SUMMARY AND ITINERARY

Antje Boetius, Christina Bienhold

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung

The rapid warming of the Arctic and sea ice retreat affect not only the hydrography of the Arctic Ocean, but also biogeochemical and biological processes in various ways. The expedition PS138 (ArcWatch-1) investigated the biology, chemistry and physics of sea ice, as well as the impact of sea ice retreat on the entire ocean system from the surface to the deep sea. We studied the dynamics of first- and multiyear ice, as well as the role of summerly ice melt and re-growth in fall for the distribution of nutrients, productivity and the composition of pelagic and benthic communities, as well as the export of particulate matter to the deep sea. During the expedition PS80 (ARK27-3, IceArc) in 2012, which took place during the largest documented sea ice minimum to date, substantial impacts on the ecosystem were found (Boetius et al. 2013). Eleven years later, the expedition PS138 assessed the current ecosystem state and enables comparative studies with previous decades. We re-visited the same regions as in 2012 (Fig. 1.1), and used interdisciplinary process studies to examine interactions between ice physics and biology, hydrography, biogeochemistry and biodiversity of the Arctic ecosystem, from the sea ice to the seafloor. In addition, we repeated some studies at former MOSAiC sites. Our work included comparative studies between working areas in the marginal ice zone and areas covered by multiyear sea ice. During PS138 a range of established and novel technologies were deployed, such as moored lander systems, towed instruments and an under-ice ROV (remotely operated vehicle). In addition to scientific operations on the sea ice and from board, buoys, and short- and long-term moorings were deployed to assess the physics, chemistry and biology of the Arctic Ocean across different temporal scales. The results of this expedition in summer 2023, which was marked by several anomalies in and around the Arctic, are an important contribution toward quantifying the effects of changes in sea ice cover on the Arctic Ocean and its ecosystems. This expedition is supported by the Helmholtz research program "Changing Earth - Sustaining our Future" Topic 2, Subtopics 1, 3 and 4, and Topic 6, Subtopics 1, 2 and 3, as well as various national and international programs.

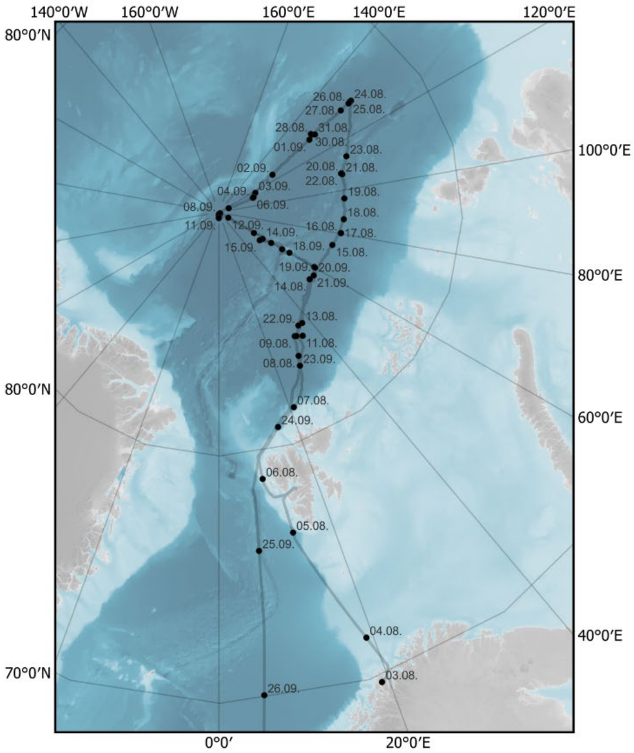

Fig. 1.1: Cruise track (grey) and ice stations (white) of the expedition PS138 (ArcWatch-1). The expedition started on 3 August 2023 in Tromsø and ends on 30 September 2023 in Bremerhaven.

The expedition PS138 (ArcWatch-1) began on 3 August in Tromsø and headed north through Norwegian waters. We passed Spitsbergen to the west on 5 August, with a stopover to pick up scientific equipment and provisions. On 6 August, buoys were deployed and a first test station with the CTD rosette was carried out before reaching the ice edge to take water samples from various depths. The research activities began on 7 August with autonomous XCTDs (eXpendable CTD) and the first sea ice thickness measurements with the "EM-Bird": The measurements are carried out from our helicopter while the EM-Bird is towed under the helicopter. The AWI has been measuring ice thickness in the Arctic Ocean for 30 years, and this time series is the only airplane- and helicopter-based measurement series that has been carried out in the Arctic over such a long period of time.

The first part of the journey took us eastward along the ice margin to the first ice station at 84°N and 30°E. The aim of the expedition is to visit selected ice stations between 30°E and 130°E and 84-90°N, in order to carry out ice-physical and oceanographic measurements and take samples for biogeochemical and biological analyses (ice, water, seafloor). Work is carried out in parallel: while the sea ice researchers investigate the processes on and under the ice, the water column is analyzed using water samples and the seabed with its benthic organisms is studied. The helicopter is used to transport people or instruments between the ship and the ice floe. We track the drift of the ice floe with the help of GPS signals sent from various buoys placed on the ice. CTD rosettes with niskin bottles and in situ pumps are used to retrieve water samples, and various nets (hand net, bongo, multi-net and under-ice ROV net) are used for sampling phytoplankton and zooplankton. Several benthic sampling devices such as the TV-MUC, giant box corer, epibenthic sledge and landers were also deployed at each station. For the latter two devices, Polarstern leaves the floe to operate in open water areas between the floes.

Fig. 1.2: First research station on the ice © Esther Horvath

The first ice station took place at 84°04.06 N 031°16.04 E from 8-12 August (Fig 1.2). The ice had melt ponds and some algal aggregations on the heavily melted underside. The first dive for ocean floor observation and bathymetry with the OFOBS (Ocean Floor Observation and Bathymetry System) showed a lot of activity on the sea floor at a depth of 4000 m and many small sunken algae clumps. The deployment and recovery of 2 benthic landers proved to be a major challenge due to the missing bow thruster and a defective Posidonia navigation system; the recovery of one lander had to be abandoned because it could not be located in the ice. On 17 August, we met the LNG-powered cruise ship Le Commandant Charcot. There was an exchange of people between the two ships for a few hours and the captain and chief scientist were invited to give talks. The second ice station was reached on 14 August at 85°N and 78°E and lasted until 18 August. The parallel work on the ice was supported by the placement of ice anchors; the position of the ship on the ice floe was adjusted depending on the wind direction, so that the wind pushed the ship’s port side against the floe and the starboard side was used for the winch-guided equipment in open water holes. Most of the equipment could thus be used in parallel with the ice work. Only the landers and the epibenthic sledge (EBS) were deployed freely in open water areas between floes. Polarstern tows the EBS directly over the sea floor and collects macrofauna and megafauna in very good condition for taxonomic studies. On 18 August, on the way to the third ice station, we reach a spur of the Gakkel Ridge, a barely surveyed seamount at 84°46.3' N and 94°56.8' E. It is mapped with a multibeam echo sounder and a sediment echo sounder.

Fig. 1.3: Giant sea anemones together with sponges colonized by bristle worms. © OFOBS

We also dived with OFOBS to the top and slope of the seamount. The seamount is covered by extensive sponge gardens, the biological community is enormously diverse and extends from the summit at 1500 m water depth to over 2000 m water depth (Abb. 1.3).

On 19 August we reached the third ice station at 84°36' N and 108°30' E, where we worked until 22 August, including two lander deployments. Ice stations also included the deployment of the remotely operated under-ice robot "Beast". It is equipped with a CTD for conductivity, temperature and depth measurements, a light sensor, a pH sensor, cameras, hyperspectral cameras for investigating algae biomass and an acoustic multibeam for mapping the ice topography. On our way to the 4th ice station, several ice buoys and XCTDs are deployed. The 4th ice station was carried out at 83°N and 130°E in heavy fog, from 24-27 August. From the western working area, we continue towards the area where the MOSAiC drift started in October 2019. The 5th ice station at 85°N and 130°E lasted from 28 August to 1 September. In addition to the standard program, we deployed a network of autonomous systems on several floes in the region, which should repeat the drift of the MOSAiC floe and - if all goes well - will generate a unique data set to compare with the MOSAiC buoy network.

Fig.1.4: Hydrographic work on the ice; here measurements with the "Suna" nitrate sensor, which measures nitrogen in water. © Esther Horvath

On 1 September, an oceanographic and a biogeochemical mooring were deployed (2 parallel moorings, one of them as a pipe mooring directly under the ice, Fig. 1.5). The recovery of these moorings is planned during the ArcWatch-2 expedition in 2024. The ice floes are unusually snow-covered, plane and still show no growth of under-ice algae. There are also hardly any algae aggregates in the deep sea, and the seafloor fauna shows considerable differences compared to 2012.

Fig. 1.5: The new pipe mooring for year-round hydrographic measurements. © Esther Horvath

On 2 September, we were able to perform two OFOBS dives at a seamount on the Lomonosov Ridge. This seamount was not rocky like the previous one on the Gakkel Ridge, but was completely covered with sediments. We found a few sponges on the summit of the ridge and on the heavily sedimented steep slopes to the south of the ridge, but above all many mating sea cucumbers. The 6th ice station took place at 88°30'N and 112°E, with full ice cover and lasted from 3 September to 5 September. In this region, the ice was also heavily melted from below and hardly any export of algae or particles was visible. On 7 September we reached the North Pole for the seventh ice station, at temperatures of -5° to -8°C (Abb. 1.6). For Polarstern it was the seventh time at the North Pole.

Fig. 1.6: At the North Pole © Esther Horvath

We were able to carry out the entire series of ice, water and seabed surveys in good weather conditions and sub-zero temperatures until 11 September. New ice was already forming in the water channels. With OFOBS, we were able to explore the seabed at a depth of around 4220 meters directly at the North Pole, where very large spoon worms and small, crawling sea anemones live. During our visit to the North Pole, we deployed 200 small wooden boats next to an autonomous measuring buoy on the sea ice. The boats can be tracked on their journey through the Arctic using the position data from the buoys (https://data.meereisportal.de/relaunch/buoy.php?lang=en&active-tab1=method&active-tab2=buoy&singlemap&buoyname=2023P286). When the ice melts, the boats continue to drift and will hopefully be found on distant shores and reported via the floatboat.org website. Float Your Boat is a project of the International Arctic Buoy Program.

Starting from the North Pole, we followed a transect at 60°E with CTDs including water sampling alternating with XCTDs. The eighth ice station was carried out at 88°N and 60°E from 13-15 September. Here, too, significant changes in the biotic communities on the sea floor were observed compared to the recordings from the OFOS camera sled in 2012 (Fig. 1.7).

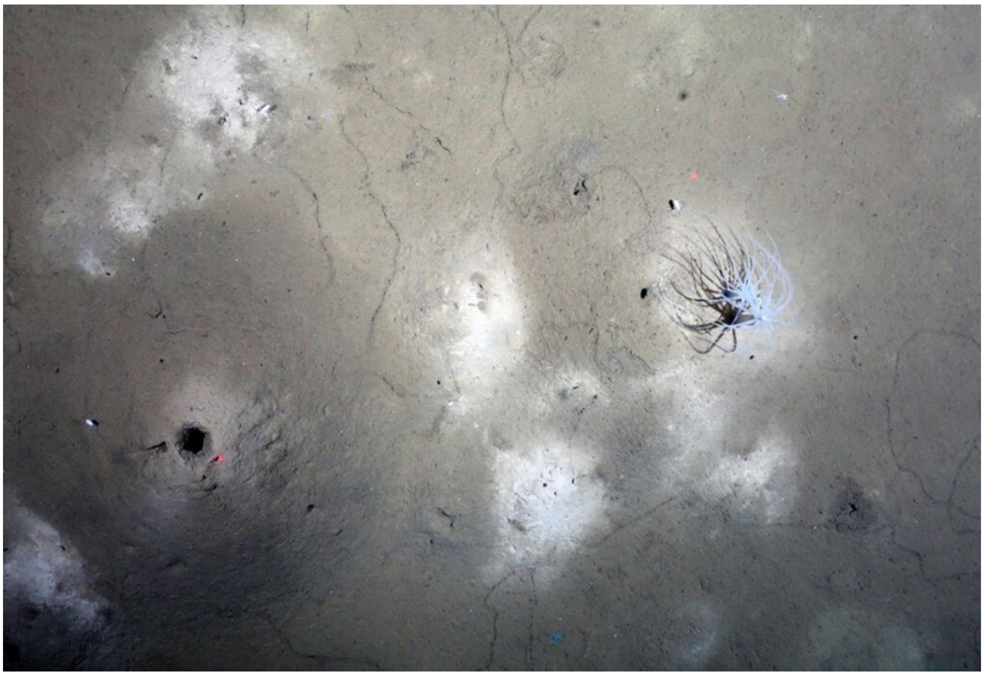

Fig. 1.7: A section of the seabed at the eighth ice station. The whitish patches are remnants of ice algae deposits from previous years © OFOBS

After the station, the 60°E transect with oceanographic measurements was continued. Every approx. 10 nautical miles, the water column is measured down to a depth of 1500 m, and every 40 nautical miles down to a depth of approx. 4 km to the sea floor. This serves to investigate the hydrography of the Eurasian Basin, which includes the Amundsen and Nansen Basins and the Gakkel Ridge. We will also investigate how much of the carbon in the dissolved fraction of the seawater comes from the Arctic coasts and the permafrost, and whether this proportion changes regionally. Pollutants such as perfluorinated and polyfluorinated alkyl compounds are also being analyzed.

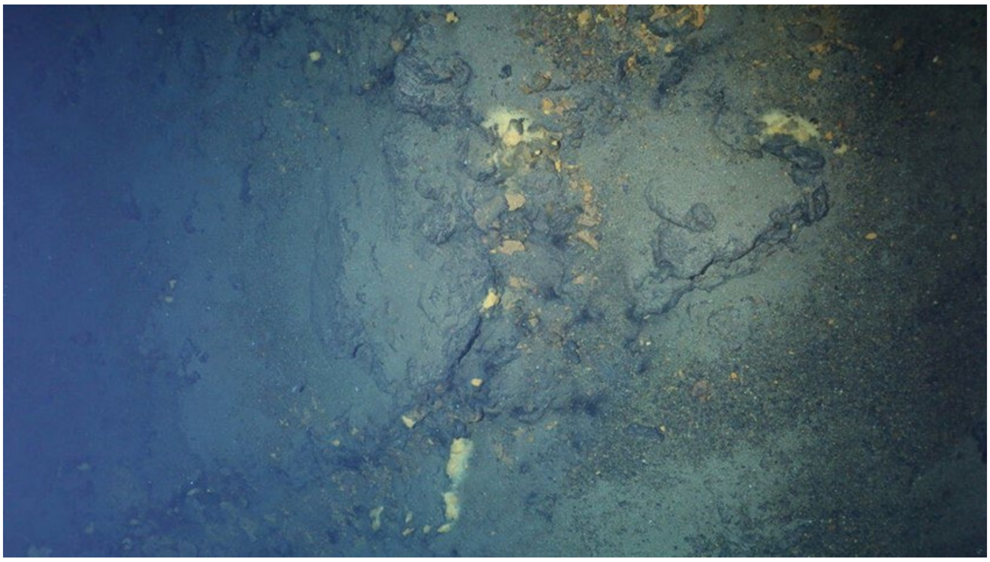

Fig. 1.8: OFOBS dive at the Polaris seamount of the Gakkel Ridge © OFOBS

On 16 September, we reached the foothills of the Gakkel Ridge at 60°E and conducted bathymetry transects as well as two OFOBS dives in the northern part of the Langseth Ridge. This part of the ridge system is also characterized by pillow basalts, but shows significantly more sedimentation than the southern chain of seamounts and no clear enrichment of benthic life. On 17 September, we continued our exploration of this area of the Gakkel Ridge with a visit to the Polaris seamount. Here, in 2016, we found traces of active hydrothermal processes at a water depth of 3250 meters. The towed camera system OFOBS passed through two thick particle clouds that probably originated from hydrothermal vents at 2500-2700 meters water depth. The seafloor was a mixture of pillow lava fields with glass sponges, steep terraces with countless small fluid seeps, covered with yellow and orange bacterial mats on blackened sediments and rocks (Fig. 1.8). Brittle stars and bristle worms seemed to feel particularly comfortable in these areas.

We then continued the hydrographic transect along 60°E. It ended with the 9th ice station at 85°28'N. A highlight of the last ice station was a commented livestream of the under-ice ROV Beast on YouTube. At the end of the cruise, we were unfortunately unable to reach the first floe for a recovery of deployed instruments on the sea ice and further measurements. It had drifted into the Russian Exclusive Economic Zone. The request to recover the equipment in free passage without research was not granted. With the deployment of further buoys along our transit through the ice, we ended the research program of expedition PS138. We left the ice edge on 23 September and passed Spitsbergen on the West on our return to Bremerhaven. We felt the remnants of a hurricane on the return journey with wave heights of about 6 m. The expedition ended in Bremerhaven on 30 September. An important contribution of the expedition to international programs is the deployment of 73 buoys and observation systems on the ice. The measurements will record the seasonal changes in the atmosphere, snow, sea ice and the ocean. From the main floe at the MOSAiC drift location photos will be sent regularly to document changes. The journey of the buoys can be followed on meereisportal (www.meereisportal.de).

Fig. 1.9: Polarstern Crew at the North Pole © Esther Horvath

We would like to thank Captain Stefan Schwarze and the crew of Polarstern expedition PS138 (Fig. 1.9) for the great collaborative teamwork, and all participating research institutes, universities and funding agencies for their support.

References

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