MARIA S.MERIAN-Berichte

Arctic Seafloor Integrity

Cruise No. MSM95 – (GPF 19-2_05)

09.09.2020 – 07.10.2020
Emden (Germany) – Emden (GERMANY)

AUTUN PURSER
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1 Cruise Summary

1.1 Summary in English

The main aim of the MSM95 research expedition was to investigate and map physical impacts on the arctic seafloor in two distinct and contrasting Arctic areas (The Svalbard shelf edge and the HAUSGARTEN time series stations in the FRAM strait) with a range of research equipment. A 'nested' data approach was conducted in each research area, with broad seafloor mapping conducted initially with the R/V MARIA S. MERIAN onboard acoustic systems (The EM122 and EM712 bathymetric systems), followed by focused subsequent mapping conducted by PAUL 3000 automated underwater vehicle (AUV) sidescan and camera deployments, Ocean Floor Observation and Bathymetry System (OFOBS) towed sidescan and camera trawls and finally with very high resolution investigations conducted with a new mini-ROV launched directly from the OFOBS for close seafloor visual analysis. These data will be used to produce spatial distribution maps of iceberg and fishery impacts on the seafloor at three locations to the north, south and west of the Svalbard Archipelago, as well as maps of drop stone and topography variations across several of the HAUSGARTEN stations.

The second aim of MSM95 was to repeat three of the regular seafloor transects conducted with towed cameras across the HAUSGARTEN stations within the Fram straight, with these transects to be subsequently analysed and compared with transects conducted over the last 15 years, to gauge changes in megafauna abundance and community composition.

Our third aim was to conduct water column work across our research areas. We conducted numerous water column camera trawls to image inhabitants at various depths, with a focus on identifying squid populations throughout the Arctic water column. We also sampled waters via CTD from throughout the water column, to continue the microbial observatory work (MicrObs) time series work carried out as part of the FRAM project by AWI and MPI researchers, to investigate the eDNA composition of the waters for analysis of squid presence / absence and bacterial community structure.

Further opportunistic work was conducted between stations, with floating litter surveys conducted to input into the ongoing records being collated by the AWI. An inspection of the NOMAD tracked vehicle, deployed last year in the HAUSGARTEN area was made, which observed the vehicle to be stuck on a stone obstruction. By reconfiguring OFOBS with hooked ropes, the NOMAD was manually freed from the obstruction by the captain and crew of MSM95.

1.2 Zusammenfassung

(Übersetzt von Lili Boehringer)

Das Hauptziel der MSM95-Forschungsexpedition war die Untersuchung und Kartierung der physikalischen Einflüsse auf den arktischen Meeresboden in zwei unterschiedlichen und kontrastreichen arktischen Gebieten (die Svalbard-Schelfkante und die HAUSGARTEN-Zeitserienstationen in der FRAM-Meerenge) mit einer Reihe von Forschungsgeräten. In jedem Forschungsgebiet wurde ein "verschachtelter" Datenansatz verfolgt, wobei eine umfassende Kartierung des Meeresbodens zunächst mit den akustischen Bordsystemen der R/V MARIA S. MERIAN (EM122 und EM712 bathymetrische Systeme) durchgeführt wurde, gefolgt von fokussierten Kartierungen durch PAUL 3000 AUV (automatisiertes Unterwasserfahrzeug) mit

Sidescans und Kameras, OFOBS (Ocean Floor Observation and Bathymetry System) mit Sidescans und Kameras und schließlich hochauflösende Untersuchungen mit einem neuen Mini-ROV, der direkt vom OFOBS zur visuellen Analyse des Meeresbodens gestartet wurde. Diese Daten werden verwendet, um räumliche Verteilungskarten von Eisberg- und Fischereieinflüssen auf den Meeresboden an drei Standorten im Norden, Süden und Westen des Svalbard-Archipel, sowie Karten von Fallstein- und Topographievariationen über mehrere der HAUSGARTEN-Stationen zu erstellen.

Das zweite Ziel von MSM95 war die Wiederholung von drei der regelmäßigen Meeresbodentransekte, die mit Schleppkameras über die HAUSGARTEN-Stationen innerhalb der Framstraße durchgeführt wurden. Diese Transekte sollten anschließend analysiert und mit Transekten der letzten 15 Jahre verglichen werden, um Veränderungen in der Megafauna und der Zusammensetzung der Lebensgemeinschaften zu messen.

Unser drittes Ziel war die Durchführung von Arbeiten in der Wassersäule in unseren Forschungsgebieten. Wir führten zahlreiche geschleppte Kameraeinsätze in der Wassersäule durch, um die Bewohner in verschiedenen Tiefen abzubilden, wobei der Schwerpunkt auf der Identifizierung von Tintenfischpopulationen in der gesamten arktischen Wassersäule lag. Wir nahmen auch Wasserproben per CTD aus der gesamten Wassersäule, um die mikrobielle Beobachtungsarbeit (MicrObs) fortzusetzen, die als Teil des FRAM-Projekts von AWI- und MPI-Forschern durchgeführt wurde, um die eDNA-Zusammensetzung des Wassers für die Analyse der Anwesenheit / Abwesenheit von Tintenfischen und der bakteriellen Gemeinschaftsstruktur zu untersuchen.

Weitere opportunistische Arbeiten wurden zwischen den Stationen durchgeführt, wobei die Anzahl an Treibgut aufgenommen wurde, um in die laufenden Aufzeichnungen des AWI einzufließen. Eine Inspektion des NOMAD-Raupenfahrzeugs, das letztes Jahr im HAUSGARTEN-Gebiet eingesetzt wurde, ergab, dass das Fahrzeug an einem Steinhindernis hängen geblieben war. Durch die Neukonfiguration von OFOBS mit Hakenseilen wurde das NOMAD vom Kapitän und der Besatzung der R/V MARIA S. MERIAN manuell von dem Hindernis befreit.

2 Participants

2.1 Principal Investigators

Name	Institution
Purser, Autun, Dr.	AWI
Merten, Véronique	GEOMAR
Dreutter, Simon	AWI

2.2 Scientific Party

Name	Discipline	Institution
Purser, Autun, Dr.	Marine Ecology / Chief Scientist	AWI
Hoge, Ulrich	OFOBS technician	AWI
Busack, Michael	AUV	AWI
Hagemann, Jonas	AUV	AWI
Dauer, Erik	Microbiology	AWI
Korfman, Niklas	Microbiology	AWI
Boehringer, Lilian	Marine Ecology / Biology	UniBremen/AWI
Merten, Véronique	eDNA, Marine Ecology	GEOMAR
Priest, Taylor	Microbiology	MPI
Dreutter, Simon	Bathymetry	AWI
Warnke, Fynn	Bathymetry	AWI
Hehemann, Laura	Bathymetry	AWI

Fig 2.1 Group photograph of the R/V MARIA S. MERIAN Cruise MSM95 (GPF 19-2_5) scientific party.

2.3 Participating Institutions

AWI	Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany
GEOMAR	Helmholtz-Zentrum für Ozeanforschung Kiel, Kiel, Germany
MPI	Max Planck Institute for Marine Microbiology, Bremen, Germany
UniBremen	University of Bremen, Bremen, Germany

3 Research Program

3.1 Cruise Working area

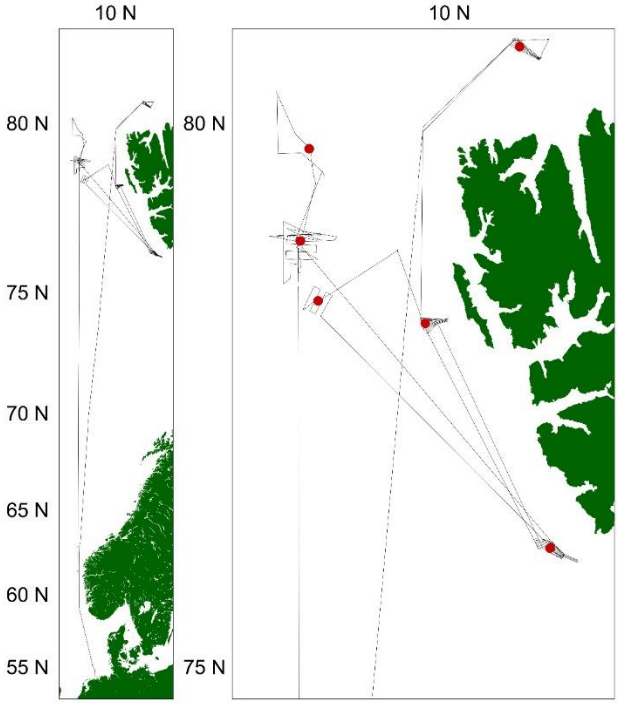


Fig. 3.1 Track chart of R/V MARIA S. MERIAN Cruise MSM95 (GPF 19-2_5). The six main working areas are indicated on the right detailed track chart by red spots.

Six main working areas were investigated during MSM95, as shown in Fig. 3.1. These six working areas comprised three areas close to the Svalbard archipelago and three areas within the Fram strait, and regularly visited as part of the HAUSGARTEN monitoring campaigns conducted over the last ~20 years by the Alfred Wegener Institute, most recently under the banner of the FRAM project.

Much of the first half of the cruise focused on the three Svalbard stations, located at 300 – 800 m depth, north, west and south of Svalbard. These areas of continental slope were reported to have been subjected to both naturally occurring ice scour impacts and recently occurring fishery action.

The second half of the station time was spent primarily investigating the three areas of the Fram strait shown in Fig. 3.1. These locations were of several 1000 m depth as a minium, down to 5,500 m depth for the final station, within the Molloy Deep. Three soft sediment abundant seafloor transects within these areas were revisited to continue the ongoing time series studies, but additional time was spent to investigate the more complex topographical regions of the central Hausgarten site.

3.2 Aims of the Cruise

The main aim of the MSM95 research expedition was to investigate and map physical impacts on the arctic seafloor in two distinct and contrasting Arctic areas (The Svalbard shelf edge and the HAUSGARTEN time series stations in the FRAM strait) with a range of research equipment. A 'nested' data approach was conducted in each research area, with broad seafloor mapping conducted initially with the R/V MARIA S. MERIAN onboard acoustic systems (The EM122 and EM712 bathymetric systems), followed by focused subsequent mapping conducted by PAUL 3000 automated underwater vehicle (AUV) sidescan and camera deployments, Ocean Floor Observation and Bathymetry System (OFOBS) towed sidescan and camera trawls and finally with very high resolution investigations conducted with a new mini-ROV launched directly from the OFOBS for close seafloor visual analysis.

These data will be used to produce spatial distribution maps of iceberg and fishery impacts on the seafloor at three locations to the north, south and west of the Svalbard Archipelago, as well as maps of drop stone abundnaces and topography variations across several of the HAUSGARTEN stations. The second aim of MSM95 was to repeat three of the regular seafloor transects conducted with towed cameras across the HAUSGARTEN stations within the Fram straight, with these transects to be subsequently analysed and compared with transects conducted over the last 15 years, to gauge changes in megafauna abundance and community composition. Our third aim was to conduct water column work across our research areas. We conducted numerous water column camera trawls to image inhabitants at various depths, with a focus on identifying squid populations throughout the Arctic water column. We also sampled waters via CTD from throughout the water column, to continue the microbial observatory work (MicrObs) time series work carried out as part of the FRAM project by AWI and MPI researchers, to investigate the eDNA composition of the waters for analysis of squid presence / absence and bacterial community structure.

3.3 Agenda of the Cruise

The initial plan was to visit each area of interest in turn (Fig. 3.1), and conduct a full set of investigations at each before progressing to the next site. This did actually not place, as a mix of technical setbacks and weather conditions rendered a more flexible schedule as more appropriate. Nevertheless, the majority of research steps in the following agenda were conduced for each of the study areas:

Optimal research agenda employed at each investigated area:

1) Initial CTD rosette deployment on arrival.

This deployment collected sound velocity data for gaining optimal quality bathymetric and USBL data, as well as for collecting samples for microbial analysis.

2) Ship based bathymetric mapping of research area conducted with EM112 or EM712, with the appropriate multibeam used for the area depth.

3) AUV deployed for benthic sidescan and visual mapping.

4) OFOBS towed camera and multibeam system towed in area previously mapped by AUV. Deployed in AUV mapped areas allow post-cruise method comparison and to allow nested maps to be produced.

5) MiniROV deployed from OFOBS for high resolution investigation of seafloor structures and fauna.

6) Final CTD rosette deployment on departure.
This deployment collected fresh sound velocity data for on route mapping, and to allow repeat water sampling where needed

7) Transit to next station.

OPTIONAL) An ADCP transect was also conducted on one occasion, and repeated AUV or OFOBS dives were conducted in areas of high interest.

NB) The AUV was not deployed in the Fram Strait following damage during the final Svalbard deployment.

4 Narrative of the Cruise

On the morning of 7th September the scientific party and a number of the crew joined R/V MARIA S. MERIAN at the docks in Emden, Germany. The previous 4 days had been spent in quarantine hotels (Ostfriesen Hof, Leer for the scientific party), during which participants were tested for the COVID-19 virus in isolation in individual rooms. Two transport containers were delivered to the ship on the morning of the 8th September containing the Ocean Floor Observation and Bathymetry System (OFOBS), the Autonomous Underwater Vehicle “PAUL 3000” and the equipment and technical supplies required by the remaining expedition participants. This equipment was unloaded and divided between laboratories on the afternoon of the 8th.

On the morning of the 9th September we cast off and passed through the sea lock, together with RV Meteor, at 10:30 CET. We then proceeded north at 10 kts until disembarking the Friesland island pilot, after which we started our ~5 day transect into the Svalbard archipelago, with an average speed of 12 Kts. Much of the transit was spent preparing our technical equipment ready for deployment and integrating our online systems with the ships network. On the morning of the 10th, at 8 am, we entered international waters and commenced underway data acquisition with the ships bathymetric and TSG systems. For several days we experienced winds of 7 – 9 Bf as we made our way from the North Sea into the Norwegian sea, with weather conditions improving on the 12th September. During the evening of the 12th September a prominent display of northern lights was evident at 69 N.

The time was spent on the transit familiarizing ourselves with the ship, the crew and the wave conditions. By 14th September all of us had acclimatized to the onboard conditions and were eager to start station work. At 6:00 (UTC) on the 15th September we arrived within our first research area, north of Svalbard and commenced our station work with a CTD. CTD waters were collected for researchers on board from GEOMAR, AWI and MPI, and the sound velocity profiles generated from cruise CTDs particularly important as much of our research work was conducted with acoustic sensing equipment (ship systems, AUV PAUL 3000, OFOBS) for which scientific data and position accuracy is increased with accurate and recent sound velocity profiles generated by the CTD. We stayed in the Svalbard North working area until the evening of the 16th September, conducting several successful AUV dives, testing our OFOBS equipment and mapping the seafloor with the ships EM712 system. On the evening of the 16th September we set a course for our second research area, Svalbard West, where we conducted a CTD and carried out EM712 mapping until the afternoon of the 17th, when we continued on to our southernmost research area, Svalbard South.

Arriving in Svalbard South during the early hours of the 18th September we commenced CTD and EM712 mapping until 07:15 am, at which point we commenced a full day OFOBS deployment, followed by EM712 mapping and a night of OFOBS deployment. The 19th September was also spent deploying OFOBS in the area, then we left the site for the southern greater Hausgarten area. The 20th – 22nd September were spent in this area conducting CTD, EM712, OFOS and AUV surveys, before returning to the Svalbard South area on the evening of the 22nd September. 23rd – 24th September were taken up with CTD, EM712, AUV and OFOBS surveys of the Svalbard South region. Poor weather resulted in some damage to the AUV system on recovery on the 23rd September. On the evening of the 24th September we moved on to the central Hausgarten area and spent the rest of our expedition time conducting EM122, CTD and OFOBS deployments across the FRAM time series stations. On the 28th and 29th of September we located a mobile tracked vehicle deployed in 2019 on the seafloor and visited it for a study with the OFOBS system. Observing the vehicle to be stuck on a rock, OFOBS was rigged with hooks and an attempt made to retrieve the vehicle to deck. Unfortunately, poor weather prevented this, so the vehicle was returned to the seafloor, ideally to continue its timed operations until August 2021 and recovery by POLARSTERN. During the last week of station time detailed hydroacoustic maps of the region were made of various areas of the Hausgarten area and three annually imaged seafloor transects were resurveyed with OFOBS.

Our final station was conducted at the Molloy Deep in the Hausgarten area during the early morning of the 1st October. Following this station, we started our homeward journey to the port of Emden, Germany, arriving on the morning of the 7th October following a week of strong winds and wave action. Container and sample unloading commenced immediately thereafter.

5 Preliminary Results

5.1 Shipborne Hydroacoustics

(S. Dreutter[1], F. Warnke[1], L. Hehemann[1])

[1]AWI

Most of the Arctic seas where never surveyed by swath bathymetry systems. Therefore, seabed topography data is unreliable and depth information is insufficient for navigation. One part of the MSM95 research program was detailed bathymetric mapping in the research area to extend our knowledge on seafloor topography in the Arctic and to use the survey results for morphological analysis of glacial seafloor features as well as artificial features like fishery trawl marks. Additionally, other parts of the research program required detailed bathymetric maps, e.g. for AUV and OFOBS dive planning purposes. Satellite altimetry data shows only very rough information of the seafloor characteristics while it cannot give correct depth information. Some bathymetry data from former research cruises was present, but cannot give the necessary detail and coverage needed for MSM95.

Therefore, the main task of the bathymetry group was to operate the multibeam echosounders (MBES) Kongsberg EM122 and EM712, including calibration and correction of the data for environmental circumstances (sound velocity, systematic errors in bottom detection, etc.), the post processing and cleaning of the data, as well as data management for on-site map creation. The MBES were run constantly throughout the cruise for underway surveying. Furthermore, systematic survey were conducted at six sites of special interest.

5.1.1 Technical description

During the MSM95 cruise, the bathymetric surveys were conducted with the hull-mounted MBES Kongsberg EM122 and EM712. The EM122 is a deep water system for continuous mapping with the full swath potential. The shallow water system EM712 was mostly useful for all surveys shallower than 1000 m, to achieve higher data resolution and quality.

The EM122 operates on a frequency of 12 kHz ranging from 10.5 to 13 kHz within the different transmit sectors. On R/V MARIA S. MERIAN, the EM122 transducer arrays are arranged in a hull-mounted Mills cross configuration of 4 m (transmit unit) by 4 m (receive unit) to achieve an angular beam accuracy of 2° × 2°. The combined motion, position, and time data comes from a Kongsberg Seapath system and the signal goes directly into the Processing Unit (PU) of the MBES to do real-time motion compensation in Pitch, Roll and Yaw in the range of +/-10°. With a combination of phase and amplitude detection algorithms the PU computes the water depth from the returning backscatter signal.

The EM712 is used for high-resolution seabed mapping in shallow waters and thus operates with higher frequencies in a range of 40-100 kHz. The possible slant ranges are between less than 5 m below the transducer up to a maximum of ~3000 m, resulting in reasonable swath opening (130°) down to about 1200 m water depth.

Both systems can cover a sector of up to 150° with each 75° per side. The EM712 distributes its 800 beams (1600 soundings in Dual Swath mode) with 0.5° × 0.5° beam width either in equidistant or equiangular mode on the swath angle. The EM122 has a lower horizontal resolution of max. 432 soundings per swath resulting in 864 soundings per ping (in Dual Swath mode). During MSM95 both systems were always set to equidistant mode.

5.1.2 Data acquisition and processing

Data acquisition was carried out throughout the entire cruise, starting the 10th of September 2020 at 06:00 UTC in the North Sea and ended the 4th of October at 20:45 UTC.

Where possible, cruise tracks were planned parallel to existing bathymetric data and the surveys were performed to extend already mapped regions. The multibeam surveys were generally run at around 7 kts. The long transit into the main research area was conducted at around 12 kts.

During deep water surveys >500 m generally a swath angle of about 120° was used. In shallow water, the swath angles were partially set to a maximum of 150° to cover wider areas.

For data acquisition, the Kongsberg SIS (Seafloor Information System, v4.3.3) software was used. It processes and logs the collected data, applies all corrections and defined filters, and finally displays the resulting depths on a geographical display. The recorded data was stored in 30 min blocks in the Kongsberg *.all format. Subsequent data processing was performed using Caris HIPS and SIPS (v11.3.7). The data editing revealed a good data quality of the EM122 with very little rejected beams. The EM712 data showed similarly good quality in shallow waters below 700 m.

For generating maps, the data were exported to QGIS in the GeoTIFF raster format and visualized with Cruise Tools (QGIS plugin).

5.1.3 Sound velocity profiles

For best survey results with correct depths, regularly CTD (Conductivity, Temperature, Depth; see also chapter 5.5) casts were performed to measure the water sound velocity in the different depths. This is essential, as the acoustic signal travels down the water column from the transducer to the seafloor and back to the surface through several different layers of water masses with each a different sound velocity. The sound velocity is influenced by density and compressibility, both depending on pressure, temperature and salinity. Wrong or outdated sound velocity profiles lead to refraction errors and reduced data quality.

The CTD measures conductivity, temperature, and depth in the water column while it is lowered to the seafloor. From these parameters, the sound velocity is calculated.

The sound velocity profiles obtained by the CTD were immediately processed with HydrOffice’s Sound Speed Manager (v2020.0.7) and applied within Kongsberg SIS for correct beamforming during the survey. 16 CTD stations were used for sound velocity correction during the expedition (Fig. 5.7). During the transits to and from the research area, synthetically modelled sound velocity profiles where generated from World Ocean Atlas 13 (WOA13) in sufficient temporal resolution for opportunistic underway measurements.

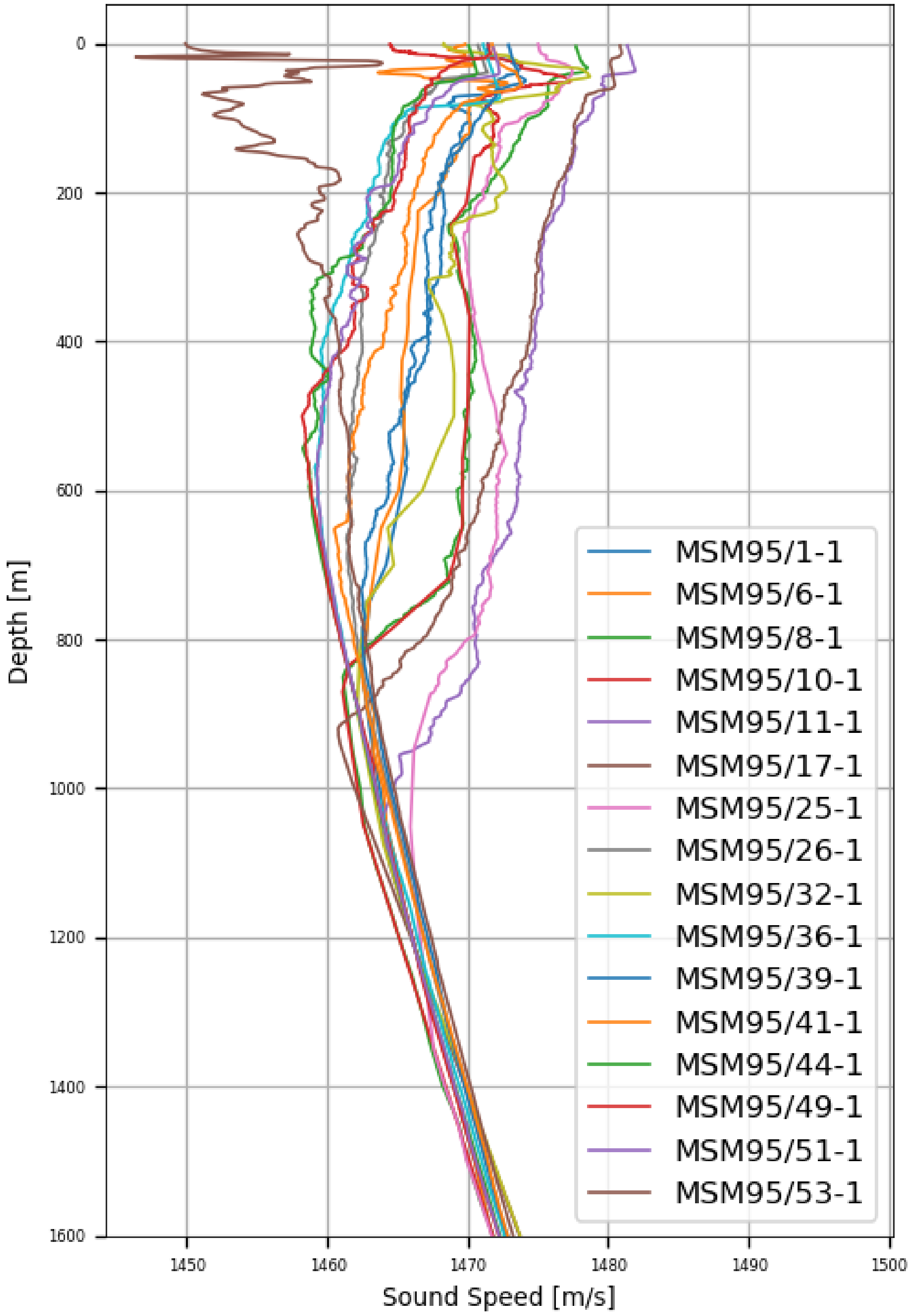


Fig. 5.1 CTD based Sound Velocity Profiles used during MSM95.

5.1.4 Preliminary Results

Throughout the cruise a continuous recording of data was achieved. By the end of the cruise, all MBES data of the main research area was processed. During 25 days of survey, a track length of 8,462 nm (15,672 km) was surveyed, covering an area of 51,864 km² (transit included), which is approximately 124 times the area of Bremen. The raw data volume of the EM712 is 33 GB with 294 separate files and 16 GB with 564 separate files from the EM122. Fig. 5.2 gives an overview over the collected data and the survey areas summarized in the following chapters.

Unexpected data quality drops due to motion artifacts showed up three times within the expedition, each lasting for a couple of minutes. The reason, as it turned out, were seagulls sitting on the GNSS (Global Navigation Satellite System) antennas. After they left, these problems were solved quickly.

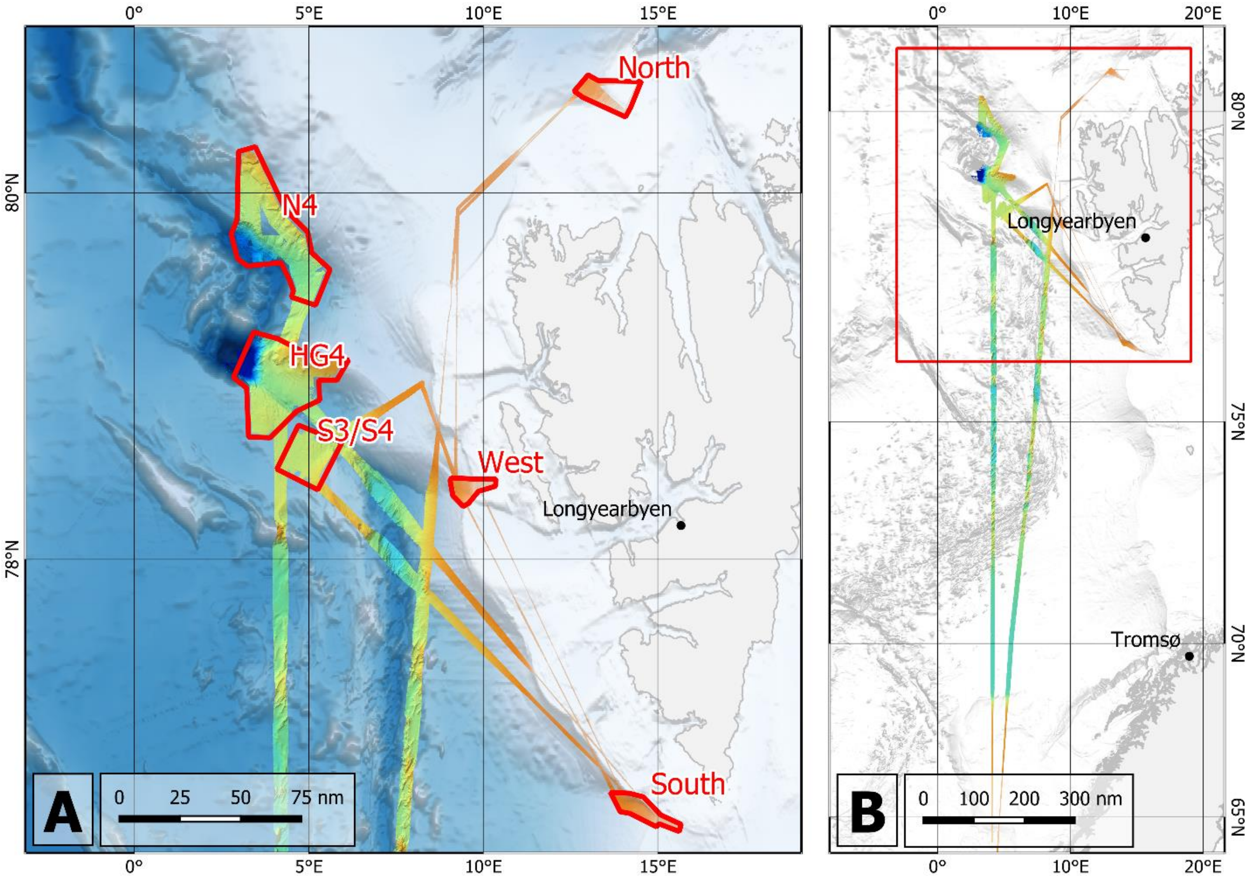


Fig. 5.2 Multibeam swath bathymetry data collected during MSM95. (A) Survey areas in the main research area. (B) Overview of all collected data, including transit to and from the research area. Projection: World Mercator (EPSG:3395), Datum: WGS84.

5.1.4.1 The Svalbard Archipelago

In the three working areas around Svalbard (South, West, and North), a couple of EM712 surveys were conducted as pre-site surveys for AUV and OFOBS dives. Table 5.1 lists the separate station numbers and details of the surveys. These were planned to cover different depth regimes between 100 m and 1000 m water depth, covering various slope morphologies. This way the survey data was an adequate basis for planning the AUV and OFOBS dives in unknown terrain.

At the southern station, a total of 330 km^2 was surveyed, showing numerous pockmarks along the shelf edge. At the western station, a total of 238 km^2 was surveyed, showing furrows along the steeper shelf break, likely of glacigenic origin. At the northern station, a total of 288 km^2 was surveyed, showing several large scale glacial features like scours probably caused by grounding icebergs.

Table 5.1 Station details of bathymetric surveys in the Svalbard Archipelago.

Area	Station Numbers	Device	Start Time (UTC)	End Time (UTC)
North	MSM95/3-1	EM712	2020-09-15 19:26	2020-09-16 07:46
West	MSM95/9-1	EM712	2020-09-17 06:22	2020-09-17 14:29
	MSM95/22-1	EM712	2020-09-20 23:27	2020-09-21 07:48
South	MSM95/12-1	EM712	2020-09-18 02:46	2020-09-18 17:23
	MSM95/14-1	EM712	2020-09-18 21:30	2020-09-18 23:06
	MSM95/16-1	EM712	2020-09-19 07:32	2020-09-19 12:30
	MSM95/33-1	EM712	2020-09-24 07:32	2020-09-24 12:33

5.1.4.2 AWI Hausgarten

For the AWI Hausgarten area in the Fram Strait, multiple surveys using the deep-sea echosounder EM122 were conducted as either pre-site surveys for OFOBS dives or to fill in existing gaps in the AWI bathymetry archive data and IBCAO (International Bathymetric Chart of the Arctic Ocean) / GEBCO (General Bathymetric Chart of the Oceans) coverage. Table 5.2 lists the separate station numbers and details of the surveys. In the Hausgarten stations S3/S4, HG4 and N4, we surveyed 676 km^2, 2191 km^2 and 1629 km^2 respectively, mostly of flat and featureless terrain.

Table 5.2 Station details of bathymetric surveys in the AWI Hausgarten

Area	Station Numbers	Device	Start Time (UTC)	End Time (UTC)
S3/S4	MSM95/28-1	EM122	2020-09-22 09:30	2020-09-22 17:34

HG4	MSM95/37-1	EM122	2020-09-25 22:20	2020-09-26 07:56
	MSM95/45-1	EM122	2020-09-28 10:33	2020-09-28 16:56
	MSM95/48-1	EM122	2020-09-30 02:30	2020-09-30 09:17
N4	MSM95/40-1	EM122	2020-09-26 20:13	2020-09-27 08:00

5.1.5 Data management

The collection of underway data during MSM95 will contribute to the bathymetry data archive at the AWI and additionally contribute to bathymetric world datasets like IBCAO and GEBCO. The raw datasets have been ingested to the long-term scientific data warehouse PANGAEA. The EM122 dataset is available at: https://doi.pangaea.de/10.1594/PANGAEA.924922. The EM712 dataset is available at: https://doi.pangaea.de/10.1594/PANGAEA.924923.

5.2 Autonomous Underwater Vehicle (AUV) PAUL “3000“

(M. Busack, J. Hagemann[1], Sascha Lehmenhecker[1], A. Purser[1], Pedro A. Riberio[2,*] Thorben Wulff[*])

[1]AWI

[2]UiB

[*]Not on board

The operations with AWIs Autonomous Underwater Vehicle (AUV) PAUL 3000 where one major task during the cruise MSM95. The specific advantage of AUV operations lie within the possibility to save valuable ship time my transferring time-consuming tasks to an autonomous robot (Fig. 5.3) while running another task with the vessel. Against this background, it was the AUV team’s specific objective during MSM95 to extensively map the seafloor and the associated benthic communities of the three major research areas by means of acoustic (sidescan sonar) and optical (still camera) methods without consuming much ship-time. These objectives involved the necessary ballasting of the vehicle, three test dives and a dive on each of the three stations, consisting of different transects and specified sidescan and camera surveys to generate an overlapping mosaic of an area of interest. All dives have been partly unattended, to conduct parallel station work with the vessel. Furthermore, a new launch and recovery operation method has been used, which redundant the use of a Zodiac and decreases the time for launch and recovery operations by many times over.

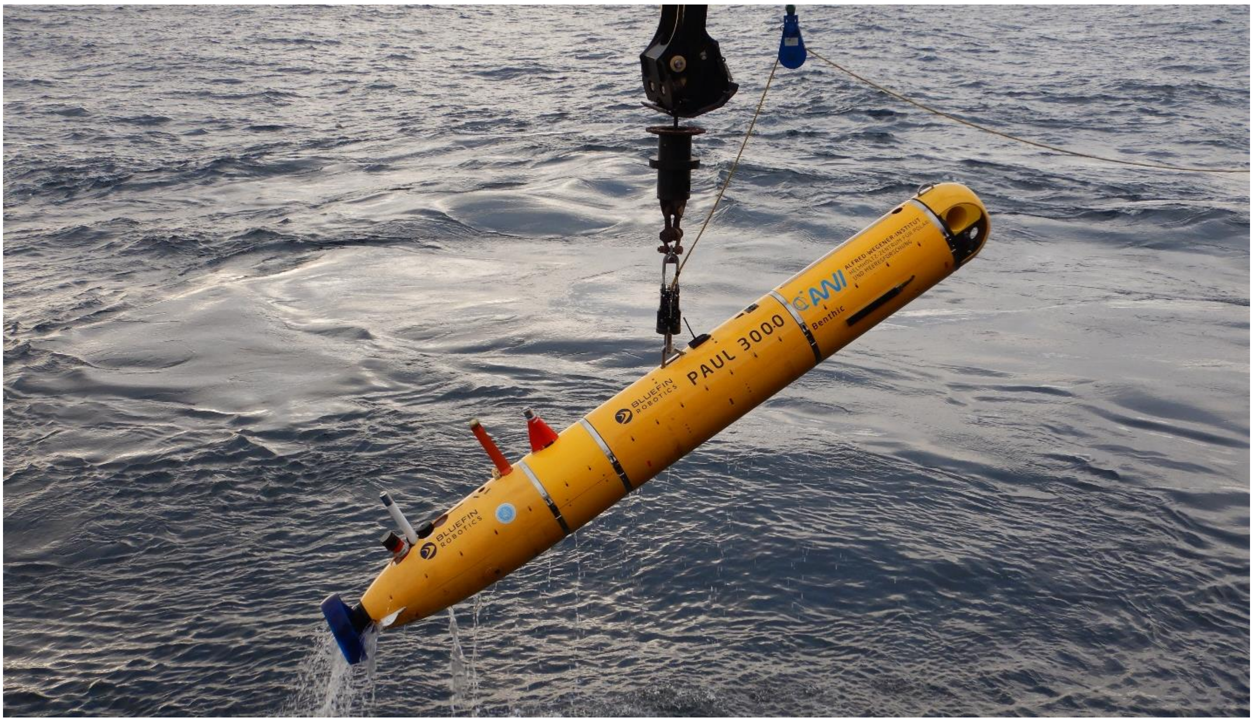


Fig. 5.3 The scientific payload installed in the benthic payload of PAUL 300 during MSM95 was a Cathx Ocean camera system, consisting of a M12-A1000 Stills Camera and two Aphos 32 LED strobe lights. The camera system was mainly operated with 4fps to generate an overlapping photo mosaic. The ARC-scout Sidescan sonar from Marine Sonic (Atlas America) has two frequencies with 600 and 1200kHz. The altitude during the photo and sidescan surveys was approximately between 5 and 6 m.

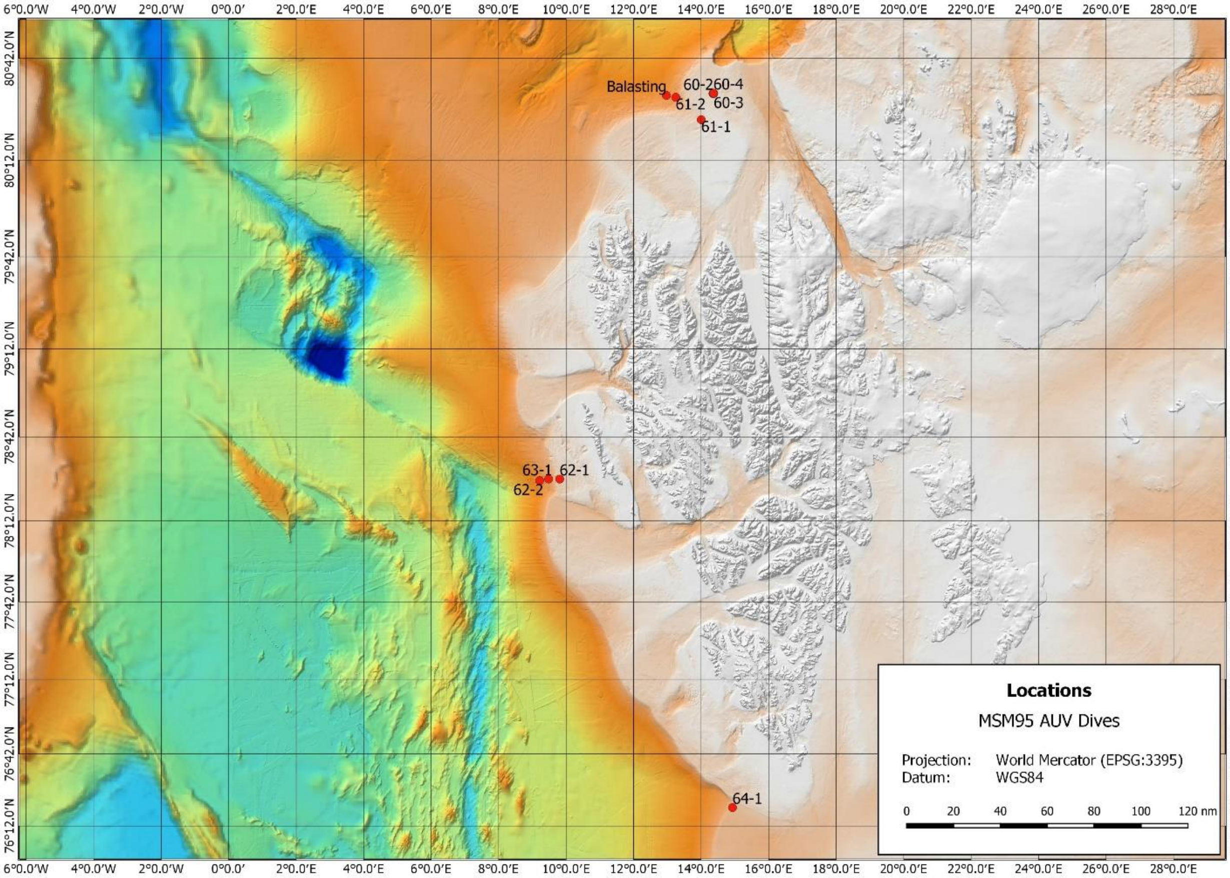


Fig. 5.4 Map of AUV deployments during MSM95.

Work at sea

During MSM95, the AUV completed five dive missions in the three locations Svalbard-North, Svalbard-East and Svalbard-South.

Following the protocol, the first station in the research are always is for ballasting reasons. The vehicles center of buoyancy to a neutral position is trimmed beforehand, but since the density of the waterbody changes, the ballasting has to be conducted on site.

- Deployment 1 (Dive-ID: 60-1 – 60-4, Station-No.: MSM95_2-1 AUV)

PAULS first series of dives during MSM95 took place on September 15 at station Svalbard North. The aim of the first two short flat dives was for diving behavior purposes. The following dive hat experimental value above all with around 30 minutes at the seafloor and with the vehicle conducted different altitudes, to test the best settings for the upcoming dives, the vehicle aborted it's dive due to undercutting the limiting distance to the seafloor. Nevertheless, the vehicle took 3164 images and logged 136 sidescan files. The last dive of this deployment was a 3-hour dive with the main focus on a photo and sidescan mosaic at 5m altitude. All dives have been supervised with the ships Sonardyne Ranger 2 USBL-System.

- Deployment 2 (Dive-ID: 61-1 and 61-2, Station-No.: MSM95_4-1 AUV)

The second deployment was conducted in the same area of PAULS first deployment at station Svalbard North. This time, the dive was split into a 23 km transect following the descending seabed from 120 m down to 600 m. While following the terrain in 5 m altitude, the AUV aborted the dive due to a steep ridge and surfaced with 27k images and 124 sonar files saved. Passing by with the vessel for inspection while the vehicle remained in water, the second dive was transmitted to the vehicle to finish the originally planned dive. PAUL covered a survey rectangle of 11 lines at 5 m altitude with a spacing of 4.3 m resulted in an overlap of images and made it possible to generate photo mosaics. The vehicle recorded another 25k images and 123 sonar files. After the post-dive checkout of the vehicle when recovered, we inspected a water-intake of one of the strobe bottles. All following dives had to be conducted with one strobe only. During all dives, the vessel has been used for parallel dives with OFOBS.

- Deployment 3 (Dive-ID: 62-1 and 62-2, Station-No.: MSM95_19-1 AUV)

The third deployment was similar to the second deployment and took place on September 20 at station Svalbard West and was also unattended. Deployed at around 200 m water depth, the vehicle followed the terrain, this time at 6 m altitude down to a plateau between 750 and 800 m. The vehicle aborted its dive just before heading into the survey rectangle due to an altitude value of 2.9 m after 4 hours. After an in-water inspection, a second dive was send to the vehicle to continue its previous planned task. The vehicle covered during this deployment a distance of 30 km, took 50k images and 241 sonar files.

- Deployment 4 (Dive-ID: 63-1, Station-No.: MSM95_23-1 AUV)

The goal of deployment 4 on the 21st of September also at Svalbard West, was a 90 degree crossing survey at the same spot than the survey of deployment 3 to increase the overlapping area for mosaicking, and a second survey between 500 and 550 m altitude. The AUV dived nearly 40 km which took 8 hours. The sidescan worked and 335 files where acquired. To make most of the use of an autonomous robot, once again, the vessel conducted another OFOBS dive, which started just after the AUV has submerged and ended just before PAUL surfaced. Unfortunately, the camera stopped working after the first line of the first survey and took only 461 images. No evidence for this behavior have been found, but it seems that the reason is a recent firmware update of the camera before MSM95.

- Deployment 5 (Dive-ID: 64-1, Station-No.: MSM95_29-1 AUV)

The last deployment of PAUL was conducted at Svalbard South station on September 23. Like all other dives, this dive was planned to be an unattended dive, yet Merian stayed within tracking range of the Sonardyne Ranger 2 USBL System to observe PAULS descend. Again, descending in a flatter area to decrease the navigational error, PAUL followed the terrain on a long transect at 6 m latitude until finally arriving the plateau at 600 m water depth for its survey. After the descend, Merian went into parallel work with OFOBS, to cross the transect path of PAUL. During the 8-hour dive, the weather got worse and the waves increased to 2 m. The exact reason is unknown, but the recovery line of the vehicle tangled up in the vehicle’s thruster. A safe recovery was in this point of time not possible anymore and during the recovery operation the vehicle slammed against the vessel’s hull and the thruster broke off. All parts have been recovered on board, but due to the current situation worldwide, the spare thruster was still in the U.S. for repair and the broken thruster could not be fixed on board. Nevertheless, the vehicle dived 36 km and took 34 k images and 267 sonar files.

Table 5.3 AUV deployments made during MSM95.

MSM95 AUV-Deployments 2020

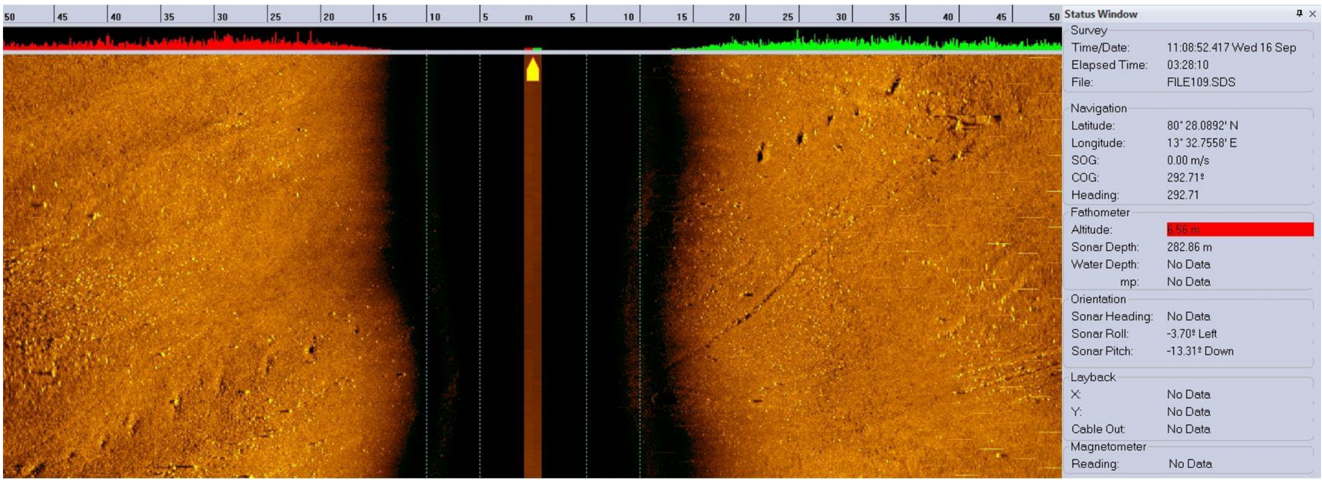
Date	Location	ID	Station	Depth [m]	Deployment Lat[°N]	Deployment Lon[°E]	Distance [km]	Images	Sonar Files
15.09.2020	Sv. North	-	MSM95_1-2	-	80.5215	12.9718	00.00	-	-
15.09.2020	Sv. North	60-1	MSM95_2-1	20	80.5309	14.3506	00.39	-	-
		60-2	MSM95_2-1	50	80.5309	14.3621	00.79	-	-
		60-3	MSM95_2-1	135	80.5309	14.3744	04.87	3164	136
		60-4	MSM95_2-2	135	80.5324	14.3654	12.05	27910	159
16.09.2020	Sv. North	61-1	MSM95_4-1	500	80.4024	14.0029	17.99	27044	124
		61-2	MSM95_4-1	695	80.5124	13.2465	13.99	25759	123
20.09.2020	Sv. West	62-1	MSM95_19-1	500	78.4523	09.8085	10.58	51055	241
		62-2	MSM95_19-1	785	78.4429	09.2134	21.01	0	0
21.09.2020	Sv. West	63-1	MSM95_23-1	780	78.4527	09.4797	38.60	492	335
23.09.2020	Sv. South	64-1	MSM95_29-1	625	76.3302	14.9289	36.40	33992	267
Total or max:				**785**			**156.67**	**169416**	**1385**

5.2.1 AUV : Hydroacoustics

The sidescan sonar, integrated into PAUL’s benthic payload module was working reliable during all dives. Sampling was started and stopped automaticly by the payload control computer at specific altitudes: enable measurement at 30m and disable measurement at 45m. This hysteresis was implemented to avoid frequent on/off operations while passing the threshold. System’s ping rate is calculated by the sonar and depends on the range setting: Lower range results in higher pings rate caused by shorter time to wait for echos. Higher ping rates offer a better resolution along the track which is more important as vehicle speed increases. With our typical vehicle speed of 1,5 m/s, range was set to 50m / 60m which results in a ping rate of 14,5 – 17,1 Hertz. The maximum, physically limited range is approx. 70m for the 600kHz channels and roughly half (35m) with the high resolution 1200kHz channels.

The transducers were mounted with 10 degree downward-looking to achieve flat viewing angle even with low altitudes, which were needed for good stills camera picture quality. This setup is appropriate for seabed and trawl mark investigations, which were a main goal of this cruise.

- Svalbard north station (Dive-ID: 60 & 61)



Survey
Time/Date: 11:08:52.417 Wed 16 Sep
Elapsed Time: 03:28:10
File: FILE109.SDS

Navigation
Latitude: 80° 28.0892' N
Longitude: 13° 32.7558' E
SOG: 0.00 m/s
COG: 292.71º
Heading: 292.71

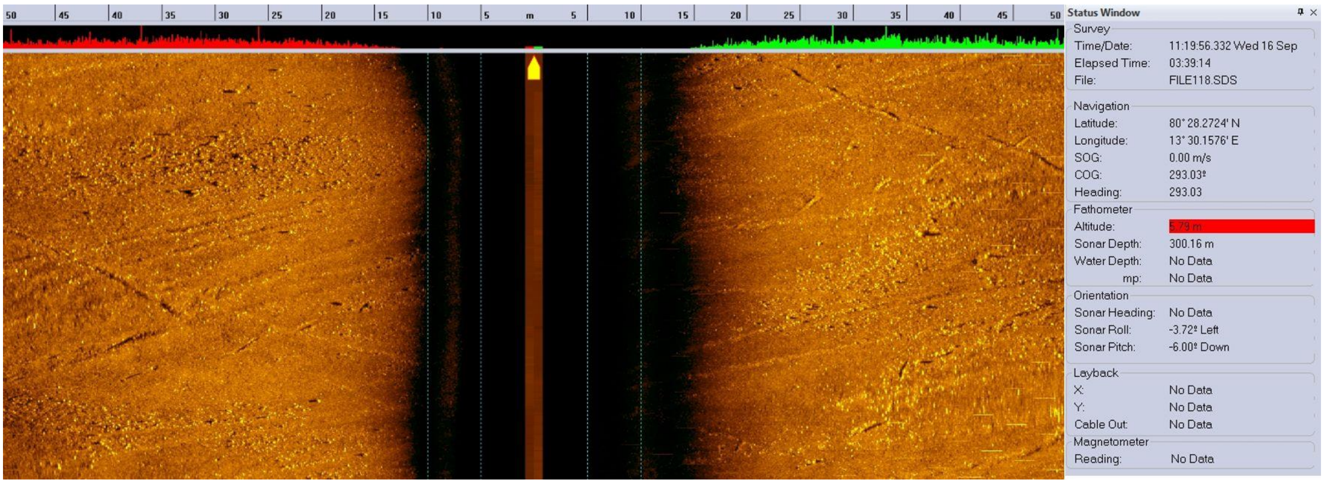
Fathometer
Altitude: 6.56 m
Sonar Depth: 282.86 m
Water Depth: No Data
mp: No Data

Orientation
Sonar Heading: No Data
Sonar Roll: -3.70º Left
Sonar Pitch: -13.31º Down

Layback
X: No Data
Y: No Data
Cable Out: No Data

Magnetometer
Reading: No Data

Fig. 5.5 Sonar data in 282m depth at Svalbard North.



Survey
Time/Date: 11:19:56.332 Wed 16 Sep
Elapsed Time: 03:39:14
File: FILE118.SDS

Navigation
Latitude: 80° 28.2724' N
Longitude: 13° 30.1576' E
SOG: 0.00 m/s
COG: 293.03º
Heading: 293.03

Fathometer
Altitude: 5.79 m
Sonar Depth: 300.16 m
Water Depth: No Data
mp: No Data

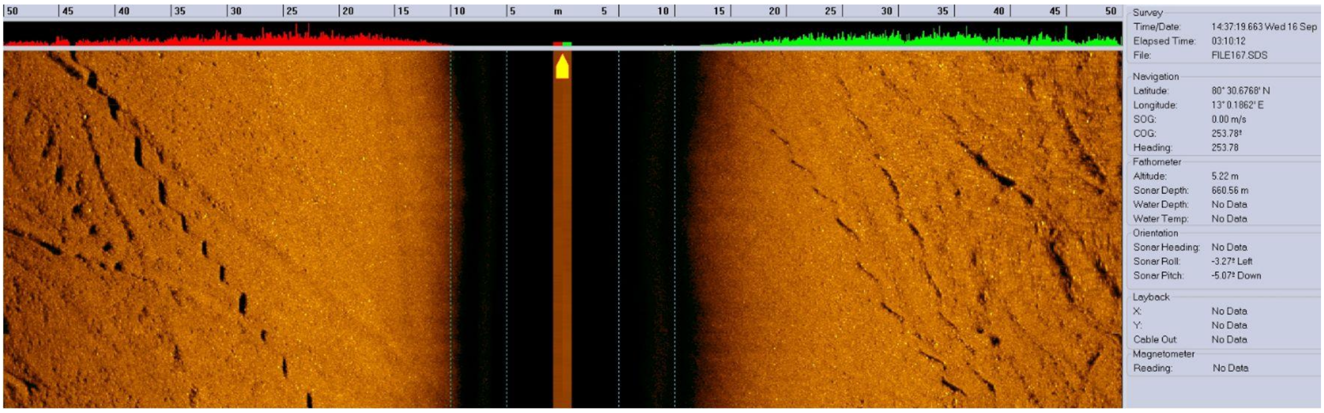
Orientation
Sonar Heading: No Data
Sonar Roll: -3.72º Left
Sonar Pitch: -6.00º Down

Layback
X: No Data
Y: No Data
Cable Out: No Data

Magnetometer
Reading: No Data

Fig. 5.6 Sonar data in 300m depth at Svalbard North.

Trawl marks were found especially in flat areas and in deeper regions like here in 660m depth.



Survey
Time/Date: 14:37:19.663 Wed 16 Sep
Elapsed Time: 03:10:12
File: FILE167.SDS

Navigation
Latitude: 80° 30.6768' N
Longitude: 13° 0.1862' E
SOG: 0.00 m/s
COG: 253.78°
Heading: 253.78

Fathometer
Altitude: 5.22 m
Sonar Depth: 660.56 m
Water Depth: No Data
Water Temp: No Data

Orientation
Sonar Heading: No Data
Sonar Roll: -3.27° Left
Sonar Pitch: -5.07° Down

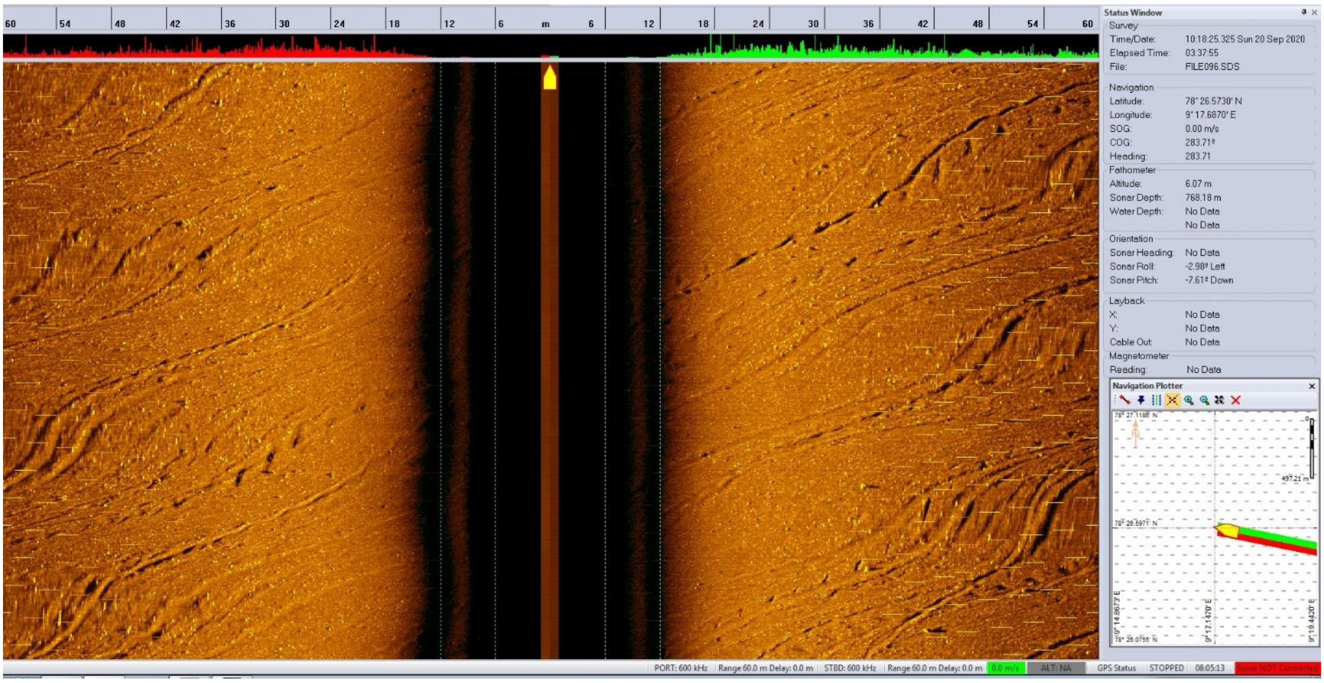
Layback
X: No Data
Y: No Data
Cable Out: No Data

Magnetometer
Reading: No Data

Fig. 5.7 Sonar data in 660m depth at Svalbard North.

- Svalbard west station (Dive-ID: 62 & 63)

The seabed here showed also intensive fishery impacts , as in the following example.



Survey
Time/Date: 10:18:25.325 Sun 20 Sep 2020
Elapsed Time: 03:37:55
File: FILE096.SDS

Navigation
Latitude: 78° 26.5730' N
Longitude: 9° 17.6870' E
SOG: 0.00 m/s
COG: 283.71°
Heading: 283.71

Fathometer
Altitude: 6.07 m
Sonar Depth: 768.18 m
Water Depth: No Data
No Data

Orientation
Sonar Heading: No Data
Sonar Roll: -2.98° Left
Sonar Pitch: -7.61° Down

Layback
X: No Data
Y: No Data
Cable Out: No Data

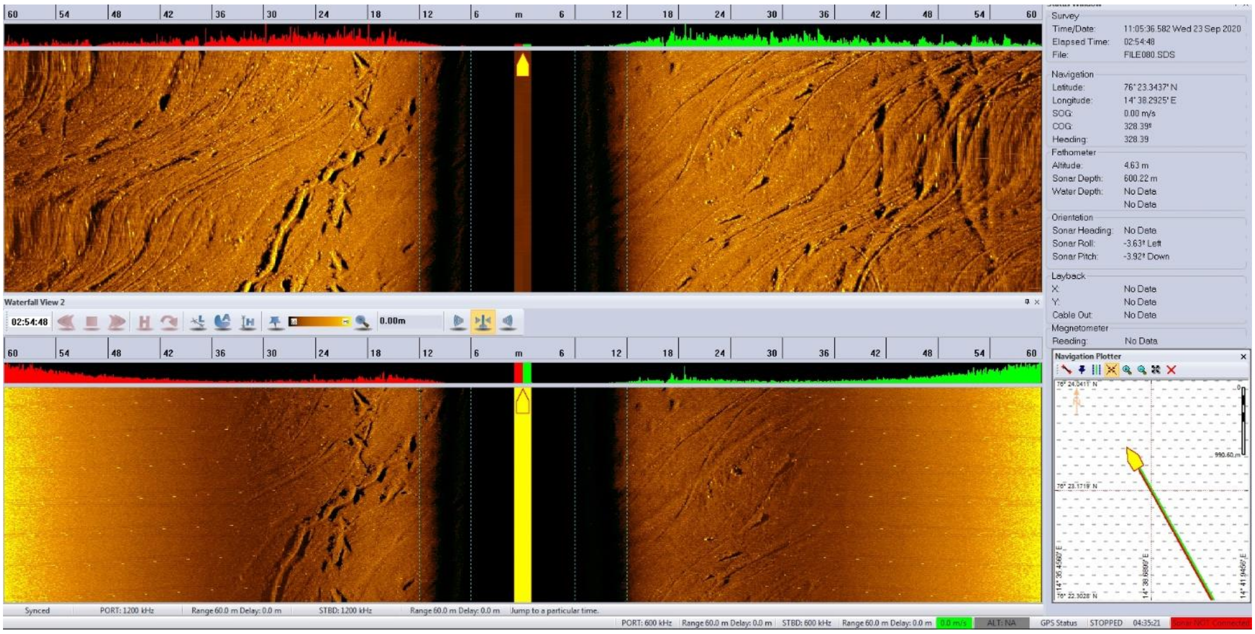
Magnetometer
Reading: No Data

PORT: 600 kHz | Range 60.0 m Delay: 0.0 m | STBD: 600 kHz | Range 60.0 m Delay: 0.0 m | 0.0 m/s | ALT: NA | GPS Status | STOPPED | 08:05:13 | Sonar NOT Connected

Fig. 5.8 Sonar data in 768m depth at Svalbard West.

- Svalbard south station (Dive-ID: 64)

This station data was again characterized by numerous trawl marks in flat seabed regions.



Survey
Time/Date: 11:05:36.582 Wed 23 Sep 2020
Elapsed Time: 02:54:48
File: FILE080.SDS

Navigation
Latitude: 76° 23.3437' N
Longitude: 14° 38.2925' E
SOG: 0.00 m/s
COG: 328.39°
Heading: 328.39

Fathometer
Altitude: 4.63 m
Sonar Depth: 600.22 m
Water Depth: No Data
No Data

Orientation
Sonar Heading: No Data
Sonar Roll: -3.63° Left
Sonar Pitch: -3.92° Down

Layback
X: No Data
Y: No Data
Cable Out: No Data

Magnetometer
Reading: No Data

Synced | PORT: 1200 kHz | Range 60.0 m Delay: 0.0 m | STBD: 1200 kHz | Range 60.0 m Delay: 0.0 m | Jump to a particular time.

PORT: 600 kHz | Range 60.0 m Delay: 0.0 m | STBD: 600 kHz | Range 60.0 m Delay: 0.0 m | 0.0 m/s | ALT: NA | GPS Status | STOPPED | 04:35:21 | Sonar NOT Connected

Fig. 5.9 Sonar data in 600m depth at Svalbard South.

This picture illustrates the higher resolution of the 1200kHz channels with the 35m physically limited range.

Conclusion

The hydroacoustic side scan sonar system successfully sampled a large amount of data during all dives and on all target research areas around Svalbard. Seabed impacts from fishery activities were found in every dive, especially in flat regions and in more than 750m depth. Further analyses with more powerful software tools will enable high resolution map generation from the survey rectangles.

5.2.2 AUV : Seafloor Imaging

A total of 169416 images were collected from the seafloor from the Svalbard Archipelago (Table 5.3). During MSM95_2-1 and MSM95_4-1 an image frequency of 1.5 images s^{-1} was used for data collection. Throughout other deployments of deployments and image frequency of 3.5 images s^{-1} was maintained. Initial dives focused on determining an optimal height for image collection, with a flight altitude of 3m allowing collection of higher quality images (Fig. 5.10) than a Flight altitude of 6 m (Fig. 5.11).

Example images from the AUV deployments:

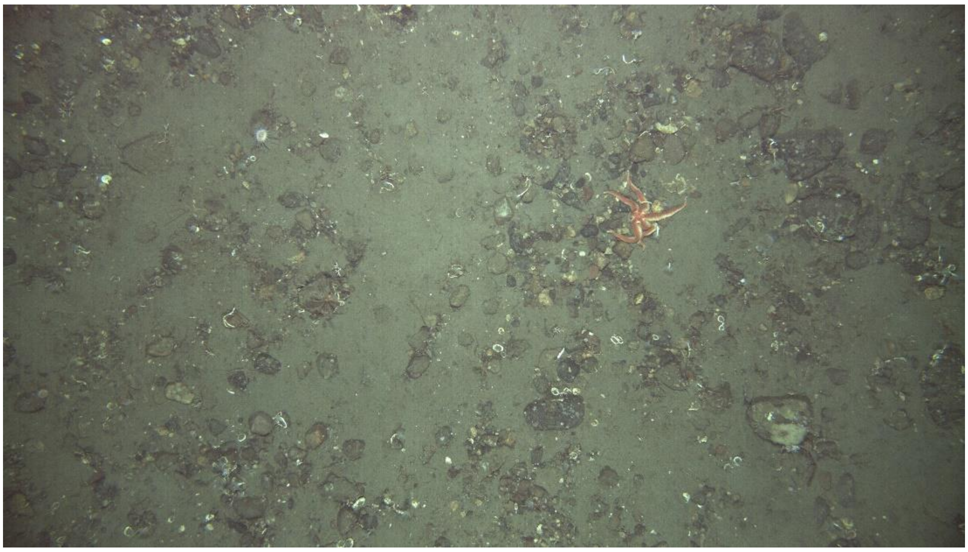


Fig. 5.10 Seafloor viewed from 3m altitude at Svalbard North

Fig. 5.11 Seafloor viewed from 6m altitude at Svalbard North.

Fig. 5.12 Seafloor at Svalbard West.

Fig. 5.13 Seafloor and fauna at Svalbard West.

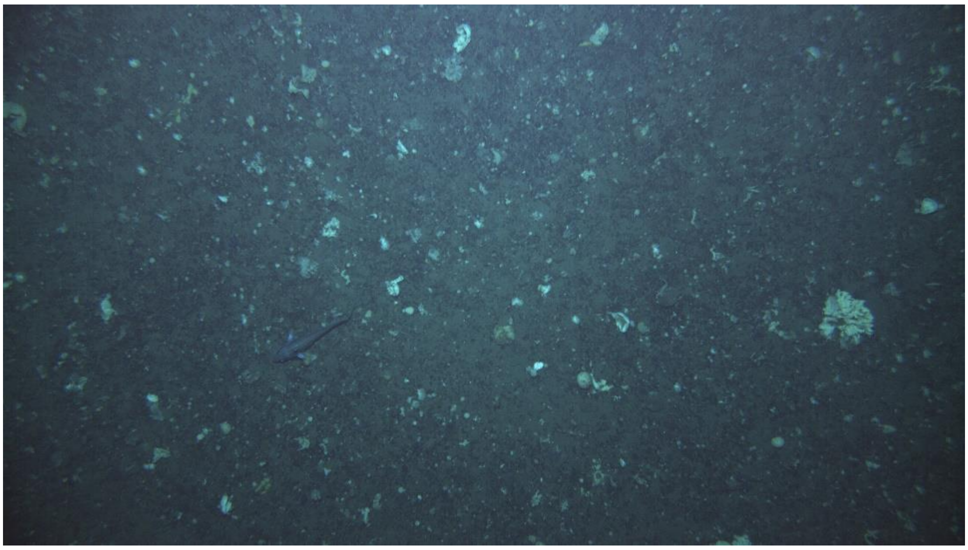


Fig. 5.14 Seafloor at Svalbard West.

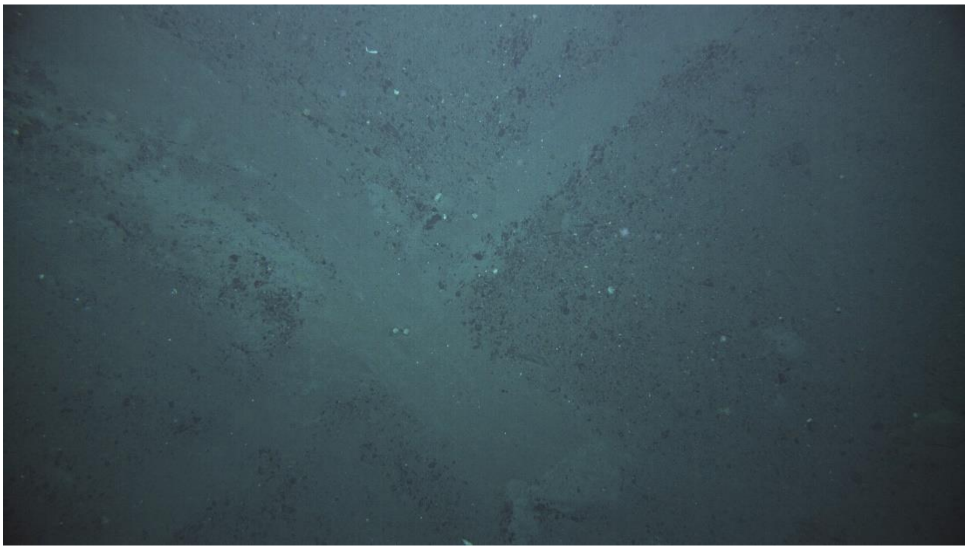


Fig. 5.15 Seafloor with trawlmarks at Svalbard South.

All images collected via the AUV will be sent to Pedro A. Ribeiro and his team at the University of Bergen. In collaboration with his group AWI and UiB will analyze fauna distribution and community structure across the areas of Svalbard archipelago seafloor surveyed during MSM95.

5.2.3 AUV : 3D Mosaicing

Following dive completion collected image data was inspected and transect stretches of interest selected for 3D modelling. Although all images were collected with the AUV downward facing 3D modelling could be conducted using the Structure From Motion approach. To produce 3D models of interest subsets of ~100 images were imported into the Agisoft Metashape 1.6.5 software application.

By generating 3D models of the seafloor, additional characteristics not immediately obvious from AUV still image transect data can become apparent, such as the depths of iceberg scours and trawl marks (Figs. 5.16 and 5.17).

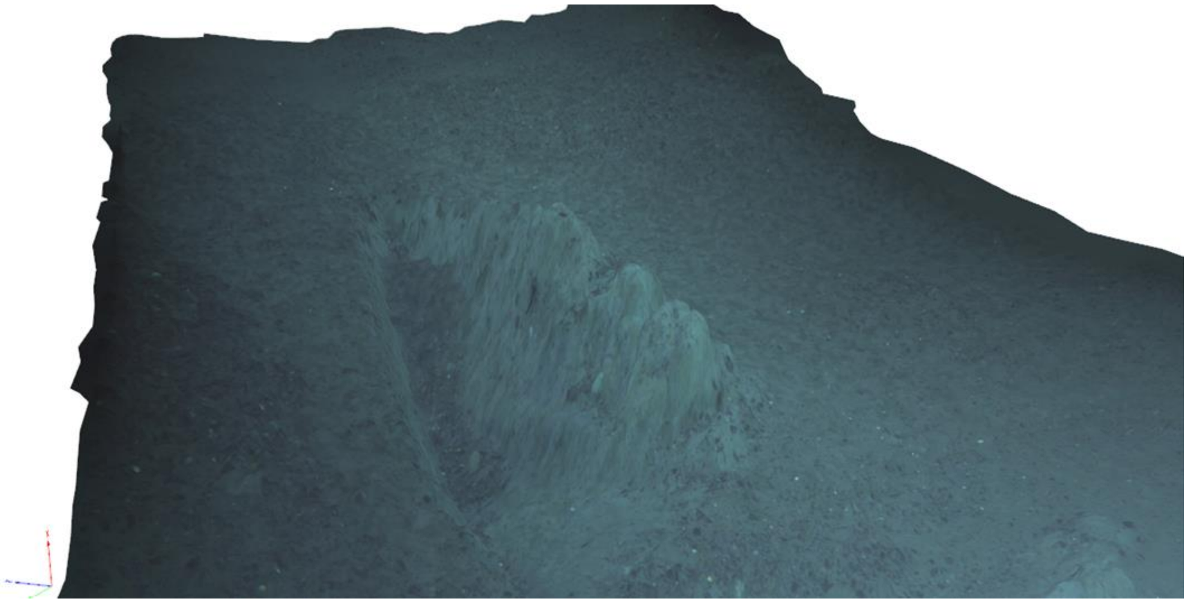


Fig. 5.16 3D model derived from ~100 sequential AUV images from the Svalbard Archipelago, showing a deep asymmetrical scour mark.

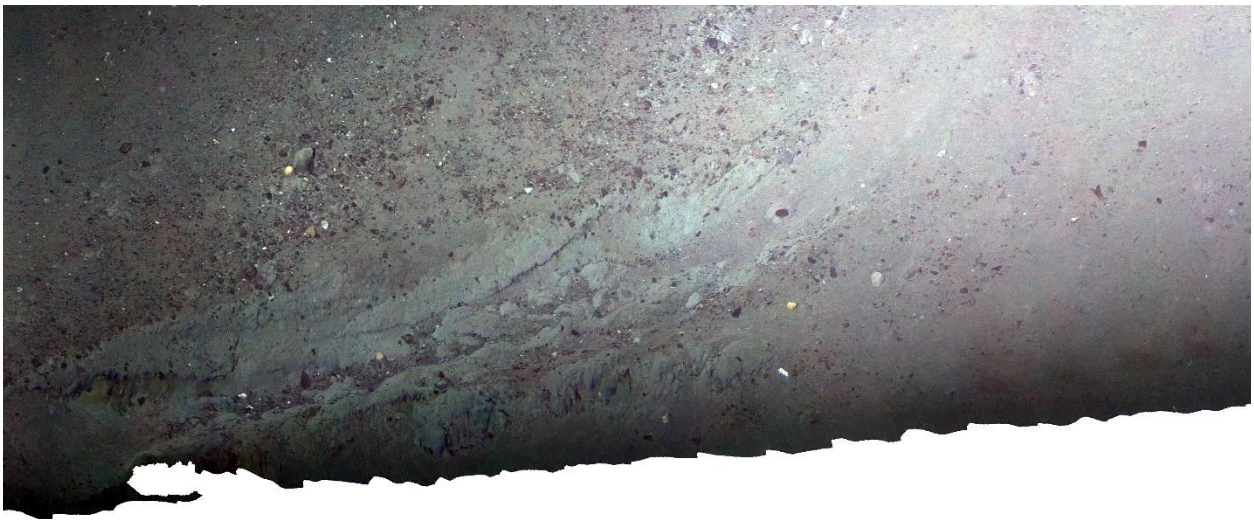


Fig. 5.17. 3D model derived from ~100 sequential AUV images from the Svalbard Archipelago, showing a shallow scour mark through a pebble strewn area of seafloor.

Post cruise it is intended to create 3D models and mosaic image maps from across all AUV deployments. These products will be uploaded into PANGAEA on completion.

5.3 Ocean Floor Observation and Bathymetry System (OFOBS)

(A. Purser[1], M. Bergmann[1,*], L. Boehringer[1,2], D. Doud[3,*], U. Hoge[1], L. Hehemann[1], J. Dannheim[1,*], A.Klesh[3,*], V. Merten[4], Pedro A. Ribeiro[5,*] , T. Soltwedel[1,*])

[1]AWI

[2]UniBREMEN

[3]NASA JPL

[4]GEOMAR

[5]University of Bergen

[*]Not on board

The Ocean Floor Observation and Bathymetry System (OFOBS) was deployed 21 times during MSM95 (**Table 5.3.1**). A full technical description of the system is given in (Purser et al., 2018). IN summary, the OFOBS is a towed survey platform equipped with 26 megapixel still camera, HD video camera (both downward facing), an POSIDONIA USBL beacon, Inertial Navigation System (INS), Dynamic Velocity Logger (DVL), sizing lazers and forward facing acoustic camera. Additionally, secondary systems may be mounted for particular deployments, such as a miniROV for deploying close to the seafloor, secondary water column camera systems and baited traps.

Throughout the MSM95 cruise the INS, DVL, multibeam and camera systems functioned well. Unfortunately, the forward facing acoustic camera did not work. For some deployments, secondary cameras were mounted to image water column fauna. A newly designed miniROV was also mounted for many dives, to collect seafloor video of regions of interest. The majority of OFOBS deployments focused on seafloor investigations, though several were made to exclusively investigate the water column, collecting image and video data to gauge presence / absence of squids or octopi in the water column (MSM95_35-1, and sections of MSM96_46-1).

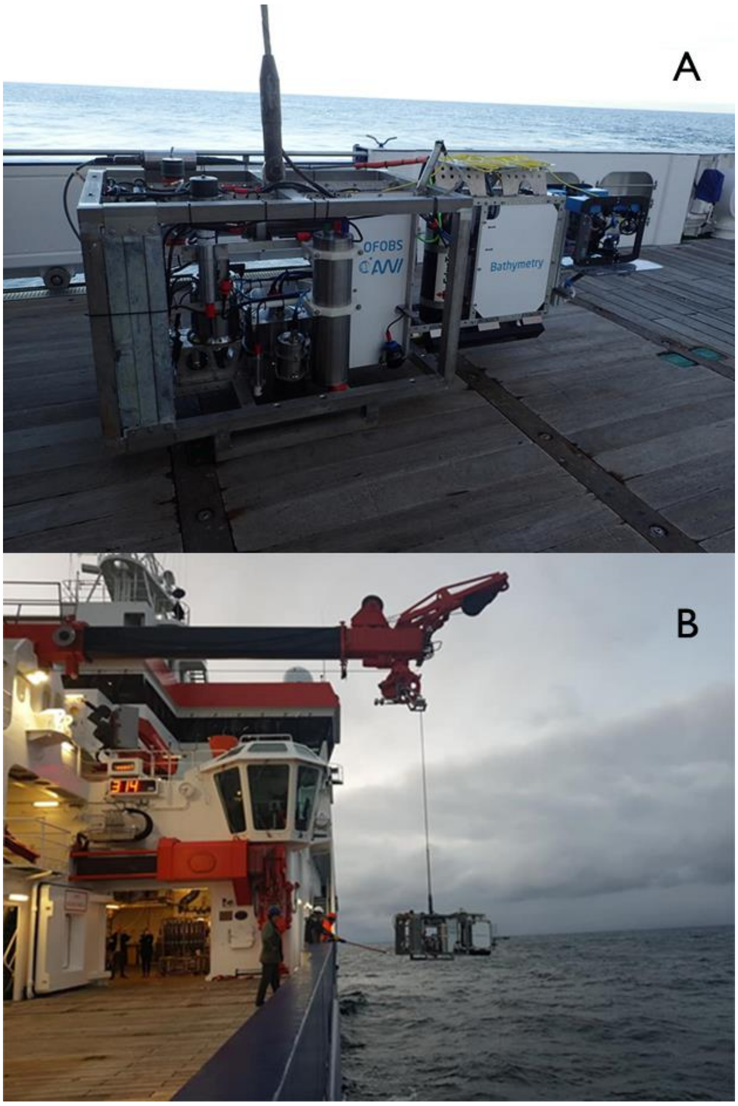


Fig. 5.18 A) The complete OFOBS as deployed during MSM95. The main frame (left) mounted the still and video cameras (integrated systems and secondary systems such as the benthopelagic video camera system), telemetry, lights and positioning systems. The second frame (central) mounted the multibeam systems and multibeam computer. The third, smaller frame (far right) was fitted for the first time during MSM95, forming the docking platform of the newly designed 'Remora' miniROV. B) OFOBS being deployed during MSM95. The side winch was used exclusively throughout the cruise, to minimize any heave on the wire which may be encountered with OFOBS deployments over the rear A-frame.

Table 5.4 Location and times of OFOBS deployments made during MSM95. The number of seafloor images collected on each deployment are also given.

Station No.	Date	Time	Latitude	Longitude	Start depth	Timer images	Hotkey images	Region
RV MERIAN		[UTC]	[°N]	[°W]	[m]	[n]	[n]	
MSM95_2-3	15/09/2020	17:17	80° 31,831' N	014° 24,598' E	130	0	0	Sval. N
MSM95_2-4	15/09/2020	18:19	80° 31,778' N	014° 25,144' E	129	0	0	Sval. N
MSM95_5-1	16/09/2020	11:32	80° 28,124' N	013° 28,991' E	325	0	0	Sval. N
MSM95_7-1	16/09/2020	17:01	80° 31,456' N	013° 00,049' E	697	0	0	Sval. N
MSM95_13-1	18/09/2020	07:40	76° 28,776' N	014° 32,122' E	220	0	0	Sval. S
MSM95_15-1	19/09/2020	00:12	76° 26,406' N	014° 32,810' E	663	1150	110	Sval. S
MSM95_18-1	19/09/2020	14:43	76° 24,848' N	014° 00,082' E	1004	890	140	Sval. S
MSM95_20-1	20/09/2020	09:21	78° 26,397' N	009° 36,440' E	432	310	15	Sval. E
MSM95_21-1	20/09/2020	19:04	78° 26,624' N	009° 15,389' E	783	1105	75	Sval. E
MSM95_25-1	21/09/2020	10:54	78° 27,150' N	009° 29,362' E	500	1150	70	Sval. E
MSM95_27-1	22/09/2020	4:48	78° 36,958' N	005° 08,696' E	230	500	15	HG S
MSM95_30-1	23/09/2020	10:47	76° 21,493' N	014° 52,598' E	413	990	40	Sval. S
MSM95_31-1	23/09/2020	18:56	76° 24,918' N	014° 49,053' E	237	1832	33	Sval. S
MSM95_34-1	24/09/2020	13:42	76° 21,373' N	015° 01,554' E	283	485	15	Sval. S
MSM95_35-1	25/09/2020	14:03	79° 03,480' N	004° 11,855' E	2449	0	0	HG C
MSM95_38-1	26/09/2020	11:43	79° 02,018' N	004° 10,806' E	2576	665	75	HG C
MSM95_42-1	27/09/2020	16:50	79° 35,619' N	005° 11,267' E	2728	750	15	HG N
MSM95_43-1	28/09/2020	0:41	79° 04,544' N	004° 07,848' E	2446	1265	0	HG C
MSM95_46-1	28/09/2020	20:08	79° 04,077' N	004° 12,598' E	2396	530	35	HG C
MSM95_52-1	30/09/2020	22:41	79° 07,641' N	005° 08,260' E	1375	690	25	HG Hill

5.3.1 OFOBS : Hydroacoustics

During MSM95, 15 OFOBS deployments focused on seafloor investigations with the camera and multibeam systems. Throughout all deployments the multibeam functioned well and the large data set is in the process of being analysed.

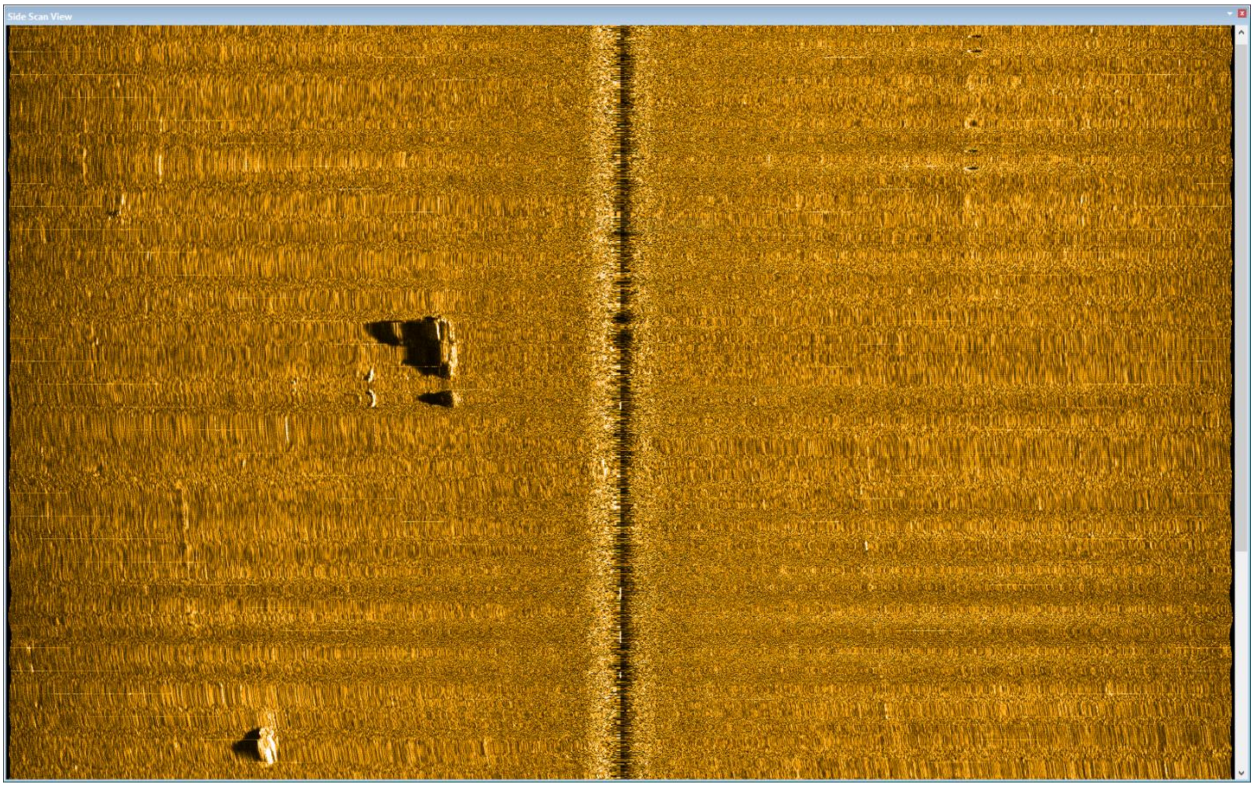


Fig. 5.19 OFOBS live multibeam output, showing the NOMAD benthic crawler on the flat seafloor of the central Hausgarten.

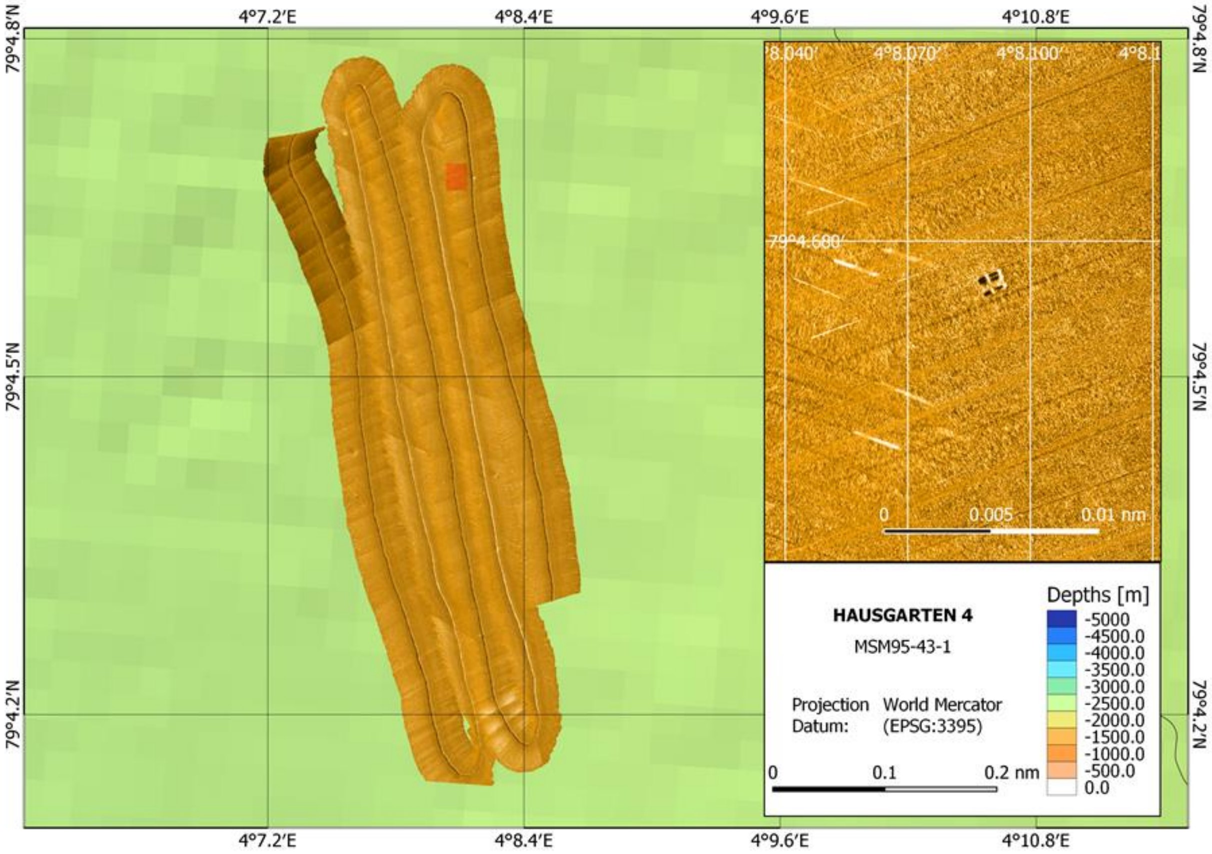


Fig. 5.20 The OFOBS sidescan was used to map an area of Hausgarten 4 during deployment MSM95_43-1. Various time series experiments, such as the CAGE experiment (INSET) were visible in the multibeam map.

5.3.2 OFOBS : Seafloor Imaging

During MSM95, 15 OFOBS deployments reached the seafloor and collected image and video data. Unless otherwise stated, the OFOBS sled was towed at an altitude of 1.5 – 2 m above the seafloor

Deployment MSM95_15-1

Fig. 5.21 OFOBS image collected during dive MSM95_15-1.

A mix of pebbles, rocks and boulders, and scoured clay made up much of the seafloor surveyed during the MSM95_15-1 deployment.

Deployment MSM95_18-1

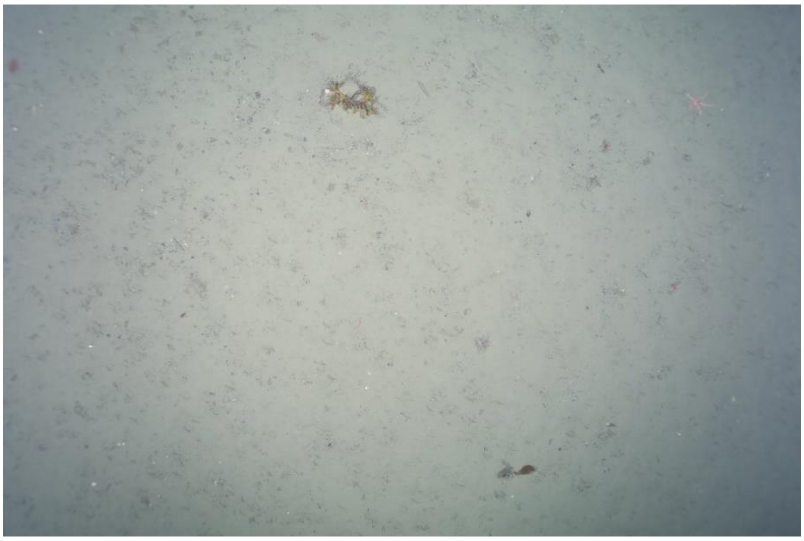


Fig. 5.22 OFOBS image collected during dive MSM95_18-1.

The seafloor surveyed during MSM18-1 was primarily soft sediment in composition, with occasional small stones colonized by epifauna.

Deployment MSM95_21-1

Fig. 5.23 OFOBS image collected during dive MSM95_21-1.

Soft sediment was the primary seafloor habitat type surveyed during MSM95_21-1. Deep iceberg or trawl scours were in evidence. In this image a ray can be seen on the seafloor adjacent to a scour mark.

Deployment MSM95_22-1

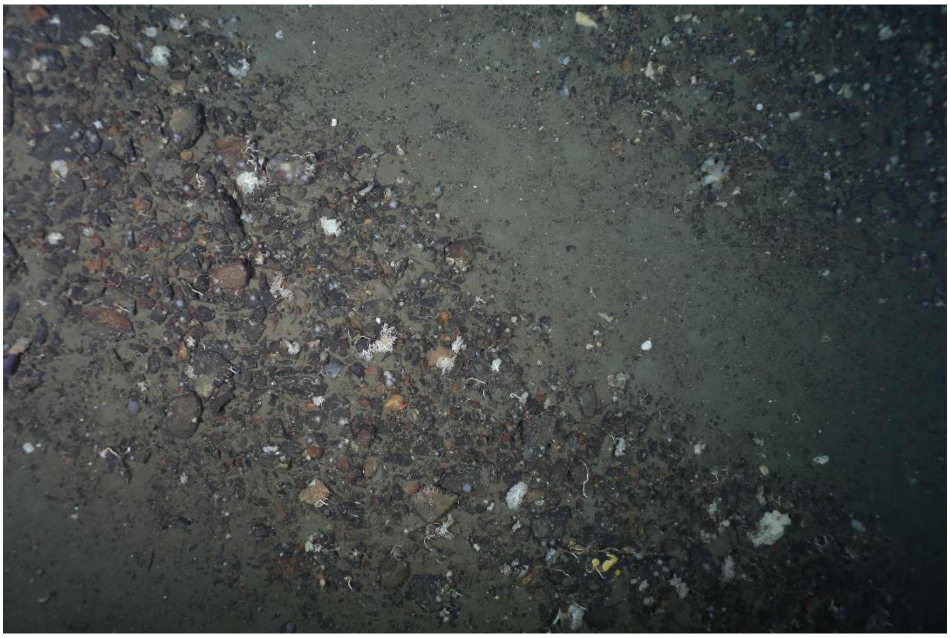


Fig. 5.24 OFOBS image collected during dive MSM95_22-1.

During MSM95_22-1 a cobble and pebble abundant seafloor was impacted by trawl and scour marks.

Deployment MSM95_27-1

Fig. 5.25 OFOBS image collected during dive MSM95_27-1.

Occasional large stones on a soft sediment substrate were imaged throughout deployment MSM95_27-1.

Deployment MSM95_30-1

Fig. 5.26 OFOBS image collected during dive MSM95_30-1.

Throughout MSM93_30-1, occasional boulder of 1 m diameter or more were observed strewn across a trawled and scoured cobbled substrate.

Deployment MSM95_31-1

Fig. 5.27 OFOBS image collected during dive MSM95_31-1.

Throughout MSM93_31-1, occasional stones were observed against a grit and underlying clay substrate.

Deployment MSM95_34-1

Fig. 5.28 OFOBS image collected during dive MSM95_34-1.

Deployment MSM95_38-1

Fig. 5.29 OFOBS image collected during dive MSM95_38-1.

Throughout MSM93_38-1 within the Fram Strait, a soft sediment seafloor was marked by occasional infauna burrows and epifauna covered sponges of variable condition.

Deployment MSM95_42-1

Fig. 5.30 OFOBS image collected during dive MSM95_42-1.

Throughout MSM93_42-1 within the Fram Strait, occasional sponges were observed a soft sediment seafloor.

Deployment MSM95_43-1

Fig. 5.31 OFOBS image collected during dive MSM95_43-1.

To maximise seafloor coverage by the OFOBS multibeam system MSM95_43-1, the device was flown ~6 m above the seafloor. Poor seafloor imaging throughout.

Deployment MSM95_46-1 – image 1

Fig. 5.32 OFOBS image collected during dive MSM95_46-1.

Again, MSM95_46-1 was flown higher than optimal, at ~4 m altitude, to improve multibeam coverage.

Deployment MSM95_46-1. Image 2.

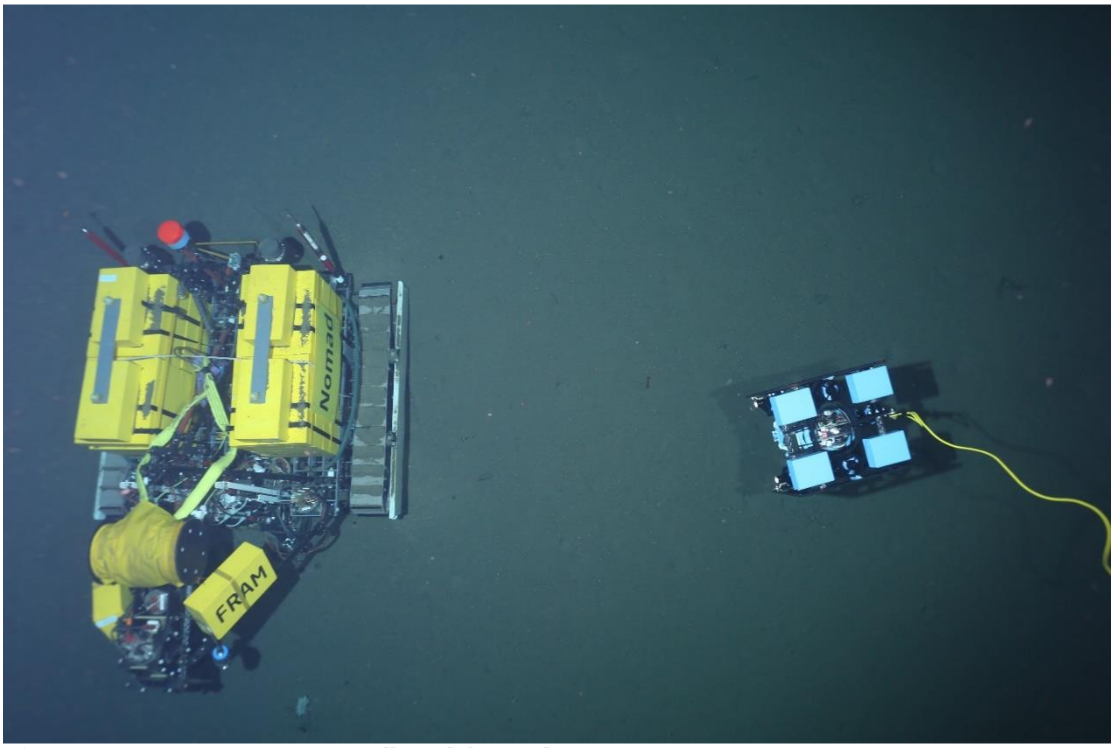


Fig. 5.33 OFOBS image collected during dive MSM95_46-1.

Deployment MSM95_46-1 focused on the attempt to retrieve the NOMAD crawler, deployed in the previous year by RV Polarstern. Here the OFOBS miniROV can be seen below the OFOBS.

Deployment MSM95_52-1

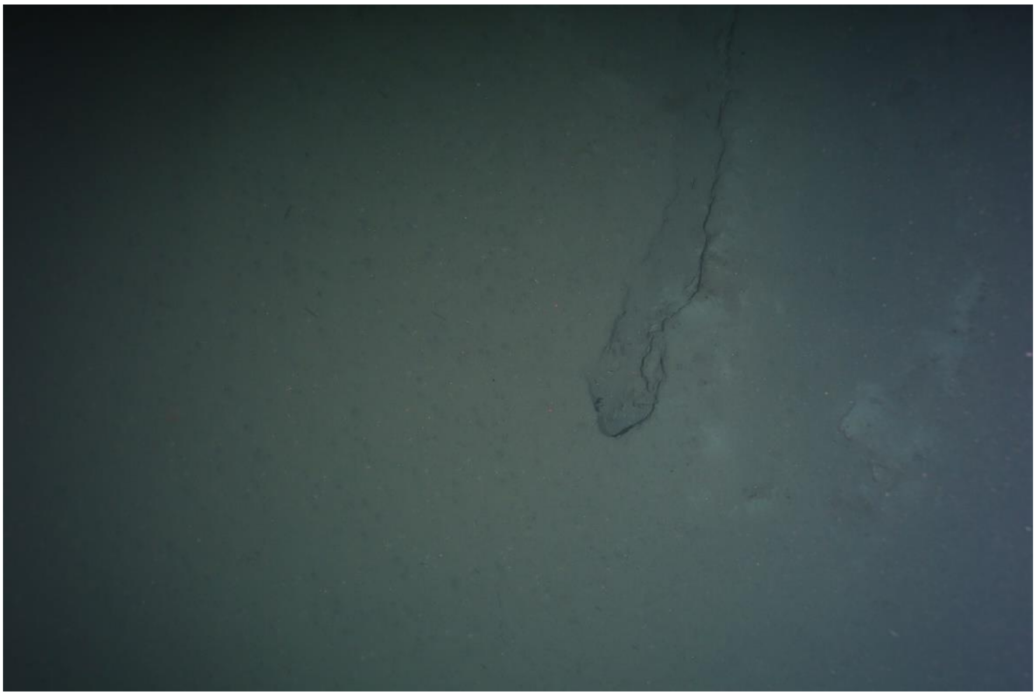


Fig. 5.34 OFOBS image collected during dive MSM95_52-1.

Deployment MSM95_52-1 surveyed the upper slopes of the central Hausgarten sloped area. Numerous pockmark features were imaged.

All images collected via the OFOBS from the Svalbard archipelago will be sent to Pedro A. Ribeiro and his team at the University of Bergen. In collaboration with his group AWI and UiB will analyze fauna distribution and community structure across the areas of Svalbard archipelago seafloor surveyed during MSM95. All images collected from the Hausgarten area will be analyzed by AWI as part of the ongoing FRAM project.

5.3.3 OFOBS : Water column Imaging (integrated camera systems)

On the majority of cruises utilizing the OFOBS system, the still and video cameras are disabled during ascent and descent. During MSM95 there was a research interest in the presence or absence of fauna in the water column, particularly squid and octopi. To provide potential useful data to augment the auxillary PlasPi and GlasPi cameras (See section 5.3.5) and Benthopelagic camera system (See section 5.4), the downward facing OFOBS cameras were set up to record data throughout almost all deployments.

Water column data collected during MSM95 is at time of writing being analysied by V. Merten (GEOMAR) and colleagues. This data was not archived to PANGAEA but is available from A. Purser on request.

5.3.4 OFOBS : MiniROV

During MSM95 the OFOBS was augmented with a ‘Remora’ class miniROV. This device was developed in-house by AWI and underwent sea trials during MSM95. The miniROV is tethered directly to the OFOBS and holds on to the rear of the system with a robotic arm. To deploy, the support vessel ceases movement and the OFOBS team take direct control of the miniROV via a laptop PC on ship.

The miniROV recorded video footage throughout all deployments (Table 5.3.4.1). The miniROV preformed well during MSM95, and footage of scientific interest was collected from within a 40 m diameter pockmark structure on the southern Svalbard shelf.

During the planning for MSM95 it was envisioned that A. Klesh and D. Doud from NASA JPL, USA would participate as active cruise participants. Unfortunately, the regulations associated with the COVID-19 pandemic prevented their joining the field campaign. The initial work and discussions on the miniROV had been carried out between AWI and NASA JPL, following the successful prototyping of a deep miniROV during the ‘RV Kronprins Hakon’ HK19 cruise in 2019. NASA JPL had intended to bring their own new prototype miniROV onto MSM95, but this will now have to be delayed until a future cruise. Experience from the MSM95 deployments was fed back to NASA JPL to inform on their ongoing miniROV developments.

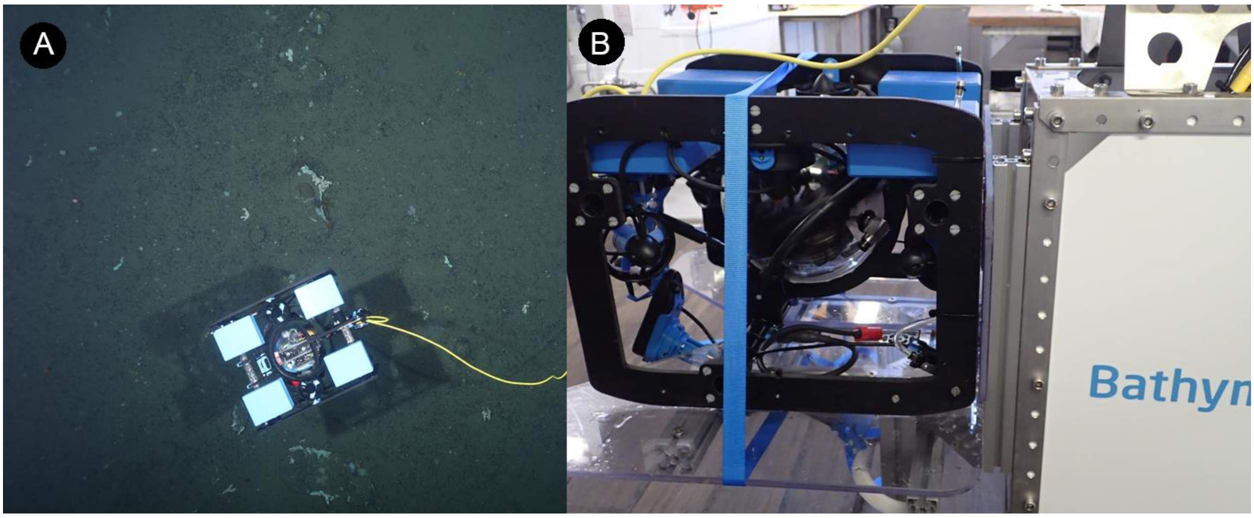


Fig. 5.35 A) ‘Remora’ miniROV deployed from OFOBS within the Svalbard Archipelago. B) ‘Remora’ minoROV on deployment sled on back of OFOBS.

Table 5.5 MSM95 OFOBS deployments where MiniROV deployments were made.

Station No.	Date	Time	Latitude	Longitude	Start depth
RV MERIAN		**[UTC]**	**[°N]**	**[°W]**	**[m]**
MSM95_13-1	18/09/2020	07:40	76° 28,776' N	014° 32,122' E	220
MSM95_15-1	19/09/2020	00:12	76° 26,406' N	014° 32,810' E	663
MSM95_20-1	20/09/2020	09:21	78° 26,397' N	009° 36,440' E	432
MSM95_34-1	24/09/2020	13:42	76° 21,373' N	015° 01,554' E	283
MSM95_43-1	28/09/2020	0:41	79° 04,544' N	004° 07,848' E	2446
MSM95_46-1	28/09/2020	20:08	79° 04,077' N	004° 12,598' E	2396
MSM95_52-1	30/09/2020	22:41	79° 07,641' N	005° 08,260' E	1375

5.3.5 OFOBS : PlasPi and GlasPi cameras

For several years the AWI has been developing cheap camera systems for mounting on various underwater devices, to either monitor the functioning of equipment or to collect replicate data from several locations at once. Using the Raspberry Pi Zero single board computer and cheap camera boards, the PlasPI camera is a ~200 euro camera capable of deployment to depths of 300 m (Purser et al., 2020). For deeper deployments, the same electronic system is placed in a glass housing capable of withstanding depths of up to 6000 m for periods of time (Dorschel et al., 2019).

During MSM95 both GlasPi and PlasPI cameras were used to take water column images from oblique directions from the OFOBS hull. The low power of the lights used in these cameras renders their depth of visibility to be rather shallow, but opportunistic images of the water column were captured with a frequency of 1 image per 30 seconds through the majority of OFOBS dives.

Both camera designs functioned perfectly throughout all deployments.

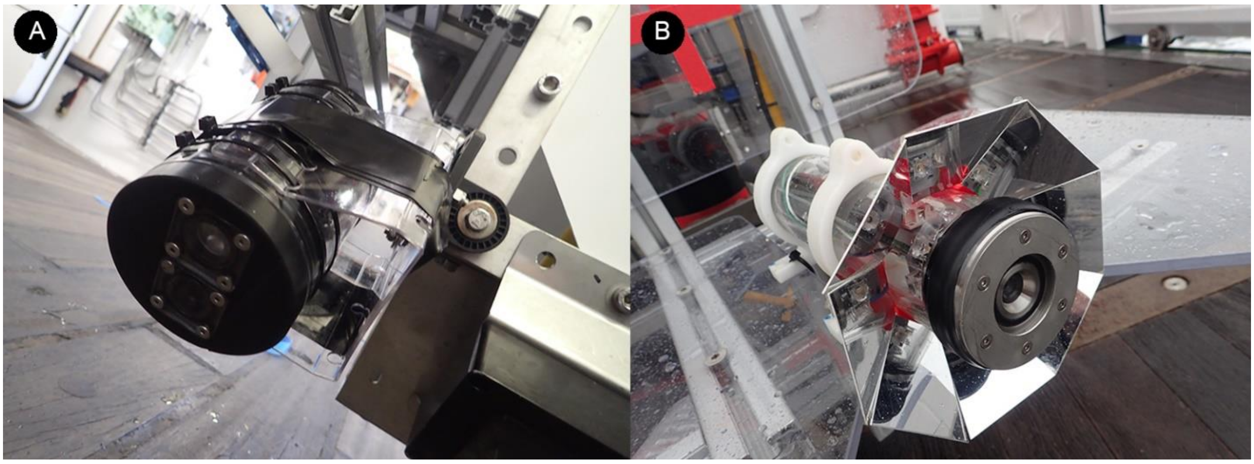


Fig. 5.36 A) A 'PlasPi' camera mounted on the OFOBS frame. B) A 'GlasPi' camera mounted on the OFOBS.

5.4 Benthopelagic camera system

(V. Merten[1], U. Hoge[2], H.-J. Hoving[1*])
[1] GEOMAR
[2] AWI
*Not on board

The deep ocean carbon budget is imbalanced in many deep ocean regions, that is, the calculations of the amount of carbon delivered to benthic organisms in the form of organic material is not enough to sustain ocean benthic communities (Smith Jr and Kaufmann, 1999). That discrepancy is as much as 30-70% in some regions (Smith et al., 2002) raising the question which organisms contribute to the missing carbon that nourish deep-sea benthic organisms. Carbon fluxes between the sea floor and overlying water masses are mainly measured by sediment traps or by observing massive foodfalls such as whale carcasses, however, these methods do not account for pelagic organisms in the middle of this size range that are larger than one cm, but smaller than a whale. Baseline information on the diversity, distribution and abundance of middle-sized nekton such as jellyfish, cephalopods and fish are lacking for most ocean regions including the Arctic Ocean (Robison, 2009; Webb et al., 2010) hampering identification of medium size contributors to the carbon pump. Video surveys are an effective method to investigate organisms in their natural habitat and especially suitable for fragile organisms that might get destroyed beyond identification when caught by nets such as gelatinous zooplankton. In situ observations also allow insight in behaviour and fine scale distribution.

Cruise objectives:

1. Identify potential sources of pelagic foodfalls via benthopelagic and pelagic video transects
2. Increase our knowledge on the biodiversity of the area and establish a biodiversity baseline

5.4.1 Transects

The benthopelagic camera system was mounted on the OFOBS (Ocean Floor Observation Bathymetry System) (Fig. 5.37). It was deployed attached to OFOBS 14 times (Table 5.6) resulting in approximately 70 hours of video. Additionally to the normal OFOBS deployments two meters above the seafloor and therefore surveying the benthopelagic with our camera system, we did five pelagic transects. For the pelagic transects, OFOBS with the mounted benthopelagic camera system was towed through the water column for 15 or 30 minutes at 0.5 knots at the following stations and depths:

Station MSM95_35_1: 1300 m, 1600 m, 1900 m, 2200 m
Station MSM95_38:1: 1300 m, 1600 m, 1900 m, 2200 m, 2500 m
Station MSM95_43_1: 850 m, 950 m, 1300 m, 1600 m, 1900 m, 2200 m, 2440 m
Station MSM95_46_2: 850 m, 950 m, 1300 m, 1600 m, 1900 m, 2200 m
Station MSM95_47_1: 350 m, 850 m, 950 m, 1300 m, 1365 m

Table 5.6 Date, dive and station number of the deployments of the benthopelagic camera system in the Arctic Ocean during MSM95 in 2020. Bold highlights the pelagic transect stations.

Dive Number	**Station Number**	**Date**
01	15-1	09/18/2020
02	18_1	09/19/2020
03	20_1	09/21/2020
04	20_2	09/21/2020
05	21_1	09/21/2020
06	24_1	09/21/2020
07	27_1	09/22/2020
08	30_1	09/23/2020
09	31_1	09/23/2020
10	**35_1**	**09/24/2020**
11	**38_1**	**09/26/2020**
12	**43_1**	**09/27/2020**
13	46_1	09/29/2020
14	**46_2**	**09/29/2020**
15	**47_1**	**09/29/2020**
16	52_1_	09/30/2020

Fig. 5.37 Left: The benthopelagic camera system mounted on the Ocean Floor Observation and Bathymetry System (OFOBS) surrounded by four LED lights on MSM95. Right: Benthopelagic camera system shortly before deployment with LED lights operating

We mostly observed chaetognaths, ctenophores, other gelatinous fauna, fishes, cirrate octopuses (*Chiroteuthis muelleri*) and squid (*Gonatus fabricii*) (Fig. 5.38). The videos will be annotated using the annotation software VARS (MBARI) and analysed for information on diversity, distribution and abundance of pelagic fauna at the FRAM Strait and close to Svalbard. The annotation data will become part of the Oceanic Biodiversity Observation Database (OBOD) at GEOMAR and will allow for comparison with annotations from previous cruises (e.g. PS121, POS520, POS532, MSM49, M119).

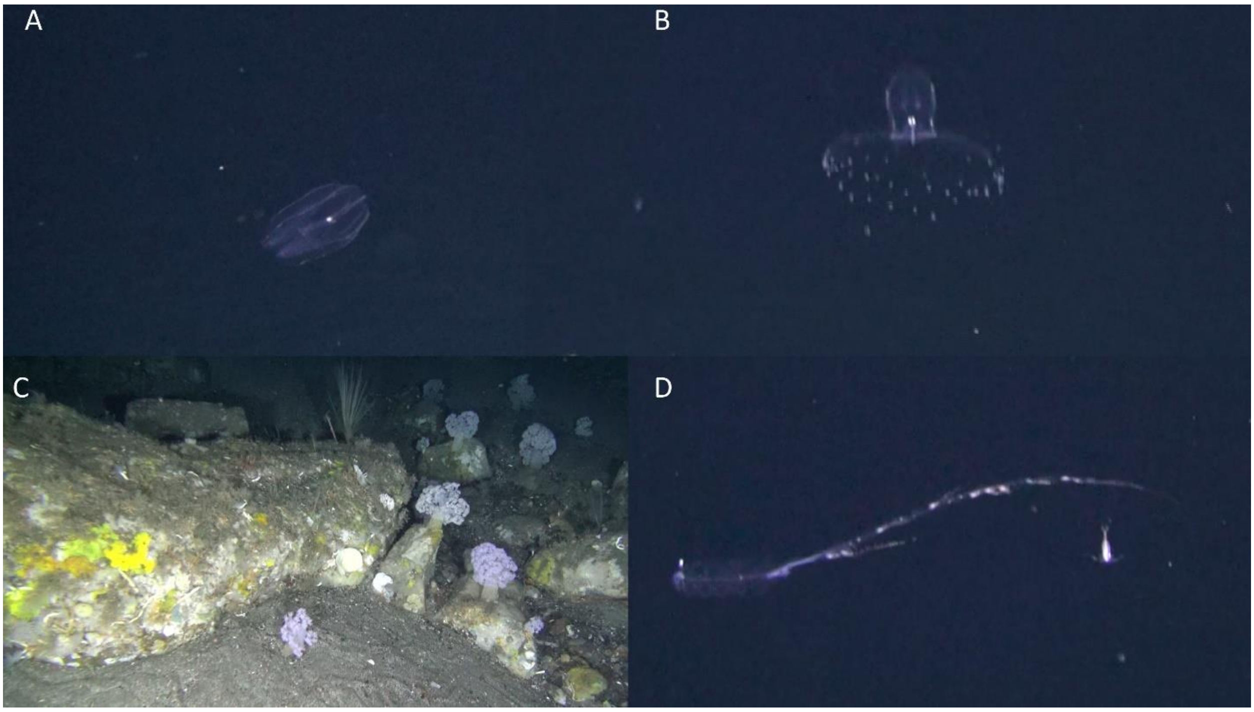


Fig. 5.38 Frame grabs from benthopelagic camera system video transects taken during MSM95. A: Combjelly Bolinopsis sp. , B: Trachymedusae Aglantha sp. , C: Seafloor close to Svalbard, D: Siphonophore and a copepod

5.5 CTD Rosette deployments

(V.Merten[1], T. Priest[2], E.Dauer[3], N.Korfmann[3])

[1]GEOMAR Helmholtz-Centre for Ocean Research Kiel

[2]Max Planck Institute for Marine Microbiology (MPI), Bremen

[3]AWI, Alfred-Wegener-Institute, Bremerhaven

5.5.1 CTD specifications

Sample collection for downstream analysis (see following sections) and measurements of physical parameters were carried out using the CTD-system “SBE 911plus”, SN-09P66504-1072, (Seabird-Electronics, USA). Parameters that were measured:

- Pressure (Paroscientific, Digiquartz, db)
- Temperature (2x SBE 3, ITS-90 °C)
- Conductivity (2x SBE 4)
- Oxygen concentrations (2x SBE 43, µm/l)
- Fluorescence (WET Labs ECO-AFL/FL, mg/m^3)
- Turbidity (WET Labs ECO, NTU)

The sensors attached to the CTD system are arranged within a tube system, where seawater is passed through in constant velocity, to minimize spiking. The fluorescence and turbidity are measured using a downwards facing WET Labs fluorimeter.

The data measured from the CTD were viewed live during the cast using SeaSave Version 7.0 and saved on a hard disk following completion. For each CTD cast, a configuration file, that contains the complete parameter set and sensor coefficients for raw data conversion, was also saved.

Water sampling was performed using a Rosette water sampler, consisting of 24 Free Flow bottles with 10 L of volume each. The Rosette system allows for bottles to be closed from the SeaSave software at depths of interest. The CTD was cast from the side of the ship, operated by winch EL1.

5.5.2 CTD Sampling

The CTD was first deployed to 10 m, with the system being started upon entry into the water to prevent air bubbles entering the pumping system. After checking all parameters, the CTD was brought to the sea surface and the CTD cast was started. Data was collected down to the bottom at all stations with an attached altimeter measuring the distance to the sea floor. The bottom depths of the stations ranged between 400 and 5500 m. All data was processed directly after the cast and stored on the ships server and on a hard drive.

Downcast registrations were used for the measurements of the CTD parameters, while the upcast was only used for water sampling. At the determined depths, the CTD was stopped to be sure to sample the correct water masses of that depth and after 60 seconds the bottles were closed manually. Back on deck, the samples for the microbial community analysis and the FRAM Microbial observatory were taken first, followed by the eDNA sampling.

5.5.3 CTD Stations

The CTD was deployed in the Arctic Ocean at six stations close to Svalbard and seven stations in the FRAM Strait (Figure 5.39 and Table 5.7). The bottom depth ranged between 159 and 5492 m.

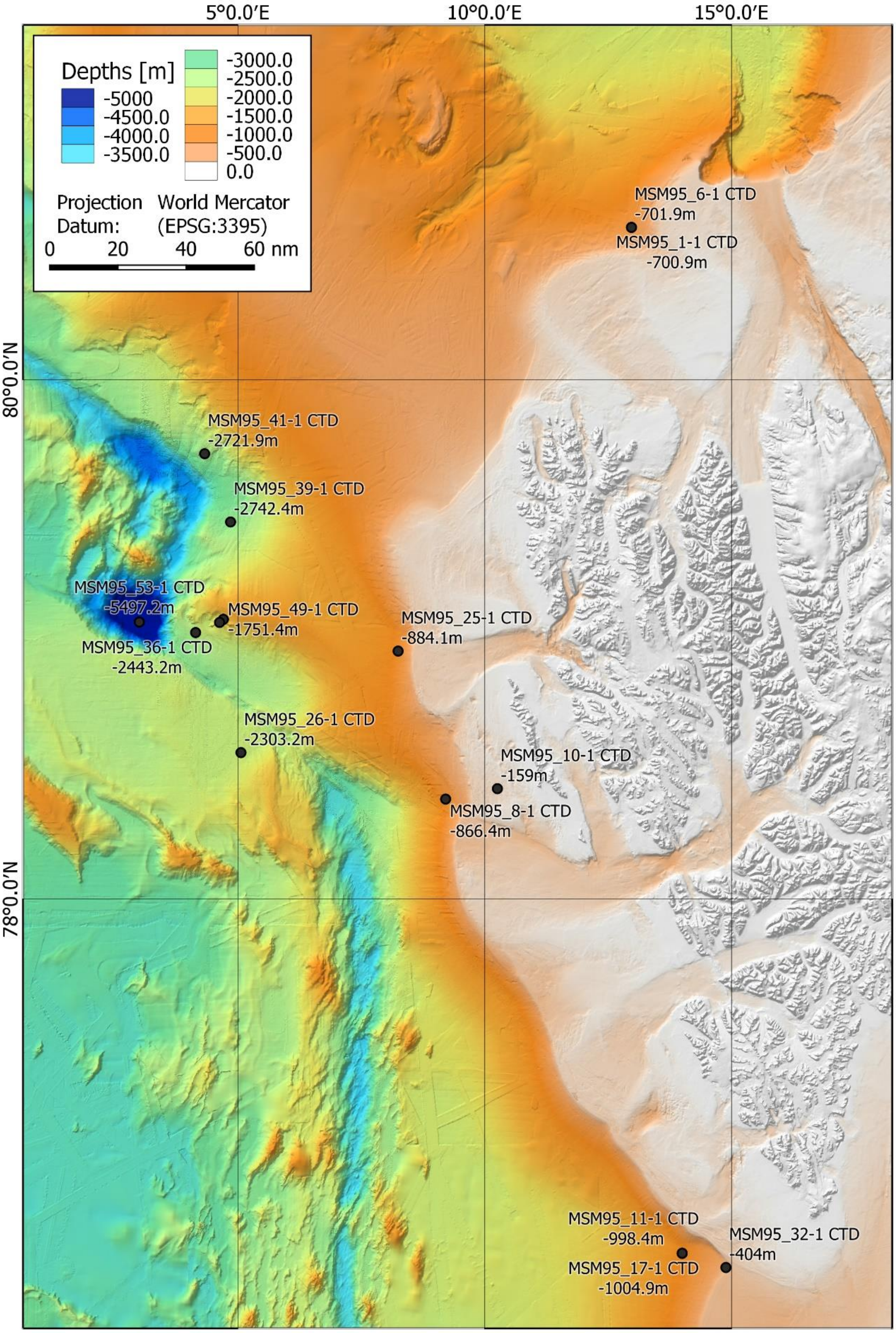


Fig. 5.39 CTD sampling stations with station names and bottom depth during MSM95

Table 5.7 Location of sampling stations where the CTD was deployed including the depths that Rosette bottles were closed. DCM = Deep Chlorophyll Maximum, this was determined using the Fluorimeter on the downcast. Samples taken by refers to the working groups sampling that specific CTD. MicrObs = FRAM Microbial Observatory (section 5.5.1), eDNA = eDNA sampling by GEOMAR (section 5.5.2), MPI = Sampling of bacterioplankton community and carbohydrates by MPI (section 5.5.3)

Station	**Latitude**	**Longitude**	**Depths sampled (m)**	**Samples taken by:**
S1-1	80.521397	12.971455	700, 600, 500, 400, 300, 200, 100, 50, DCM, 20, <5	MicrObs, eDNA , MPI
S6-1	80.521426	12.971969	200, 100, DCM, 20, <5	MicrObs, eDNA , MPI
S8-1	78.4136327	10.256424	852, 700, 600, 500, 400, 200, 100, 50, DCM, 20, <5	MicrObs, eDNA , MPI
S10-1	78.455829	10.256424	200, 100, DCM, 20, <5	MicrObs, eDNA , MPI
S11-1	76.414619	14.000364	988, 800, 700, 600, 500, 400, 200, 100, 50, DCM, 20, <5	MicrObs, eDNA , MPI
S17_1	76.4138297	14.0004614	990, 800, 700, 600, 500, 400, 200, 100, 50, DCM, <5	MicrObs, eDNA , MPI
S25-1	78.998513	8.247126	870, 400, 200, 100, 50, DCM, <5	MicrObs, eDNA , MPI
S26-1	78.600982	5.061096	2283, 2250, 2000, 1600, 1000, 400, 200, 100, 50, DCM, 20, <5	MicrObs, eDNA , MPI
S36-1	79.071368	4.142604	2420, 2250, 2000, 1600, 1300, 1000, 400, 200, 100, 50, DCM, 20, <5	MicrObs, eDNA , MPI
S39-1	79.48768	4.850669	200, 100, DCM, 20, <5	MicrObs, MPI
S41-1	79.736652	4.325782	2705, 2500, 2250, 2000, 1600, 1300, 1000, 400, 200, 100, 50, DCM, 20, <5	MicrObs, eDNA , MPI
S44-1	79.110118	4.628079	1863, 1600, 1300, 1000, 400, 200, 100, 50, DCM, 20, <50	MicrObs, eDNA , MPI
S53_1	79.1116613	3.0016881	5423, 5000, 4000, 3000, 2500, 2250, 2000, 1600, 1300, 1000, 400, 200, 50	MicrObs, eDNA

5.5.4 CTD: FRAM Microbial Observatory sampling

(E. Dauer[1], N. Korfman[1], K. Metfies[1], M. Wietz[1,2])

[1]AWI
[2]MPI

5.5.4.1 Background and aims of the project

To continue the ongoing monitoring taking place under the FRAM microbial observatory, two representatives from the AWI (E. Dauer and N. Korfman) were on-board to collect filtered water samples. The FRAM microbial observatory was established to monitor and understand how ongoing environmental changes affect Arctic marine prokaryotic and eukaryotic microbial communities and their contributions to, or roles within global element cycling.

5.5.4.2 Sampling procedure

The sampling campaign consisted of filtering seawater at five depth intervals from the surface down to 200 m: surface, 20 m, deep chlorophyll maximum (DCM), 100 m and 200m. The deep chlorophyll maximum is the depth at which Chlorophyll a or fluorescence is measured at its maximum and was identified on the down-cast using the Fluorimeter sensor on the CTD. In some cases, the DCM was at 20 m and therefore only four depths were sampled or, in other cases, the DCM was not clear and instead the depth at which fluorescence began to decrease was chosen. At each depth:

- 4 L of water was filtered through a 0.7 µm Sterivex filter for DNA and RNA analysis of microbial communities
- 2 x 2 L was sequentially filtered through a 3 µm and 0.4 µm polycarbonate membrane filter for Chlorophyll *a* quantification.

Fig. 5.40 Water filtration system set up for the Fram Microbial Observatory sampling.

5.5.5 CTD: eDNA sampling

(V. Merten[1], H.-J. Hoving[1])

[1]GEOMAR

5.5.5.1 Background and aims of the project

Biodiversity assessments of pelagic medium-sized fauna in the deep sea by physical or optical methods are often hampered by the patchy distribution and avoidance behaviour of the organisms of interest. A potential alternative method for the efficient and complete assessment of regional deep-sea biodiversity is environmental DNA (eDNA) analysis. eDNA analysis takes advantage of the fact that every organism leaves DNA traces behind in its environment such as mucus, skin cells or feces. By sequencing these DNA traces, the identity of the organism can be revealed without the actual donor being present in the sample (Thomsen and Willerslev, 2015). This method has been used successfully in the open ocean to study distribution and diversity of pelagic organisms (Sigsgaard et al., 2017; Thomsen et al., 2016).

Our aim with eDNA during MSM95 is to investigate the biodiversity and distribution of deep-sea cephalopods and gelatinous zooplankton in the Arctic Ocean which will contribute to unravelling their role in the oceanic carbon cycle via the deposition of carcasses on the seafloor. There are 32 species from 15 families of cephalopods known from the Arctic, from which only 10 are found at high Arctic latitudes and complete their entire life cycle including reproduction in the Arctic (Xavier et al., 2018). Ocean warming and periodic inflows of warmer Atlantic waters in the Arctic regions have led to range expansion of several warm-water cephalopod species (Golikov et al., 2014), and such expansions may be continuing. We will apply eDNA to determine distribution and diversity of cephalopods and large gelatinous zooplankton (Robison, 2009; Webb et al., 2010) to allow identification of potential foodfall species and understand their role in subsidizing deep-sea benthic communities and identify their importance in the Arctic carbon flux.

Cruise objectives:

1. Use eDNA to establish distribution and diversity of cephalopods and meso – and macrozooplankton in the Arctic deep sea
2. Temporal comparison of cephalopod community composition and distribution

5.5.5.2 Sampling procedure

In total, 358 seawater samples were collected at 12 stations (Table 5.7). Every depth was filtered in triplicate (3x 2 L) directly from the CTD to reduce contamination risk using a peristaltic pump and enclosed sterivex filter capsules (Merck) (Fig. 5.41). Tubing and connectors were cleaned with RNAaway and changed regularly. Filtered seawater samples were frozen at -80°C.

Samples were taken for GEOMAR, AWI and the Senckenberg-Institute, Frankfurt. Five sampled stations in the FRAM Strait (Stations 25_1, 26_1, 36_1, 41_1, 44_1, see Fig. 5.39) overlapped with samples taken during PS121 in 2019 and will be used for temporal comparison of cephalopod and gelatinous zooplankton communities.

For investigating cephalopod eDNA, the following depths have been targeted:

50, 200, 400, 1000, 1300, 1600, 2000, 2250, 2500, 3000, 4000, 5000 and 5423 m.

For investigating gelatinous zooplankton eDNA:

Chlorophyll maximum, 5, 50, 100, 200, 400, 1000, 1600, 2000, 2250 and 2500 m.

All sampled filters will be analysed at AWI or GEOMAR in the following months via eDNA metabarcoding using universal primers.

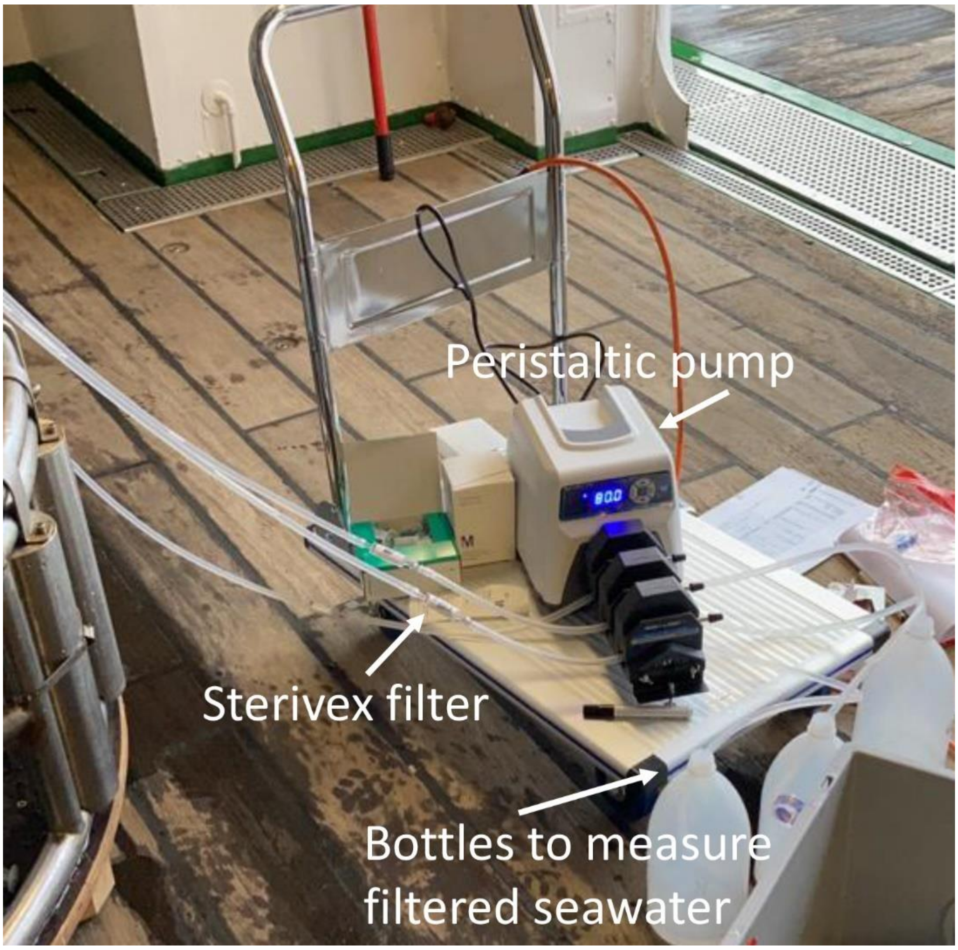


Fig. 5.41 Set up of water filtration system for eDNA sampling with a peristaltic pump and sterivex filters directly from the CTD Niskin bottles.

5.5.6 CTD: Sampling of bacterioplankton community and carbohydrates

(T. Priest[1], B. Fuchs[1,*], R.Amann[1,*])

[1]MPI

*Not on board

5.5.6.1 Background and aims of the project

The over-arching aim of this project is to ecologically characterize heterotrophic bacterial communities across distinct water masses and their ability to degrade dissolved organic carbon (DOC) compounds, particularly carbohydrates. The total marine DOC pool is one of the largest actively cycled reservoirs of organic carbon on Earth and is composed of thousands of different compounds (Hansell and Carlson, 2014). One of the most important fractions within this pool is carbohydrates, that have been reported as consistuting >50% of high molecular weight DOC in surface waters (Benner et al., 1992). The term carbohydrates represents chemically and structurally diverse compounds that range from smaller oligosaccharides to larger, complex polysaccharide molecules (Borch and Kirchman, 1997; Ruocco et al., 2016). Polysaccharides are one of the major organic compounds produced by photosynthetic organisms and have important storage and structural roles (Mühlenbruch et al., 2018). In the marine environment, the degradation of such compounds is largely dominated by heterotrophic microbial communities. Due to the molecular weight of carbohydrates typically being greater than 600 Da, which is larger than bacterial porins (Weiss et al., 1991), heterotrophic bacteria must use extracellular enzymes or outer-membrane bound enzymes to perform preliminary hydrolysis before substrate uptake. The detection, hydrolysis and uptake machinery required to use polysaccharides as a substrate are metabolically expensive and therefore, bacteria typically occupy more focused substrate niches and harbor specific enzyme repertoires that reflect this (Teeling et al., 2012; Krüger et al., 2019). As a result, the degradation of complex marine DOM can only be carried out by a diverse assemblage of bacteria. The community-wide functional capacity to degrade polysaccharides in particular, has been shown to vary with latitude, with more limited substrate hydrolysis being observed at higher latitudes, coinciding with a reduction in temperature and community richness (Arnosti et al., 2011). Despite this, microbial phylogeny and function are poorly correlated. Further work is required to evidence patterns and driving factors in polysaccharide degradation by heterotrophic bacteria across latitudinal gradients and different water masses. Our project aims to address such gaps by using the unique region of the Fram Strait. The Fram Strait is a deep water channel that acts as the primary gateway for water exchange between the Arctic and Atlantic oceans. Warm and saline water originating from the North Atlantic flows north into the Arctic ocean through the West Spitsbergen current whilst cold, less saline Arctic water flows south through the East Greenland current (Fahrbach et al., 2001). Here, both water masses occupy distinct regions whilst mixing also occurs due to recirculation (de Steur et al., 2014) and eddies (Hattermann et al., 2016). This provides a valuable opportunity to assess the polysaccharide degradation by heterotrophic bacteria from different water masses, with unique sources, influences and nutrient compositions at the same latitude.

In order to address such a research topic, we aim to analyse community-wide taxonomic and functional variations as well as specific differences within the Bacteroidetes phylum. The

Bacteroidetes are one of the most dominant and frequently reported groups associated with phytoplankton blooms and the degradation of phytoplankton-derived polysaccharides (Teeling et al., 2012; Krüger et al., 2019) and are known to be ubiquitous in the world's oceans (Pommier et al., 2007). Some of the more specific research questions that we aim to address:

1. Are there distinct patterns in the composition of carbohydrate-related degradation genes (CAZymes) across water masses? Are there signature CAZymes that we can associate with specific water masses?

2. Are the same taxonomic groups that are largely responsible for polysaccharide degradation in temperate latitudes also dominant in higher latitudes or are unique compositions evident?

3. Within the Bacteroidetes inhabiting the Fram Strait, what are the taxonomic similarities or differences from those in lower latitudes? How do their metabolic capabilities differ, particularly with respect to their CAZyme gene repertoires?

4. Are the similarities and differences in Bacteroidetes functional capacities to degrade carbon evident on a gene level? Or are patterns more clear on an 'expressed' level?
5.

These are some of the main aspects that will be addressed through the sampling for this project. Samples from previous cruises to the Fram Strait region have supplied the foundation for this work and the sampling on this cruise will provide a higher resolution of samples within the West Spitsbergen Current, coastal samples around Svalbard to determine potential coastal influences and allow for a wider range of techniques to be used in the analysis due to the higher variety of samples being taken.

5.5.6.2 Sampling procedure

With each CTD cast that was sampled (outlined in Table 5.7), 10 L of water was obtained at specific depth intervals from the surface down to 200 m: surface, 20 m, deep chlorophyll maximum (DCM), 100 m and 200 m. The deep chlorophyll maximum is the depth at which Chlorophyll *a* or fluorescence is measured at its maximum and was identified on the down-cast using the Fluorimeter sensor on the CTD. In some cases, the DCM was at 20 m and therefore only four depths were sampled or, in other cases, the DCM was not clear and instead the depth at which fluorescence began to decrease was chosen. The 10 L of water was divided to provide samples for different analyses:

- 4 L of water was sequentially filtered through a 3 µm and 0.2 µm polycarbonate membrane filter (142 mm in diameter) and stored at -80 °C. These filters will be used for DNA and RNA extraction and downstream genomics analysis.

- 4 L of water was filtered through a 0.7 µm pre-combusted GF/F filter and stored at -80 °C. These samples will provide the material for polysaccharide and monosaccharide analysis.

- 2 x 500 ml of water was filtered through 0.2 µm polycarbonate membrane filters (47 mm diameter) and stored at -80 °C. These samples will be used for separating out specific populations of bacteria from the community using fluorescence *in situ* hybridization (FISH) and flow-assisted cell sorting techniques.

- 2 x 30 ml of water was fixed for 1 hour in 2 % formaldehyde at room temperature before being filtered through a 0.2 µm polycarbonate membrane filter and washed in milliQ water, to remove any chemical residues. Filters were stored at -20 °C. These samples will be used for epifluorescence microscopy-based methods such as FISH, in order to quantify the total number of cells in a sample, see section 5.5.3.3, the total number of bacterial cells and the contribution of specific bacterial taxa to the total community.

5.5.6.3 On-board microscopy

In order to allow for direct observations of the community inhabiting the water column, a microscope was brought on board. The microscope is a Zeiss Axiolab stand with a customized LED illumination system for epifluorescence microscopy. Sections of filters that had been fixed in formaldehyde (see section 5.5.6.2) were mounted on glass microscopy slides in a CitiFluor:Vectashield (3:1) mounting medium mix which contained 2 µg ml^{-1} of 4′,6-diamidino-2-phenylindole (DAPI). DAPI is a fluorescent stain that binds to adenine-thymine rich regions in DNA and can be excited with ultraviolet light. Fluorescent signals (Fig. 5.42) were then enumerated under the microscope by counting a minimum of 10 counting grids and 1000 cells.

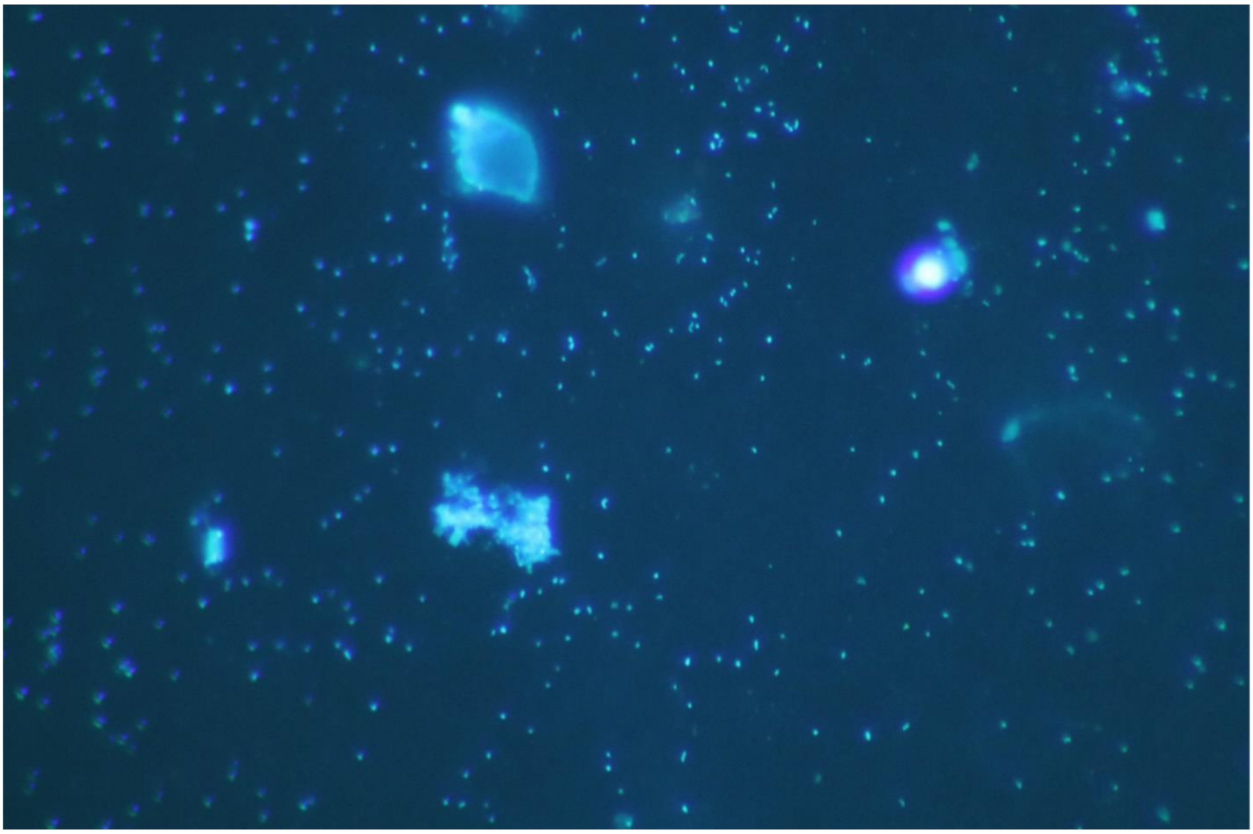


Fig. 5.42 Epifluorescence microscopy image taken under UV light at 100x magnification using a Zeiss Axiolab microscope and a Canon EOS M100. Blue fluorescence = DAPI.

5.6 ADCP Transect

(A. Purser[1], S.Dreutter[1], F.Warnke[1], A. Abreu[2,*], K. Sharavanan[2,*], E. L. Sieling[2,*], S. Us[2,*])

[1]AWI

[2]International School Bremen

[*]Not on board

The R/V MARIA S. MERIAN shipbourne ADCP system was used to conduct one transect on 30th September 2020. The aim of the transect was to transition from 1700 m depth waters of the central Hausgarten region in a westerly direction to cover the flank and depths of the Molloy Deep. Follow a three hour 6 knot transit, the R/V MARIA S. MERIAN reversed course and returned to the starting point of the transect. The intention was to determine whether or not seafloor relief played an influencing role on the northerly flowing Svalbard Current in the area, given the reasonably rapid change in depth, as well as getting a profile of the current conditions in the late Autumn, a period of the year seldom surveyed during the FRAM project.

Data collected with the ADCP, and the CTD, was used for the preparation of two 'Jugend forscht' projects by students from the International School Bremen.

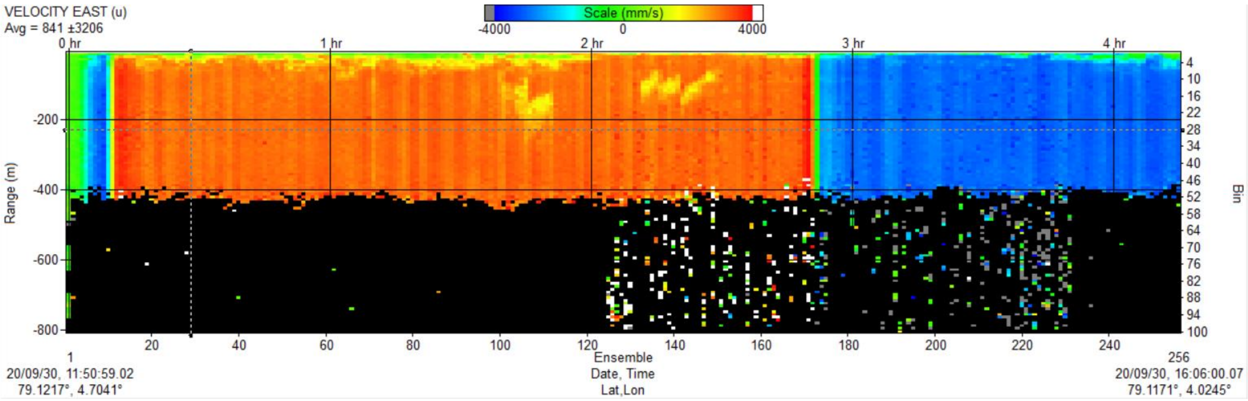


Fig. 5.43 75MHz ADCP profile collected on the 30th September 2020 with the MARIA. S. MERIAN ADCP system. Data shows the raw east velocity values measured.

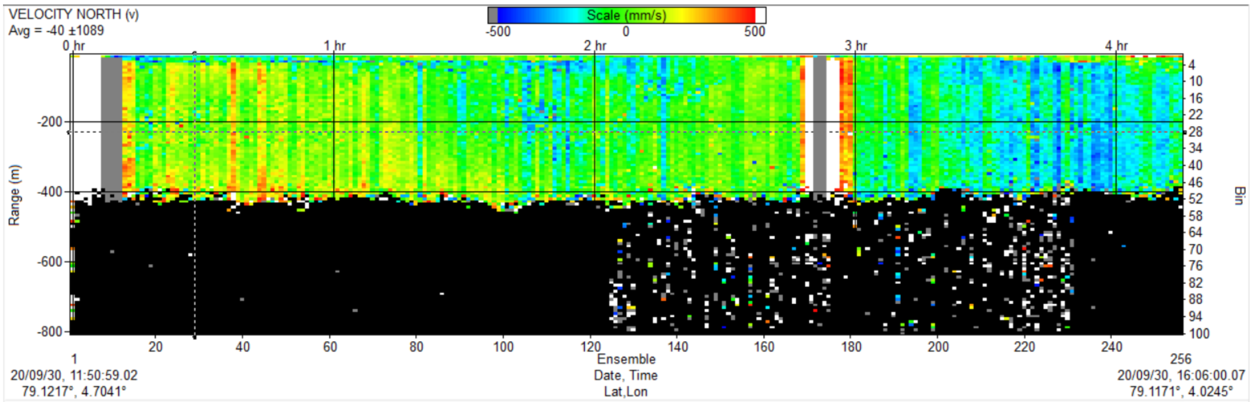


Fig. 5.44 75MHz ADCP profile collected on the 30th September 2020 with the MARIA. S. MERIAN ADCP system. Data shows the raw north velocity values measured.

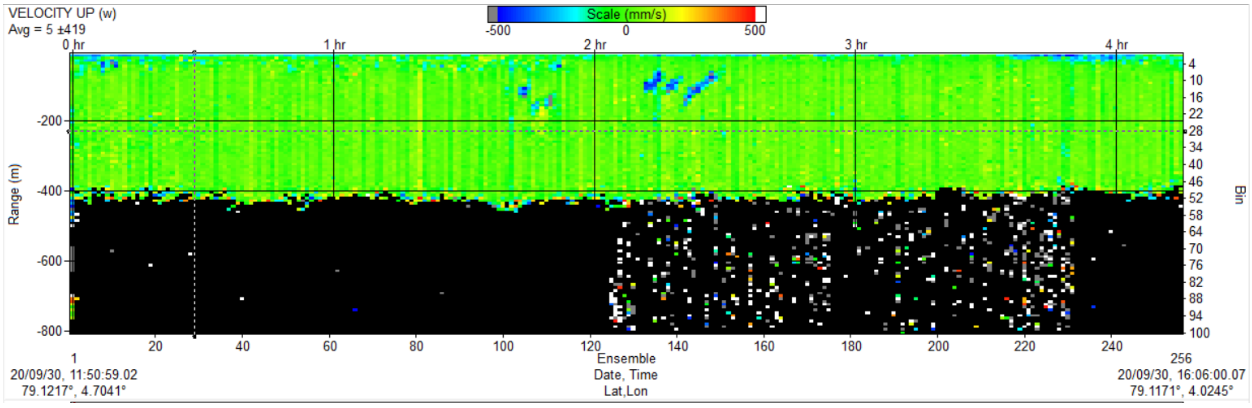


Fig. 5.45 75MHz ADCP profile collected on the 30th September 2020 with the MARIA. S. MERIAN ADCP system. Data shows the raw vertical velocity values measured.

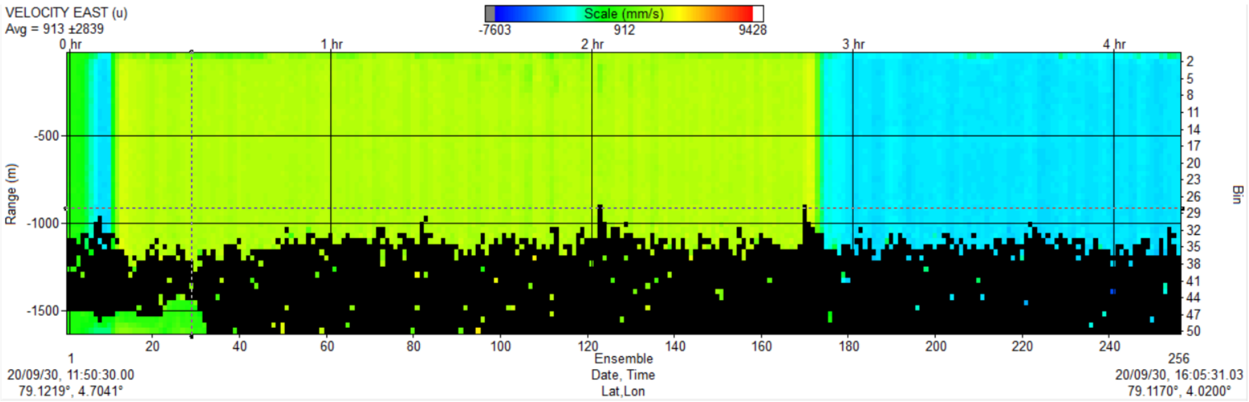


Fig. 5.46 38MHz ADCP profile collected on the 30th September 2020 with the MARIA. S. MERIAN ADCP system. Data shows the raw east velocity values measured.

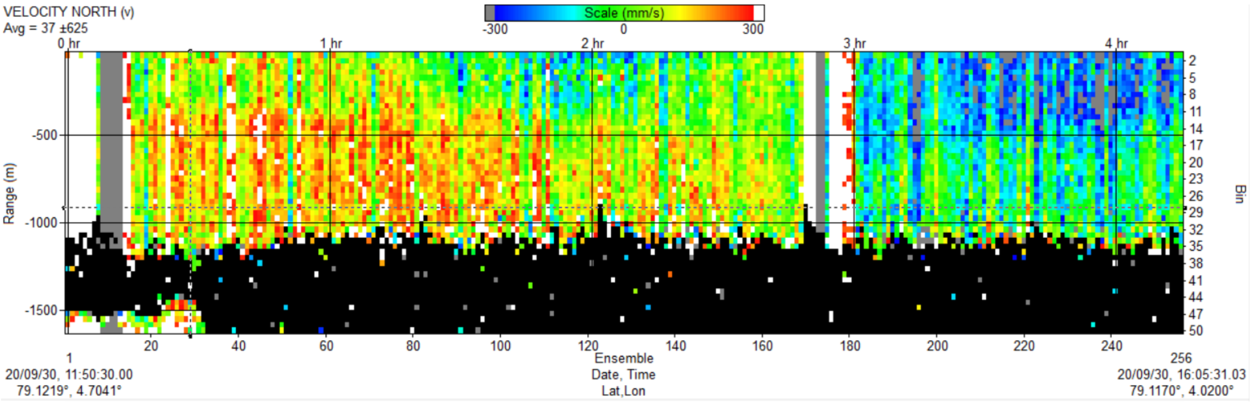


Fig. 5.47 38MHz ADCP profile collected on the 30th September 2020 with the MARIA. S. MERIAN ADCP system. Data shows the raw north velocity values measured.

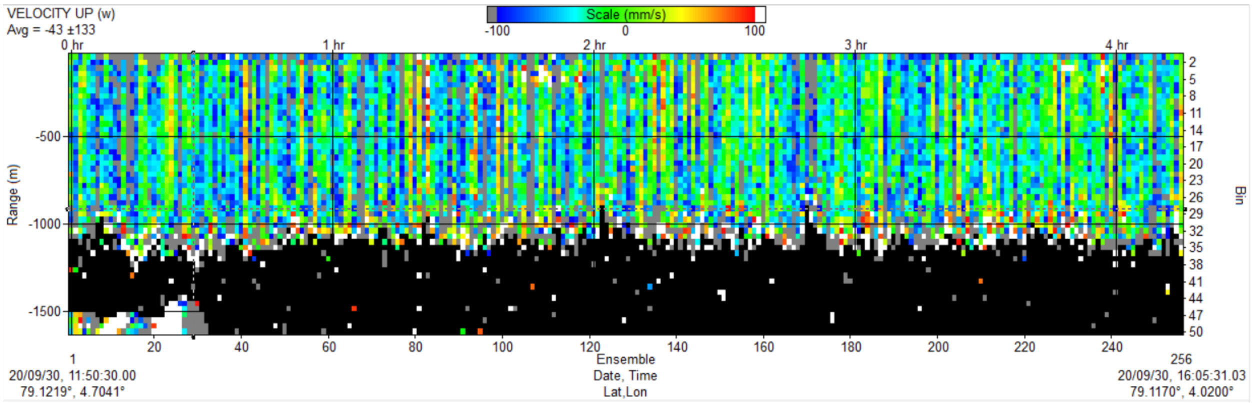


Fig. 5.48 38MHz ADCP profile collected on the 30th September 2020 with the MARIA. S. MERIAN ADCP system. Data shows the raw vertical velocity values measured.

5.7 Floating Litter Surveys

(L. Boehringer[1,2], L. Gutow[1*])

[1]AWI
[2]Universität Bremen

[*]Not on board

During the transit to and from the working stations 16 floating litter surveys were conducted at different locations throughout the North Sea and the Arctic Ocean around Svalbard (Fig. 5.49). During one hour all floating objects, such as litter, algae and others, inside a 10 m transect beginning at the end of the bow wave were counted and identified by the use of binoculars. The survey was conducted from the forecastle deck on the starboard side of the vessel. For each transect the exact start and end time and for each object the exact encounter time was noted to the second. Additional information such as weather, swell and view were noted as well. The recording of the ships position at any time was used afterwards to determine the exact geographic location of each transect and object. In total 118 objects were observed. Of these, 65% were algae, mainly of the genus *Ascophyllum,* 19% were plastic, 8% were of animal origin and 8% were drift wood (Fig. 5.50).

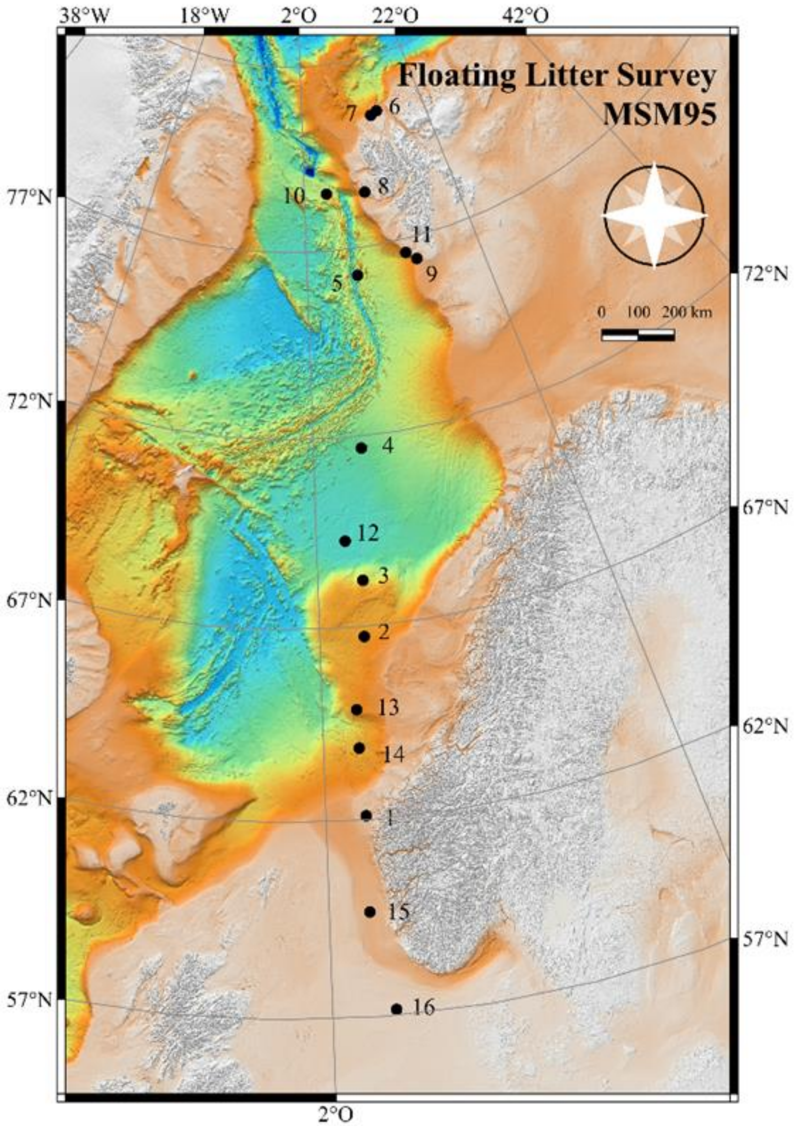


Fig. 5.49 Map of the 16 floating litter surveys (black dots) conducted on the way to and from the working stations around Svalbard. Numbers represent the transect number.

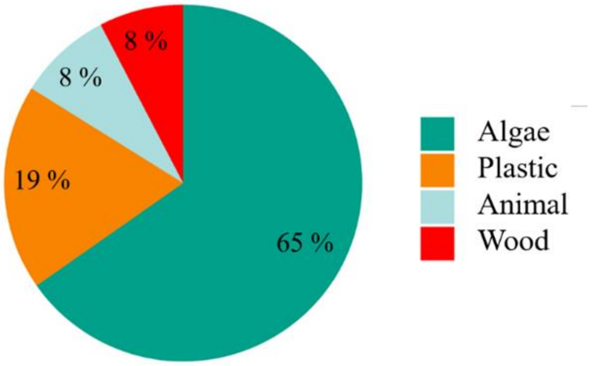


Fig. 5.50 Percentage of categories of observed floating objects during all 16 floating litter surveys combined.

6 Ship's Meteorological Station

There was no mereorologist onboard during MSM95 (GPF 19-2_05).

7 Station List MSM95 – (GPF 19-2_05)

7.1 Overall Station List

Station No.	Date	Time	Gear	Latitude		Longitude		Water Depth	Remarks/ Recovery
RV MERIAN		[UTC]		[°N]		[°W]		[m]	
MSM95_1-1	15/09/2020	06:07	CTD	80°	31.284´	12°	58.287´	707.3	
MSM95_1-2	15/09/2020	07:28	AUV	80°	31.291´	12°	58.310´	703	
MSM95_2-1	15/09/2020	09:20	AUV	80°	31.847´	14°	22.612´	140.3	
MSM95_2-2	15/09/2020	13:14	AUV	80°	31.853´	14°	22.507´	142.7	
MSM95_2-3	15/09/2020	17:05	OFOS	80°	31.828´	14°	24.585´	130.8	
MSM95_2-4	15/09/2020	18:05	OFOS	80°	31.777´	14°	25.031´	130.8	
MSM95_3-1	15/09/2020	19:26	EM712	80°	24.149´	13°	59.967´	133.6	
MSM95_4-1	16/09/2020	08:04	AUV	80°	24.149´	13°	59.856´	134.3	
MSM95_5-1	16/09/2020	11:14	OFOS	80°	28.122´	13°	28.991´	330.2	
MSM95_6-1	16/09/2020	14:29	CTD	80°	31.286´	12°	58.318´	701.8	
MSM95_7-1	16/09/2020	16:58	OFOS	80°	31.456´	13°	0.048´	696.5	
MSM95_8-1	17/09/2020	05:11	CTD	78°	24.817´	9°	12.440´	865.1	
MSM95_9-1	17/09/2020	06:22	EM712	78°	24.852´	9°	13.096´	859.7	
MSM95_10-1	17/09/2020	12:01	CTD	78°	27.350´	10°	15.385´	159	
MSM95_11-1	18/09/2020	01:36	CTD	76°	24.877´	14°	0.022´	997.5	
MSM95_12-1	18/09/2020	02:46	EM712	76°	24.879´	14°	0.033´	1000.5	
MSM95_13-1	18/09/2020	07:15	OFOS	76°	28.777´	14°	32.121´	220.6	
MSM95_14-1	18/09/2020	21:30	EM712	76°	28.947´	14°	32.580´	230.7	
MSM95_15-1	18/09/2020	23:40	OFOS	76°	26.382´	14°	32.671´	666.5	
MSM95_16-1	19/09/2020	07:32	EM712	76°	28.671´	14°	20.465´	575.3	
MSM95_17-1	19/09/2020	12:47	CTD	76°	24.830´	14°	0.028´	1003.3	
MSM95_18-1	19/09/2020	13:45	OFOS	76°	24.848´	14°	0.010´	1004.1	
MSM95_19-1	20/09/2020	07:19	AUV	78°	27.020´	9°	48.427´	191.8	
MSM95_20-1	20/09/2020	09:05	OFOS	78°	26.394´	9°	36.428´	432.9	
MSM95_20-2	20/09/2020	13:39	OFOS	78°	26.623´	9°	15.479´	783.9	
MSM95_21-1	20/09/2020	18:09	OFOS	78°	25.898´	9°	12.440´	812.6	
MSM95_22-1	20/09/2020	23:27	EM712	78°	23.574´	9°	16.053´	855	
MSM95_23-1	21/09/2020	08:26	AUV	78°	27.168´	9°	28.756´	506.1	
MSM95_24-1	21/09/2020	10:37	OFOS	78°	27.150´	9°	29.007´	503.9	
MSM95_25-1	21/09/2020	21:10	CTD	78°	59.911´	8°	14.828´	880.4	
MSM95_26-1	22/09/2020	01:40	CTD	78°	36.059´	5°	3.666´	2300.6	
MSM95_27-1	22/09/2020	03:53	OFOS	78°	36.958´	5°	8.698´	2313.8	
MSM95_28-1	22/09/2020	09:30	EM122	78°	32.698´	4°	25.349´	2326.6	
MSM95_29-1	23/09/2020	08:37	AUV	76°	19.771´	14°	55.249´	326.3	
MSM95_30-1	23/09/2020	09:47	OFOS	76°	20.855´	14°	54.081´	385.8	
MSM95_31-1	23/09/2020	18:44	OFOS	76°	24.917´	14°	49.056´	237.7	
MSM95_32-1	24/09/2020	06:44	CTD	76°	20.801´	14°	53.152´	405	
MSM95_33-1	24/09/2020	07:32	EM712	76°	21.581´	15°	4.626´	257	
MSM95_34-1	24/09/2020	12:50	OFOS	76°	21.369´	15°	1.522´	283.3	
MSM95_35-1	25/09/2020	12:48	OFOS	79°	3.236´	4°	12.971´	2460.3	
MSM95_35-2	25/09/2020	18:15	OFOS	79°	4.277´	4°	8.580´	2446.1	
MSM95_36-1	25/09/2020	19:27	CTD	79°	4.282´	4°	8.556´	2447.3	
MSM95_37-1	25/09/2020	22:20	EM122	79°	4.854´	4°	56.502´	1856.6	
MSM95_38-1	26/09/2020	09:07	OFOS	79°	1.134´	4°	6.634´	2645.7	
MSM95_39-1	26/09/2020	18:29	CTD	79°	29.261´	4°	51.040´	2752.1	

MSM95_40-1	26/09/2020 20:13	EM122	79°	29.302´	4°	51.182´	2746.9	
MSM95_41-1	27/09/2020 08:38	CTD	79°	44.199´	4°	19.547´	2724.8	
MSM95_42-1	27/09/2020 12:34	OFOS	79°	34.171´	5°	15.387´	2606.6	
MSM95_43-1	27/09/2020 21:22	OFOS	79°	4.655´	4°	4.571´	2483.1	
MSM95_44-1	28/09/2020 08:59	CTD	79°	6.607´	4°	37.685´	1899.5	
MSM95_45-1	28/09/2020 10:33	EM122	79°	6.601´	4°	37.827´	1978.1	
MSM95_46-1	28/09/2020 17:54	OFOS	79°	4.109´	4°	12.355´	2396.3	
MSM95_46-2	29/09/2020 03:03	OFOS	79°	4.083´	4°	12.361´	2386.3	
MSM95_47-1	29/09/2020 06:30	CRAWL	79°	4.056´	4°	11.094´	2402.6	
MSM95_48-1	30/09/2020 02:30	EM122	78°	50.017´	4°	11.784´	2367.7	
MSM95_49-1	30/09/2020 10:37	CTD	79°	7.315´	4°	42.246´	1754.4	
MSM95_50-1	30/09/2020 12:05	ADCP	79°	7.290´	4°	42.223´	1755.5	
MSM95_51-1	30/09/2020 17:39	CTD	79°	7.310´	4°	42.227´	1748.2	
MSM95_52-1	30/09/2020 20:37	OFOS	79°	7.666´	5°	12.812´	1357.9	
MSM95_53-1	01/10/2020 06:19	CTD	79°	6.699´	3°	0.106´	5498.9	

7.2 CTD Profile Station List

Station No.	**Profile Station No.**	**Date**	**Time**	**Latitude**		**Longitude**		**CTD max depth**	**Water Depth**
RV MERIAN			**[UTC]**	**[°N]**		**[°W]**		**[m]**	**[m]**
MSM95_1-1	1	15/09/2020	06:07	80°	31.284´	12°	58.287´	700	707.3
MSM95_6-1	2	16/09/2020	14:29	80°	31.286´	12°	58.318´	695	701.8
MSM95_8-1	3	17/09/2020	05:11	78°	24.817´	9°	12.440´	855	865.1
MSM95_10-1	4	17/09/2020	12:01	78°	27.350´	10°	15.385´	150	159
MSM95_11-1	5	18/09/2020	01:36	76°	24.877´	14°	0.022´	980	997.5
MSM95_17-1	6	19/09/2020	12:47	76°	24.830´	14°	0.028´	990	1003.3
MSM95_25-1	7	21/09/2020	21:10	78°	59.911´	8°	14.828´	870	880.4
MSM95_26-1	8	22/09/2020	01:40	78°	36.059´	5°	3.666´	2290	2300.6
MSM95_32-1	9	24/09/2020	06:44	76°	20.801´	14°	53.152´	395	405
MSM95_36-1	10	25/09/2020	19:27	79°	4.282´	4°	8.556´	2437	2447.3
MSM95_39-1	11	26/09/2020	18:29	79°	29.261´	4°	51.040´	2740	2752.1
MSM95_41-1	12	27/09/2020	08:38	79°	44.199´	4°	19.547´	2710	2724.8
MSM95_44-1	13	28/09/2020	08:59	79°	6.607´	4°	37.685´	1880	1899.5
MSM95_49-1	14	30/09/2020	10:37	79°	7.315´	4°	42.246´	1740	1754.4
MSM95_51-1	15	30/09/2020	17:39	79°	7.310´	4°	42.227´	1735	1748.2
MSM95_53-1	16	01/10/2020	06:19	79°	6.699´	3°	0.106´	5485	5498.9

8 Data and Sample Storage and Availability

All data collected from this cruise will be made publicly available by 01/10/2022.
At time of writing a selection of data is already publicly available:

EM712 data: (https://doi.org/10.1594/PANGAEA.924923)
EM122 data: (https://doi.org/10.1594/PANGAEA.924922)
OFOBS image data: (https://doi.org/10.1594/PANGAEA.928815)

The remainder of the data collected during the cruse will be made available or can be acquired on request from the contact scientist / technician as outlined in **Table 8.1**.

Table 8.1 Overview of data availability

Type	Database	Available	Free Access	Contact
EM122 hydroacoustic data	PANGAEA	01/12/2020	01/12/2020	Simon.dreutter@awi.de
EM712 hydroacoustic data	PANGAEA	01/12/2020	01/12/2020	Simon.dreutter@awi.de
OFOBS seafloor still images	PANGAEA	01/02/2021	01/02/2021	Autun.purser@awi.de
CTD profile data	PANGAEA	01/06/2021	01/06/2021	Autun.purser@awi.de
ADCP profile data	PANGAEA	01/06/2021	01/06/2021	Autun.purser@awi.de
AUV image data	PANGAEA	01/06/2021	01/06/2021	Jonas.hagemann@awi.de
AUV acoustic data	PANGAEA	01/06/2021	01/06/2021	Jonas.hagemann@awi.de
OFOBS acoustic data	PANGAEA	01/06/2021	01/06/2021	Laura.hehemann@awi.de
OFOBS video data	AWI ARCHIVE	01/09/2021	01/09/2021	Autun.purser@awi.de
MiniROV video data	AWI ARCHIVE	01/09/2021	01/09/2021	Ulrich.hoge@awi.de
Water column camera data	PANGAEA	01/01/2022	01/01/2022	vmerten@geomar.de
Water sampling data	PANGAEA	01/01/2022	01/01/2022	vmerten@geomar.de
Secondary water column camera data	AWI ARCHIVE	01/01/2022	01/01/2022	Autun.purser@awi.de

9 Acknowledgements

This cruise was put together under the early months of the global COVID-19 crisis and represents a huge logistical success under difficult and uncertain circumstances. The Deutsche Forschungsgemeinschaft (DFG) kindly funded this cruise (replacing an AWI led cruise intended for RV Heincke before the crisis). The Leitstelle Deutsche Forschungsschiffe in Hamburg, Germany and Briese Schifffahrts GmBH & Co. KG are acknowledged for their support and assistance throughout. The Alfred Wegener Institute ship coordination team oversaw the discussions between the various planned expeditions for RV Heincke for 2020 (pre-COVID), and facilitated the moving of some of these, such as MSM95 (GPF 19-2_5) onto R/V MARIA S. MERIAN.

Great support was offered by the Deep Sea Ecology and Technology group of the Alfred Wegener Helmholtz Institute for Polar and Marine Research. Normen Lochthofen took charge of equipment shipping to the vessel whilst the scientific party was in the quarantine hotel. The AWI medical team, Martin Gerken and the Werksarztzentrun Fischereihafen supported the numerous last minute medical checks required by cruise participants against the backdrop of the ongoing MOSAIC mission support admirably.

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11 Abbreviations

ADCP	Acoustic Doppler Current Profiler
AUV	Autonomous Underwater Vehicle
CTD	Conductivity, Temperature, Depth sensor
eDNA	Environmental DNA , Environmental Deoxyribonucleic acid
MiniROV	Miniature Remote Operated Vehicle
OFOBS	Ocean Floor Observation and Bathymetry System
ROV	Remote Operated Vehicle