap (S/N: 2015427) on the FEVI-32 mooring which had a jammed motor. Consequently, for this sediment trap series, only nine of the potential 20 samples were collected. Additionally, the McLane Remote Access Sampler (RAS) 500 only collected four of the 48 programmed water samples. The reason for this failure appears to be due to a short circuit on the controller electronic stack which drained the battery from 29 Vb to 0 Vb in mid-August between sampling events 4 and 5, rendering the system devoid of power for the remainder of the deployment. Additionally, there was significant corrosion on the micro-pump (Fig. 11.1.1), which appears to have been caused by corrosion due to a metal spacer on the pump head. McLane acknowledge this as a design flaw and are now manufacturing instruments with plastic spacers.

The Green eyes Aquamonitor water sampler that was deployed on the TD-2015-LT mooring was recovered and the instrument had collected 46 of the 48 samples. Certain components of the device were also badly corroded and attempts to communicate with the instrument failed and it will be returned to the manufacturer to retrieve the deployment data. The 46 samples collected were processed at sea. Sub-samples were taken for inorganic and organic nutrient analysis and the remainder of the 1-litre sample volumes was filtered onto 0.2 µm Sterivex filter cartridges and stored at -20°C for DNA extraction and sequencing back in the home laboratory. Three lab-on-a-chip nitrate sensors were also deployed on the water sampler frames and they were successfully recovered and appeared to have worked well for the deployment period. This was part of the FixO3 - DYNAMITE project in collaboration with the National Oceanography Centre, Southampton (NOCS) and further details can be found in Chapter 14 of this cruise report.

Tab. 11.1.1: Station data of moorings and sediment trap bottom-lander systems recovered and deployed during *Polarstern* cruise PS99

Recoveries of moored instruments during PS99					
Recovered	**Gear**	**Latitude**	**Longitude**	**Depth [m]**	**Comment**
26/06/16	Mooring	79°00.43’ N	04°19.92’ E	2605	FEVI-32
26/06/16	Free-falling System	79°04.74’ N	04°06.58’ E	2497	Long-term Bottom-Lander

Recoveries of moored instruments during PS99					
30/06/16	Mooring	78°50.11’ N	02°47.96’ W	2526	TD-2015-LT
03/07/16	Mooring	79°44.39’ N	04°30.36’ E	2716	FEVI-31
Deployments of moored instruments during PS99 (recovery planned for summer 2017)					
Deployed	**Gear**	**Latitude**	**Longitude**	**Depth [m]**	**Comment**
30/06/16	Mooring	78°49.86’ N	02°47.63’ W	2583	EGC-2016
05/07/16	Mooring	79°44.19’ N	04°29.42’ E	2657	FEVI-33 (N4)
10/07/16	Mooring	79°00.71’ N	06°57.89’ E	1260	F4S-2016
11/07/16	Mooring	79°00.00’ N	04°19.97’ E	2612	FEVI-34 (HG-IV)
11/07/16	Mooring	79°01.38’ N	04°15.71’ E	2602	HG-IVS-2016
12/07/16	Winch-Mooring	79°01.40’ N	04°24.30’ E	2536	SWIPS-2016
12/07/16	Free-falling System	79°04.67’ N	04°06.74’ E	2494	Long-term Bottom-Lander

Fig. 11.1.1: Image showing the corrosion on the micro-pump of the McLane Remote Access Sampler RAS-500 deployment at HG-IV, which failed after four sampling events

As part of the cruise several new moorings were deployed in the Fram Strait, to combine physical and biological autonomous observations. The TD-2015-LT and N4 (FEVI-33) moorings were redeployed in the same configuration as 2015. In addition, we also deployed four out of six moorings comprising two new triangular cluster arrays that aim to combine physical and biogeochemical measurements in the eastern part of the Fram Strait at the existing HG-IV and F4 stations (Fig. 11.1). The HG-IV (FEVI-34) mooring was redeployed configured with

three sediment traps and a McLane RAS 500 water sampler at 80 m and renamed as HG-IV traditional. Two near-surface moorings were also deployed at HG-IV (HG-IV-S) and F4 (F4-S) that were equipped with McLane RAS 500 water samplers and McLane PPS particle samplers at 20 m (Fig. 11.1.2). Furthermore, biogeochemical sensor packages were attached to these frames that included the following: SBE37-SMP-ODO (temperature, salinity, oxygen), SAMI pH, SAMI pCO_2, Wetlabs PAR (photosynthetically active radiation), and Wetlabs Ecotriplet (Chlorophyll and CDOM fluorescence). In addition to the traditional and near-surface moorings, the third component of these triangular cluster arrays are surface profiling winches. One of these moorings, the so-called SWIPS system, is equipped with a CTD sensor package (Fig. 11.1.3). The physical oceanography group at AWI will complete the installation of these two triangular cluster arrays during the *Polarstern* cruise PS100 by deploying an NGK winch and the F4 traditional mooring. A summary of the mooring recoveries and deployments is presented in Table 11.1.1.

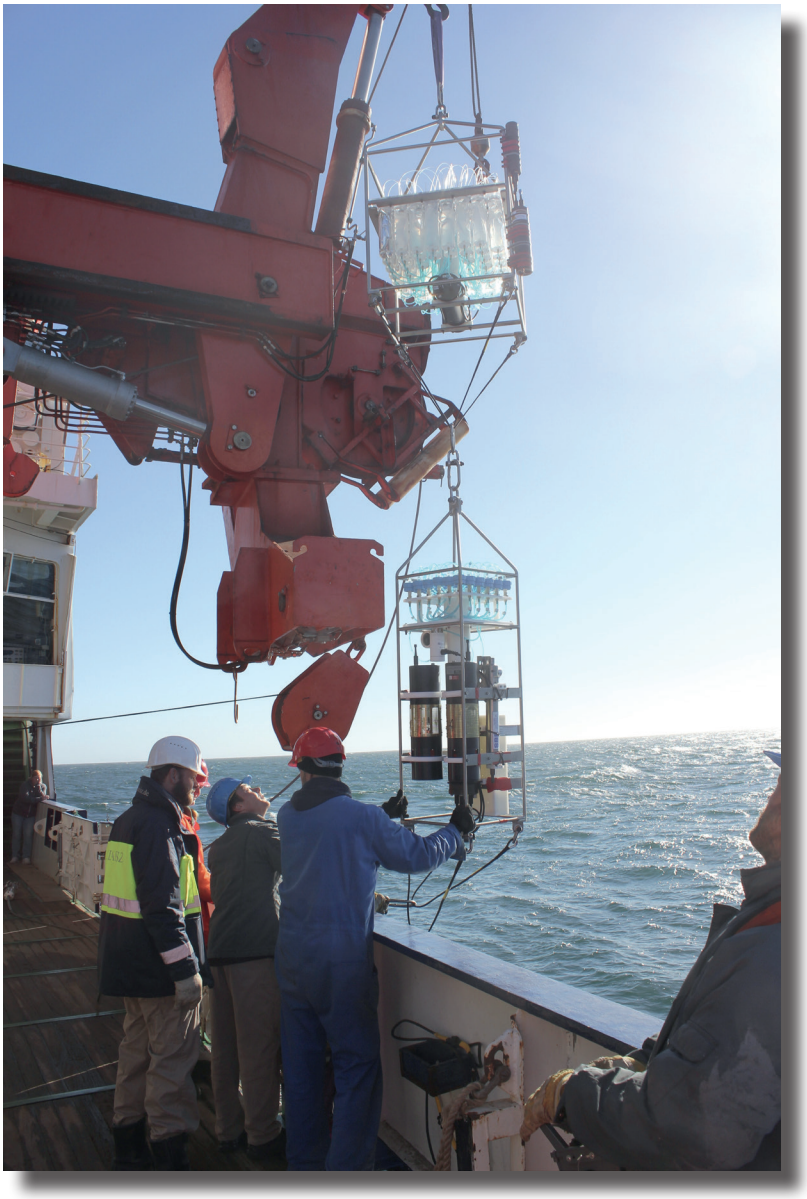

Fig. 11.1.2: Deployment of the HG-IV-S mooring on board Polarstern during PS99 showing the configuration of McLane RAS-500 and PPS automated samplers with biogeochemical sensors mounted to the deployment frames

Preliminary results

At present there are only few preliminary results available from the moorings recovered at HAUSGARTEN observatory, as the samples collected by the sediment traps and water samples require detailed analysis in the laboratory. A visual inspection of the contents of the sediment trap sampling cups can provide a few general observations. The seasonal pattern in sedimentation observed in previous years was evident from these samples and present at all depths. The last three years have been characterised by a huge abundance of amphipods in late summer in the uppermost traps at HG-IV and N4 (Fig. 11.1). Amphipods appeared to be less abundant during 2015-2016, although detailed analysis in the laboratory is required to confirm these observations.

Fig. 11.1.3: Deployment of the SWIPS winch mooring during Polarstern PS99

Assuming that all of the instruments work as intended on the PS99 mooring deployments we can expect an unprecedented dataset characterising the seasonal progression of physical, biological, and chemical parameters in the Arctic Ocean. We will be able to document the onset of stratification in the water column and how this is related to salinity and temperature. We should also be able to follow the development of the phytoplankton bloom and look at the seasonal phenology of dominant eukaryotic and bacterioplankton groups. Nutrient inputs to the surface layer and the ensuing biological consumption will allow us to estimate the magnitude of new production. Through comparison with the fluxes measured in sediment traps allow us to estimate the fraction of production exported out of the surface layer and the dominant mechanisms characterising this export.

Data management

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.

11.2 Biogenic sediment compounds and meiofauna

Christiane Hasemann, Marie Huchler, Florian Krauß, Tim Küber,Ingo Schewe, Thomas Soltwedel — AWI

Objectives

Benthic investigations at the HAUSGARTEN observatory comprised biochemical analyses to estimate the input of organic matter from phytodetritus sedimentation and to determine the activity and biomass of the small benthic biota. Further sediments were retrieved to study the composition of small sediment-inhabiting organisms (meiofauna). Results from these studies will help to describe the eco-status of the benthic system. Moreover, an *in-situ* experiment was established to study the distribution patterns of the small sediment inhabiting organisms in the modified bottom-current regime in the surrounding of artificial dropstones (Fig. 11.2.1).

Work at sea

Virtually undisturbed sediment samples were taken by push-corers using a video-guided multiple corer (MUC) at all 21 HAUSGARTEN stations along a bathymetric gradient crossing Fram Strait at 79°N and along a latitudinal transect following the 2500 m isobaths in eastern parts of the strait with stations extending from permanent ice-free regions in the south to the ice-edge in north-westerly parts of Fram Strait (Table 11.2.1). Benthic stations between 1,000 and 2,500 m water depth (EG-I to EG-IV) on the East Greenland continental margin were also sampled within the framework of the BMBF project TRANSDRIFT (System Laptewsee – Das transpolare System des Nordpolarmeeres).

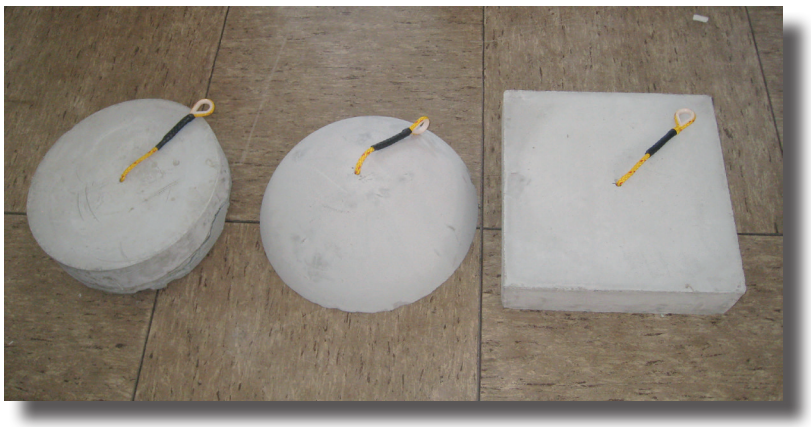

Fig. 11.2.1: Artificial dropstones (40x40x10 cm) in different shapes (cylindrical, spherical, rectangular)

The uppermost five centimetres of sediments retrieved with the MUC were sub-sampled to analyse parameters indicating the input of organic matter to the seafloor as well as sediment-bound biomass and benthic activity. Additional samples were taken to analyse the abundance and biomass of bacteria as well as meiofauna densities and the diversity patterns of nematodes. Sediment-bound chloroplastic pigments (chlorophyll *a* and its degradation products) represent a suitable indicator for the input of phytoplanktonic detritus to the seafloor, representing the major food source for benthic organisms. They can be analysed with high sensitivity by fluorometric methods. To estimate the potential heterotrophic activity of bacteria, we measured cleaving rates of extracellular enzymes using the model-substrate FDA (fluorescein-di-acetate) in incubation experiments. Bacterial activity and chloroplastic pigments were analysed on board. All other sub-samples were stored for later analyses of various biochemical bulk parameters at the home lab.

By means of a camera equipped launcher system, we established a new *in-situ* experiment and deployed nine artificial dropstones with different shapes (cylindrical, spherical and rectangular) at 2,500 m water depth at station HG-IV. The dropstones were deployed roughly along a short

transect within the main current direction, with distances of approximately 10 m to each other. The experiment will be sampled during next year's expedition to HAUSGARTEN observatory.

Tab. 11.2.1: Stations sampled for biogenic sediment compounds and meiofauna and site selected for the *in-situ* experiment to study the effects of dropstones at the deep seafloor

Station ID	Sampling sites/ experimental site	Date	Latitude	Longitude	Water Depth [m]
PS99/0065-3	SV-I	09/07/16	79°01.65' N	11°05.60' E	272
PS99/0064-5	SV-II	09/07/16	78°58.88' N	09°30.32' E	218
PS99/0062-1	SV-IV	08/07/16	79°02.02' N	07°00.03' E	1308
PS99/0066-3	HG-I	10/07/16	79°08.36' N	06°05.27' E	1282
PS99/0057-2	HG-II	06/07/16	79°07.86' N	04°54.17' E	1540
PS99/0069-5	HG-III	10/07/16	79°06.49' N	04°35.81' E	1877
PS99/0042-13	HG-IV	27/06/16	79°03.89' N	04°10.93' E	2462
PS99/0044-2	HG-V	28/06/16	79°04.52' N	03°42.70' E	2877
PS99/0045-2	HG-VI	28/06/16	79°03.82' N	03°36.40' E	3324
PS99/0046-2	HG-VII	29/06/16	79°03.73' N	03°29.29' E	3949
PS99/0047-2	HG-VIII	29/07/16	79°03.66' N	03°17.94' E	5087
PS99/0059-9	HG-IX	07/07/16	79°08.02' N	02°50.64' E	5568
PS99/0051-9	EG-I	02/07/16	78°59.47' N	05°27.05' W	981
PS99/0050-2	EG-II	01/07/16	78°56.03' N	04°38.59' W	1551
PS99/0049-2	EG-III	01/07/16	78°51.31' N	03°57.33' W	1982
PS99/0048-12	EG-IV	30/06/16	78°48.97' N	02°44.09' W	2603
PS99/0041-9	S3	25/06/16	78°36.51' N	05°04.13' E	2337
PS99/0054-2	N3	04/07/16	79°35.26' N	05°10.46' E	2778
PS99/0052-3	N4	03/07/16	79°44.26' N	04°25.96' E	2625
PS99/0053-7	N5	04/07/16	79°57.79' N	02°55.99' E	2613
PS99/0078-1	Dropstone Experiment	12/07/2016	79°04.53' N	4°07.84' E	2463

Preliminary results

Comparing the concentrations of sediment-bound pigments (Fig. 11.2.2) and the potential bacterial activity (Fig. 11.2.3) at the northernmost, southernmost, westernmost, and easternmost HAUSGARTEN sites (all stations at about 2,500 m water depth) we found conspicuous differences. All four stations exhibited generally decreasing values with increasing sediment depth. Steepest gradients were found for station EG-IV on the East-Greenland rise (chloroplastic pigments) and at HG-IV (FDA), slightest gradients occurred at the northernmost HAUSGARTEN site N5 (both parameters). However, at all four stations similarly high values for chloroplastic pigment concentrations (around 20 µg ml^{-1}) as well as for bacterial activity (around 2 nmol ml^{-2} h^{-1}) occurred within the upper sediment layer (0-1 cm).

Data management

Final sample processing will be carried out at AWI. Expenditure of time needed for the respective data acquisition of the several types of investigation will be different. The time periods from post

processing to data provision will vary from one year maximum for biogeochemical assessments, to several years for organism-related datasets. Until then preliminary data will be available to the cruise participants and external users on 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.

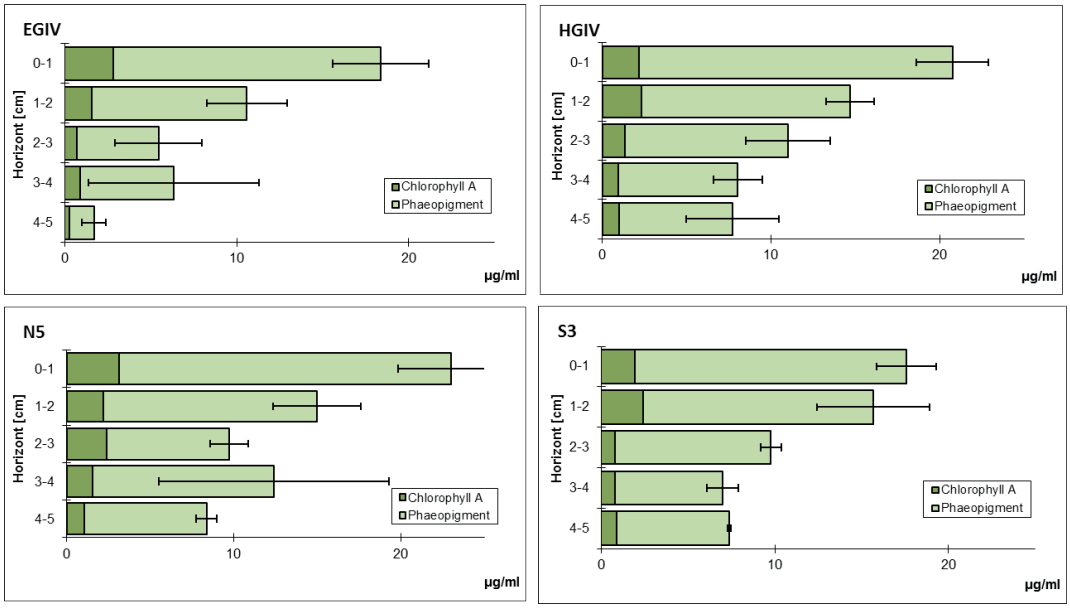

Fig. 11.2.2: Chloroplastic pigments in the upper five sediment centimetresat four selected stations at ~2,500 m water depth

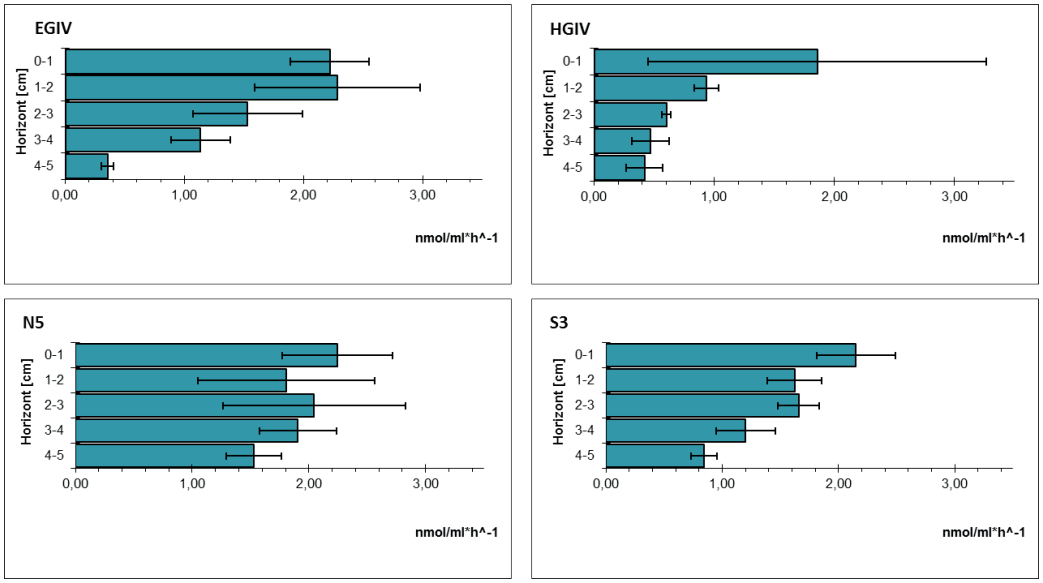

Fig. 11.2.3: Hydrolytic activity of bacteria (FDA) in the upper five sediment centimetres at four selected stations at ~2,500 m water depth

11.3 Spatial and temporal variability in deep-sea macrofauna

Andrey Vedenin[1], Melissa Käß[2] [1] IORAS, [2] AWI

Preface

The HAUSGARTEN observatory has been extensively studied for more than 16 years. However, the macrofaunal samplings remain insufficient for the complete understanding of the spatial and temporal structure of macrobenthos within the Fram Strait. Previous investigations revealed the unusually high values of biomass, density and species richness compared with the communities of the deep-sea Central Arctic, permanently covered with ice (Budaeva et al., 2008; Degen et al., 2015; Vedenin et al., 2016). Włodarska-Kowalczuk et al. (2004) reported community replacement along the bathymetric HAUSGARTEN transect with four different types of species compositions (i.e. communities) from the depth range of 200-3,000 m. Horizontal distributional patterns in the structure of macrofauna communities at 2,500 m water depth were analysed by Budaeva et al. (2008) and Vedenin et al. (2016). The analysis of macrofauna assemblages showed the presence of a single, but highly variable community along the latitudinal transect (~120 km long).

The previous studies were based on a limited set of samples and did not take into account temporal variations in local communities. Besides, the studies were focused on the eastern part of the Fram Strait, whereas the western part (the Greenland slope) was never sampled. The present study of spatial variation in the structure of macrobenthic communities along the bathymetric transects within the HAUSGARTEN area and the Greenland slope (Fig. 11.3.1) aims to compare the macrofaunal structure along the bathymetric transects in the Eastern and Western Fram Strait.

Objectives

- To collect a series of box-core samples along the bathymetric HAUSGARTEN transect including the maximum depth at the Molloy Deep (1,000-5,500 m depth range);
- To collect a series of box-core samples along the bathymetric transect at the eastern Greenland slope at the depth range 1,000-2,500 m;
- To compare the structure of macrofaunal communities at the eastern and western slopes of the deep-sea Fram Strait;
- To repeat the box-core samples along the latitudinal HAUSGARTEN at the northern-most and southern-most stations;
- To trace temporal changes in deep-sea arctic benthic macrofauna communities (by species composition, richness, diversity, evenness, density, and biomass) over 16 years in relation to changes in the position of the Marginal Ice Zone.

Work at sea

Sixteen samples from 0.25 m^2 USNEL box-corer were collected during the *Polarstern* cruise PS99.2 along the bathymetric and latitudinal HAUSGARTEN transect and eastern Greenland slope (Fig. 11.3.1). Each box-core sample was divided into nine subsamples: one subsample of the water layer and eight 0.03 m^2 of the surface sediment layer (0-12 cm) (Fig. 11.3.2). All subsamples were washed by hand through the 0.5 mm mesh size sieve and separately preserved in 96 % ethanol on board. Sample sorting, identification of species and assessment of species density and biomass will be performed in the laboratory after the cruise.

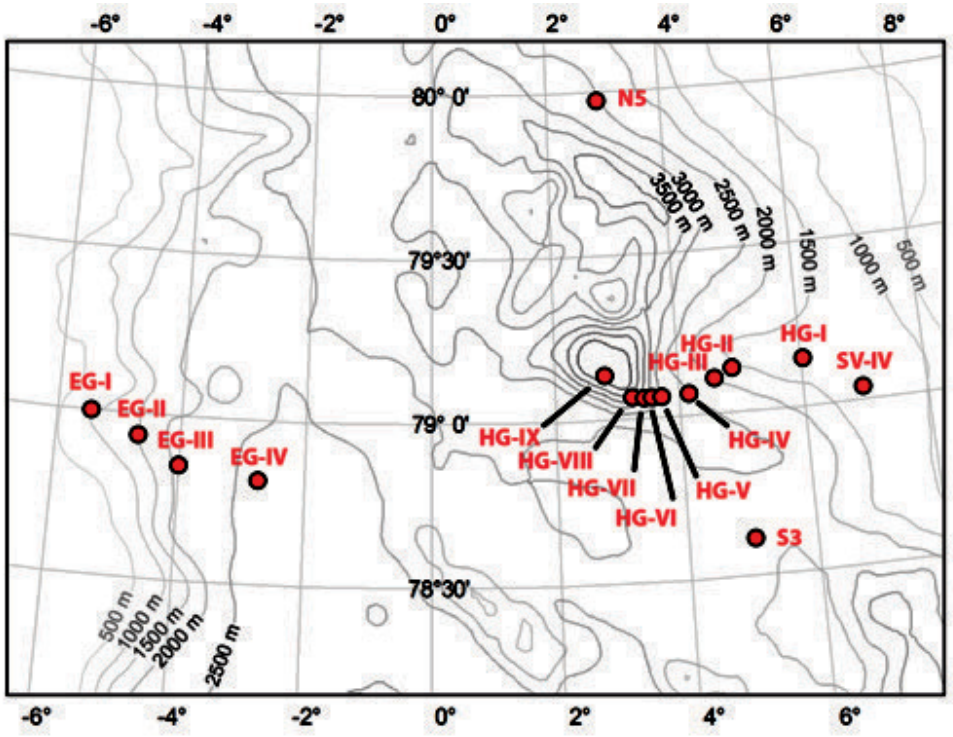

Fig. 11.3.1: Macrofauna sampling sites during Polarstern expedition PS99.2

Fig. 11.3.2: USNEL box corer (left) and dividing of the sample into subsamples (right)

Preliminary results

The following parameters will be estimated during the analytical phase of the project: species composition, species richness, density, biomass, species diversity expressed in Shannon-Wiener index, Pielou index, and Hulbert rarefaction index. The comparison of previously obtained data from the same area and similar studies conducted in other high-latitude areas will enhance our understanding of spatial changes in deep-sea macrobenthic communities in general. The comparison of the samples from the eastern and western parts of the Fram Strait taken at the same latitude will allow to understand the influence of the warm West-Spitsbergen waters and cold East-Greenland waters on the deep-sea macrofauna. The repeated sampling of the stations investigated by Włodarska-Kowalczuk et al. (2004), Budaeva et al. (2008), and Vedenin et al. (2015) will provide a unique opportunity to evaluate changes in deep-sea macrofaunal communities over a 16-year time period. Knowledge gained on the spatial variations in macrofaunal community structure at different spatial scales will enable us to detect and separate the effects of the climate change from spatial heterogeneity in the distribution of deep-sea macrofauna.

Data management

The macrofauna densities, biomasses as well as taxonomical data will be transferred to the PANGAEA database and to the appropriate national data centres.

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Włodarska-Kowalczuk M, Kendall MA, Węsławski JM, Klages M, Soltwedel T (2004) Depth gradients of benthic standing stock and diversity on the continental margin at a high latitude ice-free site (off West Spitsbergen, 79°N). Deep-Sea Research I 51, 1903-1914.

11.4 Spatial and temporal variability in deep-sea megafauna

Melanie Bergmann, Mine Tekman; AWI
not on board: James Taylor

Objectives

Epibenthic megafauna, often arbitrarily defined as organisms large enough to be seen with a camera, play an important role in the deep-sea community. They influence benthic respiration, nutrient cycles and bioturbation, shape community structure through predation and also provide structure at the sediment-water interface. Thus, it is important to understand variations in the megafaunal community with depth, latitude, time and habitat features such as hard substrates. To assess megafaunal dynamics over time, we repeatedly conduct camera surveys along the same transect positions (megafaunal time-series) (Bergmann et al., 2011; Meyer et al., 2013).

Work at sea

To sample the benthic megafauna by a non-destructive method at a large scale and to gain *in-situ* views of the organisms, we used a towed camera system (OFOS; Fig. 11.4.1). Photographed transects were located along the latitudinal transects (stations N3, HG-IV, and S-3) and will be used to continue our image time-series. An additional transect was done off East Greenland at 2,500 m depth to enable comparisons between the megafaunal assemblages from the eastern and western Fram Strait. Two more planned transects in the Molloy Hole (HG-IX) and at the shallow station HG-I could not be realized as the fibre-optic cable was broken.

Fig. 11.4.1: The Ocean Floor Observation System (OFOS)

Preliminary results

Results of time-series, latitudinal, and substrate analyses will only be available once the collected images will have been analysed and species present have been identified. However, a few selected images and photographed species are shown in Fig. 11.4.2. At first impression, the western station EG-IV harboured many patches of phytodetritial matter or sunken clumps of the ice alga *Melosira*. As in the previous year, tracks of stones with attached sponges were visible at station N3, indicating strong bottom currents dragging stones on the seafloor.

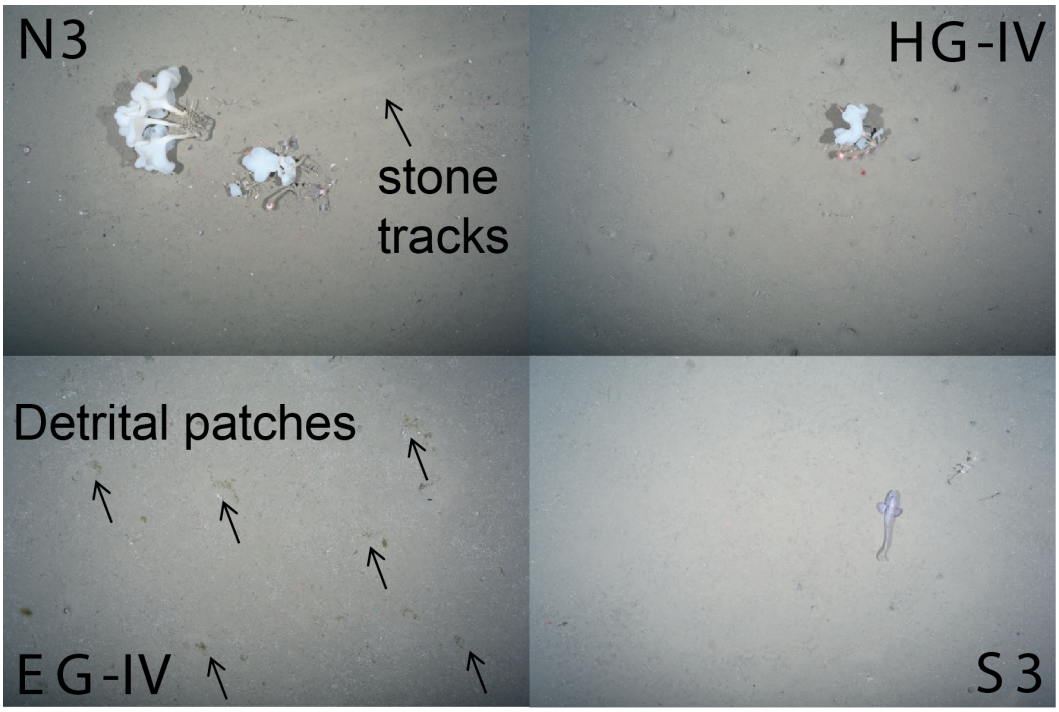

Fig. 11.4.2: Example Images of LTER megafauna work at HAUSGARTEN: (N3) tracks left behind by stones dragged along the seafloor, (HG-IV) sponge Caulophacus arcticus visited by shrimps and holes of Neohela lamia in the surrounding sediments, (EG-IV) Detrital patches observed on most images from this transect, (S3) Zoarcid fish Lycodes frigidus, which was quite abundant in the middle part of the transect.

Data management

All OFOS images, videos and metadata will be uploaded to PANGAEA. In addition, all images have been uploaded to the online image data base BIIGLE to enable image analysis.

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11.5 Remineralisation at the deep seafloor

Frank Wenzhöfer[1], Volker Asendorf[2], Michael Hofbauer[1], Ulrich Hoge[1], Johannes Lemburg[1], Tim Küber[1]

[1] AWI
[2] MPIMM

Objectives

Benthic organic matter remineralisation rates were assessed based on oxygen uptake rates measured *in-situ* with free-falling systems (benthic lander) and crawler, and ex situ on retrieved sediment cores. Micro-scale distributions of oxygen at the sediment-water interface and within the sediments were studied in order to assess diffusive oxygen uptake rates

(DOU). To quantify total oxygen consumption rates (TOU, i.e. DOU plus fauna-mediated oxygen uptake) sediments were enclosed and oxygen decrease in the overlying water monitored. Benthic lander derived flux rates provide snapshot measurements at a given time point and continue a time-series while the crawler derived fluxes provides high-resolution benthic oxygen consumption rates over a seasonal cycle.

Work at sea

Autonomous benthic lander systems (Fig. 11.5.1) and a newly developed benthic crawler system (Fig. 11.5.2; HGF Alliance ROBEX) were used to study benthic oxygen consumption and fluxes of other solutes at the sediment-water interface. Two landers (KL-1 & -2) were deployed during this cruise (Table 11.5.1). Each of the landers was equipped with three benthic chambers and a 2-axis re-locatable micro-profiler. After arrival at the seafloor the benthic chambers enclose a 0.04 m^2 large sediment patch together with an approx. 0.15 m high layer of overlying water. During the respective deployments that lasted for approx. two days, the overlying water was kept mixed by gentle stirring and changes in oxygen concentrations were monitored by means of optical oxygen sensors attached to the chamber lid (optodes type 4330, AADI, Bergen, Norway). At pre-programmed times a total of seven samples per chamber were taken from the overlying water by means of glass syringes. Subsamples for dissolved inorganic carbon (DIC), total alkalinity (TA) and nutrients were taken from the syringes after instrument retrieval and stored for later analysis. Samples for the analysis of organic carbon and photopigments were taken from the sediments that were retrieved within the chambers at the end of the deployments. Total fluxes of oxygen (TOU) across the sediment-water interface are calculated from the change in concentration per time (as determined from optode recordings or discrete measurements obtained from samples) times the overlying water column height. The fine-scale distribution of dissolved oxygen at the sediment-water interface and within pore waters was determined by means of Clark-type oxygen micro-electrodes that were incrementally inserted into the sediment. The individual sensors were custom-made from glass with typical tip-diameters in the range of some tens of micrometres. Up to eight oxygen electrodes were attached to a 150 mm diameter titanium housing that contained electronics for signal amplification and processing. In some deployments single sensors for temperature and conductivity (for sediment surface detection) were additionally installed. Up to 200 mm long profiles were recorded at a 100 µm vertical resolution. In addition to the linear drive responsible for vertical profiling a second, horizontally-oriented drive allowed for lateral relocation (4-times during each deployment) of the electronic housing and sensors between profiler runs to make sure that replicate profiles were measured at distinct sediment spots. Diffusive oxygen uptake is calculated from the change in oxygen concentration across the diffusive boundary layer (DBL) or the uppermost sediment layer times the diffusion coefficient $\boldsymbol{d}_{(T,\,S)}$ or based on the derivative of the entire profile.

To investigate the seasonal variation in benthic oxygen consumption the crawler TRAMPER was tested and deployed for a one-year mission. TRAMPER was developed and build as part of the HGF Alliance ROBEX and allows to monitor sediment oxygen distributions year-round. The autonomous benthic crawler is equipped with a multi-optode-profiler carrying 24 optodes separated in three revolver magazines allowing a successive use of the sensors during the deployment. During the test deployment at HG-II, TRAMPER performed seven measuring cycles (Table 11.5.1). Each of such cycles include: a movement of 10-25 m, taking a picture of the sediment, oxygen profiling with four optical Sensors (PyroScience), and ‘sleeping’ to save energy. At the end of cruise TRAMPER was deployed at HG-IV for year. During this mission the crawler will perform >52 measuring cycles (one very year) to get a high-resolution seasonal benthic oxygen consumption.

Fig. 11.5.1: Deployment of a benthic lander carrying incubation chambers and a micro-profiling unit

Fig. 11.5.2: Recovery of the benthic crawler TRAMPER after the test deployment

In addition to the *in-situ* flux measurements, oxygen micro-profiles were also measured ex situ in the laboratory. Sediment cores from 12 sites (EG-I, EG-II, EG-III, EG-IV, HG-IX, HG-VII, HG-IV, HG-III, HG-II, HG-I, SV-IV, SV-I) were stored in a water bath at *in-situ* temperature and the overlying water gently stirred. In each core, six profiles of 5 cm length were measured at a resolution of 100 µm. Ex situ diffusive fluxes will be calculated from the obtained profiles.

Preliminary (expected) results

During this cruise the benthic landers were deployed five times at the HAUSGARTEN time-series stations S3, N4, and HG-IV (Table 11.5.1). At station N4 and HG-IV both lander systems (KL-1 & -2) were deployed at the same time. Technical problems with the benthic chambers and

the micro-profiler during the first deployment prevented successful oxygen flux measurements at S3. All in all, the lander deployments during PS99.2 resulted in 12 successful benthic chamber measurements of total oxygen uptake (TOU) and almost 60 oxygen micro profiles suitable for quantification of diffusive oxygen uptake (DOU). These data continue the time-series on *in-situ* benthic oxygen consumption at the three sites. In addition, pore water and sediment samples for diverse parameters (see above) have been obtained from the chamber sediments for analysis in the home laboratory.

The expected data from the fully autonomous crawler deployment (recovery will take place in 2017 during *Polarstern* expedition PS108) will help to establish long-term benthic observatories in order to determine seasonal variations in organic matter turnover and benthic community respiration activity, and to close the carbon budget for the deep Arctic Ocean.

Tab. 11.5.1: Overview of all lander and crawler deployments

DATE	STATION	POSITION	SITE	DEPTH [m]	GEAR
25/06/2016	PS99/0041-10	78°36.594' N05°04.052' E	S3	2338	Benthic-Lander (KL-2) Deployment time: 44 hours
03/07/2016	PS99/0052-4	79°44.421' N04°25.464' E	N4	2563	Benthic Lander (KL-2) Deployment time: 46 hours
03/07/2016	PS99/0052-5	79°44.217' N04°22.925' E	N4	2629	Benthic Lander (KL-1) Deployment time: 46 hours
06/07/2016	PS99/0057-4	79°07.839' N04°54.116' E	HG-II	1505	Crawler TRAMPER Start
08/07/2016	PS99/0061-1	79°07.804' N04°54.446' W	HG-II	1507	Crawler TRAMPER EndDeployment time: 47 hours
08/07/2016	PS99/0060-4	79°00.124' N04°19.743' E	HG-IV	2554	Benthic Lander (KL-2) Deployment time: 44 hours
08/07/2016	PS99/0060-5	79°00.234' N04°22.398' E	HG-IV	2542	Benthic Lander (KL-1) Deployment time: 43 hours
11/07/2016	PS99/0073-1	79°03.579' N 04°11.870'E	HG-IV	2437	Crawler TRAMPER Start

Data management

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.

12. PEBCAO: PLANKTON ECOLOGY AND BIOGEOCHEMISTRY IN THE CHANGING ARCTIC OCEAN

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Grant No. AWI_PS99_00

General objectives

The project PEBCAO (Plankton Ecology and Biogeochemistry in a Changing Arctic Ocean) is focused on the plankton community and the microbial processes relevant for biogeochemical cycles of the Arctic Ocean. This research focus is acknowledging that the Arctic Ocean has gained increasing attention over the past years because of the drastic decrease in sea ice and increase in temperature, which is about twice as fast as the global mean rate. In addition, the chemical equilibrium and the elemental cycling in the surface ocean will alter due to ocean acidification. These environmental changes will have consequences for the biogeochemistry and ecology of the Arctic pelagic system. The effects of changes in the environmental conditions on the polar plankton community can only be detected through long-term observation of the species and processes. Our studies on plankton ecology have started in 1991 and sampling in the Fram Strait at ~79°N has been intensified by the PEBCAO team since 2009. Since then our studies are based on combining a broad set of analysed parameters. This includes e.g. classical bulk measurements and microscopy, optical measurements and satellite observations, molecular genetic approaches, or cutting edge methods for zooplankton observations to study plankton ecology in a holistic approach.

Over the past six years, we have compiled complementary information on annual variability in plankton composition, primary production, bacterial activity or zooplankton composition. Recent investigations have shown that rising temperatures as well as freshening of surface waters promote a shift in phytoplankton community towards a dominance of smaller cells. A change in size of the primary producers could have significant consequences for the entire food web in polar waters as well as for the cycling and sequestering of organic matter. The type of plankton present has an influence but may not be the only factor playing a role (LeMoigne et al., 2015); modelling and observational studies imply that reduced sea-ice in the future will strengthen Arctic primary production (PP) (Arrigo et al., 2008; Pabi et al., 2008). The fraction of PP that is exported below the euphotic zone or below the surface layer (export/primary production, or export efficiency,) is a key determinant in how efficiently the biological carbon pump sequesters carbon to depth (Buesseler & Boyd, 2009). The specific ecosystem related processes which drive the considerable variability observed in export efficiency remain largely unknown (Buesseler & Boyd, 2009; Henson et al., 2011; Giering et al., 2014) for much of the polar oceans. An increase in ice free water surface as well as CO_2- and temperature-related changes in the carbonate chemistry of the ocean will also affect the cycling of biogenic

elements. Because of the vast spatial dimensions of the oceanic system, even small changes in the biological pump could significantly affect atmospheric CO_2 concentration.

Objectives

Biogeochemistry and phytoplankton

Climate induced changes will impact the biodiversity in pelagic ecosystems. At the base of the food web, we expect small algae to gain more importance in mediating element and matter turnover as well as matter and energy fluxes in future Arctic pelagic systems. In order to examine changes, including the smallest fractions, molecular methods are applied to complement traditional microscopy. The characterization of the communities with molecular methods is independent of cell-size and distinct morphological features. The assessment of the biodiversity and biogeography of Arctic phytoplankton will be based on the analysis of ribosomal genes with next generation sequencing technology, Automated Ribosomal Intragenic Sequence Analysis (ARISA), and quantitative PCR. Besides molecular methods the set of parameters investigated includes classical bulk measurements (e.g. chlorophyll *a*, POC/N, biogenic silica) and microscopy.

Automated sampling for molecular analyses

Marine phytoplankton distribution displays high spatial heterogeneity or “patchiness”. As a consequence, comprehensive observation of marine phytoplankton requires sampling with high spatial and temporal resolution. The latter is a labour intensive task and requires high amounts of ship time. The newly developed automated filtration system for marine microbes

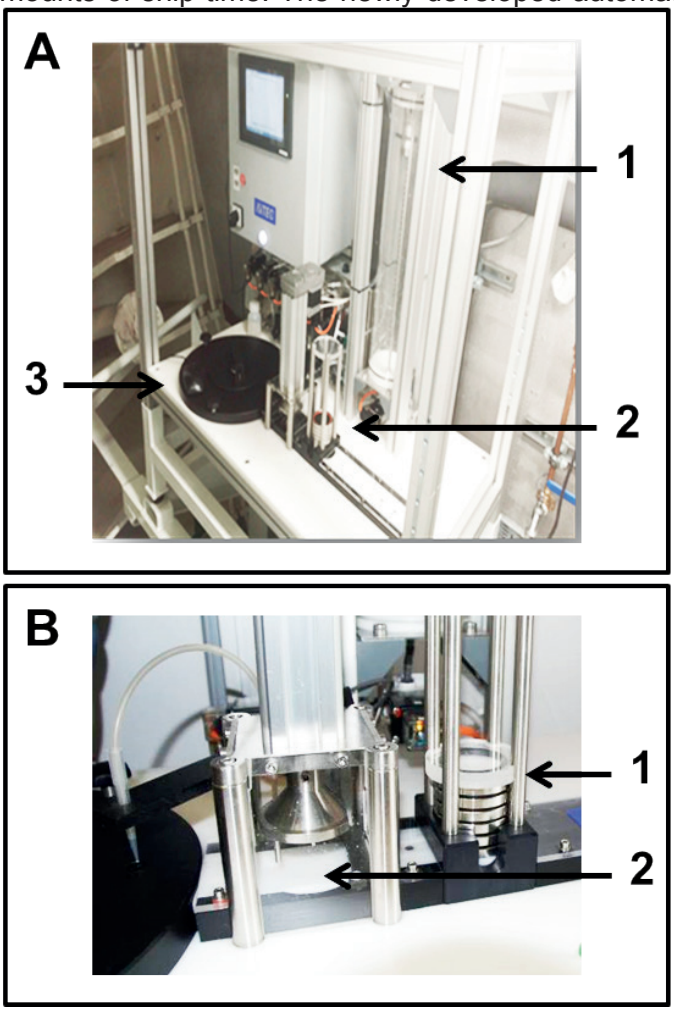

Fig. 12.1: A) AUTOFIM installed on board RV Polarstern; B) close-up of the filtration-module (1: filter stacker; 2: filtration cap; 3: archive for preserved filters)

(AUTOFIM) has high potential to reduce the described effort related to adequate sampling of marine phytoplankton. It is coupled to the ships pump system and allows filtration of a sampling volume up to 5 litres. In total 12 filters can be taken and stored in a roundel. Prior to the storage a preservative can be applied to the filters to prevent degradation of the sample material that can be used for molecular or biochemical analyses. Filtration can be triggered after defined regular time intervals or remote controlled from a scientist. Alternatively, filtration could be event-triggered if the filtration system would be operated in connection with the FerryBox System, an *in-situ* measurement device for the monitoring of oceanographic parameter (temperature, salinity, pH etc.) installed on-board *Polarstern*. AUTOFIM (Fig. 12.1) provides the technical background for automated high resolution collection of marine samples for molecular analyses (Metfies et al., 2016). During expedition PS92 of the RV *Polarstern* to the Arctic Ocean in summer 2015, AUTOFIM was used for the first time to collect samples from the upper water column at a depth of ~10 m, which is the depth of the inlet of the ships water pump system.

Phytoplankton community structure and coloured dissolved organic matter (CDOM)

The distribution and composition of phytoplankton and CDOM in the Fram Strait are influenced by different environmental factors such as the water masses exchanges between the Arctic and Atlantic basins, the intensity of phytoplankton blooms and the riverine outflow. At this cruise, we focused on collecting a high spatial and temporal resolved data set on phytoplankton biomass and composition, particulates and CDOM at the surface and for the full euphotic zone in the Fram Strait by taking continuous optical measurements which directly give information on inherent and apparent optical properties (IOPs and AOPs, respectively). These will be validated by direct biological and chemical analysis of frequently taken water samples in order to derive information on abundance and composition of phytoplankton, other particulates and CDOM. The whole large data set on phytoplankton and CDOM and the measurements of optical properties by radiometers at stations will also be used to validate the new Sentinel-3 sensor OLCI level-2 ocean products for high latitudes.

Bacterioplankton

The bioreactivity of particulate and dissolved organic matter is determined by its biochemical composition and diagenetic state. The loss of organic matter within and below the euphotic zone is mainly mediated by the degradation activity of heterotrophic bacteria, colonizing sinking particles and their surroundings. Hence, bacterial activity co-determines the efficiency of carbon export to the deep ocean. Furthermore, bacterioplankton plays a fundamental role at the basis of microbial foodwebs. Dissolved organic matter is almost exclusively accessible for bacterial cells that make it available for higher trophic levels by the production of bacterial biomass. Effects of increasing temperature and decreasing pH on bacterial communities and their activity are thereby of outstanding importance, but yet hardly considered. Studies conducted in the past decades revealed strong physiological responses of marine bacteria to changing temperature and pH, but their relevance for biogeochemical cycles in the future ocean is only poorly investigated.

Zooplankton

Many zooplankton species are associated with a specific water mass. For example, the boreal copepod *Calanus finmarchicus* is transported northward with the North Atlantic current whereas the sibling species *C. glacialis* inhabits Arctic water masses. Rising water temperatures and altered hydrographical conditions could therefore result in a shift in the zooplankton species composition in the Fram Strait and the Arctic Ocean. Zooplankton might also be affected by a

decrease in seawater pH due to uptake of anthropogenic carbon dioxide (ocean acidification). This could have severe consequences for the ecosystem functioning. To detect the impact of climate change on pelagic ecosystems of the Arctic, we studied the zooplankton community composition and depth distribution in the HAUSGARTEN area during PS99.2 and compare these with previous studies from the same area.

Work at sea

Samples for a large variety of parameters have been collected in the area of the deep-sea long-term observatory HAUSGARTEN of the Alfred Wegener Institute located in the Fram Strait including the frontal zone separating the warm and cold water masses originating from the West Spitsbergen current and the East Greenland current. Sampling as accomplished by the PEBCAO team from CTD casts and by net hauls is summarized in Tables 12.1-3.

Biogeochemistry and phytoplankton

Seawater samples were taken at 6-12 depths by a CTD/Rosette Water Sampler in the HAUSGARTEN area to determine the impact of microbial processes on organic matter cycling. The water from the Rosette Water Sampler was filtered for analysing biogeochemical parameters such as chlorophyll *a* (unfractionated, and fractionated on 10 µm, 3 µm and 0.2 µm), seston, total, dissolved and particulate organic carbon (TOC, DOC and POC), total, dissolved and particulate organic nitrogen (TN, DON and PON), carbohydrates (CHO), amino acids (AA), particulate organic phosphorus (POP), and particulate biogenic silica (PbSi). In addition, samples were collected for microscopy to determine phyto- and protozooplankton abundance. Additionally, water samples were collected from the top 100 m depth for molecular analyses in order to assess differences in the phytoplankton community composition by automated ribosomal intragenic spacer analysis (ARISA) and 454-next generation sequencing. These samples were fractionated by three filtrations on 10.0 µm, 3.0 µm and 0.2 µm filters. All samples were preserved, refrigerated or frozen at -20°C or -80°C for storage until analyses in the home laboratories (AWI, Bremerhaven; GEOMAR, Kiel).

^{14}C primary production was determined according to (Engel et al., 2013). Polycarbonate bottles were filled with 300 mL pre-filtered (mesh size 200 µm) sample and spiked with $NaH^{14}CO_3$ solution. For determination of added activity, 200 µL were removed immediately after spiking, transferred to a 5 mL scintillation vial. Then, 200 µL of 2N NaOH and 4 mL scintillation cocktail were added and samples were counted. Duplicated samples were incubated for 24 h at six light intensities (5, 30, 50, 100, 300, 600 µE cm^{-2} s^{-1}) and in darkness (blanks) at the temperature of the sea surface. Incubations were stopped by filtration of a 50 to 300 mL sub-sample onto 0.4 µm polycarbonate filters (Nuclepore). Primary production of POC (PPPOC) was determined from material collected on the filter, while the filtrate was used to determine primary production of DOC (PPDOC). After removing the vials collecting the filtrate of the associated filter, all filters were rinsed with 10 mL sterile filtered (<0.2 µm) seawater, and then acidified with 250 µL 2N HCl in order to remove inorganic carbon. Filters were transferred into 5 mL scintillation vials, 200 µL of 2N NaOH, and 4 mL scintillation cocktail (Ultima Gold AB) were added. For determination of PPDOC, 4 mL of filtrate were transferred to 20 mL scintillation vials.

Tab. 12.1: Biogeochemical parameters sampled from CTD casts (Chl*a*: chlorophyll *a*; POC/PON/POP: particulate organic carbon, nitrogen and phosphorus; bPSi: biogenic particulate silica; DOC: dissolved organic carbon; TDN: total dissolved nitrogen; TEP: transparent exopolymer particles; CSP: Coomassie stainable particles; CHO: carbohydrates; AA: amino acids; TA: total alkalinity; in addition, ^{15}N and Seston (TPM, total particulate matter) samples was taken at stations where sediment trap moorings were deployed (HG-IV, N4, EG-IV). Here particulate parameters were taken down to close above bottom.

Station	Chl*a*	POC/ PON/ POP	bPSi	DOC/ TDN	TEP/ CSP	CHO AA	TA
HG-I	x	x	x	x	x		x
HG-II	x	x	x	x	x	x	x
HG-III	x	x	x	x	x	x	x
HG-IV	x	x	x	x	x	x	x
HG-V	x	x	x	x	x	x	x
HG-VI	x	x	x	x	x	x	x
HG-VII							
HG-VIII	x	x	x	x	x	x	x
HG-IX				x	x	x	x
N5	x	x	x	x	x	x	x
N4	x	x	x	x	x	x	x
N3	x	x	x	x	x	x	x
EG-I	x	x	x	x	x	x	x
EG-II	x	x	x	x	x	x	x
EG_III	x	x	x	x	x	x	x
EG-IV	x	x	x	x	x	x	X
SV-IV	x	x	x	x	x	x	x
SV-III	x	x	x	x	x	x	x
SV-II	x	x	x	x	x	x	x
SV-I	x	x	x	x	x	x	x
S3	x	x	x	x	x	x	x

Phytoplankton pigments, particulate matter absorption (PAB), and coloured dissolved organic matter (CDOM)

We continuously ran an *in-situ* hyperspectral transmission and absorption meter (AC-s, WETLabs) during the first and second leg of *Polarstern* expedition PS99 for underway surface water sampling. The instrument was mounted to the surface seawater supply with a membrane and operated in flow-through mode to allow alternating measurements of the total and CDOM + water beam attenuation and absorption (IOPs) of seawater (see online measurements in Fig. 12.1). Flow-control and a debubbler system ensured water flow through the instrument with no air bubbles. To validate the instrumental measurements, we took regularly samples (every 3 hours) from surface water for HPLC pigment analysis and the absorption of particulate matters, phytoplankton and CDOM. In addition, we took water samples from four CTD stations with six depths, and seven CTD stations with one depth (the Deep Chlorophyll Maximum, DCM) for above analysis during the first leg of PS99.

Tab. 12.2: Biological parameters (AUTOFIM: samples automatically collected for molecular analyses on a 0.4 µm filter; DNA Euk: DNA of eukaryotes)

Station	AUTOFIM	DNA Euk	Bacterial cell no.	Bacterial biomass production	PP	Zoo-plankton
HG-I	x	x	x	x	x	x
HG-II			x	x	x	
HG-III			x	x	x	
HG-IV	x	x	x	x	x	x
HG-V			x	x	x	
HG-VI			x	x	x	
HG-VII			x	x	x	
HG-VIII						
HG-IX	x	x	x	x	x	x
N5	x	x	x	x	x	x
N4	x	x	x	x	x	x
N3			x	x	x	
EG-I	x	x	x	x	x	x
EG-II	x	x	x	x	x	
EG-III	x	x	x	x	x	
EG-IV	x	x	x	x	x	x
SV-IV			x	x	x	
SV-III			x			
SV-II	x			x	x	
SV-I	x	x	x	x	x	
S3	x	x	x	x	x	x

During the second leg, in addition to the underway programme, a second AC-s instrument was mounted on a steel frame together with a pressure sensor and a set of hyperspectral radiometer (RAMSES sensor, TRIOS) that operated successfully during 13 CTD stations (Fig. 12.2). The frame was veered down to 140 m with a continuous speed of 0.1 m s^{-1} and heaved at a speed of 0.2 m s^{-1} with stops every 5 m to allow a better collection of radiometric data. For the validation of both devices, we further took samples at five water depths (surface, DCM, Below DCM, 75 m and 100 m) for HPLC pigment analysis and the absorption of particulate matters, phytoplankton and CDOM at 20 CTD stations in the Fram Strait. In addition to that, we mounted a third RAMSES sensor on the monkey deck during the whole cruise for continuous spectrally resolved measurements of down welling irradiance in air (bottom of atmosphere irradiance). The RAMSES underwater radiance and irradiance data corrected by the in-air RAMSES incoming irradiance data will be used to calculate Remote Sensing Reflectance (R_{RS}). The *in-situ* R_{RS} data obtained under clear sky (5 out of 13 stations, the rest of the stations the sky was cloudy or it was very foggy) will be used to validate the ESA-Sentinel-3 OLCI imaging spectrometer R_{RS} data which are used to derive information on surface biogeochemistry (phytoplankton, other particulates, and CDOM). All RAMSES R_{RS} data will be used to optimize models linking those to the inherent optical properties (measured by the AC-s) and to the geophysical quantities derived from those.

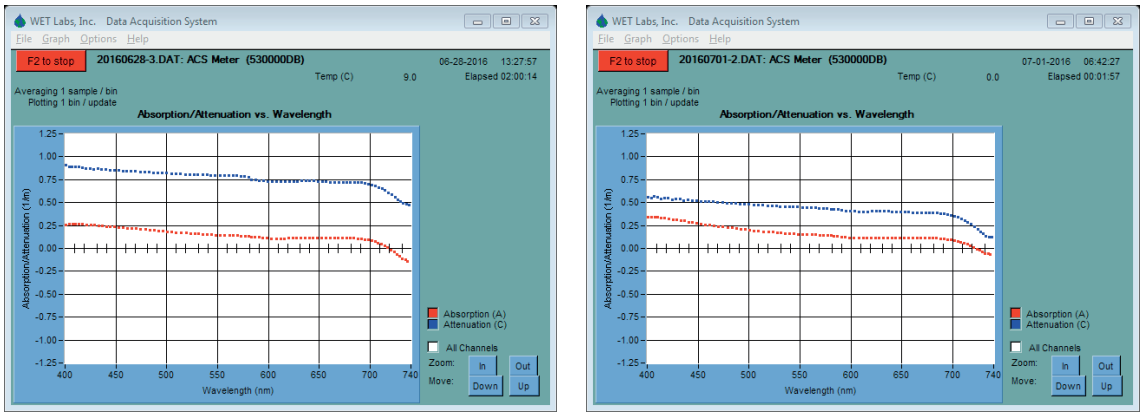

Fig. 12.2: Underway absorption (red) and beam attenuation (blue) measurements from AC-s for: Phaeocystis bloom waters on 28 June 2016 (left); non-bloom waters on 1 July 2016 (right)

Tab. 12.3: Bio-optical parameters sampled at PS99.2 stations (HPLC: High Pressure Liquid Chromatography; CDOM: Coloured Dissolved Organic Matter; PAB: Particulate absorption; RAMSES: upwelling and downwelling radiation in the water)

Station	HPLC pigments	CDOM	PAB	RAMSES
HG-I	x	x	x	x
HG-II	x	x	x	
HG-III	x	x	x	x
HG-IV	x	x	x	x
HG-V	x	x	x	
HG-VI	x	x	x	
HG-VII				
HG-VIII	x	x	x	
HG-IX	x	x	x	x
N5	x	x	x	x
N4	x	x	x	x
N3	x	x	x	
EG-I	x	x	x	x
EG-II	x	x	x	
EG-III	x	x	x	
EG-IV	x	x	x	x
SV-IV	x	x	x	x
SV-III	x	x	x	x
SV-I	x	x	x	x
S3	x	x	x	x

Bacterioplankton

During PS99 three *on-board* experiments were conducted to investigate potential effects of expected changes in temperature and pH of the Arctic Ocean on the turnover of organic carbon by the *in-situ* bacterioplankton communities. For this purpose, bioassays amended with different carbon sources were incubated at different temperatures and pH values. Samples were collected to analyse bacterial growth and degradation activity as well as changes in the community composition. Furthermore, the transect at 78°50'N was sampled to better understand interacting effects of temperature and substrate availability on bacterial activity and diversity in the Fram Strait. At 19 stations samples were taken to determine bacterial cell numbers and bacterial biomass production.

Zooplankton

To investigate community composition and depth distribution of the mesozooplankton in the HAUSGARTEN area, we used a multi net equipped with five nets (mesh size: 150 µm). Vertical net hauls sampling five depth strata (1500-1000-500-200-50-0 m) were conducted at eight stations (HG-I, HG-IV, HG-IX, S3, N4, N5, EG-I, and EG-IV; Fig. 11.1). The samples were immediately preserved in formalin buffered with borax and will be analysed at the AWI laboratories in Bremerhaven. In addition to net sampling, the optical zooplankton recorder LOKI (Light frame On-sight Key species Investigations) was deployed, taking 20 pictures per sec of the organisms (100 µm - 2 cm in length) in the water column from 1,000 m depth to the surface. The LOKI frame was also equipped with an AQUA*scat*, which uses very high frequency (300 kHz - 4 MHz) acoustic backscatter to derive mean particle size and concentration. Simultaneous optical images allow the backscatter characteristics across multiple acoustic frequencies to be attributed to specific (plankton) organisms. The goal is to gain more reliable biomass estimates from acoustics, which reduce the target avoidance that limits conventional methods.

Automated sampling for molecular analyses

During this cruise, we carried out further tests with AUTOFIM on *Polarstern* in order to assess its applicability on board ships. We collected water samples by AUTOFIM and a CTD/Rosette Water Sampler (five depths) at 12 stations in Atlantic Water, polar water and on the Svalbard shelf. Samples were collected with AUTOFIM in parallel to the CTD/Rosette Water Sampler in order to evaluate to what extent the protist community composition in the AUTOFIM sample is representative for the protist community in the photic zone at the same sampling site. All samples were filtered and preserved or frozen at -20°C for further molecular genetic analyses in the home laboratory.

Preliminary results

Most samples will be analysed in home laboratories at AWI in Bremerhaven (biogeochemical parameters, phytoplankton abundance and molecular biology, zooplankton community composition and distribution), respectively GEOMAR in Kiel (bacterioplankton).

Bacterioplankton

First results of acidification experiments reveal that degradation activity of bacterioplankton communities in the Fram Strait was sensitive to moderate changes in seawater pH. Rates of extracellular beta-glucosidase and bacterial growth rates increased in acidified incubations. Also a temperature increase of 4°C that is projected for the near future had stimulating effects on bacterial growth and activity. These results suggest impacts of global change on

heterotrophic carbon turnover in the Arctic Ocean. Samples were taken to determine bacterial abundance by flow cytometry and microscopy. At four selected stations, colonization of gel particles by bacteria will be investigated by microscopy of double-stained filters (DAPI/Alcian Blue). Samples for bacteria cell abundance have to be analysed in the flow cytometer back to GEOMAR, Kiel.

Data management

Analyses of net or sediment trap samples, require tedious and time-consuming processing (species identification and enumeration) and, therefore, these analyses will take longer than chemical measurements. Thus, depending on the parameter as well as on the methods used for the analyses, it will take up to three years to complete our analyses. As soon as the data sets are available, other cruise participants may request and use them. When the data are to be published, they will also be submitted to the PANGAEA Data Publisher for Earth & Environmental Science and are then open for external use.

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13. SEAPUMP: SEASONAL AND REGIONAL FOOD WEB INTERACTIONS WITH THE BIOLOGICAL PUMP

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Grant No. AWI_PS99_00

Objectives

Due to anthropogenic activities, atmospheric carbon dioxide concentration has increased drastically. The oceans have the capacity to sequester large amounts of CO_2 and, thereby, buffer the high atmospheric CO_2 concentrations by exporting biologically fixed carbon into the deep ocean, where it can be stored for up to millions of years. Therefore, it is increasingly important to understand and quantify the role of the oceans in the global carbon cycle. Presently, we know little about the future ocean's capacity for carbon sequestration and studies suggest that past years have had phases of increased and decreased sequestration rates. Due to the long-term monitoring on carbon fluxes, we slowly gain insight into the overall processes that affect the annual carbon export, but we still know little about the processes affecting the export on a regional, diurnal or seasonal scale. Especially the Arctic is currently undergoing rapid environmental changes including warming, acidification and sea ice loss, as well as changes in ecosystem structure and functioning. The rapid changes in the Arctic Ocean will have large impacts on carbon cycling in the region. Therefore, there is an urgent need for more extensive investigations to obtain a good understanding of the flux processes in this changing environment. Hence, during *Polarstern* expedition PS99, we performed various studies to determine and quantify the processes shaping the vertical particulate organic carbon flux in the euphotic zone and the twilight zone (100-1,000 m), focussing on the composition of the carbon flux, settling velocities of marine particles, microbial degradation, and flux attenuation processes.

Underwater Vision Profiler

An Underwater Vision Profiler (UVP) was used to measure abundances, size distributions and community composition of particles and planktonic organisms throughout the water column. It consists of an intelligent camera, which acquires images of particles and plankton within a defined water volume illuminated by collimated of red light. The light is provided by LEDs that are flashing with a frequency of 20 Hz. The UVP was mounted to the CTD frame and equipped with its own depth sensor (Fig. 13.1). In that way, we are able to calculate vertical profiles of particle and plankton abundance, size-distribution, and species (plankton or particle) composition.

Marine Snow Catcher

In-situ formed marine snow was collected using a so-called Marine Snow Catchers (MSC). The MSC consists of a 100 L cylindrical water sampler with a particle collection tray at the bottom (Fig. 13.2). The instrument is deployed by a winch to the target depth and closed via a release mechanism that was activated with a drop weight. After a few hours to allow the settling of the particles in the collection tray, the water is gently drained and the collection tray, which now contained the settling particles, could be removed.

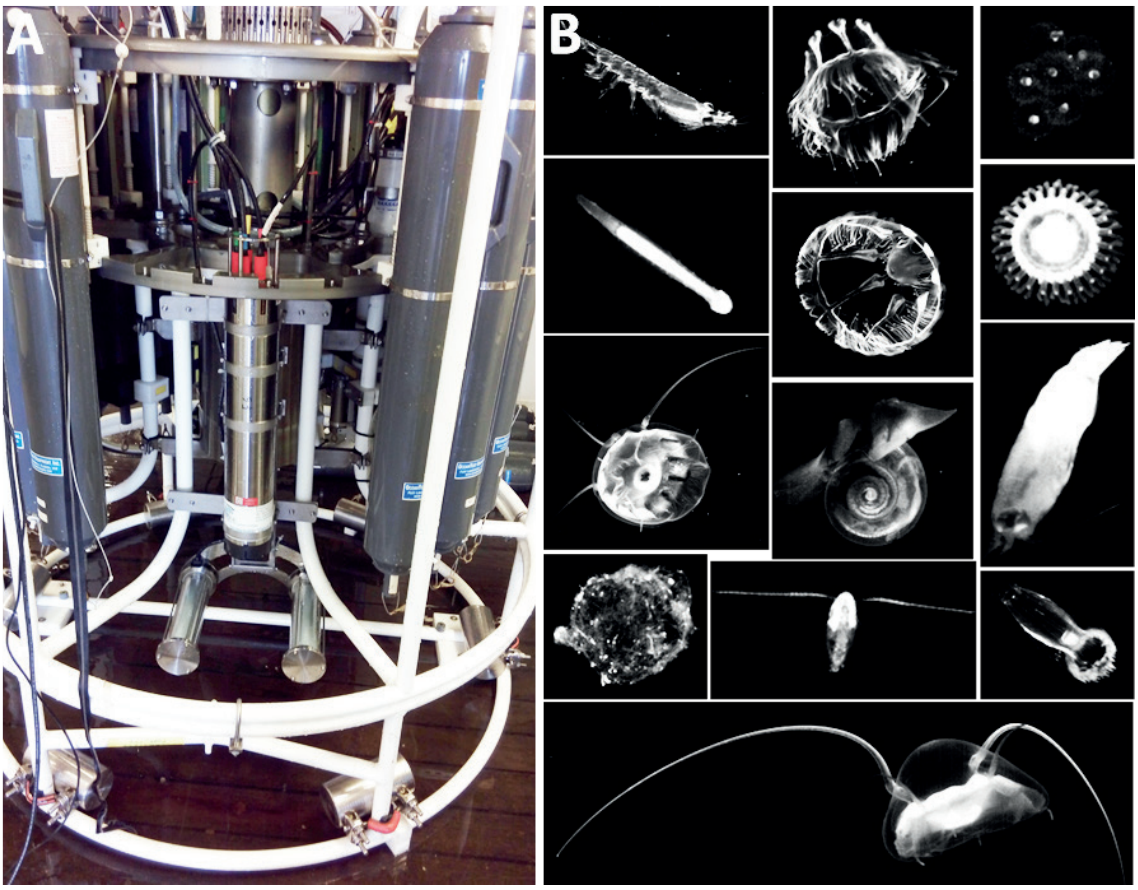

Fig. 13.1: A) Underwater Vision Profiler (UVP; highlighted by the red square) mounted at the bottom of the CTD/Rosette Water Sampler; B) Selection of high quality UVP images from different depths and areas in Fram Strait

In-situ pumps

Algae synthesize large quantities and varieties of polysaccharides with different functions and heterotrophic microbes catabolize polysaccharides to gain energy and carbon. In seawater, polysaccharides occur as mixtures at low concentrations, and are highly diverse. The role of polysaccharides in the marine carbon cycle, i.e. microbial production and turnover rates, remains unclear due to the lack of appropriate technologies that enable stereo- and sequence specific analysis and extraction of polysaccharides in crude and diluted samples. By using a new method based on carbohydrate active enzymes (CAZymes) we want to quantify the

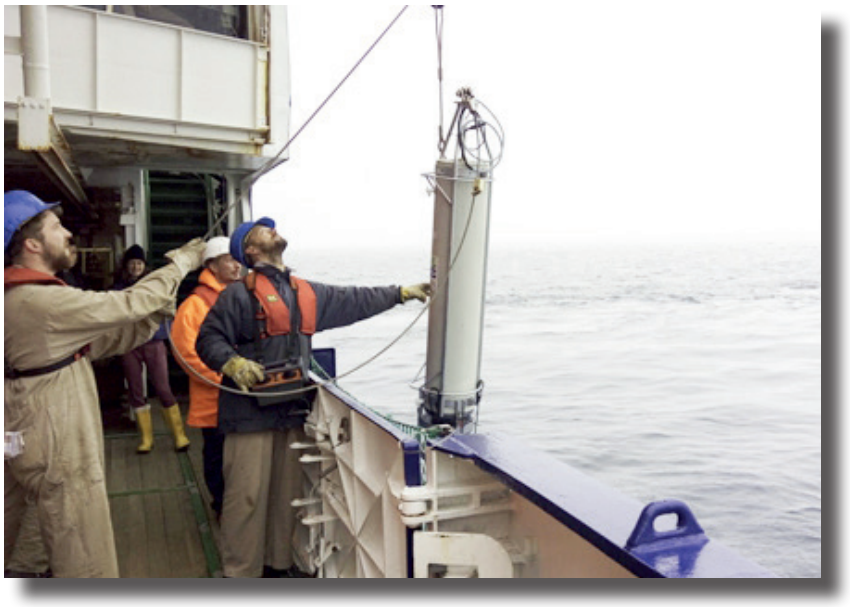

Fig. 13.2: Deployment of the Marine Snow Catcher (MSC) during PS99

polysaccharide laminarin, one of the most produced marine polysaccharides, in polysaccharide mixtures from marine algae. To assess laminarin concentrations, we took water samples by using Large Volume Water Transfer Systems (WTS-LV), also known as *in-situ* pumps (Fig. 13.3).

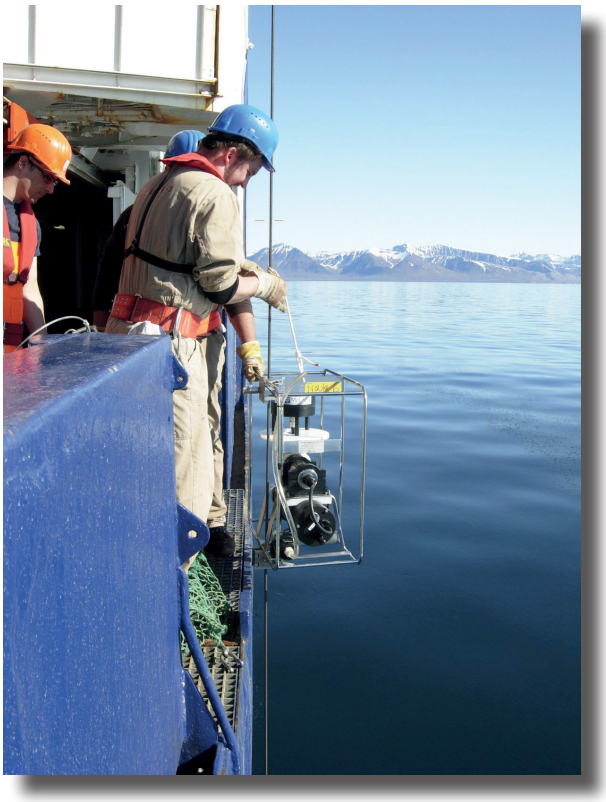

Fig. 13.3: Deployment of in-situ pumps off Svalbard

Drifting sediment traps

To estimate export fluxes in the upper 400 m of the water column, we used an array of free-drifting sediment traps (Fig. 13.4 a). Each drifting trap array carried three racks, each with four cylindrical traps attached gyroscopically (Fig. 13.4 b). The racks were deployed in 100, 200, and 400 m water depth. Three of the four trap cylinders at each depth were used to collect samples to estimate bulk fluxes and to conduct microscopical investigations as well as biogeochemical and genetic analyses. The fourth trap cylinder at each depth was equipped with a viscous gel that preserved the structure, shape, and size of the fragile particles settling into it (Fig. 13.4 c).

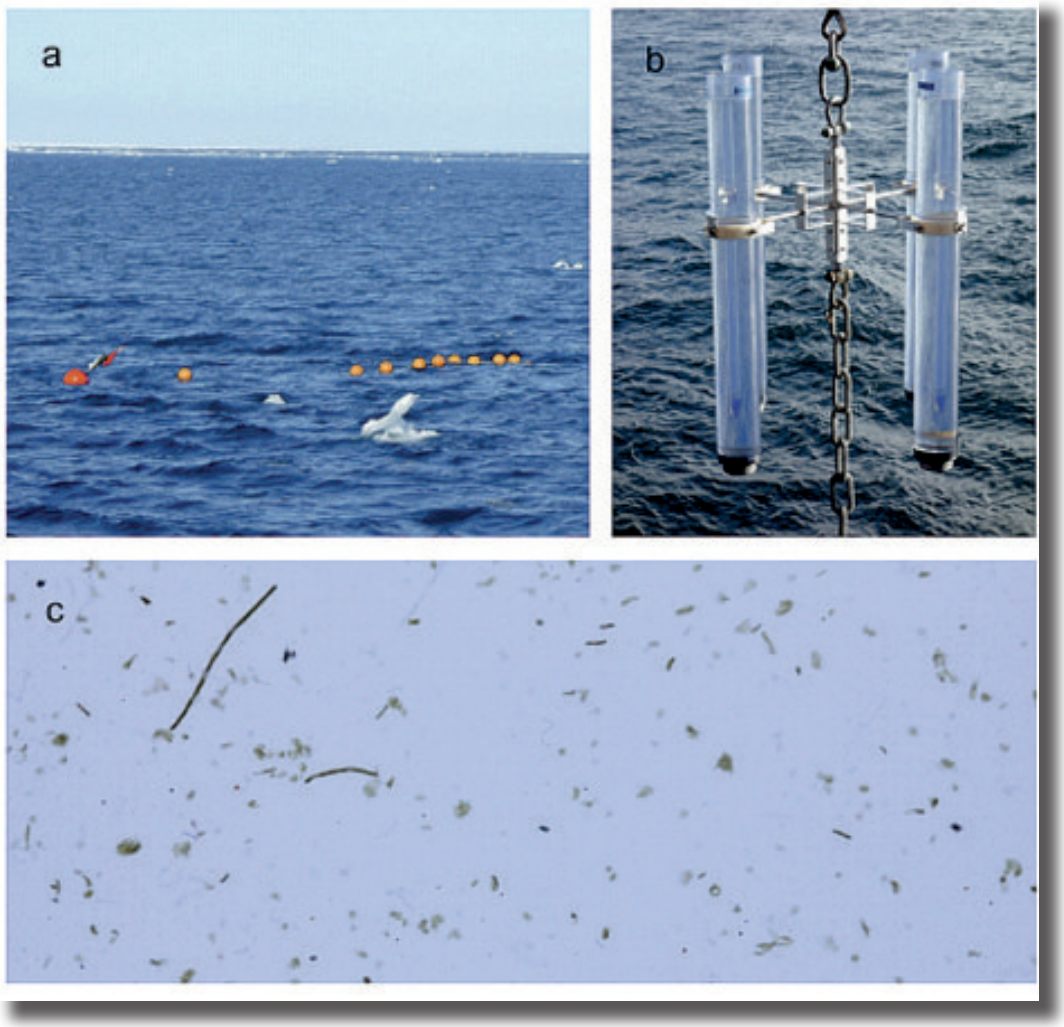

Fig. 13.4: Free-drifting sediment trap floating close to the ice shelf; only the buoy with the GPS positioning system and a number of the wave-breakers could be seen (a). Sediment trap rack with four trap cylinders (b). Settling particles from a deployment off Svalbard (c).

Bio-optical platform

The Bio-optical Platform (BOP) enables us to follow aggregate dynamics at high temporal resolution throughout the year. BOP uses an *in-situ* camera system to determine daily size-distributions, abundances and size-specific sinking velocities of the settling particles. This is done by having a settling cylinder where particles sink through. At the bottom part of the settling cylinder we have attached a perpendicular camera system that records 5-minutes image sequences daily. A rotation table with 20 cups collects the settling particles at pre-determined time periods (Fig. 13.5). The cups are filled with a viscous gel which preserves the size and three dimensional structures of particles sinking into the gel. This allows to identify and quantify different particle types as well as their compositions.

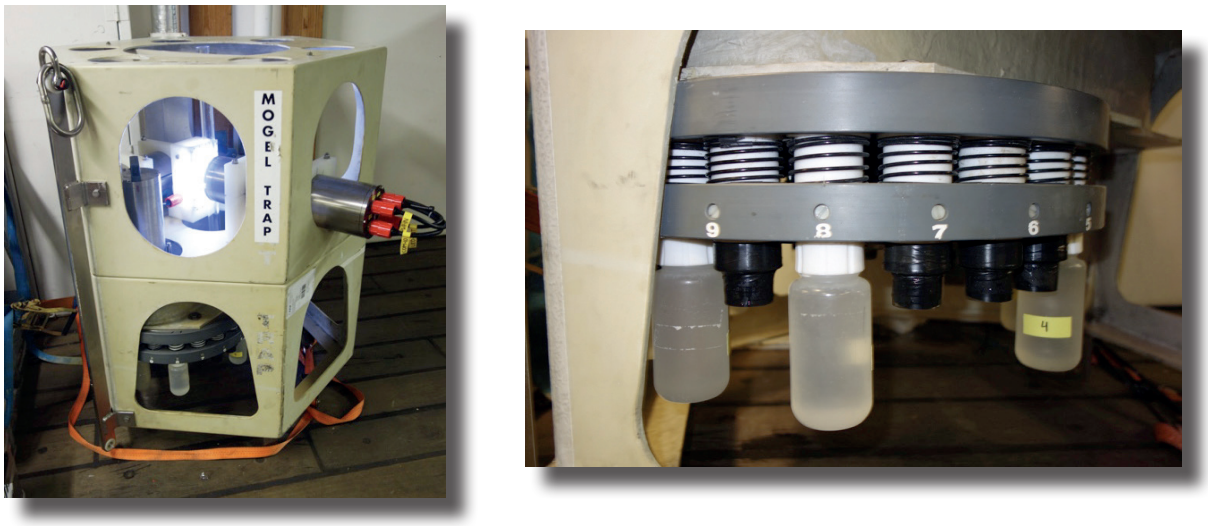

Fig. 13.5: The BOP with the polycarbonate settling column and the camera system switched on (left) and the rotation table with collection cups (right image). The large cups are for long collection periods and the small black cup are filled with viscous gel for short period collection.

Work at sea

In total, we obtained 41 vertical profiles with the Underwater Vision Profiler, UVP (see Table 13.1). Due to difficulties in identifying small objects from the images, we only stored images or particles larger than 0.62 mm². The maximum depth of the deployments was 5,569 m and in total we acquired 480,000 images (a few examples are presented in Fig. 13.1).

Tab. 13.1: Successful deployments of the UVP with information about station name, date of deployment, time for deployment start, latitude, longitude, and bottom depth

Profile ID	Date	Time (UTC)	Bottom Depth	Latitude	Longitude
PS99/002-1	19/06/2016	05:09	376	74°51.52' N	16°05.91' E
PS99/007-1	19/06/2016	22:51	159	74°59.75' N	17°59.75' E
PS99/010-1	20/06/2016	03:08	288	74°47.60' N	18°08.82' E
PS99/011-1	20/06/2016	04:06	178	74°43.48' N	18°01.41' E
PS99/012-1	20/06/2016	05:10	109	74°41.95' N	17°38.49' E
PS99/015-1	20/06/2016	07:45	294	74°50.55' N	17°38.52' E
PS99/016-1	20/06/2016	08:28	317	74°51.90' N	17°38.62' E
PS99/018-1	20/06/2016	09:59	133	74°56.04' N	17°38.38' E
PS99/019-1	20/06/2016	10:59	167	74°55.58' N	17°22.24' E
PS99/020-1	20/06/2016	11:47	306	74° 52.41' N	17° 21.52' E
PS99/021-2	20/06/2016	14:48	306	74°52.40' N	17°21.62' E
PS99/026-1	20/06/2016	23:16	273	74°57.32' N	16°08.84' E
PS99/038-2	22/06/2016	15:16	1046	77°38.78' N	10°16.81' E
PS99/039-1	22/06/2016	17:26	1352	77°35.18' N	10°05.53' E
PS99/041-1	25/06/2016	04:00	2339	78°36.59' N	05°03.81' E
PS99/041-6	25/06/2016	12:26	2344	78°36.44' N	05°03.13' E
PS99/042-1	26/06/2016	03:42	2462	79°03.90' N	04°10.89' E

Profile ID	Date	Time (UTC)	Bottom Depth	Latitude	Longitude
PS99/043-3	27/06/2016	16:16	2357	78°36.47' N	05°01.96' E
PS99/045-1	28/06/2016	11:17	3431	79°03.63' N	03°34.66' E
PS99/046-1	28/06/2016	19:45	4037	79°03.47' N	03°28.01' E
PS99/047-1	29/06/2016	04:55	5130	79°03.79' N	03°16.89' E
PS99/048-1	29/06/2016	23:41	2594	78°49.67' N	02°46.68' W
PS99/048-11	30/06/2016	19:45	2604	78°48.98' N	02°43.73' W
PS99/049-1	01/07/2016	11:55	1983	78°51.50' N	03°58.39' W
PS99/050-1	01/07/2016	19:05	1550	78°56.24' N	04°38.97' W
PS99/051-2	02/07/2016	01:51	1004	78°59.42' N	05°24.95' W
PS99/053-2	03/07/2016	17:07	2568	79°55.67' N	03°08.63' W
PS99/054-1	04/07/2016	18:29	2778	79°35.16' N	05°10.28' W
PS99/057-1	06/07/2016	03:37	1540	79°07.88' N	04°54.21' W
PS99/059-2	06/07/2016	19:42	5569	79°08.05' N	02°50.48' E
PS99/059-6	07/07/2016	09:04	5501	79°07.42' N	02°48.98' E
PS99/062-4	08/07/2016	20:27	1305	79°02.09' N	06°58.33' E
PS99/063-2	09/07/2016	01:28	760	79°00.13' N	08°21.87' E
PS99/064-2	09/07/2016	05:49	229	78°58.86' N	09°30.87' E
PS99/065-2	09/07/2016	11:06	270	79°01.61' N	11°05.30' E
PS99/066-2	09/07/2016	23:12	1268	79°08.31' N	06°05.30' E
PS99/066-5	10/07/2016	01:44	1283	79°08.32' N	06°04.93' E
PS99/069-2	10/07/2016	20:04	1890	79°06.44' N	04°35.86' E
PS99/074-1	12/07/2016	00:16	1283	79°08.30' N	06°05.14' E
PS99/075-2	12/07/2016	07:28	2381	79°02.66' N	04°31.85' E

The Marine Snow Catcher (MSC) was deployed at a total of nine stations (Table 13.2). We used the collected aggregates to determine their size-specific sinking velocities and microbial respiration. This was done in a vertical flow chamber where we measured all dimensions of the individual aggregates (height, length, and depth). On the same aggregates, we determined sinking velocities by adjusting the upward water flow in the flow chamber until it balanced the sinking velocity of the aggregates. The microbial respiration was measured with oxygen micro-sensors on the individual aggregates.

Tab. 13.2: Deployments of the marine snow catcher with information about station name, date of deployment, time for deployment, latitude, longitude, and deployment depth

Station name	Date	Time (UTC)	Latitude	Longitude	Depth (m)
PS99/041-2	25/06/2016	06:33	78°36.56’ N	05°03.164’ E	44
PS99/041-7	25/06/2016	13:25	78°36.49’ N	05°03.13’ E	40
PS99/042-7	26/06/2016	17:17	79°04.62’ N	04°08.18’ E	50
PS99/042-8	26/06/2016	17:46	79°04.65’ N	04°08.42’ E	50
PS99/048-4	30/06/2016	11:21	78°52.31’ N	02°46.76’ W	30
PS99/048-5	30/06/2016	11:37	78°52.30’ N	02°46.38’ W	30

Station name	Date	Time (UTC)	Latitude	Longitude	Depth (m)
PS99/051-3	02/07/2016	04:43	78°59.65' N	05°23.20' W	20
PS99/051-4	02/07/2016	05:07	78°59.53' N	05°23.21' W	20
PS99/053-3	03/07/2016	21:03	79°54.18' N	02°56.21' E	30
PS99/053-4	03/07/2016	21:22	79°54.09' N	02°55.29' E	100
PS99/055-3	05/07/2016	01:47	79°44.46' N	04°30.04' E	45
PS99/055-4	05/07/2016	02:43	79°44.62' N	04°28.70' E	45
PS99/059-7	07/07/2016	14:09	79°08.03' N	02°50.78' E	85
PS99/059-8	07/07/2016	14:35	79°07.98' N	02°51.02' E	150
PS99/062-5	08/07/2016	22:00	79°02.07' N	06°58.28' E	150
PS99/062-6	08/07/2016	22:31	79°02.10' N	06°57.94' E	45
PS99/064-3	09/07/2016	06:27	78°58.85' N	09°30.63' E	50
PS99/064-4	09/07/2016	06:45	78°58.87' N	09°30.51' E	50
PS99/069-3	10/07/2016	21:55	79°06.48' N	04°35.84' E	30
PS99/069-4	10/07/2016	22:08	79°06.48' N	04°35.83' E	40

In addition, we performed laboratory incubations of the *in-situ* formed marine snow in roller tanks. We added stable isotope labelled substrates to measure remineralisation, nitrate, and glucose uptake, and transformations by the microbial communities associated with the marine snow, collected at different depths and different stations. After the incubations we embedded several aggregates for later microscopic analyses of their porosity and the distribution of the active microbial community.

Since the methods used to determine size, sinking, and microbial respiration are all non-invasive, we stored each measured aggregate individually and will, therefore, be able to determine their chemical composition back in the home laboratory. Additionally, we made stack images of individual aggregates from each station using a microscope. These images provide a detailed semi three dimensional composition of the aggregates, however, we did not have fluorescence microscopes on board and did not stain the aggregates. Thus, we are only able to determine the phytoplankton and protist composition of the different aggregates.

Water samples for the quantification of the polysaccharide laminarin were taken with *in-situ* pumps. During the expedition PS99.2 we were able to sample at six stations (HG-IV, EG-IV, EG-I, N5, HG-IX, and SV-I; Table 13.3). The pumps were attached to the CTD rope at the following depths: sea surface, Chl*a* max, 300 m, 1,000 m, and at bottom depth. Over a time period of one hour, the pumps filtered volumes between 100 and 550 L onto 142 mm glass fibre filters with a pore size of 2.7 µm. Since we were not able to further process the samples on board, the filters were cut and frozen at -20°C.

Tab. 13.3: Sampling sites for the quantification of the polysaccharide laminarin at various water depths using *in-situ* pumps

Station name	Date	Latitude	Longitude	Sampling Depths
PS99/042-1	26/06/2016	79°03.91' N	04°10.81' E	Surface, ChlA max, 300 m, 1,000 m, bottom
PS99/048-1	30/06/2016	78°50.10' N	02°47.96' W	Surface, ChlA max, 300 m, 1,000 m, bottom

Station name	Date	Latitude	Longitude	Sampling Depths
PS99/051-2	02/07/2016	78°58.40' N	05°17.43' W	Surface, ChlA max, 300 m, bottom
PS99/053-2	03/07/2016	79°56.28' N	03°11.70' E	Surface, ChlA max, 300 m, 1,000 m, bottom
PS99/059-2	07/07/2016	79°08.01' N	02°50.54' E	Surface, ChlA max, 300 m, 1,000 m, bottom
PS99/065-2	09/07/2016	79°01.70' N	11°05.20' E	Surface, ChlA max, bottom

Drifting Sediment Traps were 4-times deployed during the cruise (Table 13.4). The drifting array consisted of a surface buoy equipped with an Iridium satellite unit, four surface float and 15 small buoyancy balls serving as wave breakers to reduce the hydrodynamic effects on the sediments traps. Each trap cylinder was 1 m tall and had a diameter 10.4 cm. After recovery of the drifting trap, the samples for bulk fluxes were preserved for later analysis for POC, PON, PIC, and silica in the home laboratory. The particles collected in the gel were photographed with a digital camera and will be used to measure the particle composition, abundance and size distribution.

Tab. 13.4: Deployments of the free-drifting sediment traps with information about station name, date of deployment, time for deployment and recovery, as well as latitude and longitude for deployments and recoveries

Station name	Date	Time (UTC)	Latitude	Longitude	Comments
PS99/042-5	26/06/2016	14:23	79°4.88' N	04°6.41' E	Deployment FDF5
PS99/042-5	27/06/2016	09:37	79°6.33' N	04°14.92' E	Recovery FDF5
PS99/048-6	30/06/2016	11:56	78°52.26' N	02°45.88' W	Deployment FDF6
PS99/048-6	01/07/2016	08:27	78°52.16' N	02°36.35' W	Recovery FDF6
PS99/052-2	03/07/2016	09:06	79°43.49' N	04°23.99' E	Deployment FDF7
PS99/052-2	04/07/2016	16:04	79°44.28' N	03°43.54' E	Recovery FDF7
PS99/068-3	10/07/2016	13:43	78°59.96' N	04°22.29' E	Deployment FDF8
PS99/068-3	11/07/2016	13:32	78°52.60' N	04°14.94' E	Recovery FDF8

During PS99.2, we recovered the BOP system attached to the mooring FEVI-31 deployed at station N4 during *Polarstern* expedition PS93.2 in 2015. The cups had all rotated through to the last cup, and all cups contained material. The camera system had captured 5 min of images daily between the 3 August 2015 and the 16 February 2016, which resulted in 191 days of image sequences. This premature end of image sequence collections was caused by drainage of the Li-battery earlier than expected. Moreover, we discovered that several of the sequences had particles that were stuck to one side of the settling column and that the number of stuck particles increased over time. This suggests that the BOP system had not

been levelled during its deployment and that several of the particles were rolling down one side of the settling column.

Before re-deployment of the BOP, we modified system by adding six glass buoyancy spheres to the side that was (most probably) weighed down during the past deployment. This was done to have the BOP system levelled on the mooring array. During the re-deployment we paid special attention to the positioning of the system as it entered the water - and it seemed to stay horizontal. We further shortened the settling column to have a shorter settling path before the particles enter the field of view from the camera. This will hopefully decrease the likelihood of encounters with the wall as the particles sinks through the settling column. Since we were not able to determine the reason for our high power consumption was during the few days we had between recovery and re-deployment, we decided to only capture an image sequence every second day. This will hopefully provide data on particle size-distribution, abundance, type, and size-specific settling velocities over a full year.

The BOP system was finally attached to the mooring FEVI-34 and deployed at station PS99/0072-1 on the 11 July 2016 at 79°00.05'N and 04°20.07'E. We programmed the cup openings according to the deep ocean sediment traps on the same mooring (see Chapter 11.1), but ensured that we would have several gel cups with just a few days of opening period (Table 13.5). This was to guarantee that we would not have particles falling on top of each other, which would prevent of from doing image analyses on the particles collected in the gel traps.

Tab. 13.5: Programming of the BOP system, periodical measurements by the camera system for 5 minutes every second day and opening times for each of the 20 gel cups

CUP	Date	Time	Remarks
	11/07/2016	12:00:00	Camera: auto start, 1 image per second for 5 minutes, auto shutdown, THIS PROCEDURE WILL BE REPEATED EVERY SECOND DAY WITHOUT END DATE
1	14/07/2016	00:05:00	Trap: First gel cup
2	15/08/2016	00:05:00	Trap: Next gel cup
3	18/08/2016	00:05:00	Trap: Next gel cup
4	31/08/2016	00:05:00	Trap: Next gel cup
5	02/09/2016	00:05:00	Trap: Next gel cup
6	30/09/2016	00:05:00	Trap: Next gel cup
7	02/10/2016	00:05:00	Trap: Next gel cup
8	31/10/2016	00:05:00	Trap: Next gel cup
9	02/11/2016	00:05:00	Trap: Next gel cup
10	24/12/2016	00:05:00	Trap: Next gel cup
11	27/12/2016	00:05:00	Trap: Next gel cup
12	28/02/2017	00:05:00	Trap: Next gel cup
13	02/03/2017	00:05:00	Trap: Next gel cup
14	31/03/2017	00:05:00	Trap: Next gel cup
15	02/04/2017	00:05:00	Trap: Next gel cup

CUP	Date	Time	Remarks
16	17/04/2017	00:05:00	Trap: Next gel cup
17	20/04/2017	00:05:00	Trap: Next gel cup
18	04/05/2017	00:05:00	Trap: Next gel cup
19	07/05/2017	00:05:00	Trap: Next gel cup
20	10/05/2017	00:05:00	Trap: Last gel cup
21	07/08/2017	00:05:00	Empty cup hole for recovery

Preliminary results

Since it had not been possible to complete all analyses on board, most samples were stored at -20°C until being processed in the laboratory in Bremen. For the determination of the polysaccharide laminarin, we will extract a crude polysaccharide mixture from the filters used in the *in-situ* pumps (Fig. 13.6).

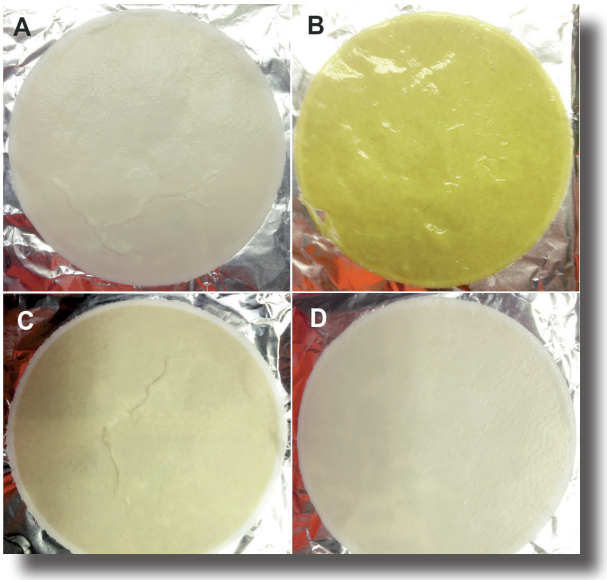

Fig. 13.6: Filtered biomass from 228 L surface water (A), 95 L Chla max. water (B), 496 L of 300 m water (C), and 542 L from bottom water at ~5,350 m (D) at station HG-IX

The majority of the settling particles collected with the Drifting Sediment Traps seemed to be marine snow particles and faecal pellets. The faecal pellets were mainly produced by copepods and krill. At several of the stations we observed many *Phaeocystis* cells both in the euphotic zone and within the marine snow aggregates. However, the marine snow aggregates also contained diatoms, and it is likely that the silica frustules of the diatoms served as ballasting causing the marine snow aggregates to settle to collection depths of the drifting trap.

Data management

The finally processed data will be submitted to the PANGAEA data library.

14. DYNAMITE: ASSESSING DYNAMICS OF NUTRIENTS USING AUTONOMOUS INSTRUMENTS IN FRAM STRAIT

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not on board: Sheldon Bacon[1],
Alex Beaton[1]

[1] NOCS
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Grant No. AWI_PS99_0

Objectives

DYNAMITE builds on previous work (Torres-Valdes et al., 2013, 2016; MacGillchrist et al., 2014), which aims to investigate carbon and nutrient biogeochemical cycling at the pan-Arctic scale. To further our understanding of biogeochemical cycling in the Arctic under climate change we need to generate baseline measurements against which current and future measurements can be compared. Our approach to date has been to assess budgets of biogeochemical variables via the calculation of transports to and from the Arctic Ocean across each of the main gateways: Davis Strait, Fram Strait, the Barents Sea Opening and Bering Strait. Nutrient transports are useful to determine the main pathways of oceanic nutrients' supply to Arctic waters and also to the North Atlantic. Net transports (budgets) then become relevant since these can be used to investigate how the combined effects of physical (e.g. water mass formation, river fresh water supply) and biological processes (e.g. primary production, bacterial production, denitrification) control the spatial and temporal distribution of nutrients and transports to/from the Arctic Ocean.

Given the difficulty in accessing the Arctic Ocean, particularly in winter, available data derive mostly from regional studies carried out in summer time. In fact, there are only few hydrographic sections across gateways and across the Arctic Ocean. Additionally, little is known about the importance of dissolved organic nutrients for the Arctic nutrient budget and about the bacterial communities associated with the degradation of these materials. This has hindered our ability to constrain nutrient transports and thus closure of the Arctic Ocean nutrient budget. One of the main gaps in our knowledge stems from the lack of continuous measurements, which could allow the assessment of temporal changes (seasonal and interannual) in nutrient transports and their impact on the nutrient budget. Relevant to such endeavours is the development of new technologies, capable of generating measurements over long periods of time (e.g. months to years). Lab-on-chip (LOC) nitrate sensors developed at NOCS (Beaton et al., 2012) have been previously proven successful in deployments in rivers, coastal waters and glacial streams. We have now had the opportunity to deploy them in the ocean under polar conditions.

DYNAMITE's aims are two fold, with scientific and technical objectives:

Scientific objectives

- To assess temporal (seasonal) changes of nutrient transports to and from the Arctic Ocean through Fram Strait.
- To quantify the significance of organic nutrients in closing the Arctic Ocean - Atlantic Ocean inorganic nutrient imbalances.
- To characterise the microbial communities associated with nutrient transport to/from the Arctic Ocean.

Technical objectives

- To test lab-on-a chip nitrate and phosphate sensors for long-term (~1 yr) deployments in the Arctic Ocean for high-resolution measurements.
- To use an autonomous water sampler in a 1 yr deployment to collect samples for dissolved organic nutrients, microbial communities and inorganic reference samples.
- To compare high-resolution sensor measurements with medium resolution water samples for N and P concentrations.

Work at sea

During *Polarstern* cruise PS99.2 we recovered three nitrate sensors and two automated samplers deployed during PS93.2 in 2015 (Fig. 14.1); two sensors and one sampler from a mooring at the HAUSGARTEN station EG-IV, and one sensor and one sampler from a mooring at station HG-IV (Fig. 14.2).

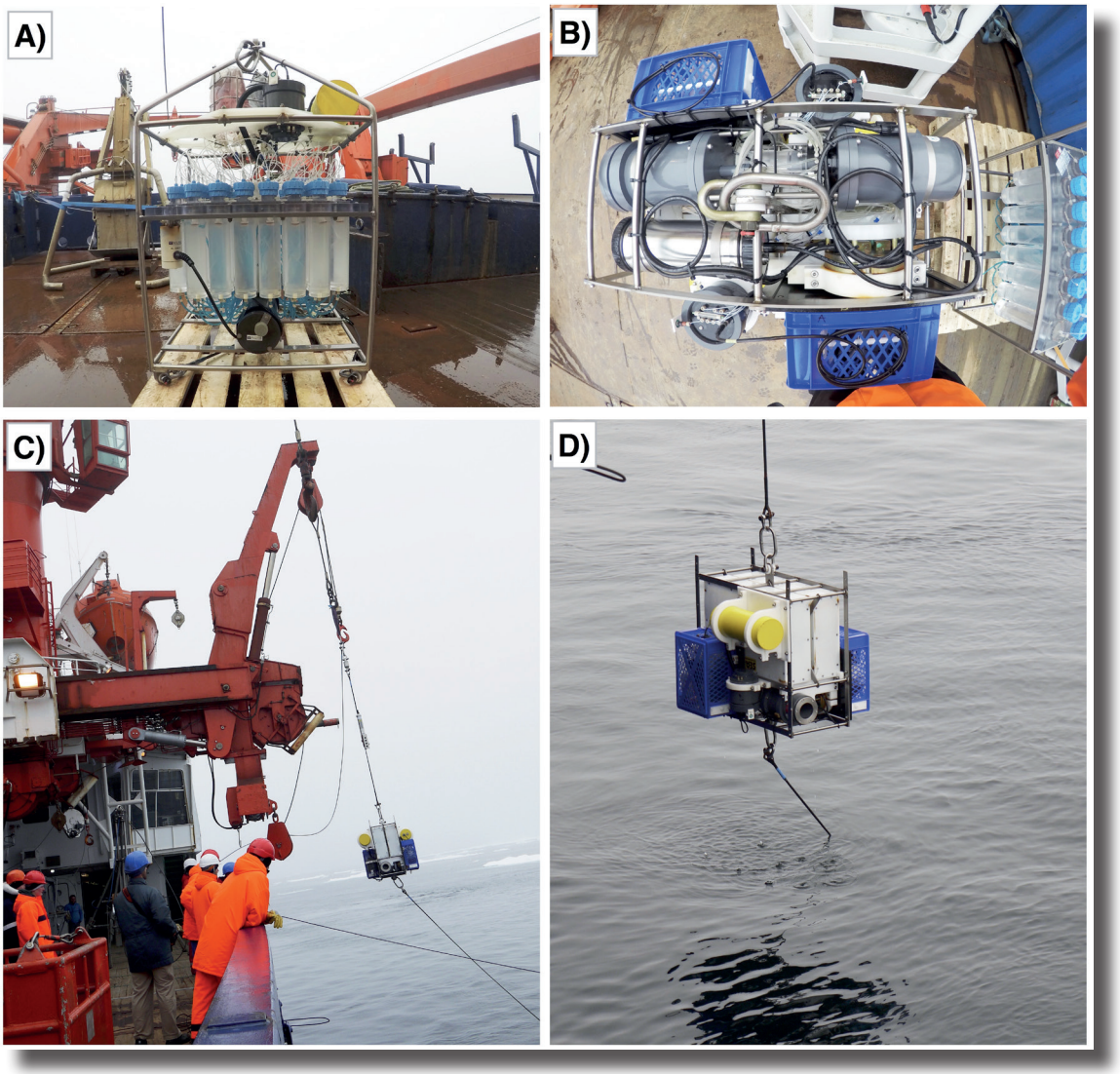

Fig. 14.1: McLane Remote Access Sampler with nitrate sensor mounted on top (A), deployed at HG-IV. Injection sampler with two nitrate sensors mounted on each side (B), deployed at EG-IV. Mooring recovery showing sampler and sensors from EG-IV (C and D).

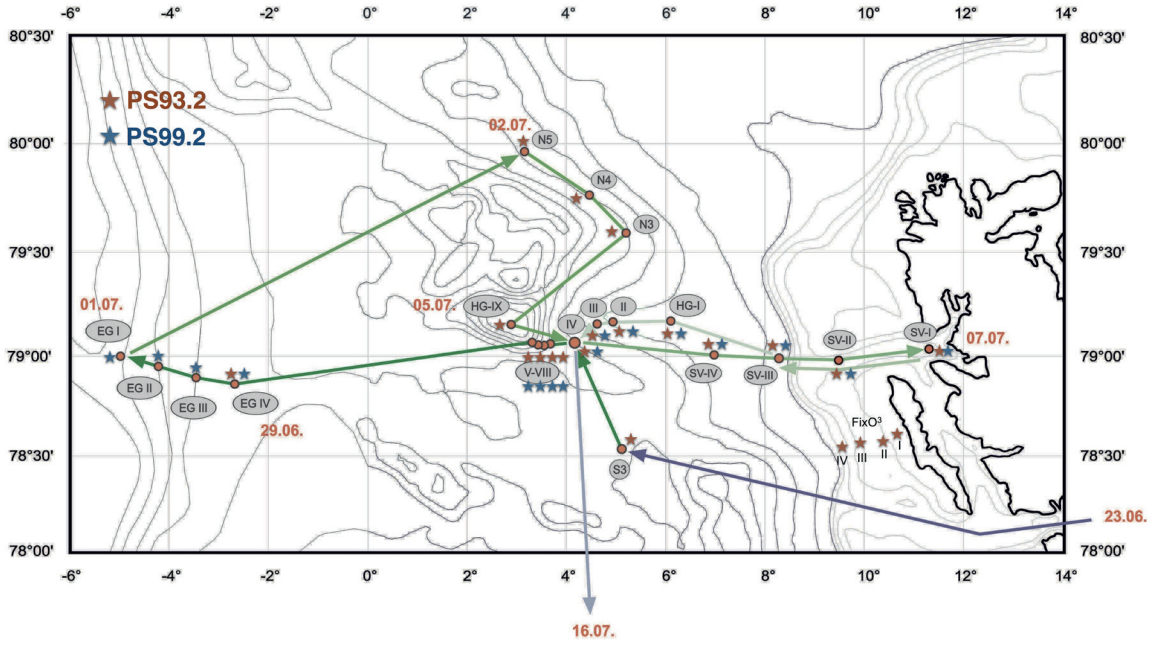

Fig. 14.2: PS99.2 programme map showing sampling and mooring stations; CTD stations where water samples were collected for dissolved organic nutrients during PS93.2 and PS99.2 are marked with red and blue stars, respectively.

Samples were collected for the analysis of dissolved inorganic constituents (nitrate + nitrite, nitrite, phosphate, silicate and ammonium) at all stations during both cruises. 229 samples for the analysis of dissolved organic nutrients (nitrogen and phosphorus) were collected during PS93.2 and 173 during PS99.2 (Fig. 14.2). Additionally, 24 samples with few randomly selected duplicated were collected from the autosampler deployed at EG-IV. Sampling stations were selected to measure nutrient concentrations associated with the polar outflow (East Greenland Current) and Atlantic Water inflow (West Spitsbergen Current). Dissolved inorganic nutrients were measured on-board, while samples for dissolved organic nitrogen and dissolved organic phosphorus were frozen for later analysis.

Preliminary results

Two of the nitrate sensors (one from each of the moorings) were transported back to NOCS immediately for data download. The remaining nitrate sensor (which was the second unit deployed at EG-IV) is being shipped back to NOCS, and we will attempt to recover data from this when it arrives.

Data was recovered from both of the nitrate sensors that arrived back to NOCS. The sensor deployed at EG-IV recorded a full year of twice-daily nitrate measurements (Fig. 14.3). As of yet we have only been able to download 3 months of data from the sensor deployed at HG-IV (Fig. 14.4). This is likely due to a software issue that we are currently trying to resolve.

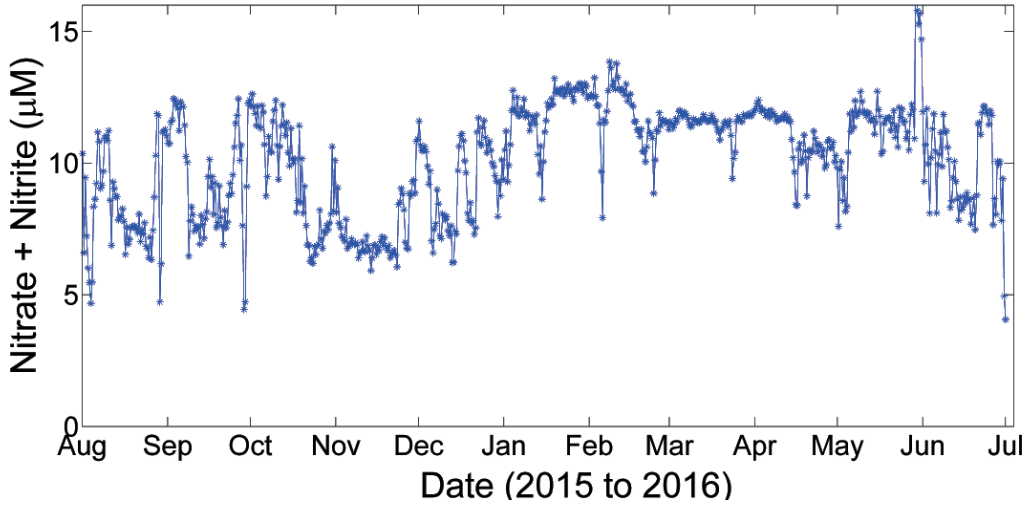

Fig. 14.3: Year-long nitrate + nitrite time series (two measurements per day at approximately 80 m water depth) at EG-IV measured using the LOC sensor developed at NOCS that was recovered during PS99.2.

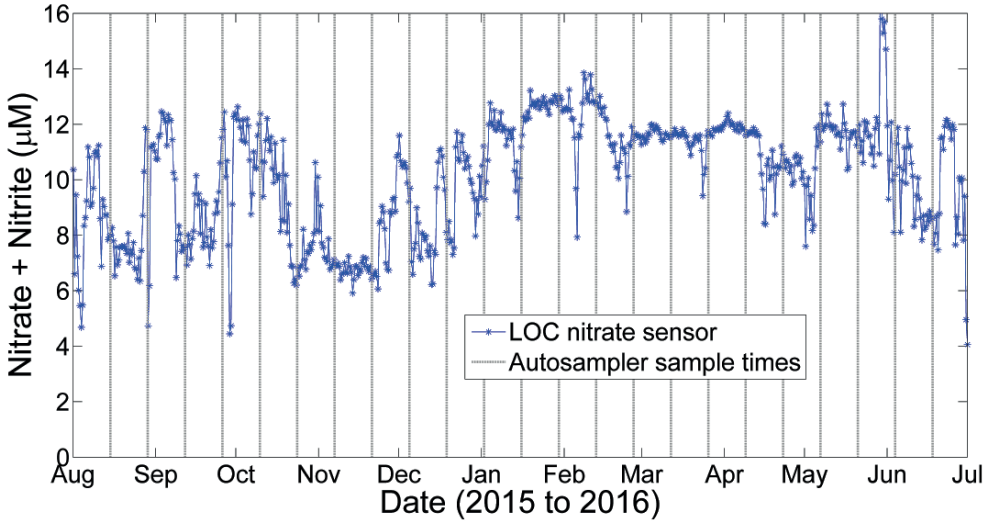

Fig. 14.4: Year-long nitrate + nitrite time series (two measurements per day) at EG-IV (approximately 80 m) measured using the LOC sensor developed at NOC that was recovered during PS99.2. The blue line is data from the LOC analyser, and vertical grey lines show the times at which the autosampler collected samples (yet to be analysed).

Initial analysis suggests no decrease in performance was visible over the year-long deployment period. The low temperatures allowed reagents to remain stable, and antifreeze compounds included in the reagents allowed them to remain liquid despite sub-zero ambient temperatures. No issues were encountered with biofouling, and the sensors proved to be robust enough to operate for a year-long deployment in the Arctic Ocean.

EG-IV represents the longest successful unattended deployment of a NOCS lab-on-chip sensor, and is a truly significant milestone in demonstrating the robustness and endurance of this technology. The deployment opportunity provided by our participation in PS93.2 and PS99.2 has provided invaluable information about the long-term performance and capability of the sensors in such extreme environments, and will help us to improve sensor reliability and performance in future work. The success of our work through the European FixO3 programme should establish the LOC nitrate sensors as a viable tool for long-term unattended nutrient measurements in the Arctic Ocean.

At the time of writing this report, our instrument to measure dissolved organic nutrients was with the manufacturer (Seal Analytical, Germany) for repair. We estimate the analysis of samples will be completed within six months once our analyser is fully functional and back at NOCS. Samples collected during PS99.2 will be freighted from AWI to NOCS when *Polarstern* is back in Bremerhaven in October 2016.

As a first step towards the analysis of data, we will combine CTD data from casts and from moorings with data from the analysis of samples and data from the LOC sensors. This will help us to identify the water masses associated our measurements and will also allow us to determine to what extent variability observed in nutrient concentrations is due to variability of water masses. Next we will compute nutrient transports either via simple calculations of geostrophic flows or by combining nutrient concentration with already existing velocity fields across Fram Strait.

Data management

When available, processed data will be submitted to the PANGAEA data repository. Data will also be made available to other participants of the expedition upon request.

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15. ABYSS: ASSESSMENT OF ARCHAEAL AND BACTERIAL LIFE AND MATTER CYCLING IN THE ARCTIC WATER COLUMN AND DEEP-SEA SURFACE SEDIMENTS

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Objectives

Abundance, diversity and physiology of ammonia-oxidizing archaea in the water column of the Arctic Ocean

For decades the nitrification process was exclusively attributed to ammonia- and nitrite-oxidizing bacteria (AOB and NOB, respectively), until a metagenomic survey of Sargasso sea water samples revealed presence of a gene encoding a distant homolog of the subunit A of the bacterial ammonia monooxygenases (AmoA) on an archaeal scaffold (Venter et al., 2004), suggesting the existence of ammonia-oxidizing archaea (AOA). This was confirmed one year later by the description of a marine ammonia-oxidizing archaeon brought to pure culture and, named *Nitrosopumilus maritimus* (Könneke et al., 2005). In the following decade AOA were identified as a widespread and abundant component of microbial communities in various environments, and therefore became a major research focus in environmental microbiology (Stahl & de la Torre, 2012). Several molecular surveys have assessed the distribution of archaeal amoA-like gene sequences in marine waters and surface sediments and showed that most of the sequences fall within two phylogenetically distinct clades referred to as α- and γ/δ-clade. The α-clade consists of sequences essentially from the euphotic zone (<200 m depth) and deep-sea surface sediments, and the γ/δ-clade comprises sequences mainly obtained from deep waters (>200 m) (Hatzenpichler, 2012).

Using samples from the LTER observatory HAUSGARTEN, we attempt to characterize the dynamics of AOAs abundance along the depth transect of the observatory and investigate the niche separation between thaumarchaeal organisms belonging to the α- and γ/δ-clade present in the marine water column and marine surface sediments of the Arctic Ocean. Collected water samples will be used for both direct microbial diversity analyses and for further physiological assays of cultured strains.

Enrichment of AOA from the water column

Up to date all published isolated strains of marine AOAs are members of the α-clade. Therefore, our goal is to enrich and purify strains belonging to the γ/δ-clade using the water and sediment samples acquired during the cruise sampling. Gain of such a strain, will allow direct testing of hypotheses regarding the metabolism and physiology of these organisms.

Long-term time series of microbial communities in deep-sea sediments

Our ocean floors are mainly covered by fine-grained deep-sea sediments, which are dominated by bacteria both in abundance and biomass. These bacteria highly depend on the exported

organic material that sinks down from the productive surface ocean as food source, which they break down and use as energy source. They therefore play important roles in carbon and nutrient recycling (Jørgensen & Boetius, 2007). We know from previous work at the HAUSGARTEN long-term observatory that changes in the concentration of sinking organic matter can affect the bacterial community structure at the deep-sea floor (Jacob et al., 2013). Long-term observations at this site have also shown that the composition of this organic material has varied greatly, which eventually may also influence benthic bacterial communities (Soltwedel et al., 2016). Our work contributes to the continuation of time-series analyses of bacterial diversity at this site to track potential impacts of environmental change on microbial community composition.

All samples from the HAUSGARTEN stations will contribute to the FRAM microbial observatory project. The work will be carried out in the framework of the European Research Council Advanced Investigator grant ABYSS (no. 294757; A. Boetius).

Benthic-pelagic coupling of microbial communities in the ice-covered Arctic Ocean

As environmental changes in the surface ocean might also have important effects on benthic microbial communities, we selected dedicated stations to further elucidate the coupling of surface environments to the deep sea. By sampling a cross section of the water column from sea ice to deep-sea sediments for prokaryotic and eukaryotic diversity analyses we want to investigate the degree of community overlap between different compartments.

Work at sea

Water samples

Water samples were obtained using 12 L Niskin bottles housed on a rosette equipped with SBE conductivity–temperature–depth (CTD) sensors (Table 15.1). Samples were collected from four different depths: 10 m, DCM (deep chlorophyll maximum), 1000 m and bottom depth (according to the bathymetry of the sampling site). For archaeal work, samples were collected in triplicates of 8 L each (in several stations only 4 L were collected from DCM depth) and filtered using peristaltic pump through nylon net filter (5 µm pore size, Millipore) for the particulate fraction and a Sterivex capsule (0.22 µm pore size, Millipore) for free living cells. For bacterial work, samples were directly filtered through 0.22 µm pore size. In addition, from each water depth a triplicate of samples was filtered and fixed for further cell counting using fluorescence *in-situ* hybridization. All samples will be analysed for community structure using 16S rRNA tag sequencing.

Tab. 15.1: Water column samples for DNA extractions and total prokaryotic cell counts. DNA samples were sequentially filtered on 5 and 0.22 µm filters and stored at -20°C. For Fluorescence In-Situ Hybridization (FISH), samples were fixed using 4 % formaldehyde, filtered on 0.22 µm membranes and stored at -20°C.

Date	Station	Site	Latitude	Longitude	Sampled depths [m]
25/06/16	PS99/041-1	S3	78°36.59' N	05°03.85' E	1000,2330
25/06/16	PS99/041-6	S3	78°36.44' N	05°02.84' E	15,28
26/06/16	PS99/042-1	HG-IV	79°03.96' N	04°11.06' E	1000,2450
26/06/16	PS99/042-11	HG-IV	79°03.93' N	04°10.55' E	28,100
28/06/16	PS99/044-1	HG-V	79°03.90' N	03°39.46' E	25,100,2600,3040

Date	Station	Site	Latitude	Longitude	Sampled depths [m]
29/06/16	PS99/046-1	HG-VII	79°03.41' N	03°31.56' E	25,100,1000,3772
29/06/16	PS99/047-1	HG-VIII	79°04.33' N	03°20.69' E	15,100,1000,5000
30/06/16	PS99/048-1	EG-IV	78°49.70' N	02°46.08' W	1000,2527
30/06/16	PS99/048-11	EG-IV	78°48.96' N	02°43.73' W	24,100
02/07/16	PS99/051-2	EG-I	78°59.45' N	05°24.56' W	13,100,971
03/07/16	PS99/053-2	N5	79°55.27' N	003°03.72' E	19,100,1000,2427
04/07/16	PS99/054-1	N3	79°35.20' N	005°10.20' E	34,100,1000,2700
05/07/16	PS99/055-1	N4	79°44.49' N	004°30.21' E	1000,2500
06/07/16	PS99/057-1	HG-II	79°07.80' N	004°54.40' E	22,100,1000,1492
07/07/16	PS99/059-2	HG-IX	79°08.04' N	002°50.46' E	24,100,1000,2499, 5500
08/07/16	PS99/062-4	SV-IV	79°02.10' N	006°58.32' E	1000
09/07/16	PS99/063-2	SV-III	79°00.12' N	008°21.90' E	100
09/07/16	PS99/064-2	SV-II	78°58.88' N	009°30.32' E	33,100
09/07/16	PS99/065-2	SV-I	79°01.66' N	011°05.62' E	18,100
10/07/16	PS99/066-2	HG-I	79°08.36' N	006°05.27' E	17
10/07/16	PS99/066-5	HG-I	79°08.34' N	006°04.92' E	100,500,1253

AOA enrichments

Aliquots (200 mL each) collected from the water samples described above were used as inoculum for enrichment cultures aimed at isolating new AOA strains. Triplicate enrichment cultures were initiated with each aliquot. The inoculum for each enrichment culture consisted of a 60 mL water sub-sample. The inoculum was injected in 144 mL serum glass bottles containing 40 mL of autoclaved Synthetic Crenarchaeota Medium, SCM (Könneke et al., 2005) through a gas tight septum using sterile syringes and needles. The SCM medium consists of an aqueous solution containing NaCl at 26 g.L^{-1}, $MgCl_2(6H_2O)$ at 5 g L^{-1}, $MgSO_4(7H_2O)$ at 5 g L^{-1}, $CaCl_2$ at 1.5 g L^{-1} and KBr at 0.1 g L^{-1}. Enrichment cultures were starved in the dark and at 4°C during the entire time span of the expedition. Upon return to the laboratory, enrichment cultures will be further starved in the dark and at 4°C for a period ranging from 4 to 12 months before being stimulated by addition of ammonia sources, i.e. NH_4Cl, urea and amino acids. Stations sampled for AOA enrichments are summarized in Table 15.2.

Tab. 15.2: Water column samples used for the inoculation of enrichment cultures

Date	Station	Site	Latitude	Longitude	Sampled depths [m]
25/06/16	PS99/041-1	S3	78°36.59' N	05°03.85' E	1000
26/06/16	PS99/042-1	HG-IV	79°03.96' N	04°11.06' E	500,2500
27/06/16	PS99/042-11	HG-IV	79°03.93' N	04°10.55' E	28,100

Date	Station	Site	Latitude	Longitude	Sampled depths [m]
28/06/16	PS99/044-1	HG-V	79°03.90' N	03°39.46' E	25,100,2600,3048
30/06/16	PS99/048-1	EG-IV	78°49.70' N	02°46.08' W	1000,2527
30/06/16	PS99/048-11	EG-IV	78°48.96' N	02°43.73' W	24,100
01/07/16	PS99/050-1	EG-II	78°56.24' N	04°38.97' W	18,100,1000,1501
03/07/16	PS99/053-2	N5	79°55.27' N	03°03.72' E	19,100,1000,2427
04/07/16	PS99/054-1	N3	79°35.20' N	05°10.20' E	34,100,1000,2700
06/07/16	PS99/059-2	HG-IX	79°08.04' N	02°50.46' E	100,1000,2499,5500
09/07/16	PS99/064-2	SV-II	78°58.88' N	09°30.32' E	100
09/07/16	PS99/065-2	SV-I	79°01.66' N	11°05.62' E	18,100
10/07/16	PS99/066-5	HG-I	79°08.34' N	06°04.92' E	100,500,1253

Sediment samples for continuation of long-term time series of microbial communities

We used a TV-guided multiple corer (TV-MUC) to sample a total of 20 different stations for undisturbed deep-sea sediment samples (Table 15.3). From each station three 20 ml cut-off syringes were collected from three different cores for each total DNA and RNA analysis and stored at -20°C or shock-frozen and then stored at -80°C, respectively. Back in the home laboratory samples will be divided into individual depth layers (0-1, 1-2, 2-3, 3-4, 4-5 cm). For all stations additional sediment samples, which were directly subsampled by depth layer, were collected in 15 ml Falcon tubes and stored for DNA (-20°C) and RNA (-80°C) extractions. Subsamples from the same stations were fixed in formaldehyde for the determination of prokaryotic cell numbers (Table 15.3), either through Acridine Orange Direct Counts (AODC) or for the quantification of specific groups through Fluorescence *In-Situ* Hybridization (FISH).

Tab. 15.3: Sediment samples for DNA/RNA extractions and total prokaryotic cell counts for the depth horizons 0-1 cm to 4-5 cm from TV-MUC deployments. DNA samples are stored at -20°C, RNA samples at -80°C, respectively. For Acridine Orange Direct Counts (AODC) samples are stored in 4% formaldehyde at 4°C, for Fluorescence In-Situ Hybridization (FISH) samples were washed with 1xPBS and stored in 1xPBS:EtOH at -20°C.

Gear	Date	Station	Site	Latitude	Longitude	Depth [m]
TV-MUC	25/06/16	PS99/041-9	S3	78°36.51' N	05°04.13' E	2338
TV-MUC	27/06/16	PS99/042-13	HG-IV	79°03.89' N	04°10.93' E	2462
TV-MUC	06/07/16	PS99/058-1	HG-IV	79°01.39' N	04°24.68' E	2536
TV-MUC	28/06/16	PS99/044-2	HG-V	79°04.52' N	03°42.70' E	2877
TV-MUC	28/06/16	PS99/045-2	HG-VI	79°03.82' N	03°36.40' E	3324
TV-MUC	29/06/16	PS99/046-2	HG-VII	79°03.73' N	03°29.27' E	3949
TV-MUC	29/06/16	PS99/047-2	HG-VIII	79°03.66' N	03°17.94' E	5087
TV-MUC	30/06/16	PS99/048-12	EG-IV	78°48.97' N	02°44.09' W	2604
TV-MUC	01/07/16	PS99/049-2	EG-III	78°51.31' N	03°57.33' W	1983

Gear	Date	Station	Site	Latitude	Longitude	Depth [m]
TV-MUC	01/07/16	PS99/050-2	EG-II	78°56.03' N	04°38.59' W	1551
TV-MUC	02/07/16	PS99/051-9	EG-I	78°59.47' N	05°27.05' W	982
TV-MUC	03/07/16	PS99/052-3	N4	79°44.26' N	04°25.96' E	2621
TV-MUC	04/07/16	PS99/053-7	N5	79°57.79' N	02°55.99' E	2614
TV-MUC	04/07/16	PS99/054-2	N3	79°35.26' N	05°10.46' E	2779
TV-MUC	06/07/16	PS99/057-2	HG-II	79°07.86' N	04°54.17' E	1541
TV-MUC	07/07/16	PS99/059-9	HG-IX	79°08.02' N	02°50.64' E	5569
TV-MUC	08/07/16	PS99/062-1	SV-IV	79°02.02' N	07°00.03' E	1308
TV-MUC	09/07/16	PS99/064-5	SV-II	78°58.88' N	09°30.32' E	218
TV-MUC	09/07/16	PS99/065-3	SV-I	79°01.66' N	11°05.62' E	272
TV-MUC	10/07/16	PS99/066-3	HG-I	79°08.36' N	06°05.27' E	1282
TV-MUC	10/07/16	PS99/069-5	HG-III	79°06.43' N	04°35.77' E	1906

At three occasions TV-MUC deployments were conducted for the collection of live sediment samples (Table 15.4), which will be used for experimental work back in the home laboratory. For this, the upper two centimetres from each core were mixed with sterile filtered (0.22 µm pore size) deep seawater in a 1:1 ratio and stored at 0°C in the dark.

All sediment samples were taken within the LTER HAUSGARTEN framework and contribute to the long-term observations. Results will be interpreted in the context of additional environmental parameters that were sampled from the same cores (see Chapter 11.2).

Tab. 15.4: Live sediments retrieved from the upper 2 cm of MUC cores. Sediments were mixed 1:1 with sterile filtered deep water and stored at 0°C.

Gear	Date	Station	Site	Latitude	Longitude	Depth [m]
TV-MUC	27/06/16	PS99/042-12	HG-IV	79°03.87' N	04°10.86' E	2464
TV-MUC	06/07/16	PS99/058-1	HG-IV	79°01.39' N	04°24.68' E	2536
TV-MUC	08/07/16	PS99/060-3	HG-IV	79°00.39' N	04°19.93' E	2601

Benthic-pelagic coupling

At four selected stations (EG-IV, EG-I, N5, and HG-IX) we conducted a coordinated sampling of different environments across a vertical profile of the water column. In collaboration with the team of Ian Salter (see Chapter 11.1) we sampled sea ice, shallow water, sinking particles, deep water and surface deep-sea sediments.

Sea ice samples

At each station four sea ice cores were taken with an ice corer (9 cm diameter) (Kovacs Enterprise, Roseburg, USA) (Table 15.5). To also capture escaping brine, cores were placed in collection vials immediately after retrieval prior to storage in plastic bags. One of the cores was used for temperature measurements in 10 cm intervals and then sliced into 10 cm

sections on the ice for subsequent nutrient and salinity analyses (Fig. 15.1). Back on deck the three remaining cores were cut into three equal sections (surface, middle and bottom) and melted over night at room temperature. Individual sections and the collected brine were filtered through 0.22 µm Sterivex filters for subsequent DNA extraction in the home laboratory and stored at -20°C. Samples for nutrient and salinity analyses were melted and 15 ml of the sample were sterile filtered through 0.22 µm pore size and stored in 15 ml Falcons at -20°C for subsequent nutrient analysis. Salinity in the remaining sample was determined on board using a salinometer. A subsample of each melted ice and brine was used for the preparation of Fluorescence In-Situ Hybridization (FISH) samples to quantify specific microbial groups back in the home lab. Either 100 ml for sea ice or 50 ml for brine were fixed in 2% formalin at 4°C for 10-12 hours, filtered onto 0.22 µm filters and stored at -20°C.

Tab. 15.5: Stations from which sea ice cores were taken. At each station three cores were taken for DNA extraction and an additional core for nutrient and salinity analyses.

Gear	Date	Station	Site	Latitude	Longitude
ICE CORER	30/06/16	PS99/048	EG-IV	78°48.941' N	02°44.341' W
ICE CORER	02/07/16	PS99/051-7	EG-I	78°59.392' N	05°25.465' W
ICE CORER	03/07/16	PS99/053	N5	80°02.634' N	02°14.048' E
ICE CORER	06/07/16	PS99/059	HG-IX	80°02.335' N	02°17.441' E

Fig. 15.1: A sea ice core being sliced into 10 cm sections for subsequent nutrient and salinity analysis

During the time of the cruise, large accumulations of the sea-ice algae *Melosira arctica* were observed (Fig. 15.2). During the ice station work at stations PS99/0051-7 and PS99/0059, we were able to obtain some samples for DNA (-20°C) and RNA (-80°C) analyses and for culturing approaches, which will be conducted in collaboration with Anique Stecher (AWI).

Shallow water samples

Duplicate shallow water samples were collected with Niskin bottles housed on a rosette from three depths, covering the surface water of the first few meters down to below the chlorophyll maximum, filtered onto 0.22 µm Sterivex filters and stored at -20°C for subsequent DNA extraction back in the home laboratory. CARD-FISH samples for quantification of prokaryotic cells were fixed in 2% formalin and filtered onto 0.22 µm filters. Sampling was conducted in collaboration with Ian Salter's team; for more details on sample processing please see Chapter 11.1.

Fig. 15.2: Melosira arctica aggregates that were collected at station PS99/059

Sinking particles

Sinking particles were sampled in collaboration with Ian Salter's team using a marine snow catcher. For each of the four stations (EG-IV, EG-I, N5, and HG-IX) duplicate samples were collected. For more information on sample processing and storage see Chapter 11.1.

Fig. 15.3: A McLane Large Volume Water Transfer System, or short in-situ pump, that was used for the filtration of large volumes of deep water

Deep water samples

We used McLane Large Volume Water Transfer Systems, on board called *in-situ* pumps, to concentrate large volumes of deep water on 0.22 µm filters for subsequent DNA extraction. For each station two *in-situ* pumps were attached to the wire on top of the CTD rosette (Fig. 15.3) and pump on depth for one hour before the regular CTD cast started to collect duplicate filters, each with approximately 100 litre throughput (Table 15.6). After recovery, filters were collected in petri dishes and stored at -20°C. Additionally, CARD-FISH samples for cell counts were taken from the CTD/Rosette Water Sampler.

Tab. 15.6: Stations with *in-situ* pump deployment. *In-Situ* Pumps (ISP) were lowered to the indicated depth and water was pumped for one hour on a 0.22 µm filter.

Gear	Date	Station	Site	Latitude	Longitude	Depth [m]
CTD/ISP	26/06/16	PS99/042-1	HG-IV	79°03.96' N	04°11.06' E	2440
CTD/ISP	30/06/16	PS99/048-1	EG-IV	78°49.70' N	02°46.08' W	2574
CTD/ISP	02/07/16	PS99/051-2	EG-I	78°59.45' N	05°24.56' W	1000
CTD/ISP	03/07/16	PS99/053-2	N5	79°55.27' N	03°03.72' E	2540
CTD/ISP	06/07/16	PS99/059-2	HG-IX	79°08.09' N	02°50.75' E	5350

Sediment samples

For all four stations deep-sea sediment samples were retrieved with a TV-guided multiple corer (TV-MUC) (Table 15.7). For details on sample collection and processing please see the sediment paragraph above within this chapter.

Tab. 15.7: Sediment samples for DNA extractions and total prokaryotic cell counts. DNA samples are stored at -20°C, for CARD-FISH samples were washed with 1xPBS and stored in 1xPBS:EtOH at -20°C.

Gear	Date	Station	Site	Latitude	Longitude	Depth [m]
TV-MUC	30/06/16	PS99/048-12	EG-IV	78°48.97' N	02°44.09' W	2604
TV-MUC	02/07/16	PS99/051-9	EG-I	78°59.47' N	05°27.05' W	982
TV-MUC	04/07/16	PS99/053-7	N5	79°57.79' N	02°55.99' E	2614
TV-MUC	07/07/16	PS99/059-9	HG-IX	79°08.02' N	02°50.64' E	5569

Data management

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

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16. FRAM: POLLUTION OBSERVATORY - ASSESSMENTS OF ANTHROPOGENIC LITTER AND MICROPLASTIC IN DIFFERENT ECOSYSTEM COMPARTMENTS

Melanie Bergmann, Lars Gutow, Mine Tekman, Ian Salter, Sascha Lehmenhecker; not on board: Gunnar Gerdts, AWI

Grant No. AWI_PS99_0

Objectives

Litter

Plastic litter contamination of the oceans is a global problem of growing environmental concern. Analyses of camera footage obtained previously at the HAUSGARTEN central station (2,500 m water depth) indicated a significant increase of litter on the seafloor between 2002 and 2011 (Bergmann & Klages, 2012). Litter was also recorded floating at the sea surface in the HAUSGARTEN area (Bergmann et al., 2015), and >80 % of the northern fulmars examined from Svalbard have plastic in their stomachs (Trevail et al., 2015).

Here, we will use the footage gained during OFOS deployments to assess if litter densities continue to increase at HAUSGARTEN. It has been proposed that the deep sea is a sink of marine litter. Here, we conduct neuston surveys in the same way as Gutow & Daniel (see Chapter 5) to determine litter densities at the sea surface. Comparison with data from the seafloor enables us to verify if the HAUSGARTEN seafloor acts as a sink for marine litter. Combination of our data with those from Gutow and Daniel (this issue) allows large-scale mapping of the distribution of litter. This will be complimented with camera-equipped aerial surveys based on Unmanned Aerial Vehicles (UAVs).

Gutow & Daniel (see Chapter 5) pointed out the potential risk of alien invasion through rafting on marine litter over long distances. Here, we sampled drifting litter to assess microbial biofilms and colonisers.

Microplastics

Recent evidence also suggests high concentrations of microplastics, a degradation product of larger plastic items, in Arctic sea ice (Obbard et al., 2014). This raises concerns about the fate of entrained microplastics during ice melts and exposure of the ecosystems underneath. Here, we investigate the concentrations of microplastics at the sea surface, in the water column and deep-sea sediments. It is currently unknown, how such large quantities of microplastics are transferred to the Arctic. One possible pathway could be atmospheric transport. Here, we sample snow deposited on ice floes, which may contain microplastics from atmospheric fallout.

Other pollutants

Plastic is known as substrate that hydrophobic substances such as persistent organic pollutants (POPs) adsorb to. Here, we fitted passive samplers (polyethylene) to the long-term

lander, to assess POP concentrations in the sediment and the nephloid layer (R. Lohmann, University of Rhode Island). Sediment samples were also taken for cell-based assays to study synergistic effects of bioactive pollutants (A. Jahnke, UFZ). In addition, water samples were taken for the Umweltbundesamt (UBA) to determine concentrations of the UV-Blocker EHMC (Ethylhexylmethoxycinnamat).

Work at sea

Litter

Analysis of the OFOS footage will enable us to determine litter densities on the seafloor along the latitudinal gradient (stations S3, HG-IV, and N3), off east Greenland (EG-IV) and over time (when compared with data extracted from previous transects). 51 neuston surveys of at least 1 h duration were conducted to determine densities of floating litter and seaweed. Eleven flights were made by the UAV covering an area of 3,762,000 m^2.

Microplastics

Sixteen sediment samples were taken from multiple corer deployments along the latitudinal and bathymetric transect and frozen in tinfoil for assessments of microplastic concentrations (G. Gerdts). Snow samples were taken during two helicopter flights for the assessment of microplastic concentration. *In-situ* pumps were deployed during deep CTD casts at selected stations (HG-IV, EG-IV, N5, HG-IX, SV-I) to determine microplastic concentrations at the sea surface, 300 m, 1000 m and near the seafloor filtrating up to 600 litres of sea water. Four sediment samples were taken for cell-based assays on bioactive pollutants (A. Jahnke, UFZ).

Preliminary results

Litter was encountered during all transects conducted. It comprised both plastic and glass. However, results of time-series, latitudinal, and substrate analyses will only be available once the images will have been analysed. One piece of plastic litter was recorded for the second time (first record in 2014; Fig. 16.1). This is important because it proves that the same ground was covered by the OFOS and because the plastic looked unchanged indicating low weathering rates on the deep seafloor.

256 litter items were recorded during 39 of a total of 51 sea surface surveys. By comparison, 1,297 pieces of floating seaweed (mostly *Fucus* spp. and *Ascophyllum*) were found. This results in a ratio of litter to natural flotsam of 1 to 5. The distribution of litter appeared to be patchy. Hardly any litter was recorded during surveys near east Greenland, where many ice floes were present. Highest litter densities were found in the central area of the Fram Strait but this has to be verified by rigorous geostatistics.

Litter was also recorded during UAV flights (Fig. 16.2), which highlights the potential of this method for litter detection. However, more detailed image analysis is necessary to determine numbers and convert them to items per km^{-2}, which can then be compared with data from observer surveys.

The floating litter collected during a dingy operation for an AUV deployment was heavily fouled with living biota (algae, nudibranch, isopod; Fig. 16.3) indicating that litter could indeed act as a means of transport of rafting biota to the Arctic. In addition, colder water temperatures in the Fram Strait appear not to affect the survival of these colonizers if they originate from the Atlantic. This has implications for the potential of biological invasions, especially in an era of warming seawater temperatures (Soltwedel et al., 2015). More detailed analysis of all litter items collected may reveal further rafting biota and bacteria (L. Gutow, G. Gerdts).

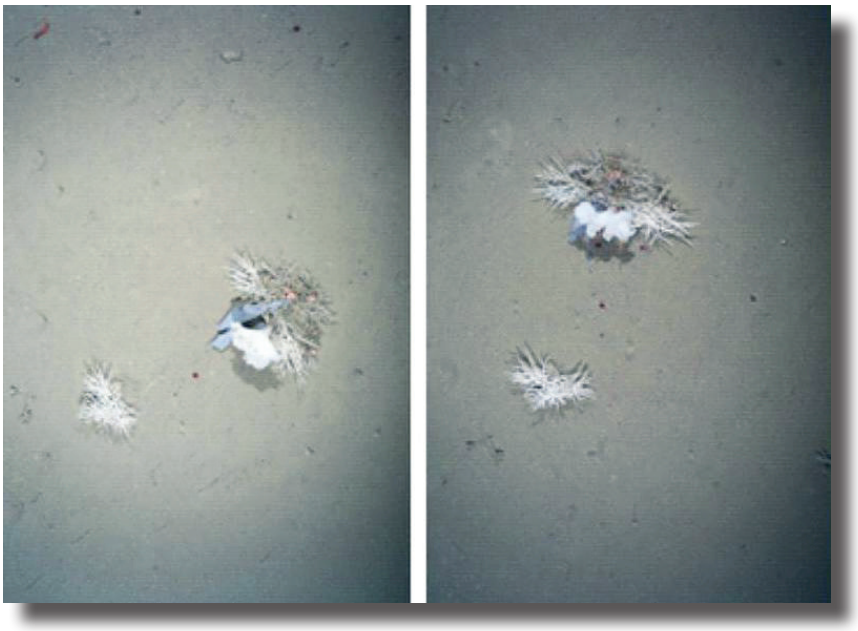

Fig. 16.1: Plastic litter entangled in the sponge Cladorhiza gelida recorded at station HG-IV in 2014 (left) and in 2016 (right) indicating that the OFOS covered the same area on the seabed

Fig. 16.2: Unmanned Aerial Vehicle (UAV) during survey flight off the Kongsfjord area (left). Example of aerial photograph showing floating litter (middle, right).

Results on microplastic concentrations of sediments, snow and *in-situ* pump deployments will only be available after a time-consuming extraction procedures and analyses.

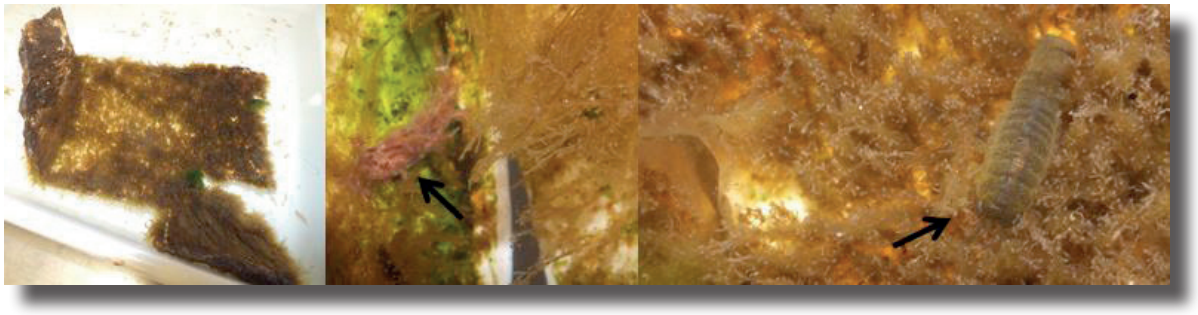

Fig. 16.3: Photograph (by A. Vedenin) of floating plastic litter inhabited by alive algae (left), a nudibranch (middle) and an isopod (right)

Data management

All OFOS images, videos and metadata will be uploaded to PANGAEA. In addition, all images have been uploaded to the online image data base BIIGLE to enable online image analysis.

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APPENDIX

A.1 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTIONS

Adresse	Address
AWI	Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung Am Handelshafen 12 27570 Bremerhaven/Germany
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe Stilleweg 2 D-30655 Hannover/Germany
DWD	Deutscher Wetterdienst Geschäftsbereich Wettervorhersage Seeschifffahrtsberatung Bernhard-Nocht Straße 76 20359 Hamburg/Germany
FIELAX	FIELAX Gesellschaft für wissenschaftliche Datenverarbeitung mbH Schleusenstraße 14 27568 Bremerhaven/Germany
GEOMAR	GEOMAR Helmholtz-Zentrum für Ozeanforschung Wischhofstr. 1-3 24148 Kiel/Germany
GIFT	Geoscience Information for Teachers, European Geoscience Union (EGU)
HeliService	HeliService international GmbH Am Luneort 15 27572 Bremerhaven/Germany
HITACHI	Hitachi Ltd. 6-6, Marunouchi 1-chome, Chiyoda-ku Tokyo, 100-8280/apan
IEO Malaga	Instituto Español de Oceanografíco Centro Oceanográfico de Málaga C/Puerto Pesquero S/N 29640 Fuengirola/Spain

Adresse	Address
IORAS	P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences Nakhimovsky Pr., 36, 117997 Moscow/Russia
ISMAR	Istituto di Scienze Marine – Consiglio Nazionale delle Ricerche Via Gobetti 101 40129 Bologna/Italy
MARUM	Zentrum für Marine Umweltwissenschaften der Universität Bremen Leobener Straße 28359 Bremen/Germany
MPIMM	Max-Planck-Institut für Marine Mikrobiologie Celsiusstraße 1 28359 Bremen/Germany
NOCS	National Oceanography Centre University of Southampton Waterfront Campus European Way Southampton SO14 3ZH/United Kingdom
OGS	Istituto Nazionale di Oceanografia e di Geofisica Sperimentale Borgo Grotta Gigante 42/C 34010 Sgonico/Italy
Polar Scientific	Polar Scientific Ltd Dallens, Appin Argyll PA38 4BN/United Kingdom
Uni Barcelona	Universitat de Barcelona Facultat de Geologia C/Martí i Franqués, S/N 08028 Barcelona/Spain
Uni Marche	Università Politecnica delle Marche Department of Life and Environmental Sciences Polo Montedago, Via Brecce Bianche 60131 Ancona/Italy
Uni Oslo	UiO Universitetet i Oslo Senter for Jordens utvikling og dynamikk Postboks 1028, Blindern N-0315 Oslo /Norway

Adresse	Address
Uni Parma	Università degli studi di Parma Department of Physics and Earth Sciences Parco Area delle Scienze, 7/A 43124 Parma/Italy
Uni Pisa	Università di Pisa Lungarno Pacinotti 43 56126 Pisa/Italy
Uni Poznań	Uniwersytet im. Adama Mickiewicza ul. Wieniawskiego 1 61-712 Poznań/Poland
Uni Rome	Università di Roma Dipartimento di Scienze della Terra Piazzale Aldo Moro 5 00185 Roma/Italy
Uni Tromsø	UiT Norges arktiske universitet Institutt for geologi Postboks 6050, Langnes N-9037 Tromsø/Norway
WERUM	Werum Software & Systems AG Wulf-Werum-Straße 3 21337 Lüneburg/Germany

A.2 FAHRTTEILNEHMER / CRUISE PARTICIPANTS

A.2.1 Fahrtteilnehmer / Cruise Participants during PS99.1

Name/Last name	Vorname/ First name	Institut/ Institute	Beruf/Profession	Fachrichtung/ Discipline
Albrecht	Sebastian	FIELAX	Technician	Oceanography
Bauerfeind	Eduard	AWI	Scientist	Biology
Bazzaro	Matteo	OGS	Scientist	Biochemistry
Bensi	Manuel	OGS	Scientist	Oceanography
Biebow	Nicole	AWI	Yeoman	Marine Geology
Carbonara	Katia	Uni Parma	Student apprentice	
Caridi	Francesca	Uni Marche	Scientist	Biology
Daniel	Claudia	AWI	Technician	Biology
De Vittor	Cinzia	OGS	Scientist	Biochemistry
Deponte	Davide	OGS	Technician	Oceanography
Dominiczak	Aleksander	Uni Poznań	Student apprentice	
Gamboa Sojo	Viviana María	Uni Pisa	Scientist	Micropaleontologist
Graziani	Stefano	Uni Rome	Technician	Oceanography
Gutow	Lars	AWI	Scientist	Biology
Hellmann	Sebastian	AWI	PhD student	
Hempelt	Juliane	DWD	Technician	Meteorology
Knüppel	Nadine	AWI	Technician	Biology
Kovacevic	Vedrana	OGS	Scientist	Oceanography
Krauß	Florian	AWI	Student apprentice	
Krocker	Ralf	AWI	Scientist	Oceanography
Krüger	Martin	BGR	Scientist	Geomicrobiologist
Langone	Leonardo	ISMAR	Scientist	Oceanography
Laterza	Roberto	OGS	Technician	
Le Gall	Christophe	GIFT	High school teacher	Teacher
Liu	Yangyang	AWI	PhD student	
Lucchi	Renata Giulia	OGS	Scientist	Sedimentology
Mazzini	Adriano	Uni Oslo	Scientist	Geochemistry
Morigi	Caterina	Uni Pisa	Scientist	Micropaleontologist
Müller	Patrick	FIELAX	Technician	Oceanography
Musco	Elena	OGS	Student apprentice	
Paulmann	Christian	DWD	Scientist	Meteorologist
Piepenbreier	Maya	WERUM	Scientist	Oceanography
Povea	Patrizia	Uni Barcelona	Scientist	Geochemistry
Relitti	Federica	OGS	Scientist	Biochemistry

Name/Last name	Vorname/ First name	Institut/ Institute	Beruf/Profession	Fachrichtung/ Discipline
Richter	Klaus-Uwe	AWI	Engineer	Biogeochemistry
Rogge	Andreas	AWI	PhD student	
Rokitta	Sebastian	AWI	Scientist	Biogeochemistry
Ruggero	Livio	Uni Rome	Technician	Oceanography
Rui	Leonardo	OGS	Student apprentice	
Sabbatini	Anna	Uni Marche	Scientist	Micropaleontologist
Sablotny	Burkhard	AWI	Engineer	Biology
Salter	Ian	AWI	Scientist	Biology
Sánchez Guillamón	Olga	IEO Malaga	Student apprentice	
Soltwedel	Thomas	AWI	Scientist	Biology
Stronzek	David	AWI	PhD student	
Tagliaferro	Massimo	HITACHI	Technician	
Tippenhauer	Sandra	AWI	Scientist	Oceanography
Topchiy	Maria	Uni Oslo	Scientist	Geochemist
Wiberg	Daniel	Uni Tromsø	Scientist	Geophysician
Wulff	Thorben	AWI	Engineer	Biology
Zoch	Daniela	BGR	Scientist	Geomicrobiologist

A.2.2 Fahrtteilnehmer / Cruise Participants during PS99.2

Name/Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession	Fachrichtung/ Discipline
Asendorf	Volker	MPIMM	Technician	Biology
Becker	Stefan	MARUM	PhD student	
Bergmann	Melanie	AWI	Scientist	Biology
Brauer	Jens	HeliService	Pilot	
Cisternas Novoa	Carolina	GEOMAR	Scientist	Biogeochemistry
Doble	Martin	Polar Scientific	Scientist	Oceanography
Fadeev	Eduard	MPIMM	PhD student	
Fong	Allison	AWI	Scientist	Biology
Garcia	Alberto	HeliService	Technician	
Hagemann	Jonas	AWI	Student apprentice	
Hargesheimer	Theresa	AWI	Technician	Biology
Hasemann	Christiane	AWI	Scientist	Biology

Name/Last name	**Vorname/ First name**	**Institut/ Institute**	**Beruf/ Profession**	**Fachrichtung/ Discipline**
Heim	Thomas	HeliService	Technician	
Hellmann	Sebastian	AWI	PhD student	
Hempelt	Juliane	DWD	Technician	Meteorology
Hofbauer	Michael	AWI	Technician	Biology
Hoge	Ulrich	AWI	Engineer	Biology
Huchler	Marie	AWI	Student apprentice	
Iversen	Morten	MARUM	Scientist	Biogeochemistry
Käß	Melissa	AWI	MSc student	
Klüver	Tania	GEOMAR	Technician,	Biology
Knüppel	Nadine	AWI	Technician	Biology
Krauß	Florian	AWI	BSc student	
Küber	Tim	AWI	Technician	Biology
Lehmenhecker	Sascha	AWI	Engineer	Biology
Lemburg	Johannes	AWI	Engineer	Robotics
LeMoigne	Frederic	GEOMAR	Biogeochemistry	
Liu	Yangyang	AWI	PhD student	
Lochthofen	Normen	AWI	Engineer	Biology
Ludszuweit	Janine	AWI	Technician	Biology
Niehoff	Barbara	AWI	Biology	
Offre	Pierre	MPIMM	Scientist	Microbiologistry
Paulmann	Christian	DWD	Scientist	Meteorology
Rapp	Josephine	MPIMM	Scientist	Microbiologistry
Rogge	Andreas	AWI	PhD student	
Salter	Ian	AWI	Scientist	Biology
Schewe	Ingo	AWI	Scientist	Biology
Scholz	Daniel	AWI	Technician	Biology
Soltwedel	Thomas	AWI	Chief Scientist	Biology
Stronzek	David	AWI	PhD student	
Tekman	Mine	AWI	Scientist	Biology
Tippenhauer	Sandra	AWI	Scientist	Oceanography
Torres Valdes	Sinhue	NOCS	Scientist	Biogeochemistry
Vaupelt	Lars	HeliService	Pilot	
Vedenin	Andrey	AWI	Scientist	Biology
Wenzhöfer	Frank	AWI	Scientist	Biogeochemistry
Wietkamp	Stephan	AWI	Scientist	Biology
Wischnewski	Laura	AWI	Technician	Biochemistry
Wulff	Thorben	AWI	Engineer	Biology

A.3 SCHIFFSBESATZUNG / SHIP'S CREW

No.	Name	Rank
1	Wunderlich, Thomas	Master
2	Laubert, Felix	1. Offc.
3	Heuck, Hinnerk	Ch. Eng.
4	Spielke, Steffen	2. Offc.
5	Kentges, Felix	2. Offc.
6	Peine, Lutz	2. Offc.
7	Scholl, Thomas	Doctor
8	Hofmann, Jörg	R. Offc.
9	Buch, Erik-Torsten	2. Eng.
10	Rusch, Torben	2. Eng.
11	Schnürch, Helmut	2. Eng.
12	Brehme, Andreas	Elec. Tech.
13	Dimmler, Werner	ELO
14	Feiertag, Thomas	ELO
15	Ganter, Armin	ELO
16	Winter, Andreas	ELO
17	Schröter, René	Boatsw.
18	Neisner, Winfried	Carpenter
19	Brickmann, Peter	A.B.
20	Clasen, Nils	A.B.
21	Hartwig-Labahn, Andreas	A.B.
22	Kretzschmar, Uwe	A.B.
23	Müller, Steffen	A.B.
24	Schröder, Norbert	A.B.
25	Sedlak, Andreas	A.B.
26	Wittek, Sönke Fritz Ole	Trainee
27	Beth, Dethlef	Storek.
28	Dinse, Horst	Mot-man
29	Klein, Gert	Mot-man
30	Krösche, Eckard	Mot-man
31	Plehn, Markus	Mot-man
32	Watzel, Bernhard	Mot-man
33	Schulz, Fabian	Trainee
34	Meißner, Jörg	Cook
35	Tupy, Mario	Cooksmate
36	Möller, Wolfgang	Cooksmate
37	Wartenberg, Irina	1. Stwdess
38	Schwitzky-S., Carmen	Stwdess.N.
39	Hischke, Peggy	2. Stwdess
40	Chen, Quan Lun	2. Steward
41	Krause, Tomsz	2. Stwdard
42	Hu, Guo Yong	2. Steward
43	Duka, Maribel	2. Stwdess
44	Ruan, Hui Guang	Laundrym.

A.4 STATIONSLISTE / STATION LIST PS99

Station	Date	Time	Gear	Action	Position Lat	Position Lon	Water Depth [m]
PS99/0001-1	17.06.2016	08:51:00	CTD/RO	max depth	67° 53.75' N	008° 04.19' E	2253.7
PS99/0002-1	19.06.2016	05:22:00	CTD/RO	max depth	74° 51.52' N	016° 05.91' E	375.8
PS99/0002-2	19.06.2016	06:13:00	MUC	max depth	74° 51.49' N	016° 05.84' E	376.1
PS99/0002-3	19.06.2016	07:10:00	MUC	max depth	74° 51.53' N	016° 05.93' E	376,0
PS99/0002-4	19.06.2016	08:14:00	OFOS	profile start	74° 51.52' N	016° 06.01' E	376,0
PS99/0002-4	19.06.2016	08:51:00	OFOS	profile end	74° 51.34' N	016° 07.18' E	370.4
PS99/0003-1	19.06.2016	10:49:00	MUC	max depth	74° 51.00' N	016° 54.52' E	317.1
PS99/0004-1	19.06.2016	12:11:00	MUC	max depth	74° 50.75' N	017° 20.86' E	304.7
PS99/0005-1	19.06.2016	13:22:00	CTD/RO	max depth	74° 50.54' N	017° 38.46' E	295,0
PS99/0005-2	19.06.2016	14:04:00	MUC	max depth	74° 50.56' N	017° 38.27' E	294.6
PS99/0005-3	19.06.2016	14:58:00	MUC	max depth	74° 50.53' N	017° 38.37' E	293.6
PS99/0005-4	19.06.2016	16:00:00	OFOS	profile start	74° 50.51' N	017° 38.32' E	293,0
PS99/0005-4	19.06.2016	16:49:00	OFOS	profile end	74° 50.50' N	017° 39.59' E	296.5
PS99/0006-1	19.06.2016	18:07:00	OFOS	profile start	74° 50.74' N	018° 10.46' E	334.3
PS99/0006-1	19.06.2016	18:49:00	OFOS	profile end	74° 50.59' N	018° 11.61' E	328.8
PS99/0006-2	19.06.2016	19:22:00	CTD/RO	max depth	74° 50.72' N	018° 10.57' E	335.5
PS99/0006-3	19.06.2016	20:38:00	MUC	max depth	74° 50.73' N	018° 10.64' E	335.9
PS99/0006-4	19.06.2016	21:29:00	MUC	max depth	74° 50.75' N	018° 10.55' E	335.7
PS99/0007-1	19.06.2016	23:01:00	CTD/RO	max depth	74° 59.72' N	017° 59.61' E	148,0
PS99/0007-2	19.06.2016	23:35:00	MUC	max depth	74° 59.68' N	017° 59.62' E	159,0
PS99/0007-3	20.06.2016	00:20:00	MUC	max depth	74° 59.69' N	017° 59.72' E	159.1
PS99/0008-1	20.06.2016	01:33:00	CTD/RO	max depth	74° 53.53' N	018° 14.20' E	152.6
PS99/0009-1	20.06.2016	02:26:00	CTD	max depth	74° 50.72' N	018° 10.60' E	336.1
PS99/0010-1	20.06.2016	03:18:00	CTD/RO	max depth	74° 47.60' N	018° 08.82' E	287.5
PS99/0001-1	17.06.2016	08:51:00	CTD/RO	max depth	67° 53.75' N	008° 04.19' E	2253.7
PS99/0002-1	19.06.2016	05:22:00	CTD/RO	max depth	74° 51.52' N	016° 05.91' E	375.8
PS99/0002-2	19.06.2016	06:13:00	MUC	max depth	74° 51.49' N	016° 05.84' E	376.1
PS99/0002-3	19.06.2016	07:10:00	MUC	max depth	74° 51.53' N	016° 05.93' E	376,0
PS99/0002-4	19.06.2016	08:14:00	OFOS	profile start	74° 51.52' N	016° 06.01' E	376,0
PS99/0002-4	19.06.2016	08:51:00	OFOS	profile end	74° 51.34' N	016° 07.18' E	370.4
PS99/0003-1	19.06.2016	10:49:00	MUC	max depth	74° 51.00' N	016° 54.52' E	317.1
PS99/0004-1	19.06.2016	12:11:00	MUC	max depth	74° 50.75' N	017° 20.86' E	304.7
PS99/0005-1	19.06.2016	13:22:00	CTD/RO	max depth	74° 50.54' N	017° 38.46' E	295,0
PS99/0005-2	19.06.2016	14:04:00	MUC	max depth	74° 50.56' N	017° 38.27' E	294.6

Station	Date	Time	Gear	Action	Position Lat	Position Lon	Water Depth [m]
PS99/0005-3	19.06.2016	14:58:00	MUC	max depth	74° 50.53' N	017° 38.37' E	293.6
PS99/0005-4	19.06.2016	16:00:00	OFOS	profile start	74° 50.51' N	017° 38.32' E	293,0
PS99/0005-4	19.06.2016	16:49:00	OFOS	profile end	74° 50.50' N	017° 39.59' E	296.5
PS99/0006-1	19.06.2016	18:07:00	OFOS	profile start	74° 50.74' N	018° 10.46' E	334.3
PS99/0006-1	19.06.2016	18:49:00	OFOS	profile end	74° 50.59' N	018° 11.61' E	328.8
PS99/0006-2	19.06.2016	19:22:00	CTD/RO	max depth	74° 50.72' N	018° 10.57' E	335.5
PS99/0006-3	19.06.2016	20:38:00	MUC	max depth	74° 50.73' N	018° 10.64' E	335.9
PS99/0006-4	19.06.2016	21:29:00	MUC	max depth	74° 50.75' N	018° 10.55' E	335.7
PS99/0007-1	19.06.2016	23:01:00	CTD/RO	max depth	74° 59.72' N	017° 59.61' E	148,0
PS99/0007-2	19.06.2016	23:35:00	MUC	max depth	74° 59.68' N	017° 59.62' E	159,0
PS99/0007-3	20.06.2016	00:20:00	MUC	max depth	74° 59.69' N	017° 59.72' E	159.1
PS99/0008-1	20.06.2016	01:33:00	CTD/RO	max depth	74° 53.53' N	018° 14.20' E	152.6
PS99/0009-1	20.06.2016	02:26:00	CTD	max depth	74° 50.72' N	018° 10.60' E	336.1
PS99/0010-1	20.06.2016	03:18:00	CTD/RO	max depth	74° 47.60' N	018° 08.82' E	287.5
PS99/0011-1	20.06.2016	04:16:00	CTD/RO	max depth	74° 43.48' N	018° 01.43' E	178.2
PS99/0012-1	20.06.2016	05:17:00	CTD/RO	max depth	74° 41.96' N	017° 38.47' E	108.7
PS99/0013-1	20.06.2016	06:16:00	CTD	max depth	74° 46.39' N	017° 37.94' E	288,0
PS99/0014-1	20.06.2016	07:06:00	CTD/RO	max depth	74° 48.58' N	017° 38.46' E	303.4
PS99/0015-1	20.06.2016	08:00:00	CTD	max depth	74° 50.55' N	017° 38.52' E	294.3
PS99/0016-1	20.06.2016	08:41:00	CTD	max depth	74° 51.86' N	017° 38.61' E	318.9
PS99/0017-1	20.06.2016	09:26:00	CTD/RO	max depth	74° 54.03' N	017° 38.70' E	186.3
PS99/0018-1	20.06.2016	10:08:00	CTD	max depth	74° 56.02' N	017° 38.35' E	133.3
PS99/0019-1	20.06.2016	11:07:00	CTD/RO	max depth	74° 55.58' N	017° 22.24' E	167.1
PS99/0020-1	20.06.2016	11:56:00	CTD	max depth	74° 52.42' N	017° 21.48' E	306.5
PS99/0021-1	20.06.2016	13:22:00	OFOS	profile start	74° 52.41' N	017° 21.66' E	305.7
PS99/0021-1	20.06.2016	14:31:00	OFOS	profile end	74° 52.40' N	017° 21.60' E	305.9
PS99/0021-2	20.06.2016	15:07:00	CTD/RO	max depth	74° 52.40' N	017° 21.64' E	306,0
PS99/0021-3	20.06.2016	16:19:00	MUC	max depth	74° 52.40' N	017° 21.57' E	305.7
PS99/0021-4	20.06.2016	17:29:00	MUC	max depth	74° 52.40' N	017° 21.62' E	305.6
PS99/0021-5	20.06.2016	18:15:00	MUC	max depth	74° 52.40' N	017° 21.60' E	305.4
PS99/0022-1	20.06.2016	20:13:00	CTD	max depth	74° 42.56' N	016° 50.43' E	170.9
PS99/0023-1	20.06.2016	21:13:00	CTD	max depth	74° 46.80' N	016° 52.61' E	277,0
PS99/0024-1	20.06.2016	22:19:00	CTD	max depth	74° 51.00' N	016° 54.46' E	317,0
PS99/0025-1	20.06.2016	23:26:00	CTD/RO	max depth	74° 57.34' N	016° 57.65' E	198.7
PS99/0026-1	21.06.2016	01:56:00	CTD	max depth	74° 43.91' N	016° 08.92' E	268.9
PS99/0027-1	21.06.2016	02:49:00	CTD	max depth	74° 47.79' N	016° 07.45' E	350.5

Station	Date	Time	Gear	Action	Position Lat	Position Lon	Water Depth [m]
PS99/0028-1	21.06.2016	03:45:00	CTD	max depth	74° 51.60' N	016° 05.96' E	376.6
PS99/0029-1	21.06.2016	04:41:00	CTD	max depth	74° 55.53' N	016° 04.54' E	287.4
PS99/0030-1	21.06.2016	05:22:00	CTD	max depth	74° 57.38' N	016° 03.62' E	261,0
PS99/0031-1	21.06.2016	16:05:59	MOR	recovery	76° 26.37' N	013° 56.93' E	1063.3
PS99/0031-2	21.06.2016	17:01:00	CTD/RO	max depth	76° 26.14' N	013° 56.75' E	1062.8
PS99/0032-1	21.06.2016	19:37:00	CTD	max depth	76° 23.78' N	013° 32.77' E	1269.8
PS99/0033-1	21.06.2016	21:01:00	CTD	max depth	76° 25.13' N	013° 44.94' E	1160.3
PS99/0034-1	21.06.2016	22:39:00	CTD	max depth	76° 27.58' N	014° 08.82' E	890.2
PS99/0035-1	21.06.2016	23:45:00	CTD	max depth	76° 28.83' N	014° 20.69' E	548.3
PS99/0036-1	22.06.2016	00:23:01	CTD	max depth	76° 29.39' N	014° 27.83' E	248,0
PS99/0037-1	22.06.2016	05:15:59	MOR	recovery	76° 26.27' N	013° 56.66' E	1062.8
PS99/0038-1	22.06.2016	14:52:59	MOR	deploy-ment	77° 39.13' N	010° 16.81' E	1036.6
PS99/0038-2	22.06.2016	15:45:00	CTD	max depth	77° 38.97' N	010° 16.89' E	1046.9
PS99/0039-1	22.06.2016	17:56:00	CTD	max depth	77° 35.20' N	010° 05.70' E	1351.5
PS99/0040-1	22.06.2016	19:37:00	CTD	max depth	77° 40.31' N	010° 22.89' E	827.6
PS99/0041-1	25.06.2016	04:56:00	CDT/RO	max depth	78° 36.62' N	005° 03.81' E	2338.7
PS99/0041-2	25.06.2016	06:36:00	MSC	max depth	78° 36.57' N	005° 03.62' E	2339.6
PS99/0041-3	25.06.2016	08:22:00	RAMSES	max depth	78° 36.56' N	005° 03.51' E	2339.2
PS99/0041-4	25.06.2016	09:34:00	LOKI	max depth	78° 36.58' N	005° 03.30' E	2341.2
PS99/0041-5	25.06.2016	11:16:00	MN	max depth	78° 36.45' N	005° 02.79' E	2344.7
PS99/0041-6	25.06.2016	12:34:00	CDT/RO	max depth	78° 36.47' N	005° 02.81' E	2344.6
PS99/0041-7	25.06.2016	13:25:00	MSC	max depth	78° 36.49' N	005° 03.13' E	2342.6
PS99/0041-8	25.06.2016	14:28:00	BC	max depth	78° 36.51' N	005° 03.16' E	2342.4
PS99/0041-9	25.06.2016	16:52:00	MUC	max depth	78° 36.51' N	005° 04.13' E	2337.6
PS99/0041-10	25.06.2016	18:36:01	LANDER	deploy-ment	78° 36.57' N	005° 04.00' E	2337.5
PS99/0041-11	25.06.2016	20:37:00	OFOS	profile start	78° 37.00' N	005° 00.32' E	2361.2
PS99/0041-11	25.06.2016	23:55:00	OFOS	profile end	78° 37.03' N	005° 09.60' E	2348.1
PS99/0042-1	26.06.2016	04:57:01	CDT/RO/ ISP	max depth	79° 03.96' N	004° 11.06' E	2457.9
PS99/0042-2	26.06.2016	08:20:00	MOR	recovery	79° 00.71' N	004° 19.68' E	2595.0
PS99/0042-3	26.06.2016	11:53:00	LANDER	recovery	79° 04.92' N	004° 06.84' E	2481.8
PS99/0042-4	26.06.2016	13:39:00	RAMSES	max depth	79° 04.79' N	004° 06.50' E	2494.1
PS99/0042-5	26.06.2016	15:24:01	DT	deploy-ment	79° 05.01' N	004° 07.86' E	2465.6

Station	Date	Time	Gear	Action	Position Lat	Position Lon	Water Depth [m]
PS99/0042-5	27.06.2016	09:17:00	DT	recovery	79° 06.32' N	004° 14.85' E	2245.8
PS99/0042-6	26.06.2016	16:15:00	LOKI	max depth	79° 04.65' N	004° 08.10' E	2481.7
PS99/0042-7	26.06.2016	17:32:59	MSC	max depth	79° 04.63' N	004° 08.32' E	2478.8
PS99/0042-8	26.06.2016	17:50:00	MSC	max depth	79° 04.65' N	004° 08.42' E	2474.5
PS99/0042-9	26.06.2016	19:09:00	MN	max depth	79° 04.58' N	004° 08.84' E	2470.1
PS99/0042-10	26.06.2016	21:36:00	OFOS	profile start	79° 03.86' N	004° 17.27' E	2408.8
PS99/0042-10	27.06.2016	01:02:00	OFOS	profile end	79° 01.99' N	004° 10.04' E	2624.5
PS99/0042-11	27.06.2016	02:36:00	CDT/RO	max depth	79° 03.91' N	004° 10.37' E	2468,0
PS99/0042-12	27.06.2016	03:49:00	MUC	max depth	79° 03.87' N	004° 10.86' E	2464.4
PS99/0042-13	27.06.2016	05:54:00	MUC	max depth	79° 03.89' N	004° 10.93' E	2462.2
PS99/0042-14	27.06.2016	07:47:00	BC	max depth	79° 03.89' N	004° 10.86' E	2462.5
PS99/0043-1	27.06.2016	13:57:00	LANDER	recovery	78° 36.39' N	005° 03.59' E	2340.6
PS99/0043-2	27.06.2016	16:00:00	AUV	profile start	78° 36.90' N	005° 02.08' E	2352.8
PS99/0043-3	27.06.2016	16:16:00	CDT/RO	max depth	78° 36.93' N	005° 01.79' E	2355.8
PS99/0043-2	27.06.2016	18:29:00	AUV	profile end	78° 37.19' N	005° 02.37' E	2351.9
PS99/0043-3	27.06.2016	20:20:00	MN	max depth	78° 36.56' N	005° 03.89' E	2336.9
PS99/0043-4	27.06.2016	22:24:00	LOKI	max depth	78° 36.46' N	005° 04.08' E	2335.9
PS99/0043-5	27.06.2016	23:59:00	BC	max depth	78° 36.60' N	005° 03.59' E	2337.5
PS99/0044-1	28.06.2016	05:16:00	CDT/RO	max depth	79° 04.03' N	003° 39.92' E	3081.9
PS99/0044-2	28.06.2016	07:41:00	MUC	max depth	79° 04.52' N	003° 42.70' E	2877.0
PS99/0044-3	28.06.2016	09:45:00	BC	max depth	79° 03.36' N	003° 43.84' E	2865.9
PS99/0045-1	28.06.2016	12:36:00	CDT/RO	max depth	79° 03.60' N	003° 34.21' E	3508.4
PS99/0045-2	28.06.2016	15:21:00	MUC	max depth	79° 03.82' N	003° 36.40' E	3324.1
PS99/0045-3	28.06.2016	17:54:00	BC	max depth	79° 03.37' N	003° 35.92' E	3356.3
PS99/0046-1	28.06.2016	21:09:00	CDT/RO	max depth	79° 03.41' N	003° 31.56' E	3812.9
PS99/0046-2	29.06.2016	00:18:00	MUC	max depth	79° 03.73' N	003° 29.29' E	3949.5
PS99/0046-3	29.06.2016	01:47:00	BC	max depth	79° 03.38' N	003° 27.87' E	4041.4
PS99/0047-1	29.06.2016	06:35:00	CDT/RO	max depth	79° 04.33' N	003° 20.69' E	5196.4
PS99/0047-2	29.06.2016	10:33:00	MUC	max depth	79° 03.66' N	003° 17.94' E	5087.3
PS99/0047-3	29.06.2016	13:34:00	BC	max depth	79° 03.53' N	003° 16.51' E	5099.6
PS99/0048-1	30.06.2016	00:47:00	CDT/RO/ ISP	max depth	78° 49.70' N	002° 46.08' W	2594.3

Station	Date	Time	Gear	Action	Position Lat	Position Lon	Water Depth [m]
PS99/0048-2	30.06.2016	04:10:00	RAMSES	max depth	78° 49.95' N	002° 43.41' W	2603.4
PS99/0048-3	30.06.2016	05:37:00	MOR	recovery	78° 50.28' N	002° 48.04' W	2583.6
PS99/0048-4	30.06.2016	11:22:00	MSC	max depth	78° 52.31' N	002° 46.74' W	2584.0
PS99/0048-5	30.06.2016	11:39:00	MSC	max depth	78° 52.29' N	002° 46.35' W	2584.4
PS99/0048-6	30.06.2016	12:34:00	DT	deploy-ment	78° 52.34' N	002° 44.75' W	2587.3
PS99/0048-6	01.07.2016	09:02:59	DT	recovery	78° 52.13' N	002° 36.01' W	2612.8
PS99/0048-7	30.06.2016	15:10:00	MOR	deploy-ment	78° 49.86' N	002° 47.63' W	2589.3
PS99/0048-8	30.06.2016	13:22:00	HN	max depth	78° 49.70' N	002° 50.05' W	2581.1
PS99/0048-9	30.06.2016	16:29:00	LOKI	max depth	78° 49.32' N	002° 43.55' W	2606.2
PS99/0048-10	30.06.2016	18:28:00	MN	max depth	78° 49.05' N	002° 43.76' W	2604.1
PS99/0048-11	30.06.2016	19:51:00	CDT/RO	max depth	78° 48.96' N	002° 43.73' W	2604.8
PS99/0048-12	30.06.2016	21:00:00	MUC	max depth	78° 48.97' N	002° 44.09' W	2603.5
PS99/0048-13	30.06.2016	22:50:00	BC	max depth	78° 49.03' N	002° 44.05' W	2603.2
PS99/0048-14	01.07.2016	02:02:00	OFOS	profile start	78° 53.73' N	003° 08.04' W	2478.4
PS99/0048-14	01.07.2016	05:00:00	OFOS	profile end	78° 55.00' N	003° 06.17' W	2474.9
PS99/0048-15	30.06.2016	16:45:00	ICE	max depth	78° 49.13' N	002° 44.05' W	2606.0
PS99/0049-1	01.07.2016	12:38:00	CDT/RO	max depth	78° 51.73' N	003° 58.40' W	1977.6
PS99/0049-2	01.07.2016	14:54:00	MUC	max depth	78° 51.31' N	003° 57.33' W	1982.9
PS99/0049-3	01.07.2016	16:21:00	BC	max depth	78° 50.99' N	003° 57.84' W	1970.7
PS99/0050-1	01.07.2016	19:40:00	CDT/RO	max depth	78° 56.20' N	004° 39.02' W	1549.1
PS99/0050-2	01.07.2016	21:07:00	MUC	max depth	78° 56.03' N	004° 38.59' W	1551.0
PS99/0050-3	01.07.2016	22:18:00	BC	max depth	78° 55.98' N	004° 38.66' W	1548.3
PS99/0051-1	02.07.2016	01:15:00	RAMSES	max depth	78° 59.57' N	005° 25.06' W	1007.0
PS99/0051-2	02.07.2016	02:29:00	CDT/RO	max depth	78° 59.45' N	005° 24.56' W	1009.7
PS99/0051-3	02.07.2016	04:45:00	MSC	max depth	78° 59.64' N	005° 23.19' W	1030.5
PS99/0051-4	02.07.2016	05:09:00	MSC	max depth	78° 59.51' N	005° 23.21' W	1026.5
PS99/0051-5	02.07.2016	06:22:00	LOKI	max depth	78° 59.49' N	005° 23.67' W	1020.7
PS99/0051-6	02.07.2016	07:50:00	MN	max depth	78° 59.39' N	005° 24.14' W	1013.9
PS99/0051-7	02.07.2016	07:38:00	ICE	max depth	78° 59.36' N	005° 24.11' W	1013.8
PS99/0051-8	02.07.2016	09:04:00	BC	max depth	78° 59.33' N	005° 25.92' W	995,0

Station	Date	Time	Gear	Action	Position Lat	Position Lon	Water Depth [m]
PS99/0051-9	02.07.2016	10:01:00	MUC	max depth	78° 59.47' N	005° 27.05' W	981.7
PS99/0052-1	03.07.2016	06:20:00	MOR	recovery	79° 44.08' N	004° 29.74' E	2726.4
PS99/0052-2	03.07.2016	09:42:01	DT	deploy-ment	79° 43.50' N	004° 23.41' E	2687.0
PS99/0052-3	03.07.2016	10:45:00	MUC	max depth	79° 44.26' N	004° 25.96' E	2620.5
PS99/0052-4	03.07.2016	12:34:59	LANDER	deploy-ment	79° 44.40' N	004° 25.82' E	2603.0
PS99/0052-5	03.07.2016	13:07:59	LANDER	deploy-ment	79° 44.24' N	004° 23.32' E	2640.0
PS99/0053-1	03.07.2016	16:17:00	RAMSES	max depth	79° 55.68' N	003° 14.11' E	2539.7
PS99/0053-2	03.07.2016	18:21:00	CDT/RO/ ISP	max depth	79° 55.27' N	003° 03.72' E	2604.2
PS99/0053-3	03.07.2016	21:06:00	MSC	max depth	79° 54.18' N	002° 56.11' E	2684.9
PS99/0053-4	03.07.2016	21:56:00	MSC	max depth	79° 53.96' N	002° 53.45' E	2706.1
PS99/0053-5	03.07.2016	23:00:00	LOKI	max depth	79° 54.32' N	002° 58.03' E	2668.8
PS99/0053-6	04.07.2016	01:05:00	MN	max depth	79° 56.88' N	003° 00.49' E	2601.2
PS99/0053-7	04.07.2016	03:13:00	MUC	max depth	79° 57.79' N	002° 55.99' E	2613.5
PS99/0053-8	04.07.2016	04:48:00	BC	max depth	79° 58.37' N	002° 54.55' E	2609.9
PS99/0053-9	04.07.2016	10:55:00	AUV	profile start	79° 54.81' N	003° 42.21' E	2415.3
PS99/0053-9	04.07.2016	13:32:00	AUV	profile end	79° 56.03' N	003° 33.49' E	2390.2
PS99/0053-10	04.07.2016	10:23:00	CDT/RO	max depth	79° 55.77' N	003° 40.38' E	2422.1
PS99/0054-1	04.07.2016	19:27:00	CDT/RO	max depth	79° 35.20' N	005° 10.20' E	2777.8
PS99/0054-2	04.07.2016	21:44:00	MUC	max depth	79° 35.26' N	005° 10.46' E	2778.6
PS99/0055-1	05.07.2016	00:20:00	CDT/RO	max depth	79° 44.49' N	004° 30.21' E	2610.9
PS99/0055-2	05.07.2016	01:21:00	RAMSES	max depth	79° 44.37' N	004° 30.85' E	2703.0
PS99/0055-3	05.07.2016	02:30:00	MSC	max depth	79° 44.57' N	004° 28.93' E	2595.0
PS99/0055-4	05.07.2016	02:47:00	MSC	max depth	79° 44.65' N	004° 28.61' E	2593.6
PS99/0055-5	05.07.2016	03:47:00	LOKI	max depth	79° 44.75' N	004° 27.46' E	2583.2
PS99/0055-6	05.07.2016	07:33:00	MOR	deploy-ment	79° 44.19' N	004° 29.42' E	2656.6
PS99/0055-7	05.07.2016	08:52:00	CDT/RO	max depth	79° 44.99' N	004° 28.71' E	2541.9
PS99/0055-8	05.07.2016	10:42:00	CAL	profile start	79° 43.98' N	004° 29.63' E	2756.4
PS99/0055-8	05.07.2016	14:27:59	CAL	profile end	79° 44.76' N	004° 25.21' E	2756.0
PS99/0055-9	05.07.2016	15:45:00	LANDER	recovery	79° 44.49' N	004° 25.21' E	2599.6
PS99/0055-10	05.07.2016	17:21:01	LANDER	recovery	79° 44.39' N	004° 22.69' E	2673.8
PS99/0056-1	05.07.2016	19:51:00	OFOS	profile start	79° 35.91' N	005° 10.00' E	2785.7

Station	Date	Time	Gear	Action	Position Lat	Position Lon	Water Depth [m]
PS99/0056-1	05.07.2016	23:45:00	OFOS	profile end	79° 34.06' N	005° 15.39' E	2659.6
PS99/0057-1	06.07.2016	04:17:00	CDT/RO	max depth	79° 07.80' N	004° 54.40' E	1544.1
PS99/0057-2	06.07.2016	05:52:00	MUC	max depth	79° 07.86' N	004° 54.17' E	1540.7
PS99/0057-3	06.07.2016	06:58:00	BC	max depth	79° 07.85' N	004° 54.38' E	1540.3
PS99/0057-4	06.07.2016	09:30:00	TRAMPER	deploy-ment	79° 07.82' N	004° 54.15' E	1545.5
PS99/0058-1	06.07.2016	11:59:00	MUC	max depth	79° 01.39' N	004° 24.68' E	2535.9
PS99/0058-2	06.07.2016	16:37:00	MOR	deploy-ment	79° 01.32' N	004° 24.12' E	2540.3
PS99/0059-1	06.07.2016	19:05:00	RAMSES	max depth	79° 08.08' N	002° 50.50' E	5569.3
PS99/0059-2	06.07.2016	21:48:00	CDT/RO/ ISP	max depth	79° 08.09' N	002° 50.75' E	5568.8
PS99/0059-3	07.07.2016	02:16:00	LOKI	max depth	79° 07.96' N	002° 51.02' E	5566.4
PS99/0059-4	07.07.2016	04:01:00	MN	max depth	79° 07.74' N	002° 51.92' E	5561.9
PS99/0059-5	07.07.2016	09:20:00	AUV	profile start	79° 07.40' N	002° 49.05' E	5502.0
PS99/0059-5	07.07.2016	13:00:01	AUV	profile end	79° 05.41' N	002° 58.15' E	5356.6
PS99/0059-6	07.07.2016	09:11:00	CDT/RO	max depth	79° 07.41' N	002° 49.03' E	5501.6
PS99/0059-7	07.07.2016	14:14:00	MSC	max depth	79° 08.03' N	002° 50.89' E	5569.1
PS99/0059-8	07.07.2016	14:41:00	MSC	max depth	79° 08.00' N	002° 50.93' E	5567.8
PS99/0059-9	07.07.2016	16:35:00	MUC	max depth	79° 08.02' N	002° 50.64' E	5568.6
PS99/0059-10	07.07.2016	20:01:00	BC	max depth	79° 07.92' N	002° 50.47' E	5566.6
PS99/0060-1	08.07.2016	01:19:00	MN	max depth	79° 00.42' N	004° 20.01' E	2600.9
PS99/0060-2	08.07.2016	03:25:00	LOKI	max depth	79° 00.41' N	004° 19.43' E	2603.7
PS99/0060-3	08.07.2016	05:25:00	MUC	max depth	79° 00.39' N	004° 19.93' E	2601.4
PS99/0060-4	08.07.2016	06:30:01	LANDER	deploy-ment	79° 00.37' N	004° 19.99' E	2601.1
PS99/0060-5	08.07.2016	07:00:00	LANDER	deploy-ment	79° 00.27' N	004° 22.65' E	2589.1
PS99/0060-6	08.07.2016	07:15:00	MOR	recovery	79° 01.21' N	004° 23.41' E	2544.4
PS99/0061-1	08.07.2016	10:49:00	TRAMPER	recovery	79° 07.67' N	004° 53.30' E	1573.7
PS99/0062-1	08.07.2016	15:48:00	MUC	max depth	79° 02.02' N	007° 00.03' E	1308.2
PS99/0062-2	08.07.2016	16:50:00	BC	max depth	79° 01.80' N	007° 00.06' E	1301.8
PS99/0062-3	08.07.2016	19:53:00	RAMSES	max depth	79° 02.11' N	006° 58.24' E	1305.6
PS99/0062-4	08.07.2016	20:58:00	CDT/RO	max depth	79° 02.09' N	006° 58.44' E	1305.8
PS99/0062-5	08.07.2016	22:13:00	MSC	max depth	79° 02.08' N	006° 58.14' E	1304.8
PS99/0062-6	08.07.2016	22:34:00	MSC	max depth	79° 02.10' N	006° 57.91' E	1305.0
PS99/0063-1	09.07.2016	00:55:00	RAMSES	max depth	79° 00.09' N	008° 21.92' E	756.0

Station	Date	Time	Gear	Action	Position Lat	Position Lon	Water Depth [m]
PS99/0063-2	09.07.2016	01:47:00	CDT/RO	max depth	79° 00.16' N	008° 21.77' E	762.9
PS99/0063-3	09.07.2016	02:54:00	MUC	max depth	79° 00.25' N	008° 21.89' E	759.1
PS99/0064-1	09.07.2016	05:15:00	RAMSES	max depth	78° 59.00' N	009° 31.16' E	236.1
PS99/0064-2	09.07.2016	05:59:00	CDT/RO	max depth	78° 58.86' N	009° 30.75' E	230.0
PS99/0064-3	09.07.2016	06:31:00	MSC	max depth	78° 58.85' N	009° 30.60' E	218.0
PS99/0064-4	09.07.2016	06:48:00	MSC	max depth	78° 58.87' N	009° 30.49' E	219.0
PS99/0064-5	09.07.2016	07:11:00	MUC	max depth	78° 58.88' N	009° 30.32' E	218.0
PS99/0064-6	09.07.2016	07:41:00	MUC	max depth	78° 58.94' N	009° 30.04' E	221.0
PS99/0065-1	09.07.2016	10:31:00	RAMSES	max depth	79° 01.65' N	011° 05.30' E	271.0
PS99/0065-2	09.07.2016	11:24:01	CDT/RO/ ISP	max depth	79° 01.58' N	011° 05.55' E	269.0
PS99/0065-3	09.07.2016	13:15:00	MUC	max depth	79° 01.66' N	011° 05.62' E	272.0
PS99/0066-1	09.07.2016	22:33:00	RAMSES	max depth	79° 08.16' N	006° 02.88' E	1300.0
PS99/0066-2	09.07.2016	23:16:00	CDT/RO	max depth	79° 08.35' N	006° 05.31' E	1270.0
PS99/0066-3	10.07.2016	00:07:00	MUC	max depth	79° 08.36' N	006° 05.27' E	1282.0
PS99/0066-4	10.07.2016	01:02:00	BC	max depth	79° 08.31' N	006° 04.93' E	1282.0
PS99/0066-5	10.07.2016	02:23:00	CDT/RO	max depth	79° 08.37' N	006° 05.03' E	1283.0
PS99/0067-1	10.07.2016	07:31:00	MOR	deploy-ment	79° 00.71' N	006° 57.89' E	1259.9
PS99/0068-1	10.07.2016	10:37:00	LANDER	recovery	79° 00.32' N	004° 19.29' E	2606.6
PS99/0068-2	10.07.2016	12:04:00	LANDER	recovery	79° 00.04' N	004° 22.17' E	2601.4
PS99/0068-3	11.07.2016	13:54:59	DT	deploy-ment	78° 52.50' N	004° 14.18' E	2485.7
PS99/0068-3	11.07.2016	13:32:00	DT	recovery	78° 52.60' N	004° 14.94' E	2518.3
PS99/0069-1	10.07.2016	19:28:00	RAMSES	max depth	79° 06.42' N	004° 35.86' E	1908.7
PS99/0069-2	10.07.2016	20:45:00	CDT/RO	max depth	79° 06.46' N	004° 35.80' E	1890.3
PS99/0069-3	10.07.2016	21:57:00	MSC	max depth	79° 06.48' N	004° 35.85' E	1889.8
PS99/0069-4	10.07.2016	22:13:00	MSC	max depth	79° 06.49' N	004° 35.81' E	1877.2
PS99/0069-5	10.07.2016	23:18:00	MUC	max depth	79° 06.43' N	004° 35.77' E	1905.7
PS99/0069-6	11.07.2016	00:40:00	BC	max depth	79° 06.48' N	004° 35.78' E	1886.6
PS99/0070-1	11.07.2016	07:36:01	MOR	deploy-ment	79° 01.38' N	004° 15.71' E	2601.8
PS99/0071-1	11.07.2016	10:32:00	BETON	deploy-ment	79° 04.55' N	004° 07.60' E	2480.7
PS99/0072-1	11.07.2016	17:46:00	MOR	deploy-ment	79° 00.00' N	004° 19.97' E	2612.4
PS99/0073-1	11.07.2016	20:52:00	TRAMPER	deploy-ment	79° 03.59' N	004° 11.90' E	2478.5

Station	Date	Time	Gear	Action	Position Lat	Position Lon	Water Depth [m]
PS99/0074-1	12.07.2016	00:47:00	CDT/RO	max depth	79° 08.29' N	006° 05.08' E	1282.5
PS99/0074-2	12.07.2016	02:17:00	MN	max depth	79° 08.40' N	006° 05.21' E	1286.2
PS99/0075-1	12.07.2016	07:49:00	AUV	profile start	79° 02.66' N	004° 31.85' E	2381.1
PS99/0075-1	12.07.2016	13:00:00	AUV	profile end	79° 05.77' N	004° 09.21' E	n.d.
PS99/0075-2	12.07.2016	07:34:00	CDT/RO	max depth	79° 02.66' N	004° 31.87' E	2380.5
PS99/0076-1	12.07.2016	16:02:00	MOR	deploy-ment	79° 01.40' N	004° 24.30' E	2535.6
PS99/0077-1	12.07.2016	16:51:59	LANDER	deploy-ment	79° 04.67' N	004° 06.74' E	2493.9
PS99/0078-1	12.07.2016	18:43:00	BETON	deploy-ment	79° 04.53' N	004° 07.84' E	2487.2

(n.d.: no data)

List of acronyms:

AUV	Autonomous Underwater Vehicle
BC	Box Corer
BETON	Dropstone-Dropper
CAL	Posidonia Calibration
CTD/RO	CTD/Rosette Water Sampler
CTD/RO/ISP	CTD/Rosette Water Sampler + in-situ Pumps
HN	Hand-net
ICE	Ice Station
LANDER	Bottom-Lander
LOKI	Light frame On-sight Key species Investigations
MN	Multi-net
MOR	Mooring
MSC	Marine Snow Catcher
MUC	Multiple Corer
OFOS	Ocean Floor Observation System
RAMSES	Radiometer
DT	Drifting Trap
TRAPS	Sediment trap mooring

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