Arctic Ocean 2022 Cruise Report

IMR Cruise ID 2022710

Tromsø - Longyearbyen

19 July – 23 August 2022

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Cruise Overview

The primary goal of NPI's Arctic Ocean 2022 cruise "AO-2022" was to collect a comprehensive set of physical, chemical, and biological observations of the ocean and sea ice in the Amundsen and Nansen Basins of Arctic Ocean intended to support research at the Norwegian Polar Institute and in external projects including Arctic PASSION (EU H2020/NPI), SUDARCO (Fram Centre/NPI) and Arctic-ABC (NFR/UiT), which have a common aim of providing the up-to-date knowledge of the ocean and sea ice ecosystem needed for sustainable development of the Arctic Ocean. Important themes were characterizing the physical environment, especially vertical transports of heat and nutrients, mapping species present in the ecosystem and quantifying ongoing changes in the sea ice cover. AO-2022 was also intended to establish the foundation for the development of a new sustained observation program in the Central Arctic Ocean that is well integrated with existing long-term initiatives both at NPI and externally.

Most of the scientific work was conducted along a 450 nm great-circle transect from the A-TWAIN mooring array and across the Nansen and Amundsen Basins, with an initial bearing of 150 °, crossing the Gakkel Ridge at approximately 90 °. The transect was designed to resolve the transition between the environments in the two basins, capture subsurface currents flowing along the Gakkel Ridge and map the eastern extent of the Transpolar Drift. A somewhat similar transect was completed during the Nansen Legacy Joint Cruise 2 in 2021 and comparison of measurements made during these two cruises should give some insight into interannual variability.

Two moorings were deployed in the Amundsen and Nansen basins intended to provide year-round observations of the situation in these two central basins, away from the influence of peripheral currents, shelf, and slope dynamics. Multi-day sea ice stations were organised at both mooring locations to provide information about that sea ice environment above the moored instrumentation and to enable longer-term current, turbulence and plankton net surveys to be made from the vessel at these key locations.

The cruise began with a passage to the north pole making opportunistic use of a lead through the ice created by the expedition cruise vessel *Le Commandant Charcot*, after which the *Kronprins Haakon* proceeded to the North-eastern end of the main transect. Scientific work was completed in a south-westerly direction with the vessel working towards the ice edge. Making use of an existing lead for much of the outward passage saved significant time and fuel compared with that required to break a path though ice along the main transect in both outward and return directions. Starting scientific work at the western end of the transect also allowed important tasks in the Amundsen Basin to be completed earlier in the cruise and reduced the amount of contingency time that needed to be allowed to overcome difficult ice conditions.

Time saved during the outward passage allowed additional scientific work to be undertaken at the North Pole and between the North Pole and the beginning of the main transect. New oceanographic and biogeochemical measurements at the North Pole collected during AO-2022 extend the time series of existing observations made by initiatives such as the North Pole Environmental Observatory and drifting ice-tethered observatories deployed there can be expected to have a longer useful lifetime before drifting into open water than if they had been deployed along the main transect. A multi-day ice station was completed at the North Pole with the aim of providing a broader context for measurements collected by these drifting observatories.

Data Availability

The data collected during the cruise are made available through the Norwegian Polar Data Centre at https://data.npolar.no/dataset/d1e609e2-08ff-4638-843c-28d039c9d33c. Measurements from different disciplines are published as separate datasets with separate DOIs, but all measurements from the cruise are linked with the common tag NPI-AO-2022.

Contents

Participants

Organisation

1	Ole Arve Misund (NPI)	**Cruise Leader**, biological acoustics
2	Paul A. Dodd (NPI)	**Chief Scientist**, physical oceanography
3	Anna Nikolopoulos (NPI)	**Deputy Chief Scientist**, physical oceanography

Technical and Safety

4	Trine Lise Sviggum Helgerud	Communication and outreach
5	Kristen Fossan (NPI)	Mooring preparation & deployment
6	Marius Bratrein (NPI)	Mooring & sea ice buoy preparation & deployment
7	Marius Nyborg (NPI)	Sea ice and polar bear safety
8	Piotr Kupiszewski (NPI)	Sea ice and polar bear safety
9	Ragni Sandvik	Medic

Physical and Biogeochemical Oceanography

10	Zoe Koenig (NPI/UiB)	Physical oceanography
11	Morven Muilwijk (NPI)	Physical oceanography
12	Mats Granskog (NPI)	Ocean and sea ice biogeochemistry
13	Håkon Sandven (NPI/UiB)	Ocean optics
14	Rafael Gonçalves-Araujo (DTU)	Dissolved organic matter
15	Yannick Kern (NPI)	Data Processing, Moored water samplers and O_2
16	Bonnie Raffel (NPI)	Carbon chemistry measurements
17	Shelby Buckley (LUMCON)	Dissolved organic matter

Bacteria and Lower Trophic Levels

18	Megan Lenss (NPI)	Chlorophyll, POC, PON, phytoplankton taxonomy
19	Venkatachalam Siddarthan (NCPOR)	Bacteria
20	Ahammed Shereef (NCPOR)	Bacteria

Pelagic Ecosystem

21	Haakon Hop (NPI)	Pelagic ecosystem
22	Vegard Stürzinger (NPI)	Pelagic ecosystem & microplastic sampling
23	Victoria Eggen (NPI)	Pelagic ecosystem

Sea Ice

24	Dmitry Divine (NPI)	Physical properties of sea ice
25	Benjamin Lange (NPI)	Optical properties of sea ice
26	Karley Campbell (UiT)	Measuring nutrient & gas fluxes at ice ocean interface
27	Janina Osanen (UiT)	Measuring nutrient & gas fluxes at ice ocean interface
28	Pedro de la Torre (UiT)	Sea ice buoy deployments & under-ice ROV operations

Daily Activities

Date	Major Activities
19/07/22 *Day 1* *34 days remaining*	**Participants joining in Tromsø boarded 13:00** Safety briefing Loaded ca. 5 pallets scientific equipment **Departed Tromsø 15:00** Transit to Longyearbyen
20/07/22 *Day 2* *33 days remaining*	Transit to Longyearbyen Diversion to Bjornøya to collect casualty with small boat, casualty transported to Longyearbyen Planning meetings with various groups onboard
21/07/22 *Day 3* *32 days remaining*	Transit to Longyearbyen **Arrival Longyearbyen 18:00** **Participants joining in Longyearbyen boarded 18:00** Safety briefing for new participants Loaded 4 containers and ca. 50 pallets Flush mounted 150 kHz ADCPs and EK80 echo sounder started Thermosalinograph started
22/07/22 *Day 4* *31 days remaining*	**Departed Longyearbyen 04:00** **SAR Image RS2-SLC-S2-DES-22-Jul-2022_06.15-KNOS_53428534 acquired** Transit to Slocum and sea glider deployment site at 78 50'N, 008 00' E Test deployment of VITO trawl near 78 50'N, 008 30' E Test deployment of Harstad trawl near 78 50'N, 008 30' E CTD 120 & CTD 121 Sea glider deployment at 78 50'N, 008 00' E Slocum glider deployment at 78 50'N, 008 00' E Transit to A-TWAIN section
23/07/22 (Saturday) *Day 5* *31 days remaining*	**SAR Image: RS2-SLC-S3-DES-23-Jul-2022_05.46-KNOS_53428537 acquired** Transit to A-TWAIN section VITO trawl 1 near 80 42' E 015 40' E
24/07/22 (Sunday) *Day 6* *30 days remaining*	CTD 122 CTD 123 & Optics 001 & LISST 001 CTD 124 ABC-buoy set out in open water for inter-ship echo sounder calibration VITO trawl near 82 05' E 022 20' E Transit to rendez-vous point with *Le Comandant Charcot*
25/07/22 *Day 7* *29 days remaining*	**SAR Image: RS2-SGF-SCWA-DES-25-Jul-2022_13.08-KNOS_53497065 acquired** Rendez-vous with *Le Comandant Charcot* Transit to North Pole following *Le Comandant Charcot* 6 x 20-minute presentations about planned work by scientific participants Surface (4 m depth) tracer sampling at N 83° 00', E 034° 36' Surface (4 m depth) tracer sampling at N 83° 33', E 034° 60'
26/07/22 *Day 8* *28 days remaining*	Transit to North Pole 6 x 20-minute presentations about planned work by scientific participants Surface (4 m depth) tracer sampling at N 85° 35', E 038° 23' Surface (4 m depth) tracer sampling at N 85° 60', E 036° 45' Surface (4 m depth) tracer sampling at N 86° 31', E 034° 18'

27/07/22 *Day 9* *27 days remaining*	**SAR Image: RS2-SGF-SCWA-DES-27-Jul-2022_13.50-KNOS_53497068 acquired** On-ice operating procedures and safety briefing for all participants Presentation of risk assessment to all participants Surface (4 m depth) tracer sampling at N 87° 00', E 040° 59' Surface (4 m depth) tracer sampling at N 87° 31', E 050° 34' Surface (4 m depth) tracer sampling at N 88° 00', E 051° 50' Surface (4 m depth) tracer sampling at N 88° 29', E 054° 21'
28/07/22 *Day 10* *26 days remaining*	Surface (4 m depth) tracer sampling at N 88° 60', E 055° 38' Surface (4 m depth) tracer sampling at 89° 30', E 069° 30' **KPH and LCC arrive North Pole** Delegation from KPH visits LCC to present KPH, NPI & AO2022 to ca.150 passengers CTD 125 & CTD 126 & CTD 127 & CTD 128
29/07/22 *Day 11* *25 days remaining*	**RS2-SGF-SCWA-DES-29-Jul-2022_12.51-KNOS_53497071 acquired** Ice floe for North Pole ice station selected. **North Pole Sea Ice Station #1 (North Pole) begins. Gangway down:** 09:15 **Summary of activity in Table 20.** AZFP-ITO deployed SIMBA-UIT0202 deployed (IMEI 300 234 065 765 510) SIMBA-UIT0204 deployed (IMEI 300 234 065 863 280) LT-ITO1 deployed LT-ITO1 deployed CTD 130 Optics-002 & LISST-002
30/07/22 (Saturday) *Day 12* *24 days remaining*	2 x Mamouth Multinet casts to the bottom 2 x MIK net casts On the ice: LISST-003 Small celebration of KPH reaching North Pole **Sea Ice Station #1 (North Pole) ends** Phytoplankton net cast 1
31/07/22 (Sunday) *Day 13* *23 days remaining*	**RS2-SLC-EH4-DES-31-Jul-2022_05.10-KNOS_53523781 acquired** CTD 131 CTD 132 CTD 133 Optics-004 & LISST-004 **Sea Ice Station #2 begins and ends (summary of activity in Table 21)** SIMBA Buoy NPI 0802 deployed (IMEI 300 534 061 788 840)
01/08/22 *Day 14* *22 days remaining*	**RS2-SLC-S8-DES-01-Aug-2022_13.05-KNOS_53428561 acquired** **Sea Ice Station #3 begins and ends (summary of activity in Table 22)** SIMBA Buoy LOCEAN0702 deployed (IMEI 300 234 065 173 780) CTD 134 CTD 135 Optics-005 & LISST-005 2 x MIK net casts
02/08/22 *Day 15* *21 days remaining*	**RS2-SGF-SCWA-DES-02-Aug-2022_10.54-KNOS_53875179 acquired** **Sea Ice Station #4 begins and ends (summary of activity in Table 23)** CTD 136 & MSS019 & MSS020 & CTD 137 & Optics 006 & LISST 006 CTD 138 CTD 139 & MSS021 & MSS022 CTD 140 Optics-006 & LISST-006 SIMBA Buoy LOCEAN 0701 deployed (IMEI 300 234 065 176 790)

03/08/22 *Day 16* *20 days remaining*	**RS2-SGF-SCWA-DES-03-Aug-2022_08.44-KNOS_53876986 acquired** **Sea Ice Station #5 begins and ends (summary of activity in Table 24)** CTD 141 & CTD 142 & MSS 023 & MSS 024 & Optics-007 & LISST-007 CTD 143 CTD 144 & MSS 025 & MSS 026 CTD 145
04/08/22 *Day 17* *19 days remaining*	**RS2-SGF-SCWA-ASC-04-Aug-2022_13.17-KNOS_53877007 acquired** CTD 146 & CTD 147 MSS 027 & MSS 028 & Optics-008 & LISST-008 CTD 148 CTD 149 & MSS 029 & MSS 030 CTD 150
05/08/22 *Day 18* *18 days remaining*	**RS2-SGF-SCWA-DES-05-Aug-2022_07.46-KNOS_53877714 acquired** CTD 151 (principally for echo sounder calibration) Multi-beam survey of target deployment site for Amundsen Basin Mooring deployment Selection of ice floe for Amundsen Basin sea ice station **Amundsen Basin Sea Ice Station #6 begins. Gangway down 08:50** **(summary of activity in Table 25)** 2 x MIK net casts Longline fishing overnight On the ice: Optics-009 & LISST-009
06/08/22 (Saturday) *Day 19* *17 days remaining*	**RS2-SGF-SCWA-DES-06-Aug-2022_08.57-KNOS_53877717 acquired** **Amundsen Basin Sea Ice Station #6 ends Gangway up 20:10** 2 x Multinet Casts to the bottom Phytoplankton net cast to 50 m Bongo net cast to 1000 m ROV operation through moonpool with single blueye SIMBA Buoy NPI 0803 deployed (IMEI 300 534 061 784 880)
07/08/22 (Sunday) *Day 20* *16 days remaining*	**RS2-SGF-SCWA-DES-07-Aug-2022_08.28-KNOS_53877720 acquired** CTD 152 & CTD 153 & MSS 047 & MSS 048 & Optics-010 & LISST-010& CTD 154 **Mooring Amundsen-1 released at N 86° 31.582’ W 005° 36.575’ 17:34:53 UTC** Echo sounder survey to verify depth of mooring components (complete mooring verified). CTD 155 CTD 156 & MSS 049 & MSS 050
08/08/22 *Day 21* *15 days remaining*	**RS2-SGF-SCWA-DES-08-Aug-2022_07 acquired** CTD 157 & MSS 051 & MSS 052 CTD 158 & CTD 159 MSS 053 & MSS 054 Optics-011 & LISST-011 CTD 160 CTD 161
09/08/22 *Day 22* *14 days remaining*	**RS2_20220809_090956_0076_SCWA_HHHV acquired** CTD 162 CTD 163 & 164 & MSS 055 & MSS 056 & Optics-0112& LISST-012 CTD 165
10/08/22 *Day 23* *13 days remaining*	**RS2_20220810_084042_0076_SCWA_HHHV_SGF_992796_4629_53877729 acquired** CTD 166 & CTD 167 & MSS 057 & MSS 058 CTD 168 & CTD 169 CTD 170 & MSS 059 & MSS 060 & Optics-013 & LISST-013
11/08/22 *Day 24* *12 days remaining*	**RS2-SGF-SCWA-DES-11-Aug-2022_06.31-KNOS_53877733 acquired** CTD 171 & MSS 061 & MSS 062 CTD 172 CTD 173 & CTD 174 & MSS 063 & MSS 064 & Optics-014 & LISST-014 CTD 175

12/08/22 *Day 25* *11 days remaining*	**RS2_20220812_074224_0076_SCWA_HHHV_SGF_993220_4669_53877736 acquired** CTD 176& MSS 065 & MSS 066 CTD 177 Multi-beam survey of target deployment site for Amundsen Basin Mooring deployment CTD 178 & 179 & 180 (for micro plastic sampling) **Nansen Basin Sea Ice Station # 8 begins (Gangway down 16:09)** **(summary of activity in Table 27)** Vessel moored to ice flow, propulsion shut down, power from harbour generator 2 x MIK net casts Bongo net cast
13/08/22 (Saturday) *Day 26* *10 days remaining*	**RS2_20220813_071258_0075_SCWA_HHHV_SGF_993447_4690_538777396 acquired** 2x Multinet casts to 1000 m On the ice: Optics-015 & LISST-015
14/08/22 (Sunday) *Day 27* *9 days remaining*	**RS2_20220814_064347_0075_SCWA_HHHV_SGF_993648_4701_53877742 acquired** **Nansen Basin Sea Ice Station ends (**Gangway up 20:30) Phytoplankton net cast to 50 m Bongo net cast to 1000 m
15/08/22 *Day 28* *8 days remaining*	**RS2_20220815_075450_0076_SCWA_HHHV_SGF_993880_4728_53877745 acquired** CTD 181 & CTD 182 & CTD 183 & MSS 095 & MSS 096 CTD 184 CTD 185 CTD 185 & MSS 097 & MSS 098 Optics-016 & LISST-016 **Mooring Nansen-1 Released at N 83° 56.566' E 022° 15.038' 16:53:33 UTC** Echo sounder survey to verify depth of mooring components (mooring verified below 400 m).
16/08/22 *Day 29* *7 days remaining*	CTD 186 CTD 187 & CTD 188 & MSS 099 & MSS 100 & Optics-017 & LISST-017 CTD 189 CTD 190 & MSS 101 & MSS 102 CTD 191
17/08/22 *Day 30* *6 days remaining*	CTD 192 & CTD 193 & & MSS 103 & MSS 104 Optics-018 & LISST-018 Mammouth Multinet Cast 1 x MIK net cast CTD 194 CTD 195 & Optics-019 Easterly gale force 8 over banks north of Svalbard, work with profiling instruments paused at 19:00 due to rough sea state. Conditions improving after 23:00. KPH continues along main transect at 4-6 kts collecting acoustic measurements.
18/08/22 *Day 31* *5 days remaining*	Harstad trawl 13:00 Sea state improved – transit north to complete CTD stations skipped during gale period CTD 197 & CTD 198 & MSS 110 & MSS 111 CTD 199 CTD 200 & MSS 112 & MSS 113
19/08/22 *Day 32* *4 days remaining*	CTD 201 CTD 202 & CTD 203 & MSS 114 & MSS 115 VITO Trawl Transit to Hinlopen

20/08/22 (Saturday) *Day 33* *3 days remaining*	Arrival Hinlopen VITO bottom trawl Transit to Longyearbyen
21/08/22 (Sunday) *Day 34* *2 days remaining*	KPH arrives Longyearbyen (town quay) 12:30 Loading/unloading equipment
22/08/22 *Day 35* *1 day remaining*	Loading/unloading equipment KPH leaves departs town quay 06:00
23/08/22 *End* *0 days remaining*	Cleaning laboratories, common work areas **Cruise participants put ashore with small boat 11:00-12:00**

Shipboard CTD measurements

Contact: Paul A. Dodd

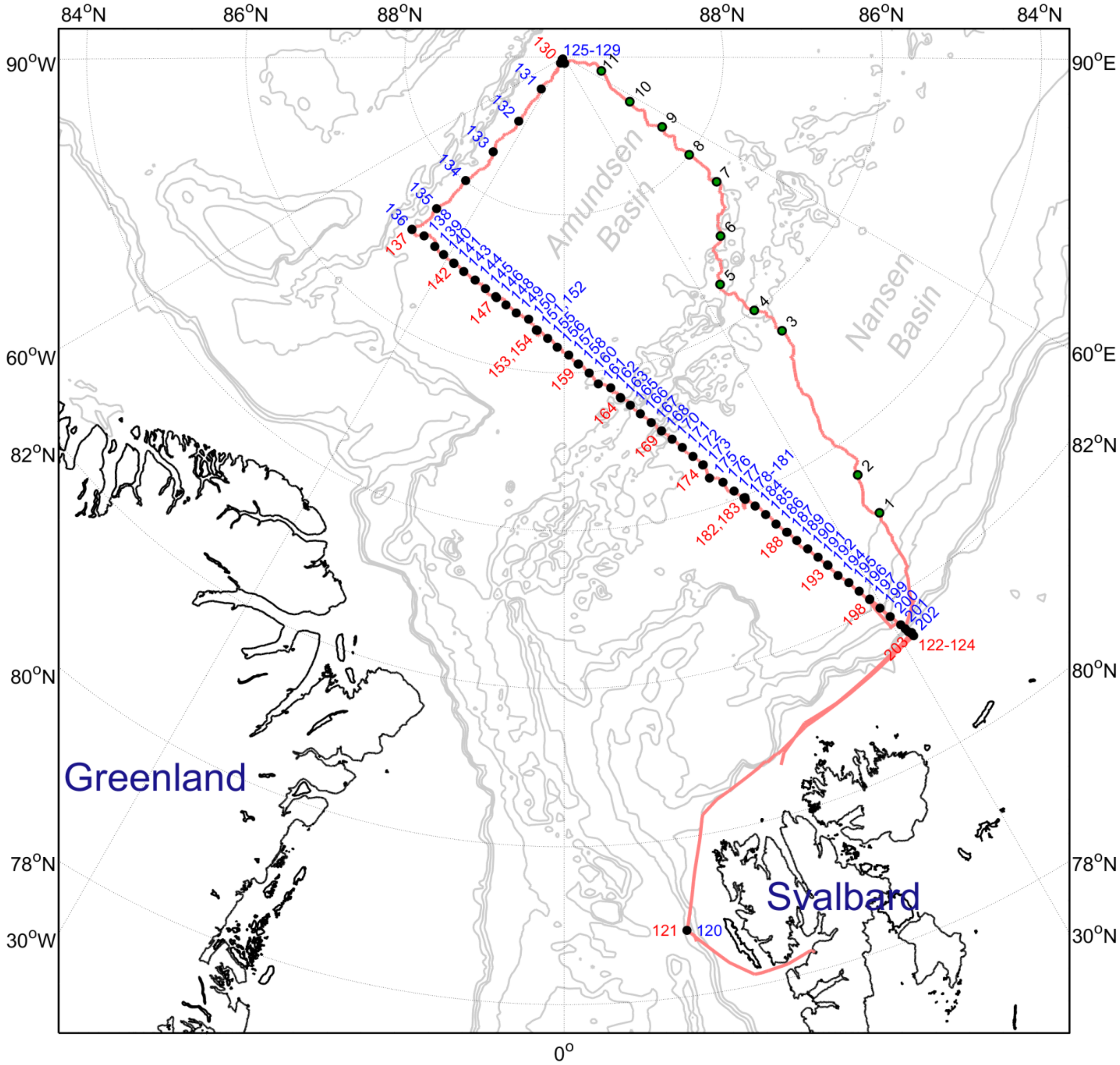


Figure 1. Location of CTD profiles. Blue numbers indicate profiles collected through the moonpool using the main CTD. Red numbers indicate profiles collected over the side using the auxiliary CTD.

General Approach

CTD stations were positioned at 10 nm increments along a great section starting at the A-TWAIN array and extending North-westward along an initial bearing of 150 degrees (Figure 1). Full depth (A), intermediate (B) and shallow (C) stations were arranged in a repeating A-C-B-C pattern so as to provide a closer horizontal spacing at the surface and intermediate depths. Over the Gakkel ridge, (B) stations were also extended to full depth to capture water masses circulating along the slope (Figure 2).

Two shipboard CTD systems were used during the cruise. The main 24-bottle CTD was lowered though the moon pool at every station. At (A) stations an auxiliary 12-bottle CTD was also lowered over the side of the vessel to capture the upper 8-10 m which is missed by the main CTD as it emerges from the moonpool at a depth of 8 m. Note that the upper 8 m of profiles taken through the moonpool describes water trapped in the moon pool and not the natural environment.

The main and auxiliary CTDs were both SBE911+ units (Table 1 and 2). To avoid problems with icing the T, S and O_2 ducts were not flushed between stations – an extended surface soak was specified to account for this. At the beginning of stations, the CTD was lowered to 20 dbar and allowed to soak for 2 minutes after the pump started. After the soak was complete and sensors stabilised the CTD was brought to the surface (or moonpool aperture) and then lowered. Data acquisition was initiated just before deployment with the CTD on deck and allowed to run until the CTD was back on deck at the end of the cast.
Niskin bottles were closed using the bottle fire command within the Sea-Bird acquisition software so that a .bl file was created for each deployment when bottles were fired. NMEA time and position information was fed to the acquisition computer and added to each scan line of the data files. Cast starting times were automatically added to the header of all data files.

Note that the first station completed during AO-2022 has the number 122 and not 001. The vessel operators specify numbers assigned to CTD stations. The first cast each year has the number 1 and each subsequent cast is numbered sequentially.

During the cruise a paper log sheet was completed for each CTD cast listing the depths at which bottles were fired and the serial numbers of water samples taken from each bottle. Scanned images of these paper log sheets are included in Appendix 1 at the end of this report.

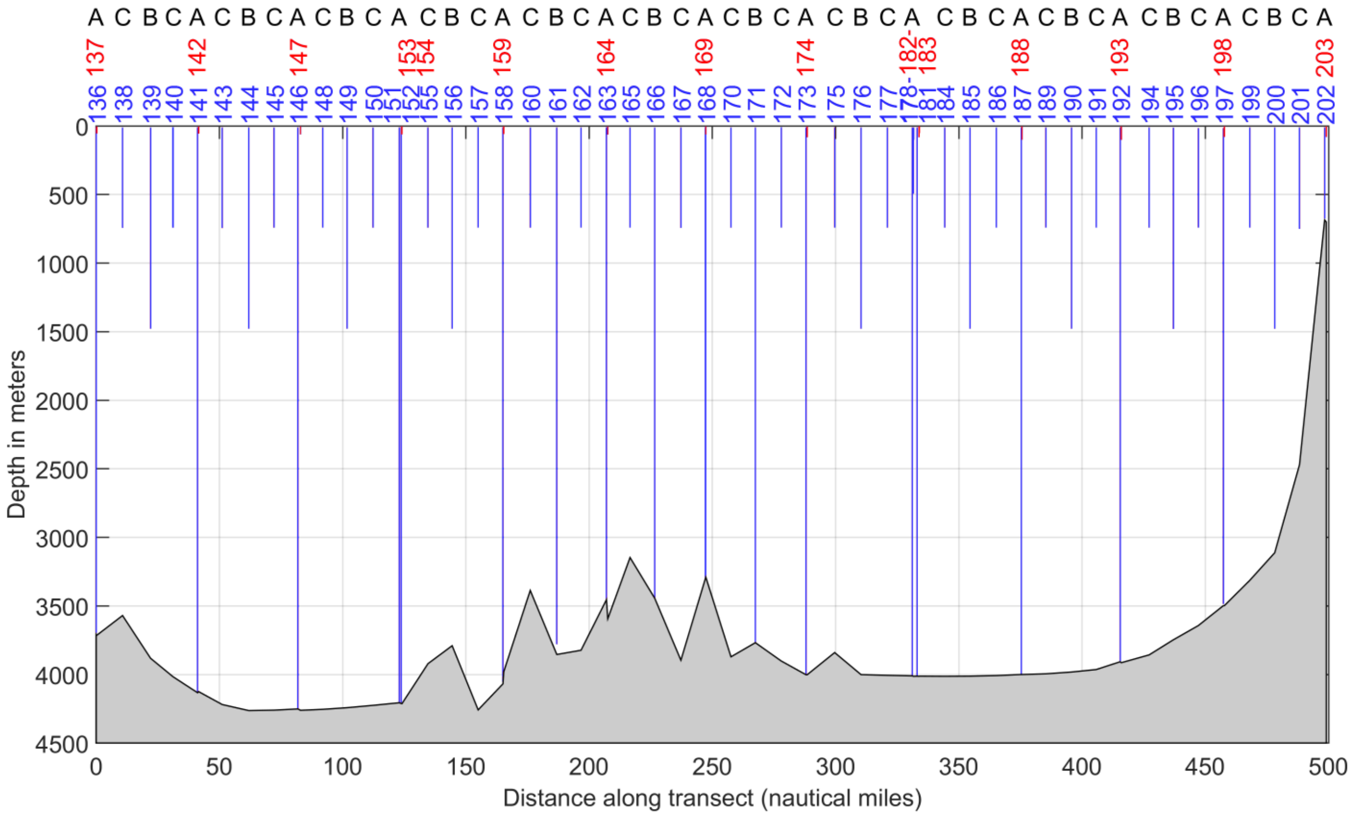


Figure 2. Vertical extent of CTD profiles along the main section. Blue lines and profile numbers indicate profiles collected through the moonpool using the main CTD. red lines and numbers indicate profiles collected over the side using the smaller auxiliary CTD.

Table 1. Main (moonpool) CTD package configuration

Channel	Sensor	Serial Number	Last Calibration
Frequency	SBE03 Temperature 1	6498	21-Jan-22
Frequency	SBE04 Conductivity 1	4726	25-Jan-22
Frequency	SBE09 Pressure	141612	19-Dec-17
Frequency	SBE03 Temperature 2	5458	26-Jan-22
Frequency	SBE04 Conductivity 2	4221	25-Jan-22
A/D Voltage 0	SBE43 Oxygen 1	3937	10-Mar-22
A/D Voltage 1	Altimeter	73084	24-Dec-2017
A/D Voltage 2	WET Labs Chl. A	FLRTD-6506	18-Sep-2020
A/D Voltage 3	None	-	-
A/D Voltage 4	Transmissometer	CST-2003DR	01-Oct-2019
A/D Voltage 5	WET Labs CDOM	FLCDRTD-1930 (stn <= 134) FLCDRTD-4531 (stn >= 135)	25-Aug-2019
A/D Voltage 6	Biosph. Licor PAR	70736	29-Oct-2018
A/D Voltage 7	SBE43 Oxygen 2	3648	10-Mar-22

Table 2. Auxiliary (over-the-side) CTD package configuration

Channel	Sensor	Serial Number	Last Calibration
Frequency	SBE03 Temperature 1	2400	26-Apr-22
Frequency	SBE04 Conductivity 1	3447	05-May-22
Frequency	SBE09 Pressure	0972	20-Feb-14
Frequency	SBE03 Temperature 2	4052	24-May-22
Frequency	SBE04 Conductivity 2	3234	05-May-22
A/D Voltage 0	WET Labs CDOM	FLCDRTD-4531 (stn<= 134) FLCDRTD-1930 (stn >= 135)	17-Dec-2021
A/D Voltage 1	None	-	-
A/D Voltage 2	WET Labs Chl. A	FLRTD-1547	1-Mar-2016
A/D Voltage 3	None	-	-
A/D Voltage 4	None	-	-
A/D Voltage 5	None	-	-
A/D Voltage 6	Altimeter	70736	-
A/D Voltage 7	None	-	-

Validation of CTD salinity measurements

Water samples for laboratory salinity measurement were collected at all sampling depths and analysed on broad using Guildline Portasal portable salinometer (see Salinity, p.24). Comparison of laboratory salinity measurements and CTD-salinity measurements revealed offsets of +0.005 +/- 0.002 and +0.007 +/- 0.002 practical salinity units for the primary and secondary sensor groups of the main CTD system and offsets of -0.004 +/- 0.001 and -0.001 +/- 0.001 practical salinity units for the primary and secondary sensor groups of the auxiliary CTD system.

All temperature and salinity sensors performed well during the cruise and the offsets determined relative to the laboratory salinity measurements are insignificant considering the expected accuracy of +/- 0.003 for the laboratory salinometer. The normal distribution of sensor – laboratory differences give additional confidence that the sensors performed consistently well.

Validation of CTD dissolved oxygen measurements

Water samples for laboratory oxygen measurement were collected at selected depths from several casts at the beginning and end of the cruise (see Dissolved Oxygen p. 21). Comparison of laboratory oxygen measurements and CTD-oxygen measurements revealed mean offsets of -11.6. +/- 4.9 and -18.5 +/- 4.9 for the primary and secondary oxygen sensors of the main CTD system (Figure 4), these offsets are large enough to justify correction of dissolved oxygen profiles. It was not possible to analyse enough laboratory oxygen samples onboard to track sensor drift though time, but this can be evaluated by comparing oxygen values measured in deep water masses (not shown). The primary oxygen sensor appeared to drift by ca 10 umoll-1 during the cruise, while the secondary sensor collected consistent deep-water readings for the duration of the cruise. The secondary sensor is therefore the preferred source of dissolved oxygen profiles.

Preliminary calibration of chlorophyll-A measurements from CTD fluorometer

Water samples for chlorophyll-A measurement were collected at selected depths along the main section (see p. 21). A preliminary regression analysis of CTD-derived chlorophyll-A values and laboratory derived chlorophyll-A values where all measurements were included in a single general analysis (summarised in Figure 3) suggests a calibration of the form corrected value = 0.61 x measured value + 0.006.

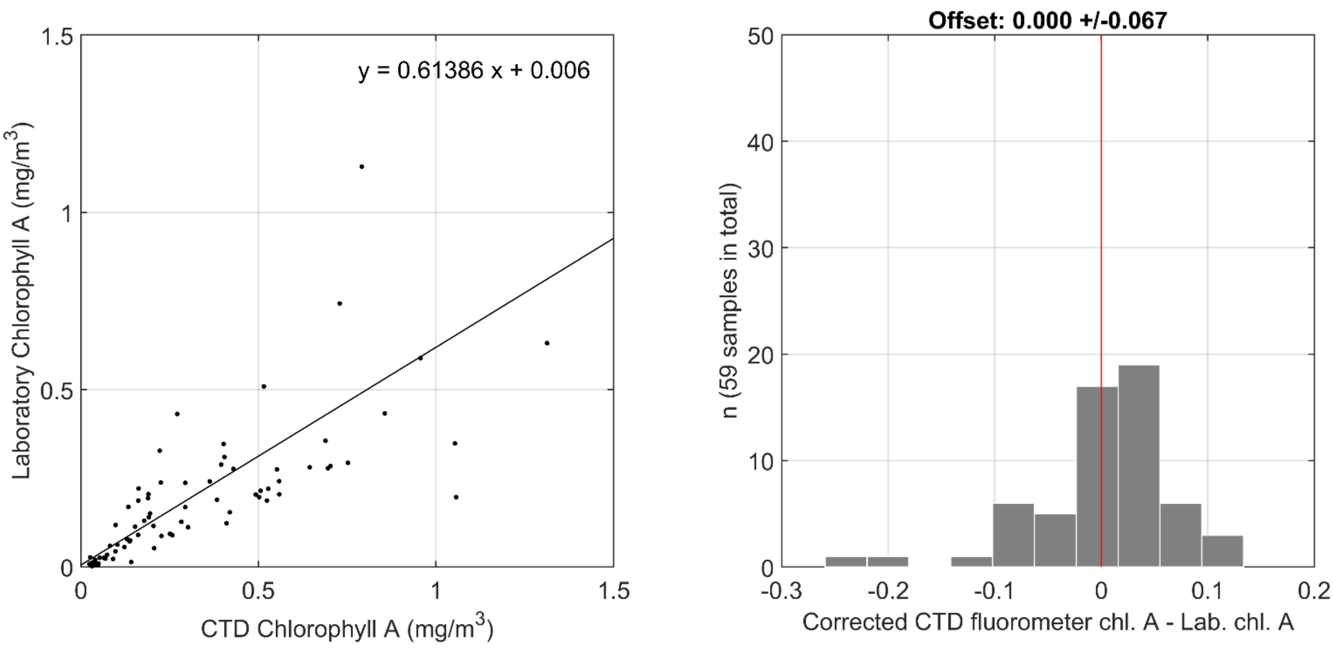


Figure 3. Preliminary calibration of CTD chlorophyll-A fluorometer.

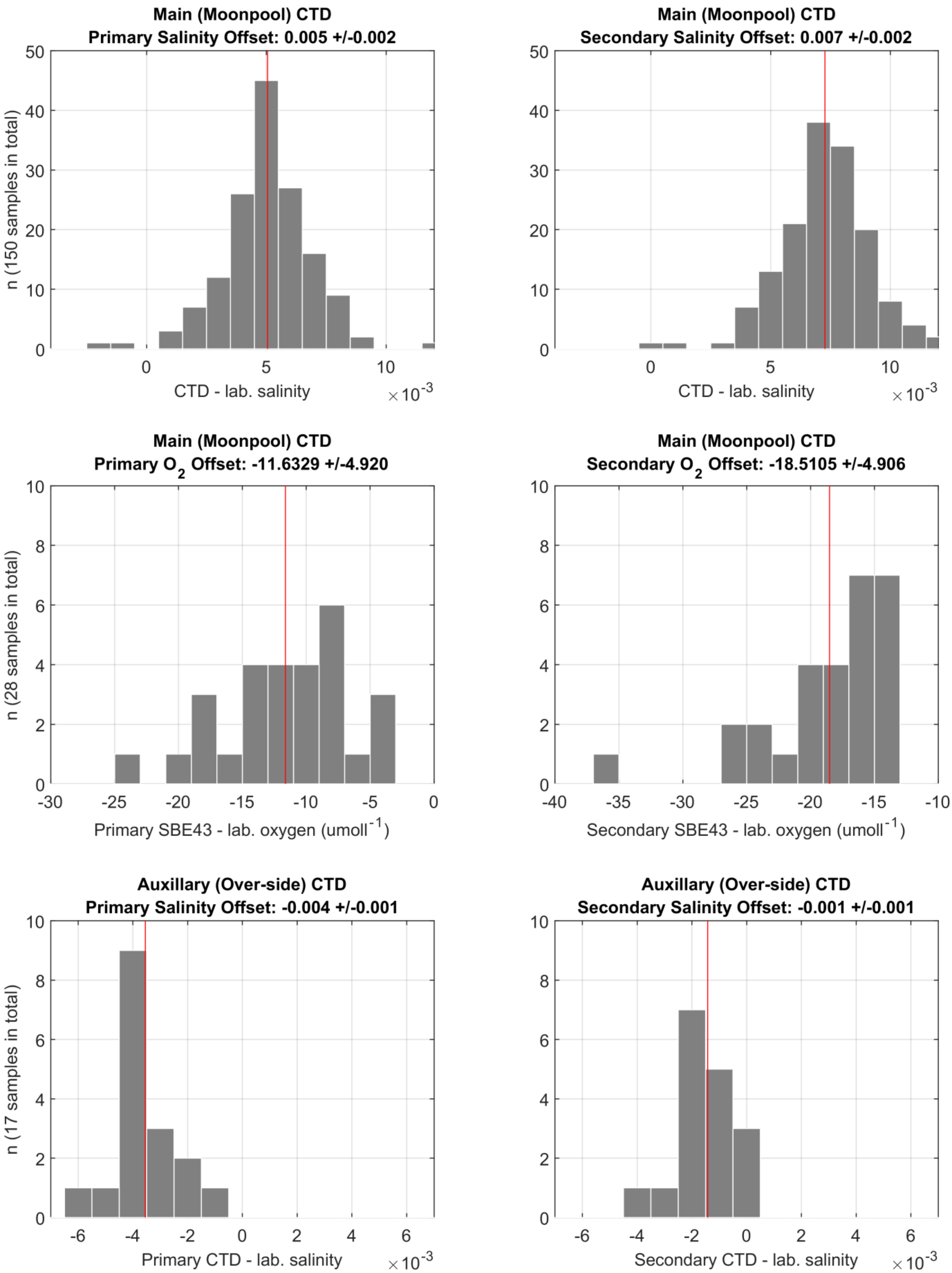


Figure 4. Histograms showing the difference between the primary (left hand panels) and secondary (right hand panels) sensor groups on the CTD and laboratory salinity and dissolved oxygen measurements. Only points deeper than 400 m are considered for salinity validation, due to step salinity gradients close to the surface.

Temperature and salinity along the main section

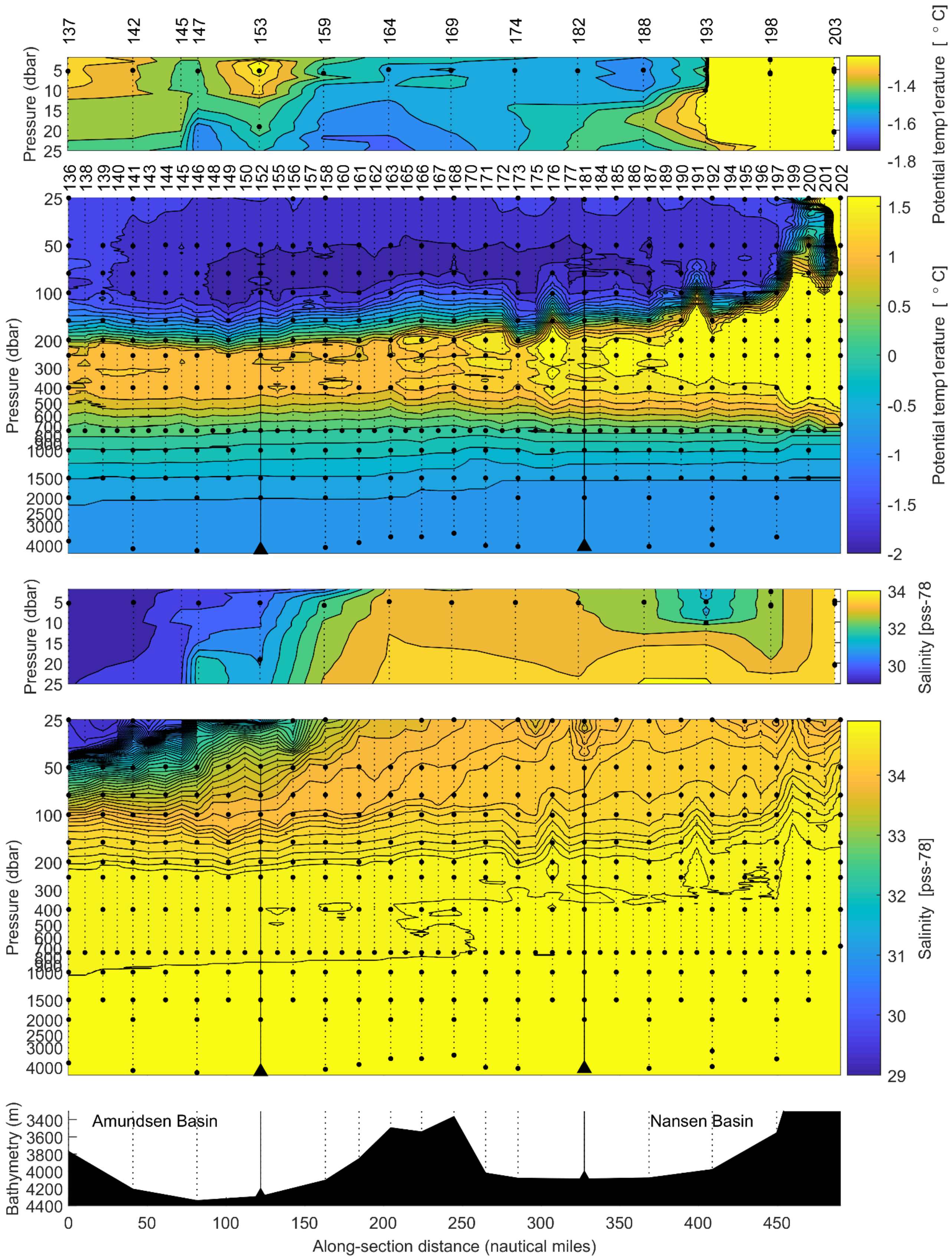


Figure 5. Temperature and salinity measurements along the main section from the main CTD (panels 2 & 3) and auxiliary CTD (panels 1& 3). Station numbers are indicated above sections. Niskin closing depths are shown as black dots. Mooring locations are shown as a solid line extending from a black triangle.

Chlorophyll-A and CDOM along the main section

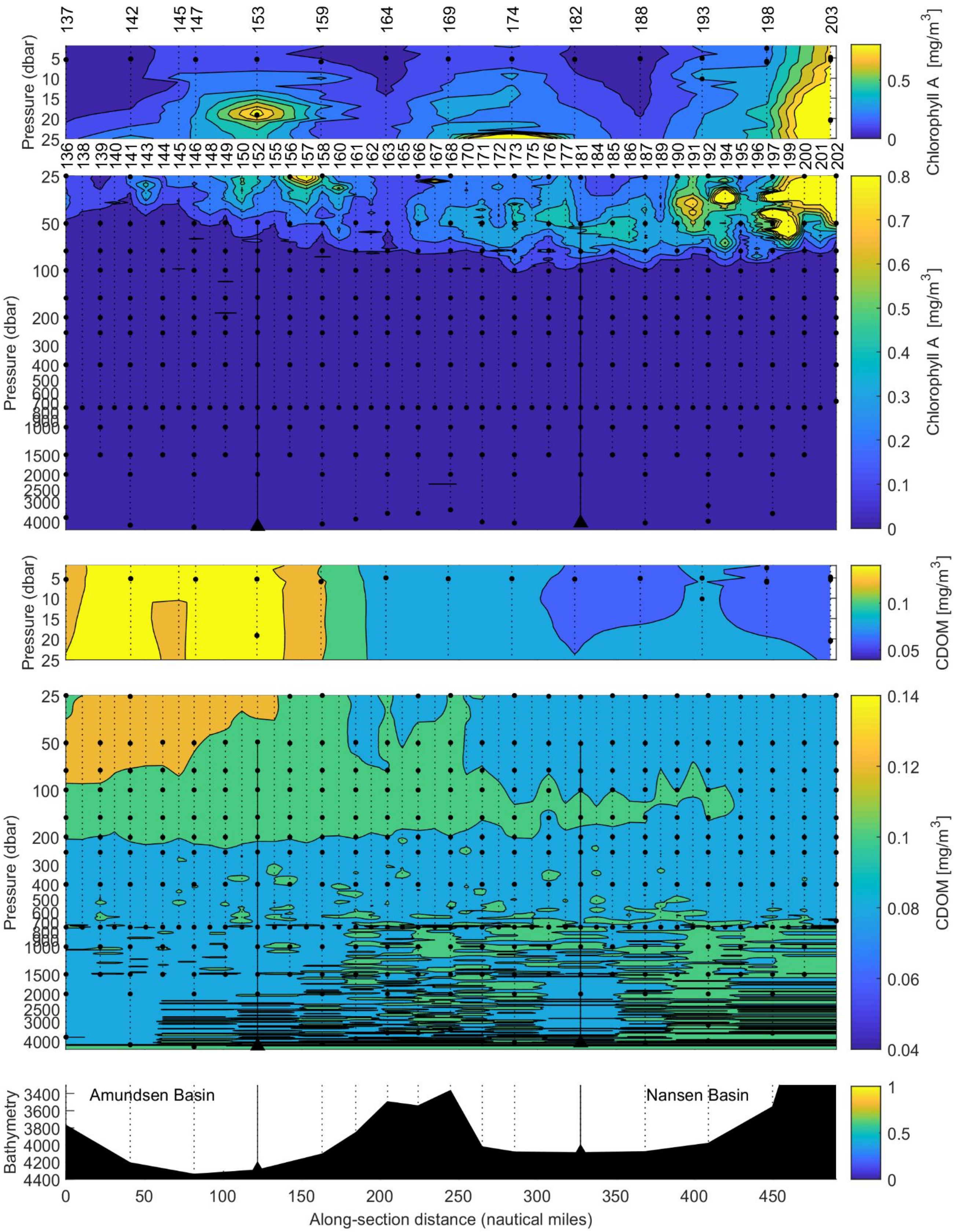


Figure 6. Chlorophyll-a and CDOM measurements along the main section from the main CTD (panels 2 & 3) and auxiliary CTD (panels 1& 3). Station numbers are indicated above sections. Niskin closing depths are shown as black dots. Mooring locations are shown as a solid line extending from a black triangle.

Table 3. Summary of CTD casts. Distances for CTDs along the main section are calculated relative to CTD136 at the northwest end of the section and can be used to quickly identify casts at the same location.

CTD #	Location / Distance (nm)	Cast depth (m)	Echo depth (m)	Latitude (dd)	Longitude (dd)	Time (UTC)
120	Fram Strait	903	1000	N 78.833	E 008.000	22-Jul-2022 16:34
121	Fram Strait	1002	1007	N 78.833	E 008.000	22-Jul-2022 18:33
122	A-TWAIN	479	480	N 81.458	E 031.077	24-Jul-2022 06:01
123	A-TWAIN	819	819	N 81.536	E 030.862	24-Jul-2022 07:21
124	A-TWAIN	1537	1529	N 81.589	E 030.767	24-Jul-2022 09:29
125	North Pole	198	4180	N 89.920	E 005.124	28-Jul-2022 12:20
126	North Pole	4214	4170	N 89.972	W 036.036	28-Jul-2022 15:53
127	North Pole	497	Not measured	N 89.957	W 036.872	28-Jul-2022 20:39
128	North Pole	99	Not measured	N 89.951	W 031.485	28-Jul-2022 21:56
129	North Pole	4213	4220	N 89.944	W 028.114	28-Jul-2022 23:04
130	North Pole	50	4215	N 89.912	W 030.659	29-Jul-2022 04:05
131	on route	987	4216	N 89.505	W 035.323	31-Jul-2022 00:55
132	on route	987	4143	N 89.008	W 035.060	31-Jul-2022 08:39
133	on route	988	Not measured	N 88.506	W 036.596	31-Jul-2022 17:35
134	on route	988	Not measured	N 88.007	W 038.348	01-Aug-2022 04:51
135	on route	987	3768	N 87.500	W 039.876	01-Aug-2022 17:19
136	0	3697	3714	N 87.098	W 041.227	02-Aug-2022 07:11
137	0	54	3714	N 87.101	W 041.276	02-Aug-2022 11:29
138	11	743	3570	N 87.133	W 037.870	02-Aug-2022 18:33
139	22	1479	3882	N 87.103	W 034.143	02-Aug-2022 23:34
140	31	742	4016	N 87.076	W 031.210	03-Aug-2022 02:52
141	41	4127	4133	N 87.046	W 028.019	03-Aug-2022 05:48
142	42	55	4125	N 87.041	W 027.912	03-Aug-2022 10:13
143	51	745	4219	N 87.005	W 024.920	03-Aug-2022 14:05
144	62	1479	4263	N 86.963	W 021.611	03-Aug-2022 18:08
145	72	742	4260	N 86.905	W 018.616	03-Aug-2022 23:10
146	82	4253	4251	N 86.847	W 015.840	04-Aug-2022 03:02
147	83	61	4261	N 86.837	W 015.580	04-Aug-2022 08:36
148	92	741	4254	N 86.777	W 013.107	04-Aug-2022 12:17
149	102	1479	4242	N 86.704	W 010.515	04-Aug-2022 16:07
150	112	742	4225	N 86.650	W 007.641	04-Aug-2022 21:22
151	123	4202	4206	N 86.522	W 005.561	05-Aug-2022 01:12
152	124	4205	4211	N 86.528	W 005.750	07-Aug-2022 02:39
153	124	61	4213	N 86.523	W 005.752	07-Aug-2022 07:22
154	124	50	4213	N 86.523	W 005.750	07-Aug-2022 08:30
155	135	742	3921	N 86.430	W 003.309	07-Aug-2022 18:27
156	144	1479	3790	N 86.324	W 001.347	07-Aug-2022 22:42
157	155	741	4258	N 86.225	E 000.894	08-Aug-2022 04:48
158	165	4056	4068	N 86.108	E 002.686	08-Aug-2022 08:23
159	165	58	3980	N 86.108	E 002.610	08-Aug-2022 12:51
160	176	742	3387	N 85.986	E 004.515	08-Aug-2022 16:44
161	187	3779	3854	N 85.838	E 005.948	08-Aug-2022 22:21
162	197	741	3823	N 85.770	E 007.985	09-Aug-2022 06:07
163	207	3475	Not measured	N 85.631	E 009.342	09-Aug-2022 10:21

CTD #	Location / Distance (nm)	Cast depth (m)	Echo depth (m)	Latitude	Longitude	Time (UTC)
164	208	62	Not measured	N 85.623	E 009.382	09-Aug-2022 14:33
165	217	741	Not measured	N 85.513	E 010.713	09-Aug-2022 18:59
166	227	3475	Not measured	N 85.382	E 012.006	10-Aug-2022 01:02
167	237	743	Not measured	N 85.242	E 013.344	10-Aug-2022 07:40
168	247	3301	3297	N 85.110	E 014.544	10-Aug-2022 12:48
169	247	61	3290	N 85.109	E 014.523	10-Aug-2022 16:33
170	258	742	3871	N 84.973	E 015.706	10-Aug-2022 21:13
171	267	3942	3768	N 84.838	E 016.769	11-Aug-2022 01:09
172	278	741	3902	N 84.690	E 017.802	11-Aug-2022 07:31
173	288	4000	4002	N 84.549	E 018.761	11-Aug-2022 11:00
174	288	82	4002	N 84.549	E 018.685	11-Aug-2022 15:25
175	300	741	3840	N 84.365	E 018.963	11-Aug-2022 20:22
176	310	1479	4001	N 84.257	E 020.403	12-Aug-2022 00:58
177	321	742	4006	N 84.104	E 021.298	12-Aug-2022 05:08
178	331	4010	4010	N 83.964	E 022.189	12-Aug-2022 08:25
179	332	494	4013	N 83.956	E 022.185	12-Aug-2022 16:38
180	332	99	4013	N 83.955	E 022.176	12-Aug-2022 17:43
181	333	4009	4012	N 83.977	E 022.235	15-Aug-2022 03:09
182	334	82	4013	N 83.978	E 022.113	15-Aug-2022 08:22
183	334	51	4012	N 83.975	E 022.114	15-Aug-2022 09:31
184	344	741	4013	N 83.829	E 022.962	15-Aug-2022 19:22
185	355	1479	4012	N 83.677	E 023.687	15-Aug-2022 23:09
186	365	741	4008	N 83.514	E 024.319	16-Aug-2022 03:13
187	375	3996	4000	N 83.365	E 025.017	16-Aug-2022 06:19
188	376	100	4000	N 83.363	E 025.056	16-Aug-2022 10:33
189	385	741	3995	N 83.216	E 025.616	16-Aug-2022 14:27
190	396	1479	3982	N 83.061	E 026.267	16-Aug-2022 18:07
191	406	741	3964	N 82.909	E 026.838	16-Aug-2022 22:06
192	415	3902	3907	N 82.760	E 027.359	17-Aug-2022 00:45
193	416	101	3914	N 82.768	E 027.342	17-Aug-2022 04:59
194	427	742	3857	N 82.588	E 027.771	17-Aug-2022 15:29
195	437	1480	3747	N 82.444	E 028.373	17-Aug-2022 18:39
196	447	741	3643	N 82.287	E 028.846	17-Aug-2022 22:07
197	457	3486	3498	N 82.131	E 029.315	18-Aug-2022 14:25
198	458	80	3498	N 82.136	E 029.351	18-Aug-2022 18:08
199	468	741	3313	N 81.973	E 029.760	18-Aug-2022 20:51
200	478	1479	3112	N 81.815	E 030.170	18-Aug-2022 23:15
201	488	750	2470	N 81.660	E 030.605	19-Aug-2022 02:11
202	498	676	685	N 81.500	E 031.003	19-Aug-2022 04:13
203	499	80	700	N 81.506	E 031.073	19-Aug-2022 05:52

Parameters measured from Niskin bottle samples

Dissolved inorganic carbon

Contacts: Agneta Fransson & Bonnie Raffel

The dissolved inorganic carbon system describes the sum of dissolved CO2, carbonic acid, bicarbonate- and carbonate ions in seawater. It is used to investigate carbonate chemistry to study ocean acidification. Samples were taken first or after dissolved oxygen preserved with 50 µl saturated mercuric chloride and stored cold and dark for analyses of total alkalinity (AT) and dissolved inorganic carbon (DIC). Samples were collected at standard depths covering the full water column, and at selected stations, to 1500 m (see map Fig.1; Table 3). At three stations across the Gakkel Ridge samples were taken from surface to 1500 m depth and one near-bottom sample for calibration. For cross-calibration, at the Nansen Legacy station P6 samples were collected at standard depths to 400m and near-bottom. Additionally, under ice seawater samples were collected at ice stations 1, 6 and 8 (Table 19) at selected depths (interface, 1 m, 5 m, 10 m, 25 m). Additional surface samples were collected underway to the North Pole from the ship's seawater intake (see p. 35; Table 7).

Bacterial community composition using Meta-OMICS techniques

Contact: Venkatachalam Siddarthan and Ahammed Shereef

Bacterial communities play a crucial role in regulating biogeochemical processes and nutrient recycling of the ocean. In the present expedition, we aim to decipher the bacterial community composition and its role in the functioning of ecosystems through Metagenomics. The water samples were collected at four different depths namely, bottom water, 400M, Deep Chlorophyll Maximum (DCM), and Surface (5 m) across all type-A CTD stations along with station 133 (Figure 1). The collected water samples (about 4 litres /per filter) in triplicates were filtered by size fractionization method using 3 µm and 0.22 µm membrane filters (Merck-Millipore). The membrane filters containing microbial cell mass were frozen at -80º C and will be further analysed at the Polar Biology laboratory, National Centre for Polar and Ocean Research, India.

Chlorophyll-a

Contact: Megan Lenss

Chlorophyll-*a* (chl *a*) is a proxy for biomass of primary producing organisms. Seawater from 6 standard depths in addition to the depth of the chl *a* maximum was collected using a Niskin bottle rosette. A measured volume of water was filtered onto 25 mm Whatmann glass fiber filters and placed in 5 mL of methanol for extraction. Immediately following an 18-24 hour extraction period, samples were analyzed onboard using a Turner Trilogy Flourometer. Chl *a* samples were collected at type A CTD casts.

Oxygen isotope ratios

Contact: Paul A. Dodd

The parameter $\delta^{18}O$ describes the ratio of ^{18}O to ^{16}O isotopes in the H_2O molecule. $\delta^{18}O$ is a tracer for water which has at some point evaporated and is useful to separate sea ice meltwater from river input & precipitation. Seawater $\delta^{18}O$ samples were collected at selected stations and will be measured ashore using a dual-inlet mass spectrometer. Additional, under ice seawater samples were collected at ice stations 1, 6, 8 and 10 at the ice/water interface and depths of 1 m, 5 m, 10 m, 25 m.

Dissolved oxygen

Contact: Paul A. Dodd

Laboratory dissolved oxygen measurements are used to validate and (if necessary) calibrate the dissolved oxygen sensors on the CTD. Samples were collected at selected depths and stations. Triplicate samples were collected from each sampling depth in 3 x 125 ml volume-calibrated glass sample bottles. Samples were immediately preserved with Winkler reagents, stored under water and in the dark for > 24 hours before potentiometric titration with Sodium Thiosulphate using a Metrohm 916 Ti-touch titrator. An NPI internal laboratory standard 0.01 M NaI solution "NPI-OXY-1" prepared on 18-June-2021 was measured before each set of 24 samples.

Dissolved Organic Matter (DOM)

Contacts: (Rafael Gonçalves-Araujo, Shelby Buckley, Mats Granskog)

Dissolved organic matter: DOM is a ubiquitous component of aquatic systems, present in all natural waters, representing a major carbon reservoir. During the AO2022 cruise, samples for the analysis of different fractions of the DOM-pool were collected from both water samples and sea ice cores. Those samples were destined for both quantification and characterization of DOM, as well as for performing experiments. DOC, CDOM and FDOM samples for DOM analysis were directly gravity filtered through 0.22 µm pore size membrane filter cartridge into 40 ml acid-washed, pre-combusted amber glass vials. Ice core samples were filtered after melting, following the same procedure. The different analysis or experiments related to DOM samples are described below.

Dissolved organic carbon (DOC) concentrations: DOC samplers were collected from A and B type casts at standard depths. This provides a quantification of bulk dissolved organic carbon concentrations, which will be further used for studies concerning biogeochemistry and in the incubation experiments. Samples were immediately acidified to pH=2 with the addition of orthophosphoric acid and stored in 4°C. The samples will be shipped to the National Institute of Aquatic Resources, Technical University of Denmark (DTU Aqua), where Prof. Colin Stedmon's group will perform the analysis of DOC concentration using a Shimadzu TOC-VCPH analyzer after sparging with oxygen.

Colored (or chromophoric) dissolved organic matter (CDOM): CDOM is the DOM fraction that is colored (i.e., absorbs light) and can be often used as a proxy to describe the amount of DOM in a given natural water sample. After filtration the samples collected in type A and B casts at standard depths were stored in dark and brought to room temperature. Measurements were performed onboard with a Shimadzu UV-2550 UV-VIS spectrophotometer using a 10 cm long quartz cuvette. Absorbance was measured in the wavelength range 240 to 700 nm with 1 nm increments. The amount of CDOM is typically reported at a single wavelength (absorption coefficient m-1), while the spectral shape of the full spectra is used to indicate the composition or origin of CDOM.

Fluorescent dissolved organic matter (FDOM): FDOM is the CDOM fraction that can further emit light in longer wavelengths (i.e., fluorescence) after excitation with ultraviolet and/or visible light. FDOM is often used to describe the composition of DOM based on the different fluorophores identified in the respective water samples. FDOM samples were collected along with CDOM and DOC samples from type A and B casts (at standard sampling depths) and stored in dark until reached room temperature for analysis onboard. The measurements were performed with a HORIBA Aqualog Spectrofluorometer, where Excitation-Emission Matrices (EEMs) were acquired in the ranges of 240–450 nm at a 5 nm increment for excitation (i.e., absorbance) and 210-620 nm at a 3 nm increment for emission (i.e., fluorescence) using an 8 second integration time. The post corrections, data processing and isolation of underlying fluorescent peaks with Parallel Factor Analysis (PARAFAC) will be later conducted at DTU Aqua. The data can also be used to calibrate the FDOM fluorometers on the ship-CTD.

DOM Molecular Characterization: Solid phase extraction was used to isolate dissolved organic matter (DOM) from seawater and sea ice in preparation for Fourier Transform Ion Cyclotron Resonance Mass Spectrometry (FT-ICR MS) and Nuclear Magnetic Resonance (NMR) analysis for DOM molecular characterization. DOM seawater samples were collected in 4 L combusted and acid washed glass bottles from pressures 1.5, 10, 100, 750, 1000, and 2000 dbar at each A type station. Four ice cores were collected from the North Pole, Amundsen Basin, and Nansen Basin ice stations and melted in artificial seawater in a 2.5 °C refrigerator. All samples were immediately filtered using a 0.22 µm pore size filter, acidified to pH=2 using 12 N hydrochloric acid (HCl), and extracted using 100 mg Agilent Bond Elut cartridges. Cartridges were dried under air for at least 3 days and extracted using 6 mL of HPLC-grade methanol. DOM extracts were stored in 2.5 °C refrigerator until shipped under cool conditions.

Experiments for DOM photochemical transformation: Samples for DOM photochemical incubation experiments were taken from three depths (10, 50 and 100 m) at six selected stations and filtered through 0.22 µm filter cartridge immediately after sampling and stored in 4 °C until analysis. The samples were shipped to Denmark, where the photochemistry experiments will be conducted by Prof. Colin Stedmon's group at DTU Aqua. These results will shed light on the effects of sunlight on Arctic DOM and can be the motivation for studies focusing on the biogeochemical implications of an ice-free Arctic with higher exposure to sunlight.

Metabarcoding (DNA and RNA) of protists and prokaryotes

Contact: Megan Lenss

Metabarcoding provides information on the species and abundance of pelagic protists and prokaryotes. Samples for metabarcoding were collected in triplicate at 2 depths (15m and 50m) at the location of the mooring deployments in the Amundsen and Nansen Basins. Approximately 7L of water was filtered onto Sterivex filters to collect cells which will be used for DNA and RNA isolation once ashore. Sampling for metabarcoding was taken as a T-0 measurement for the RAS water samplers attached to the moorings.

Flow Cytometry

Contact: Megan Lenss

Flow cytometry provides information on the abundance and size distribution of microorganisms. Seawater from 6 standard depths in addition to the depth of the chl *a* maximum was collected using a Niskin bottle rosette at type A CTD casts for flow cytometry analysis. 1.8 mL of water was fixed with 25% glutaraldehyde for 2 hours at +4˚C before flash freezing at -80˚C. Samples will be further analyzed ashore.

Nutrients

Contacts: Melissa Chierici and Bonnie Raffel

The parameter inorganic nutrients include measurements of nitrate, nitrite, phosphate and silicate in seawater. Samples were collected for the full water column and at selected stations at standard sampling depths. Additional samples were collected along the way to the North Pole using the underway system (see p.35). The samples were preserved with 250 µl chloroform and kept cool and dark for post cruise analysis. Additionally, under ice seawater samples were collected at sea ice stations #1, 6 and 8 at the ice-water interface and selected depths of 1 m, 5 m, 10 m and 25 m.

Microplastic

Contacts: Vegard Stürzinger and Ingeborg Hallanger

Water samples for microplastics were taken at Ice station 1 (CTD profiles 126-129) and 8 (CTD profiles 178-180) using Niskin bottles mounted to the CTD through the moonpool of RV Kronprins Haakon. Samples were taken from the bottom, 1000 m, 500 m, 250 m, 100 m, 50 m, and 20 m.
To get adequate sample volume and replicates 12 bottles were fired at each depth which required several casts to collect all samples. At each depth 3 sets of 3 bottles were emptied in to a 50 µm metal sieve, which was later rinsed down using filtered freshwater in to a 500 ml Nalgene bottle which was stored in a freezer for preservation and transport. At each depth water from 3 Niskin bottles was collected for POC analysis. To account for pollution of the samples as soon as they came onboard the ship, an empty sieve was placed near the Niskin bottles during sieving of replicate two. This blank sample then followed the same procedure as regular samples.

Particulate absorption

Contacts: Håkon Sandven and Mats Granskog

Particulate absorption measurements were collected by filtering water from CTD Niskin-bottles, through GF/F 0.7 µm filters (diameter 25 mm). Here, particulate absorption is the absorption of visible light due to particles in the water and is linked to water constituents like phytoplankton and non-algal particles. For the most part, 1000 mL of water was used in the filtration. Samples were collected on A stations and depths were typically 5, 10, 25, 50, 75 and 100 meters, in addition to the chl-max. Some additional stations were sampled before starting on the main transect. At the Amundsen and Nansen ice stations, water samples were also collected from the ice floe, from 2 and 5 meters. In total, 120 particulate absorption filters were collected, which will be analyzed at HZG Geestadt after the cruise for particulate absorption and non-algal particle absorption (and the difference gives the absorption by pigments).

Particulate organic carbon/nitrogen (POC/PON)

Contact: Megan Lenss

POC/PON is a proxy for organic biomass in the water column. Seawater from 6 standard depths in addition to the depth of the chlorophyll-a maximum was collected using a Niskin bottle rosette. A measured volume of water was filtered onto pre-combusted Whatmann glass fiber filters. Filters were dried at 60˚C for approx. 24 hours and packed for further analysis ashore. POC/PON samples were collected from 6 standard depths in addition to the depth of the chl a maximum at type A CTD casts.

Phytoplankton Taxonomy

Contact: Megan Lenss

Samples for phytoplankton taxonomy are taken to understand the community composition of phytoplankton. Samples from 6 standard depths in addition to the depth of the chl a maximum was collected using a Niskin bottle rosette. 190 mL of sample was spiked with 0.8 mL of 25% glutaraldehyde and 20% hexamine-buffered formaldehyde for fixation and stored at +4˚C. Once ashore, fixed samples will be shipped to IOPAN (Sopot, Poland) for further identification and analysis.

Salinity

Contact: Paul A. Dodd

Laboratory salinity measurements are used to validate and (if necessary) calibrate conductivity sensors on the CTD. Salinity samples were collected at all depths on all casts (where multiple nicking were closed only one was sampled). 250 ml glass sample bottles were filled from Niskin bottles and analysed onboard using a Guildline Portasal salinometer (SN 70177). The air temperature remained at 19 +/- 2 °C for the duration of the cruise and the bath temperature was set at 21 degrees for the entire cruise. Samples were stored next to the salinometer for at least 24 hours before analysis and the salinometer was standardised with OSIL P-Series reference seawater before and after each batch of 24 samples.

Total suspended matter

Contact: Håkon Sandven

Total suspended matter measurements (TSM) were collected by filtering water from CTD Niskin-bottles, through GF/F 0.7 µm filters (diameter 47 mm); rinsed, baked and pre-weighted at University of Bergen. TSM (or suspended particulate matter) is the (dry) weight of particulate matter in the water column and can be a proxy for biomass in open waters. Between 3000 and 5500 mL of water was used in the filtration, depending on availability. Sampled depths were typically 5 meters and at the chl-max depth. Samples were collected at all “A” stations during the main transect, in addition to some extra stations before starting on the main transect. At the Amundsen and Nansen ice stations, water samples were also collected from the ice floe, from 2 and 5 meters. In total, 44 TSM filters were collected, which will be analysed at University of Bergen after the cruise.

Uranium-236 activity

Contact: Paul A. Dodd

Uranium-236 is an anthropogenic radionuclide released into the North Sea by reprocessing facilities in France and the UK. Releases are well documented, allowing the parameter to be used to trace Atlantic water entering the Arctic Ocean. 10 to 25 litre samples were collected from standard depths at selected stations. Samples will be analysed ashore at an accelerator mass spectrometer facility.

Lowered acoustic Doppler current profilers (LADCPs)

Contacts: Zoe Koenig and Morven Muilwijk

Two LADCP-profilers (RD Instruments) were mounted on the large 24 bottle CTD rosette to obtain vertical profiles of horizontal currents. The ADCPs are 6000-m rated, 300 kHz Sentinel Workhorses. The units received power from an external battery canister with a housing identical to that of the instruments. All three units are installed on the rosette in a balanced distribution to ensure minimum tilt. Each ADCP has the LADCP option installed. The ADCPs were configured to sample in master and slave mode to ensure synchronization. The master ADCP pointed downward (SN 24474) and the slave ADCP pointed upward (SN 24472). The compass of each instrument was last calibrated in Tromsø, in their respective orientation in 2018. The resulting compass errors were less than 4°. Because the batteries are in an external canister, we expect the compass calibration to be valid.

In total 28 profiles of LADCP were taken. The vertical bin size (and pulse length) was set to 8 m for each ADCP. Single ping data were recorded in beam coordinates, with blank distance set to zero.

Glider deployments

Contacts: Zoe Koenig and Laura de Steur

A SeaGlider and a Slocum V2 glider were deployed over the continental slope west of Svalbard close to position N 78 00’, E 008 00’ in about 1000 m water depth between 19:30 and 19:45 UTC on 22 July 2022. Two CTD casts were performed before the deployment CTD 120 (moonpool) and CTD 121 (over the side) to enable calibration of the sensors on the glider.

The Slocum glider will operate a section across Fram Strait along the latitude 78 50’ N between the continental shelf and the ice edge. The seaglider operates along a section further south in Fram Strait, as part of the Infrastructure project NorEMSO.

Gliders were deployed from the starboard side of the ship. The Seaglider was deployed first using a pin system around the fin at the tail. The Slocum glider was deployed with a pin system with a horizontal steel bar as it should be deployed flat. During the deployment, the ship maintained a straight course northward at about 2 knots.

Optical and light scattering measurements

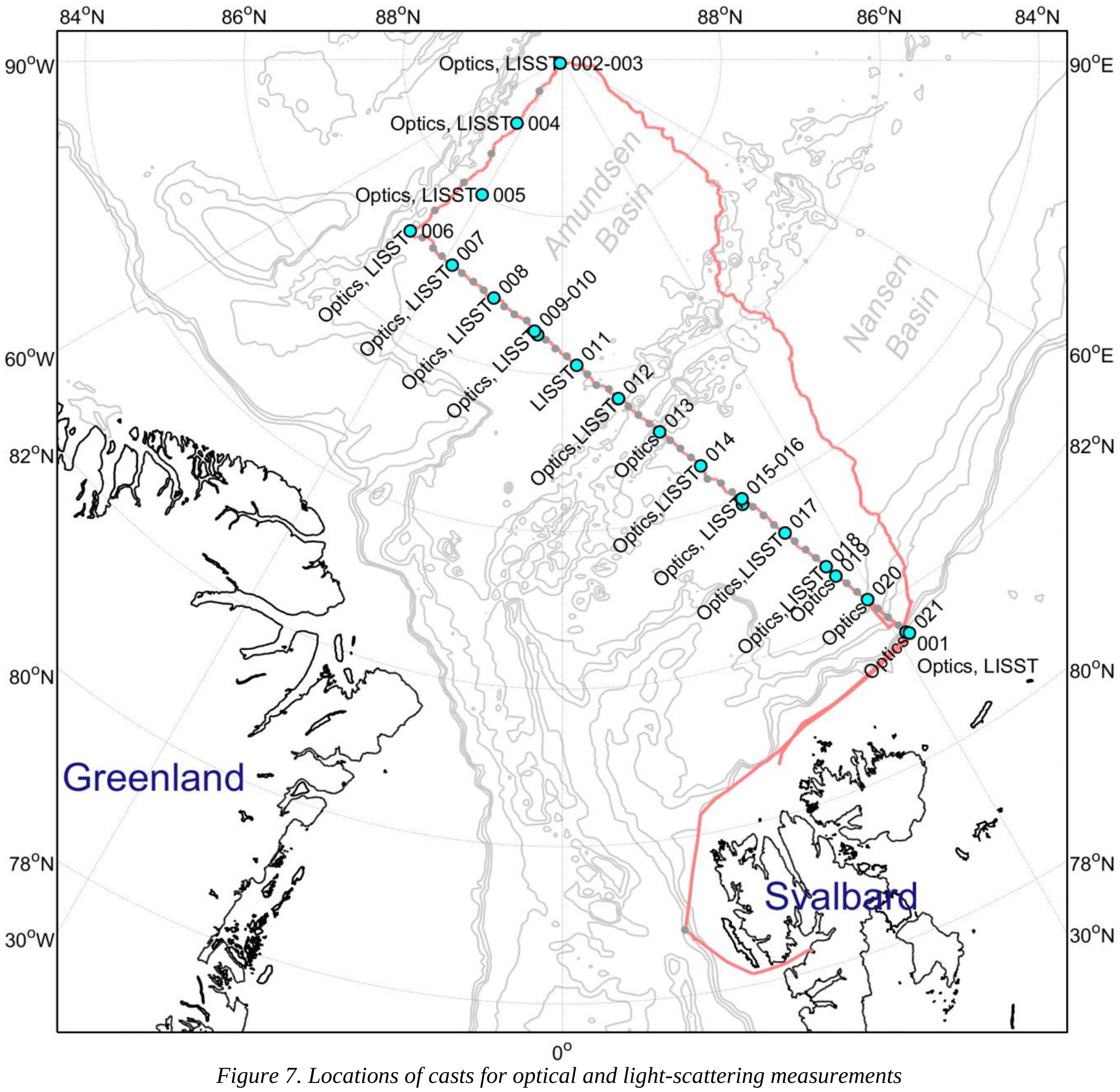


Figure 7. Locations of casts for optical and light-scattering measurements

Optical property measurements

Contacts: Håkon Sandven and Mats Granskog

Optical properties of the upper ocean (down to approx. 300 m depth) were measured using an instrument package for profiling deployment. The aim is to characterize the attenuation (absorption and scattering) of visible light in the water column, and relate this to the water properties (e.g. CDOM and particle absorption and scattering). The instrument package consisted of a SeaBird ac-s (NPI, SN 311), a SeaBird Eco FDOM fluorometer (DTU, SN 7470), a chl-a fluorometer (NPI, SN 725) and a SBE37 CTD (NPI, SN 20177). The SeaBird ac-s measures hyperspectral absorption and attenuation from 402 to 750 nanometers. This can be used to estimate chlorophyll and CDOM concentration with high vertical resolution, as well as the concentration of particulate matter. FDOM and chl a fluorometers also provides DOM and chl-a estimates, based on fluorescence.

The optical profiling package was deployed at all “A” stations during the main transect, in addition to some extra stations before starting on the main transect (see Figure 7). First, the optical profiler was lowered to 20 meters for allowing de-bubbling of the pumped systems and stabilization of the sensors. Then, the instrument package was brought to the surface before a profiling deployment was conducted down to about 350 meters. A descent speed of 0.4-0.5 meters was used to achieve good vertical resolution. At some stations, data was lost due to technical problems with the battery pack.

The optical package was also deployed at ice stations 1, 6 and 8 through a hole in the ice floe. It was then deployed down to a depth of 70-95 meters (limited by the length of the rope used for lowering the profiler). In total, 20 successful casts were done with the optical profiler.

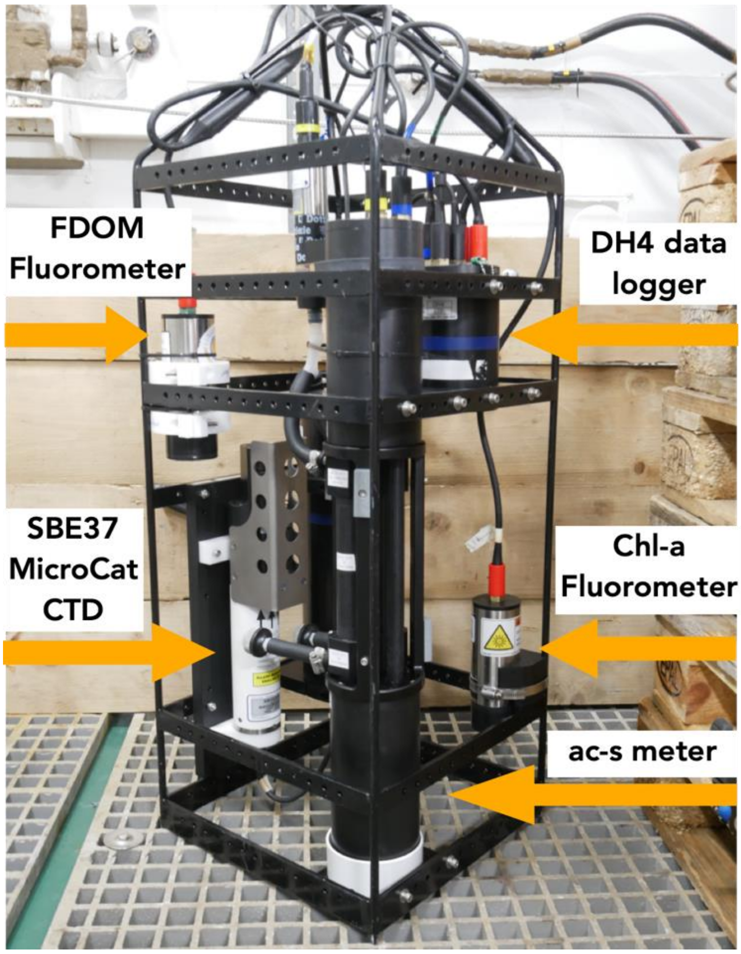


Figure 8. The optical profiler, with the different instruments and datalogger indicated (external battery pack is positioned behind the ac-s).

Table 4. Summary of optical profiler configuration.

Instrument	Serial number	Remarks
Wetlabs ac-s	311	In situ absorption and attenuation meter
Wetlabs DH4	277	Data logger
Seabird SBE 37 SIP	20177	CTD
Chla fluorometer		From NPI
CDOM fluorometer		From DTU
External battery pack		

Light scattering measurements

Contacts: Håkon Sandven and Mats Granskog

In situ optical measurements of particulate scattering were collected with a Sequoia Sci. LISST-VSF instrument (SN 1667). The instrument measures the volume scattering function (the angular distribution of scattered light) and the attenuation coefficient at 515 nanometers. Backscattering coefficients are accurately computed from the volume scattering function. The measured scattering properties can also be used to estimate suspended particle properties like particle size distributions or bulk refractive index.
The LISST-VSF was deployed from the shipside-CTD hangar at all "A" stations during the main transect, in addition to some extra stations before starting on the main transect. The cast was conducted immediately after deploying the optical profiler. The instrument measured at constant depths for 5 minutes. These constant depths corresponded to the same depths as the TSM water samples were collected from, typically 5 meters and the chl-max depth.

The LISST-VSF was also deployed at ice stations #1, 6 and 8 through a hole in the ice floe. It was then deployed at 2 and 5 meters. In total, 18 successful casts were done with the LISST-VSF.

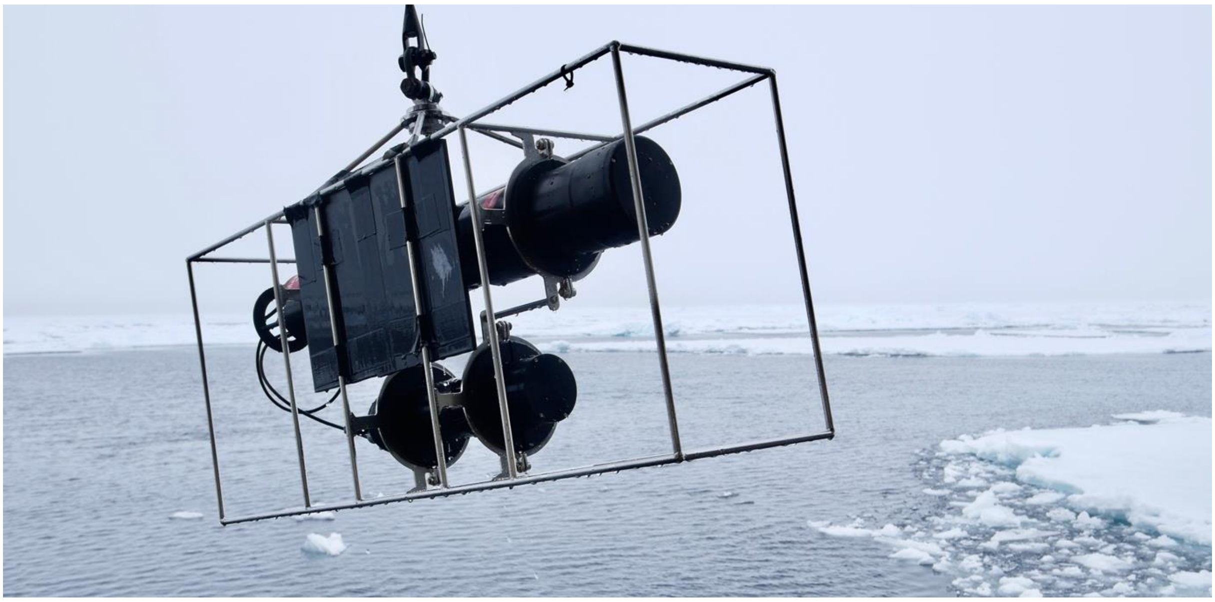


Figure 9. The LISST-VSF being recovered after deployment from the shipside CTD-hangar.

Microstructure and turbulence measurements (MSS)

Contacts: Zoe Koenig and Morven Muilwijk

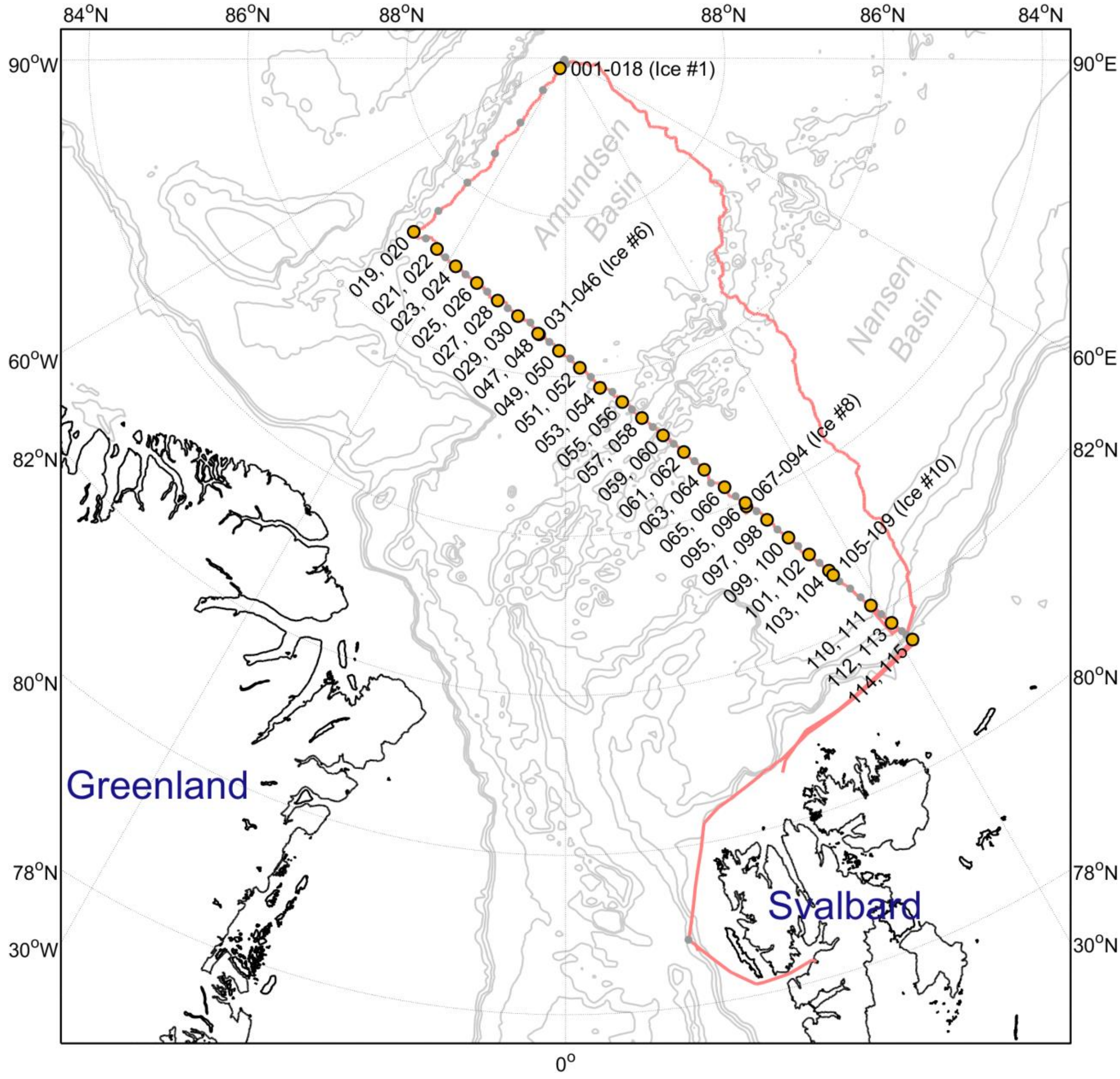


Figure 10. Locations of MSS casts

Microstructure profiling during the cruise was performed using an MSS (Microstructure Sensor Profiler, Sea & Sun Technology, Germany).

MSS configuration: Ocean microstructure measurements were made using the MSS90L profiler (SN 053), a loosely-tethered free-fall instrument equipped with two airfoil probes aligned parallel to each other, a fast-tip thermistor (FP07), an acceleration sensor, conventional CTD sensors for precision measurements and a Chlorophyll a fluorescence sensor. The shear probes used were SN116 (sensitivity 3.59e-04, SHE2) and SN149 (sensitivity 3.52e-4, SHE1). After cast 52, the instrument was swapped for MSS046 as sh1 on MSS053 show signed of degradation (data nosier). MSS046 does not have a Chlorophyll a fluorescence sensor. The shear probes on MSS046 were SN032 (sensitivity 3.86e-04, SHE1) and SN033 (sensitivity 4.59e-04, SHE2). 4 weight rings were also used for this profiler.

The sensors point downward when the instrument profiles vertically, and all sample at 1024 Hz. The instrument is ballasted for a typical fall speed of 0.6-0.7 m s^{-1} and is decoupled from operation induced tension by paying out cable at sufficient speed to keep it slack. Data are transmitted in real time to a ship-board data acquisition system. The casts were done using 4 ring weights. In total 115 casts were done. The profiler is equipped with a sensor protection guard at the leading end. Two different setups of the MSS were implemented, depending on if it was operated from the ship or from the sea ice.

Profiling from the ship: The deployment of the MSS from the ship was done from the starboard side, from the "small" CTD room. A motor-driven winch was mounted on several pallets and an arm was used to extend the cable from the winch to outside. The profiler was lowered in the water and brought back on board by pulling on the data cable transmission by hand. One to two casts were performed at each station. Because of the keel of the ship, the upper 12 m of each cast were excluded from dissipation estimates.

Profiling during ice stations: The MSS was operated from the sea ice during the ice stations. We deployed the MSS through an around 0.7 m x 0.7 m hole. The hole was ideally located approximately 150-200 m away from the ship, ensuring sampling of undisturbed waters. A manual winch was set up by the hole, 4 to 5 sets of 2 to 3 casts each were performed each day. See Table 5 for a total overview of the casts.

Overview of different ice stations: At the North Pole ice station (#1), the MSS was deployed at Site 5 (Figure 33), only about 100 m away from ship. This was not ideal because of the influence from the ship on turbulence measurements, but this was the maximum distance that could be reached regularly under foggy weather conditions. The site was characterized by thick (1.8m) level ice with thin layer of slushy snow. There were no large ridges in vicinity of the MSS hole. Weather was calm and drift speed was low. At the Amundsen Basin ice station (#6), the MSS was deployed through a large ice hole at Site 1 (Figure 38), located approximately 150 m from the ship. The site was shared with ROV operations and used also for optical and LISST casts. The location was characterized by level ice (1.8 m) covered with multiple melt ponds and surrounded by ridges and deformed ice in all directions. The ice was soft and mushy. Approximately 40 m away from Site 1 was a large ridge with a 3 m sail. Weather was calm and drift speed was nearly zero.

*Table 5. Summary of MSS casts. *Planned site refers to sites listed in the original cruise plan*

MSS File (.mrd)	Date	Time UTC	Ship/ice	Closest CTD cast	Planned Site*	Comments
001	29/07/2022	13:00	Ice	N/A		Test cast
002	29/07/2022	16:00	Ice	N/A		Ice station 1 (North Pole)
003	29/07/2022	16:00	Ice	N/A		Ice station 1 (North Pole)
004	29/07/2022	16:00	Ice	N/A		Ice station 1 (North Pole)
005	29/07/2022	21:00	Ice	N/A		Ice station 1 (North Pole)
006	29/07/2022	21:00	Ice	N/A		Ice station 1 (North Pole)
007	30/07/2022	4:00	Ice	N/A		Ice station 1 (North Pole)
008	30/07/2022	4:00	Ice	N/A		Ice station 1 (North Pole)
009	30/07/2022	4:00	Ice	N/A		Ice station 1 (North Pole)
010	30/07/2022	7:00	Ice	N/A		Ice station 1 (North Pole)
011	30/07/2022	7:00	Ice	N/A		Ice station 1 (North Pole)
012	30/07/2022	7:00	Ice	N/A		NP ice station
013	30/07/2022	7:00	Ice	N/A		Ice station 1 (North Pole)
014	30/07/2022	12:00	Ice	N/A		Ice station 1 (North Pole)
015	30/07/2022	12:00	Ice	N/A		Ice station 1 (North Pole)
016	30/07/2022	12:00	Ice	N/A		Abbort. Low battery
017	30/07/2022	12:00	Ice	N/A		Ice station 1 (North Pole)
018	30/07/2022	12:00	Ice	N/A		Ice station 1 (North Pole)
019	02/08/2022	10:55	Ship	136	49	
020	02/08/2022	11:10	Ship	136	49	

MSS File (.mrd)	Date	Time UTC	Ship/ice	Closest CTD cast	Planned Site*	Comments
021	02/08/2022	23:00	Ship	139	47	
022	02/08/2022	23:15	Ship	139	47	
023	03/08/2022	9:45	Ship	141	45	
024	03/08/2022	10:00	Ship	142	45	
025	03/08/2022	17:40	Ship	144	43	
026	03/08/2022	17:55	Ship	144	43	
027	04/08/2022	8:00	Ship	146	41	
028	04/08/2022	8:15	Ship	146	41	
029	04/08/2022	15:43	Ship	149	39	
030	04/08/2022	16:07	Ship	149	39	
031	05/08/2022	13:11	Ice	N/A		Ice station 6 (Amundsen Basin)
032	05/08/2022	13:27	Ice	N/A		Ice station 6 (Amundsen Basin)
033	05/08/2022	13:38	Ice	N/A		Ice station 6 (Amundsen Basin)
034	05/08/2022	15:10	Ice	N/A		Ice station 6 (Amundsen Basin)
035	05/08/2022	15:23	Ice	N/A		Ice station 6 (Amundsen Basin)
036	05/08/2022	15:33	Ice	N/A		Ice station 6 (Amundsen Basin)
037	05/08/2022	18:39	Ice	N/A		Ice station 6 (Amundsen Basin)
038	05/08/2022	18:49	Ice	N/A		Ice station 6 (Amundsen Basin)
039	06/08/2022	4:52	Ice	N/A		Ice station 6 (Amundsen Basin)
040	06/08/2022	5:03	Ice	N/A		Ice station 6 (Amundsen Basin)
041	06/08/2022	5:16	Ice	N/A		Ice station 6 (Amundsen Basin)
042	06/08/2022	9:13	Ice	N/A		Ice station 6 (Amundsen Basin)
043	06/08/2022	9:25	Ice	N/A		Ice station 6 (Amundsen Basin)
044	06/08/2022	9:38	Ice	N/A		Ice station 6 (Amundsen Basin)
045	06/08/2022	13:27	Ice	N/A		Ice station 6 (Amundsen Basin)
046	06/08/2022	13:39	Ice	N/A		Ice station 6 (Amundsen Basin)
047	07/08/2022	7:04	Ship	152	37	
048	07/08/2022	7:20	Ship	152	37	
049	07/08/2022	22:31	Ship	156	35	
050	07/08/2022	22:46	Ship	156	35	
051	08/08/2022	12:40	Ship	157	33	
052	08/08/2022	12:53	Ship	157	33	
053	08/08/2022	21:47	Ship	158	31	Change to MSS O46
054	08/08/2022	22:02	Ship	158	31	Change to MSS O46
055	09/08/2022	14:15	Ship	163	29	
056	09/08/2022	14:32	Ship	163	29	
057	10/08/2022	0:52	Ship	166	27	
058	10/08/2022	0:00	Ship	166	27	
059	10/08/2022	16:17	Ship	170	25	
060	10/08/2022	16:31	Ship	170	25	
061	11/08/2022	1:01	Ship	171	23	
062	11/08/2022	1:14	Ship	171	23	
063	11/08/2022	15:03	Ship	173	21	
064	11/08/2022	15:18	Ship	174	21	
065	12/08/2022	0:50	Ship	176	19	
066	12/08/2022	1:01	Ship	176	19	
067	13/08/2022	7:38	Ice	N/A		Ice Station 8 (Nansen Basin)
068	13/08/2022	7:48	Ice	N/A		Ice Station 8 (Nansen Basin)
069	13/08/2022	7:59	Ice	N/A		Ice Station 8 (Nansen Basin)
070	13/08/2022	10:25	Ice	N/A		Ice Station 8 (Nansen Basin)

MSS File (.mrd)	Date	Time UTC	Ship/ice	Closest CTD cast	Planned Site*	Comments
071	13/08/2022	10:36	Ice	N/A		Ice Station 8 (Nansen Basin)
072	13/08/2022	10:48	Ice	N/A		Ice Station 8 (Nansen Basin)
073	13/08/2022	10:58	Ice	N/A		Ice Station 8 (Nansen Basin)
074	13/08/2022	13:22	Ice	N/A		Ice Station 8 (Nansen Basin)
075	13/08/2022	13:33	Ice	N/A		Ice Station 8 (Nansen Basin)
076	13/08/2022	13:46	Ice	N/A		Ice Station 8 (Nansen Basin)
077	13/08/2022	16:46	Ice	N/A		Ice Station 8 (Nansen Basin)
078	13/08/2022	17:00	Ice	N/A		Ice Station 8 (Nansen Basin)
079	13/08/2022	17:14	Ice	N/A		Ice Station 8 (Nansen Basin)
080	13/08/2022	21:00	Ice	N/A		Ice Station 8 (Nansen Basin)
081	13/08/2022	21:12	Ice	N/A		Ice Station 8 (Nansen Basin)
082	14/08/2022	4:46	Ice	N/A		Ice Station 8 (Nansen Basin)
083	14/08/2022	4:56	Ice	N/A		Ice Station 8 (Nansen Basin)
084	14/08/2022	5:07	Ice	N/A		Ice Station 8 (Nansen Basin)
085	14/08/2022	8:13	Ice	N/A		Ice Station 8 (Nansen Basin)
086	14/08/2022	8:26	Ice	N/A		Ice Station 8 (Nansen Basin)
087	14/08/2022	8:39	Ice	N/A		Ice Station 8 (Nansen Basin)
088	14/08/2022	8:50	Ice	N/A		Ice Station 8 (Nansen Basin)
089	14/08/2022	12:11	Ice	N/A		Ice Station 8 (Nansen Basin)
090	14/08/2022	12:22	Ice	N/A		Ice Station 8 (Nansen Basin)
091	14/08/2022	12:32	Ice	N/A		Ice Station 8 (Nansen Basin)
092	14/08/2022	16:45	Ice	N/A		Ice Station 8 (Nansen Basin)
093	14/08/2022	16:57	Ice	N/A		Ice Station 8 (Nansen Basin)
094	14/08/2022	17:07	Ice	N/A		Ice Station 8 (Nansen Basin)
095	15/08/2022	8:11	Ship	181	17	
096	15/08/2022	8:25	Ship	181	17	
097	15/08/2022	23:02	Ship	185	15	
098	15/08/2022	23:16	Ship	185	15	
099	16/08/2022	10:22	Ship	187	13	
100	16/08/2022	10:38	Ship	187	13	
101	16/08/2022	17:57	Ship	190	11	
102	16/08/2022	18:11	Ship	190	11	
103	17/08/2022	4:45	Ship	192	9	
104	17/08/2022	5:01	Ship	192	9	
105	17/08/2022	8:58	Ice	N/A		Ice station 10 (Marginal ice zone)
106	17/08/2022	9:11	Ice	N/A		Ice station 10 (Marginal ice zone)
107	17/08/2022	9:25	Ice	N/A		Ice station 10 (Marginal ice zone)
108	17/08/2022	10:56	Ice	N/A		Ice station 10 (Marginal ice zone)
109	17/08/2022	11:05	Ice	N/A		Ice station 10 (Marginal ice zone)
110	18/08/2022	17:59	Ship	197	5	
111	18/08/2022	18:10	Ship	197	5	
112	18/08/2022	23:08	Ship	200	3	
113	18/08/2022	23:22	Ship	200	3	
114	19/08/2022	5:43	Ship	202	1	Wire got stuck on ship.
115	19/08/2022	5:54	Ship	202	1	

Vessel-mounted acoustic Doppler current profilers (VMADCP)

Contact: Paul Dodd

Acoustic Doppler current profilers provide profiles of water velocity relative to a transducer mounted in the ship's hull, by analysing the extent to which the frequency of reflected sound waves is shifted relative to the frequency of a transmitted ping at different distances from the transducer and at different angles.
The length of the profiles is dependent on the frequency of the pulse transmitted and the density of scattering particles in the water column. Lower frequencies travel further but result in a coarser vertical profile resolution. If there are few scattering particles in the water column, the strength of the reflected sound waves is reduced. This can lead to large uncertainties or data gaps if the returned signal is too weak.

Lowered ADCPs (typically attached to the CTD package) provide data over the full depth range but are dependent on the quality of data provided by an internal magnetic compass to determine direction. Close to the magnetic poles, poor data from internal magnetic compasses can limit LADCP data quality – this is not an issue with VMADCPs which determine heading from the vessels motion reference unit (MRU) based which uses a 3D-GPS system. Comparison with VMADCP profiles is one way to validate the quality of orientation information used by LADCPs. Moreover, VMADCP data is generally preferred over LADCP when studying the upper water column where coverage is available. This is both due to the more accurate heading and because VMADCP runs continuously, collecting many more hours of ping data which can be averaged to reduce noise compared with the LADCP instruments are only active during CTD casts. However, VMADCP data quality is dependent on correct alignment of the transducer relative to the vessels hull and MRU system. Poor transducer or MRU alignment and position information can result in a component of the vessel motion being included in VMADCP profiles.

Table 6. Summary of the positioning of ADCP transducers and MRU's installed on the Kronprins Haakon. This information is from the Parker Survey completed from 11 January to 25 February 2017 in La Spezia (Parker Document reference 1606090-17000028) and is needed for accurate VMADCP data processing. Positioning of ADCP transducers if relative to centre MRU (centre MRU is connected to sea path system).

		Transducer position relative to centre MRU measured in meters		
	Transducer Depth (ED)	X (+FWD)	Y (+STB)	Z (+DOWN)
ADCP 38 kHz Flush Mount	8.4	27.432	0.658	9.670
ADCP 150 kHz Flush Mount	8.4	28.789	0.661	9.661
ADCP 38 kHz Drop keel	11.8	18.46	-1.089	13.114
ADCP 150 kHz Drop keel	11.8	16.549	1.029	13.181

The Kronprins Haakon is equipped with 150 kHz and 38 kHz VMADCPs which typically give profiles extending to 250 and 750 m respectively. Due to dense ice in the area of operation the flush-mounted transducers were used rather than transducers mounted in drop keels. The 150 kHz VMADCP was run continuously for the duration of the cruise. However, the 38 kHz VMADCP was only run only while the vessel drifted with the ice over the Nansen and Amundsen mooring deployment sites. The 38 kHz VMADCP was not expected to collect good data while the vessel was breaking ice and would have reduced the quantity of fisheries echo sounder data collected using the same frequency if it was operated continuously.

150 kHz ADCP Configuration:

- The ADCP deployed was a 150 kHz RDI Ocean Surveyor
- Navigation and ping data from the ADCP were collected using the RDI VMDAS data acquisition system and saved in the RDI binary format.

The ADCP was started with the following commands:

```
Set for narrowband single-ping profile mode (NP), sixty-five (NN) 8 meter bins (NS), 8 meter blanking
distance (NF)
WP00000
NP00001
NN065
NS0800
NF0800
Synchronization parameters to synchronize unit with K-Sync
CX 0,0
Disable single-ping bottom track (BP),
BP000

Set maximum bottom search depth to 800 meters (BX)
BX08000
Output velocity, correlation, echo intensity, percent good
ND111100000
1 seconds between bottom and water pings
TP000100
Two seconds between ensembles
Since VmDas uses manual pinging, TE is ignored by the ADCP.
You must set the time between ensemble in the VmDas Communication options
TE00000200
Set to calculate speed-of-sound, no depth sensor, external synchro heading sensor, no pitch or roll being
used, no salinity sensor, use internal transducer temperature sensor
EZ1020001
Output beam data (rotations are done in software)
EX00000

Set transducer misalignment (hundredths of degrees)
EA04642

Set physical pitch alignment error (hundreths of degrees)
EJ0008

Set physical roll alignment error (hundreths of degrees)
EI-017

Set transducer depth (decimeters)
ED00084

Set Salinity (ppt)
ES35

Save this setup to non-volatile memory in the ADCP
CK
```

38 kHz Configuration

- The ADCP deployed was a 38 kHz RDI Ocean Surveyor
- Navigation and ping data from the ADCP were collected using the RDI VMDAS data acquisition system and saved in the RDI binary format.

The ADCP was started with the following commands:

```
Set for narrowband single-ping profile mode (NP), 128 (NN) 8 meter bins (NS), 16 meter blanking distance (NF)
WP00000
NP00001
NN128
NS0800
NF1600
Synchronization parameters to synchronize trigger with K-Sync
CX 0,0
Set maximum bottom search depth to 1700 meters (BX)
BP000

Disable single-ping bottom track (BP)
BX17000
```

```
Output velocity, correlation, echo intensity, percent good
ND111100000
3 seconds between bottom and water pings
TP000300
Three seconds between ensembles Since VmDas uses manual pinging, TE is ignored by the ADCP. You must set the
time between ensemble in the VmDas Communication options
TE00000300
Set to calculate speed-of-sound, no depth sensor, external synchro heading sensor, no pitch or roll being
used, no salinity sensor, use internal transducer temperature sensor
EZ1020001
Output beam data (rotations are done in software)
EX00000
Set transducer misalignment (hundredths of degrees)
EA004688
Set physical pitch alignment error (hundreths of degrees)
EJ-009
Set physical roll alignment error (hundreth of degrees)
EI001
Set transducer depth (decimeters)
ED00084
Set Salinity (ppt)
ES35
Save this setup to non-volatile memory in the ADCP
CK
```

Underway thermosalinograph & water sampling

Contacts: Bonnie Raffel, Yannick Kern

The ship thermosalinograph was equipped with a conductivity sensor (S/N 3429) and a temperature sensor (S/N 3429) that started logging on departure from Longyearbyen. There was a test measurement from Tromsø to Longyearbyen but it is not part of the main cruise data set. In the default configuration the system drew water from a point 4 m below sea level, on the outside of the hull. When this configuration is on, the temperature is measured by a remote temperature sensor (S/N 0965). In ice this water intake became clogged, and water was instead collected from within a void around the drop-keels at a depth of around 8 m (just above the hatch opening). This void is partially open to the ocean and visibly turbulent when the ship is moving, however, it likely takes several hours for the water in this void to be completely exchanged. Temperature measurements from the void are therefore unreliable. Water samples were collected for AT-CT, salinity, nutrients, coloured dissolved organic matter (CDOM) and δ^{18}O from the underwater supply every time the ship crossed 30 minutes of latitude, starting at 83°N and ending at the North Pole (see Figure 1). At 84°N, 84.5°N and 85°N no samples were taken since the water intake outside of the hull was clogged with ice and we switched to the void configuration. Samples are summarised in Table 7. Within the Thermosalinograph box there is also a Fluorometer (S/N WSCHL-1511) installed which operated continuously during the cruise.

Table 7. Summary of samples collected from the underway water supply

Stn	Lat	Lon	Date	Time (UTC)	Source	AT-CT Sample #	Salinity sample #	Nutrient Sample #	CDOM sample #	d18O sample #
1	N 83° 00'	E 034° 36'	25.07.2022	10:15	Outside of hull	13	36	13	13	13
2	N 83° 33'	E 034° 60'	25.07.2022	14:51	Outside of hull	14	37	14	14	14
3	N 85° 35'	E 038° 23'	26.07.2022	09:33	Drop keel void	15	38	15	15	15
4	N 85° 60'	E 036° 45'	26.07.2022	13:20	Drop keel void	16	39	16	16	16
5	N 86° 31'	E 034° 18'	26.07.2022	17:30	Drop keel void	17	40	17	17	17
6	N 87° 00'	E 040° 59'	27.07.2022	00:04	Drop keel void	18	41	18	18	18
7	N 87° 31'	E 050° 34'	27.07.2022	10:22	Drop keel void	19	42	19	19	19
8	N 88° 00'	E 051° 50'	27.07.2022	14:32	Drop keel void	20	43	20	20	20
9	N 88° 29'	E 054° 21'	27.07.2022	20:36	Drop keel void	21	44	21	21	21
10	N 88° 60'	E 055° 38'	28.07.2022	01:46	Drop keel void	22	45	22	22	22
11	N 89° 30'	E 069° 30'	28.07.2022	06:27	Drop keel void	23	46	23	23	23

Acoustic fishery survey with SIMRAD EK80 echo sounder

Contacts: Ole Arve Misund, Hans Kristian Eide and Yannick Kern

R/V "*Kronprins Haakon*" is equipped with state-of-the art instruments for acoustic surveying of the water column along the ship track. With the chosen survey track from Longyearbyen – west and north of Svalbard – to the ice edge – the North Pole – southwest to the transect, approximately midway between the North Pole and the northern tip of Greenland– then southeast along the transect – and return to Longyearbyen, this gave the opportunity to survey the pelagic ecosystem in the entire Atlantic sector of the Polar Ocean. This was done by continuous recordings of the hull-mounted transducers of the Simrad EK80 echo sounder (Table 8). The backscatter (s_v) at the 18, 38, 70, 120, 200 and 333 kHz frequencies was recorded from surface to 500 m depth and stored for subsequent post processing.

The echo sounder recordings were post processed using the LSSS software. The 38 kHz recordings were chosen as the main source for the post processing. The post processing was done by setting a lower detection threshold to a volume back scattering strength (s_v) of – 82 dB as recommended for traditional fisheries acoustic surveys. The recordings were integrated to obtain an area back scattering strength (s_A). This was done over distances of five nautical miles using adequate depth layers from surface to 500 m depth. During this process, a nautical area back scattering coefficient for each five nautical mile sailed (nasc/5 nm) was obtained.

Allocation of the recorded nautical area back scattering coefficients to fish species (capelin, cod, mesopelagic species, redfish) or plankton was done based on catches from aimed pelagic trawling with the Harstad (in ice-covered waters) and the larger Vito (in open waters) pelagic trawl, and the Bongo, Mik or Multinet plankton samplers hauled vertically. Recordings from the other frequencies were also used in the scrutinizing process when appropriate. Especially the 18 kHz recordings were useful to identify and sort out recordings of false bottom, and the 70, 120, and 200 kHz recordings were used to distinguish plankton recordings from near-surface noise.

When sailing in ice covered waters, R/V "*Kronprins Haakon*" was navigated manually to take advantage of open leads as much as possible along the planned cruise tracks. From the ice edge and north to the North Pole, the ship was sailing in the lead 0.5 – 1.0 nautical miles behind the Polar Class 2 expedition cruise ship "*Le Commandante Charcot*". For the remaining cruise tracks the ship sailed alone. From the North Pole and south along the 41°W longitude the ship encountered ice at a thickness of about 1.6 – 2.0 m, but floes of thicker multiyear ice of up to 4 m were also identified. Often the ship hit the ice at the sides of the leads, and regularly ice breaking was necessary to progress along the planned cruise tracks. Likewise, along the transect southeast across the Amundsen and Nansen basins there were dense ice concentrations of 1.0 – 2.0 m thick ice that the ship had to break through. In such situations, much noise and vibrations in the hull were detected by the echo sounder.

During post processing these noise recordings were removed using the convenient removal functions of the LSSS system (Figure11). For distances where heavy ice conditions were encountered, there were a few five nautical miles sailed where the recordings had to be removed completely because of continuous noise recordings. This was the case towards the end of the ice-covered area when sailing south along the hydrographic transect just after deployment of the Nansen-1 mooring and towards the ice-edge in the south-east when large, dense ice floes were encountered that the ship had to break through. But for most five nautical miles sailed, there were sections with representative recordings, generally when the ship was navigated to take advantage of open leads in ice covered waters. Then allocation of area back scattering coefficients to the recording categories was possible (Figure 12).

Table 8. Operational characteristics of the hull mounted Simrad ES80 echo sounder onboard F/F "Kronprins Haakon" during the Arctic Ocean survey July – August 2022.

Channel	Frequency (kHz)	Beam width (°)	Pulse type	Pulse duration (ms)	Power (W)	Ramping
ES18	18	11°	cw	1.024	1600	fast
ES38B	38	7°	cw	1.024	2000	fast
ES70	70	7°	cw	1.024	750	fast
ES120	120	7°	cw	1.024	250	fast
ES200	200	7°	cw	1.024	150	fast
ES333	333	7°	cw	1.024	50	fast

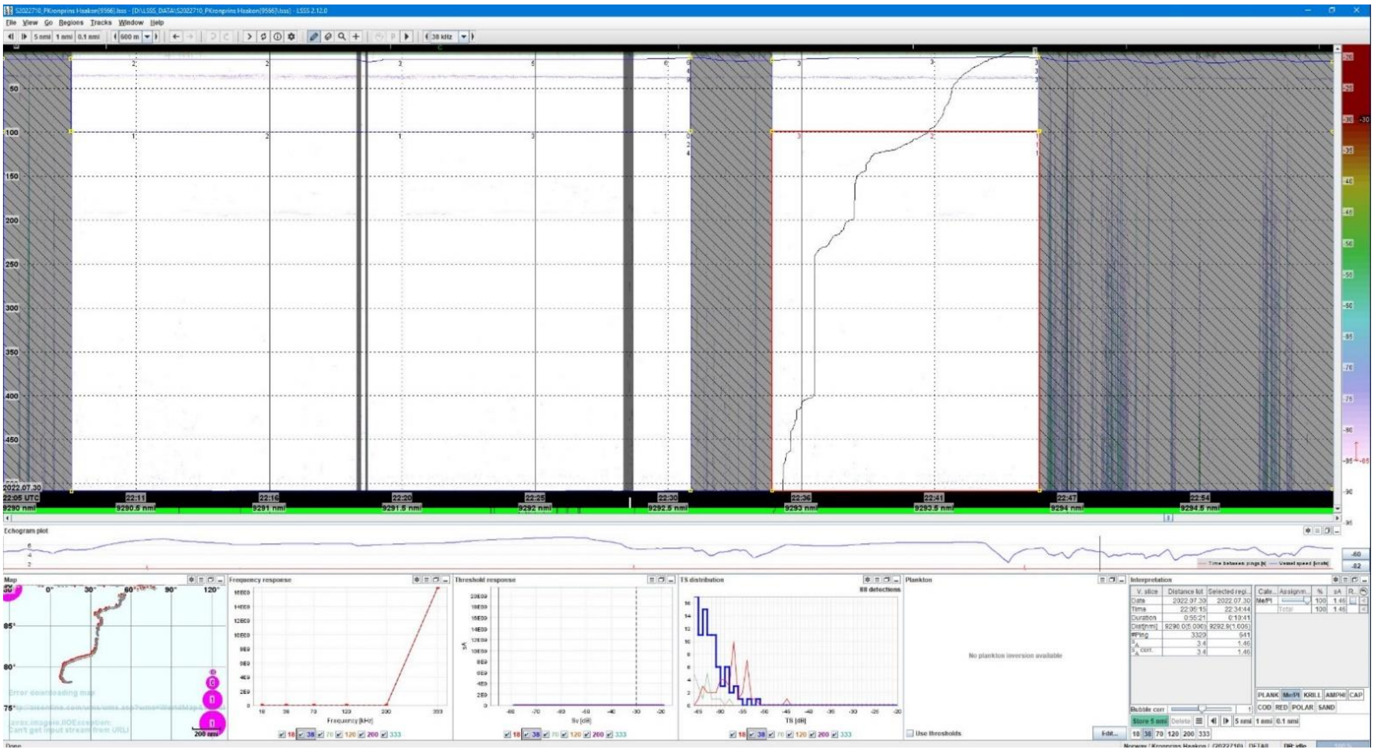


Figure 11. Scrutinizing of the 38 kHz Simrad E80 recordings using the LSSS post processing software. Screen dump from the LSSS after post processing of a five nautical mile distance along the 41° W longitude from the North Pole to the transect. Shaded areas removed because of noise, and 641 of 3320 pings used for final allocation of s_A – values to the different species groups (here plankton in the upper 100 m layer and mesopelagic/plankton in the deeper layer).

Initial results: Along the coast west and north of Svalbard, there were good recordings of capelin and cod in a layer from about 100 m to about 300 m depth (Figure 13). Krill was recorded in swarms from the about N 80° and north to N 81°, just south of the ice edge at N82° 05'. A more or less continuous plankton layer was recorded near surface throughout the cruise. The densest plankton recordings were encountered along the coast west and north of Svalbard, and along W41° from the North Pole and south to about N°87 05' (Figure 14). In the ice-covered areas north of N82 05°, a more or less continuous weak mesopelagic layer was recorded at depths from about 300 m to 500 m. There were no distinct fish recordings in this layer.

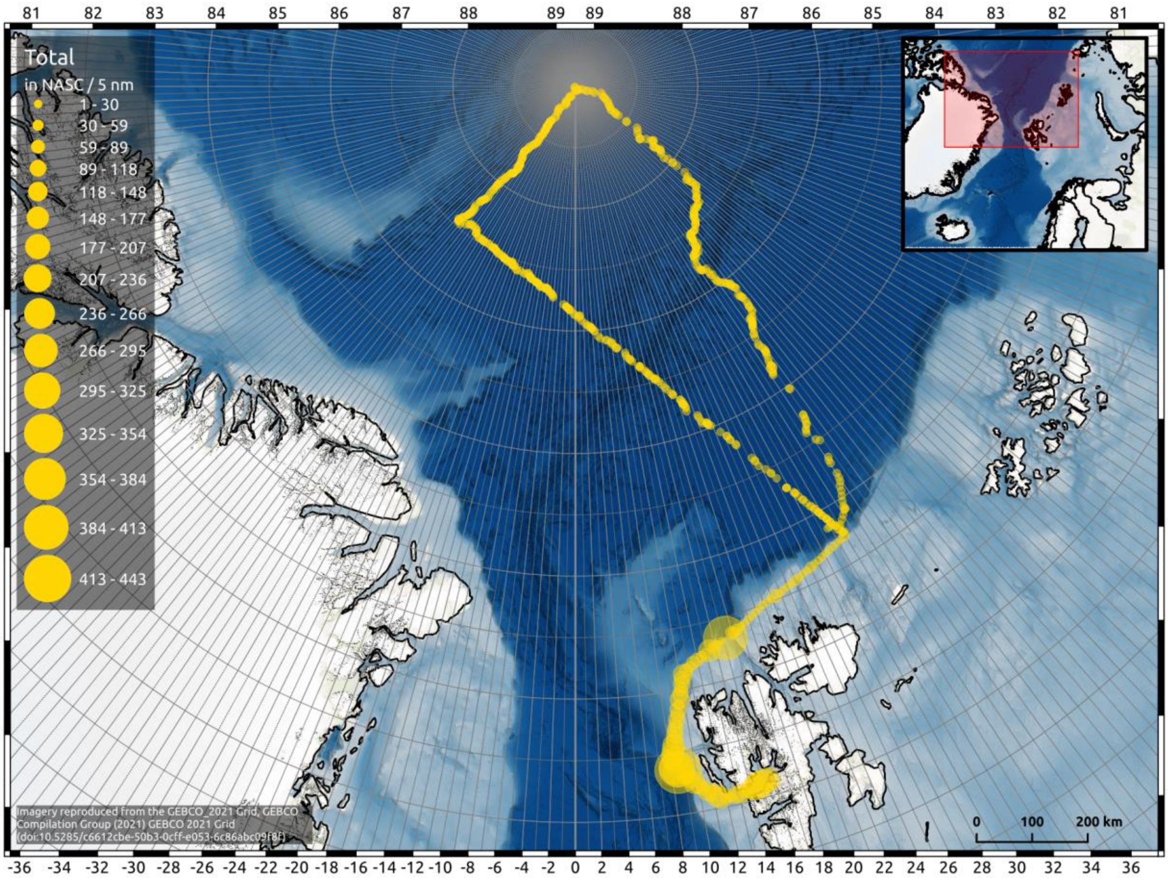


Figure 12. Recordings (Nautical Area Scattering Coefficients/5 nautical mile) made by the Simrad EK80 echo sounder and post processed in LSSS during the Arctic Ocean cruise 2022.

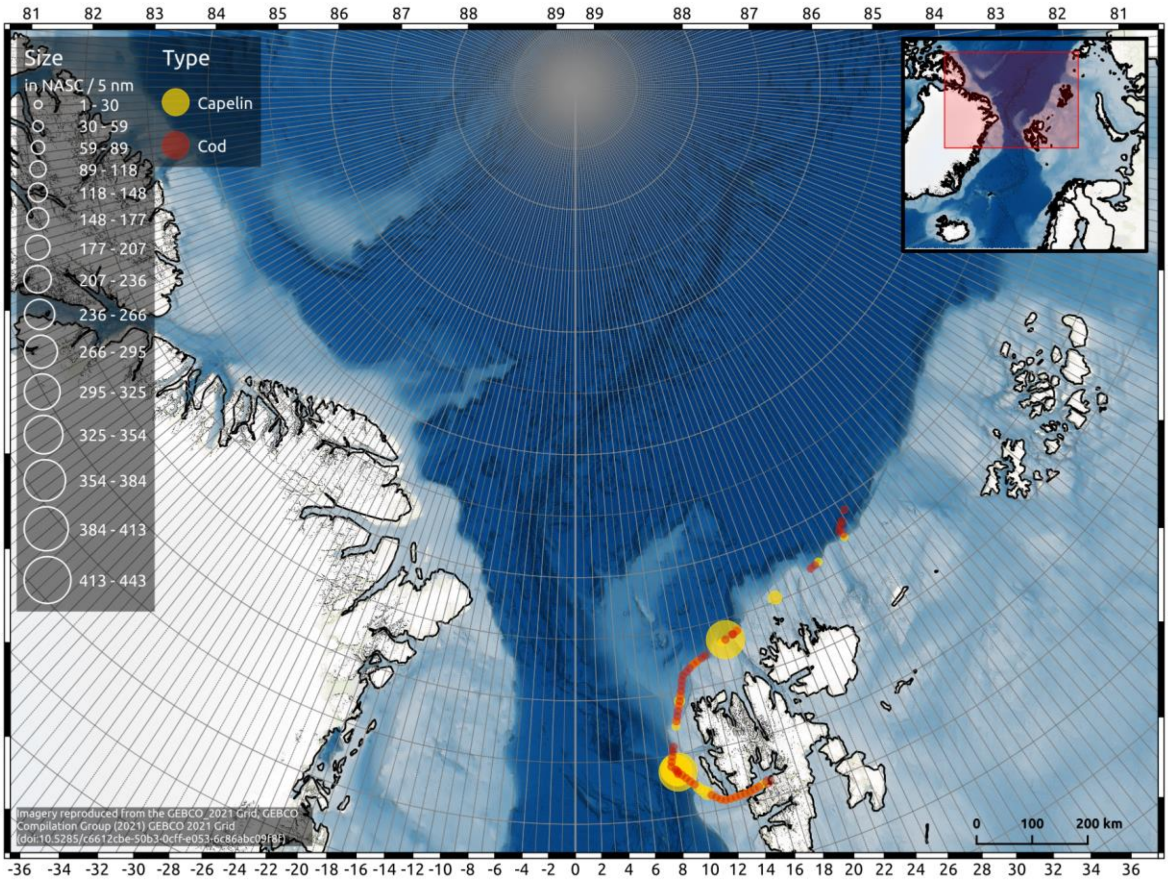


Figure 13. Recordings (Nautical Area Scattering Coefficients/5 nautical mile) of capelin and cod made by the Simrad EK80 echo sounder and post processed in LSSS during the Arctic Ocean cruise 2022.

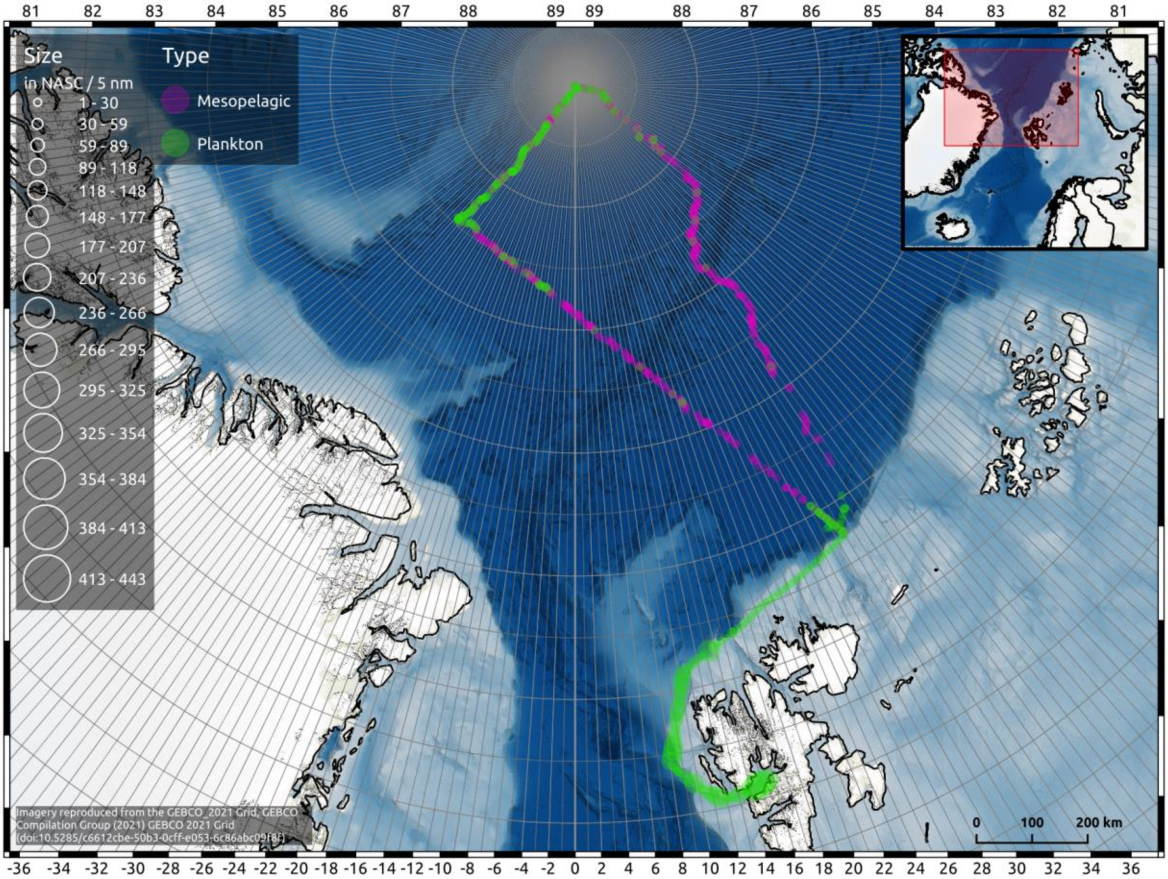


Figure 14. Recordings (Nautical Area Scattering Coefficients/5 nautical mile) of plankton and mesopelagic species made by the Simrad EK80 echo sounder and post processed in LSSS during the Arctic Ocean cruise 2022.

Pelagic trawl sampling

Contacts: Ole Arve Misund, Haakon Hop, Victoria Eggen and Vegard Stürzinger

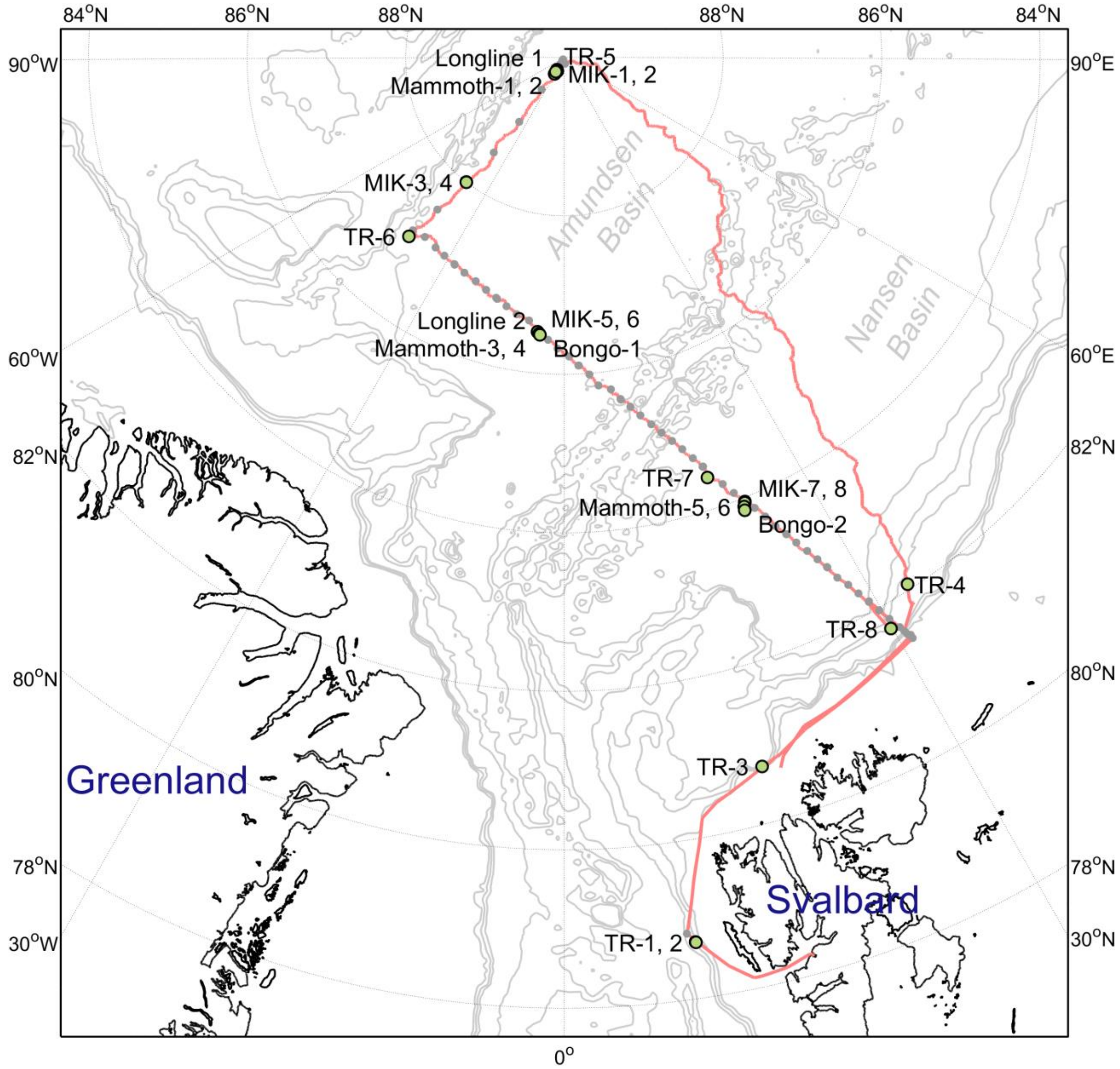


Figure 15. Locations of pelagic trawl sampling and zoo- and phytoplankton net sampling (Tables 10 and 11)

Pelagic trawl sampling was carried out to identify recordings on the Simrad EK80 echo sounder. Two types of pelagic trawls were used (Table 9). In ice-free waters both the traditional Harstad pelagic trawl and the new Vito pelagic trawl were used. In ice-covered areas, only the lighter and easier to operate Harstad pelagic trawl was used. Both trawls were operated according to the procedures for scientific trawling at Institute of Marine Research (KS&SMS-07-1-1-01) and rigged and used according to the procedures for the Harstad pelagic trawl (KS&SMS-07-1-2-2-2-03) and the Vito pelagic trawl (KS&SMS07-1-3-2-6-06). The Vito pelagic trawl replaced the Åkra pelagic trawl used by IMR since the mid nineteen nineties to identify and sample acoustic recordings of pelagic fish (Valdemarsen and Misund, 1995).

Table 9. Rigging and operation of the Harstad and Vito pelagic trawls (Weight refers to the chains attached to the lower wing ends to open the trawl, data on warp length, warp tension, towing depth, towing speed and height were read from the Scanmar trawl performance system of the vessel).

Trawl type	**Floats**	**Weight (kg)**	**Warp length (m)**	**Warp tension (tons)**	**Towing depth (m)**	**Towing speed (kn)**	**Vertical opening (m)**
Harstad pelagic trawl	4 x 9.5''	80 x 2	291 – 962	6.1 – 8.8	180 - 402	2.8 – 3.3	9 - 12
Vito pelagic trawl	30 x 9.5''	350 x 2	570 – 810	4.9 – 8.0	200 - 350	2.9 – 3.6	11 – 20

After leaving Longyearbyen on 22 July, and cruising west and north of Svalbard, pelagic trawling was conducted to identify acoustic recordings of fish, krill and planktonic organisms (stations TR-1 to TR-4; Figure 15). Entrances of fish and other organisms were recorded on the acoustic trawl eye on the Scanmar Scanbas trawl performance system during these tows (Figure 16). Northwards from the ice edge and to the North Pole, priority was given to sail in the lead after "Le Commandante Charcot". After completing the ice station near the North Pole, a pelagic trawl station was taken in an open lead nearby (Figure 18).

When sailing south from the North Pole, pelagic trawling was carried out occasionally in open leads of minimum 3 nautical miles long (Figure 19). The ice gallows of the vessel were then used to lower the warps close to the trawl ramp of the vessel to lower the probability for getting ice floes under the trawl warps. After spooling the trawl nets on the net drum during hauling, they were driven down on deck and carefully spooled on the net drum again while manually shaking the net to obtain samples of juvenile fish, squid, medusae, krill, and arrow worms hanging in the meshes.

Representative catches of capelin (*Mallotus villosus*), juvenile redfish (*Sebastes mentella*), and cod (*Gadus morhua*) were obtained by both trawl types from west of Svalbard (N78.71°) and northeast to N 80.71° at depths of 200 m to 350 m (Figure 15, Table 10). Then a catch of krill was taken at 180 m depth N 82.09° (Figure 17). In the ice covered Polar Ocean, only marginal catches of arrow worms (*Eukrohnia hamata*) and ctenophore (*Mertensia ovum*) were taken at depth from 200 m to 350 m (TR-5, TR-6, TR-7; Table 10). Many of the arrow worms were carefully picked from the meshes of the trawl when hauling. In open waters on the way south, a tiny catch of polar cod, deepwater lantern fish (*Benthosema glaciale*) and krill was taken at N81.70° E29.87° (TR-8; Table 10).

Table 10. Catches obtained during pelagic trawl sampling in the Polar Ocean July–August 2022 by R/V "Kronprins Haakon".

Trawl st. nr.	Gear (trawl type)	Date	Latitude	Longitude	Trawl depth (m)	Biomass caught (kg)	Main species
TR-1	Vito	20220722	N 78.71°	E 08.49°	200	496.270	*Mallotus villosus, Sebastes mentella*
TR-2	Harstad	20220722	N 78.71°	E 08.50°	200	103.760	*Mallotus villosus, Sebastes mentella*
TR-3	Vito	20220723	N 80.71°	E 15.65°	350	52.105	*Mallotus villosus, Gadus morhua, Thysanoessa* sp., *Meganyctiphanes* sp., etc.
TR-4	Vito	20220724	N 82.09°	E 33.29°	180	33.569	*Thysanoessa* sp., *Meganyctiphanes* sp.
TR-5	Harstad	20220730	N 89.82°	W 31.19°	200	0.020	*Eukrohnia hamata, Mertensia ovum*
TR-6	Harstad	20220802	N 87.01°	W 41.01°	200	0.316	*Mertensia ovum,* Medusa sp., *Eukronia hamata*
TR-7	Harstad	20220810	N 84.40°	E 18.84°	150 - 350	0.055	*Mertensia ovum, Eukrohnia hamata*
TR-8	Harstad	20220818	N 81.70°	E 29.87°	60 - 420	0.06	*Boreogadus saida, Benthosema glasiale, Meganychtiphanes* sp.

Figure 16. Screen of Scanmar Scanbas monitor with school of capelin entering the opening of the Vito pelagic trawl at TR-1 west of Svalbard on 22 July 2022.

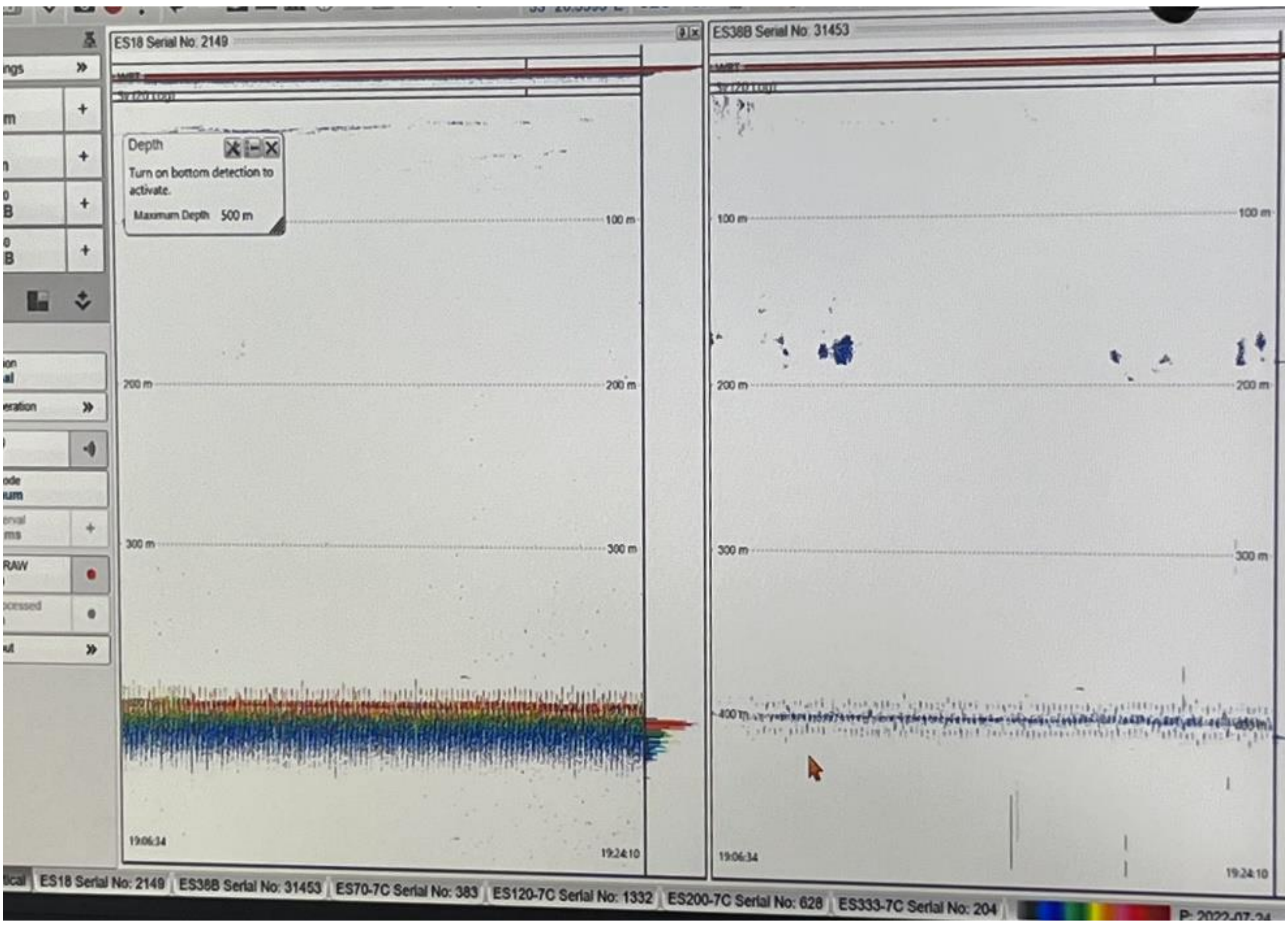


Figure 17. Example from TR-4, 24 July 2022, where krill swarms we recorded at about 180 m depth on the 38 kHz channel (right) of the Simrad EK80 echo sounder, but not visible on the 18 kHz channel (left). False bottom detection on both channels at 400 m depth.

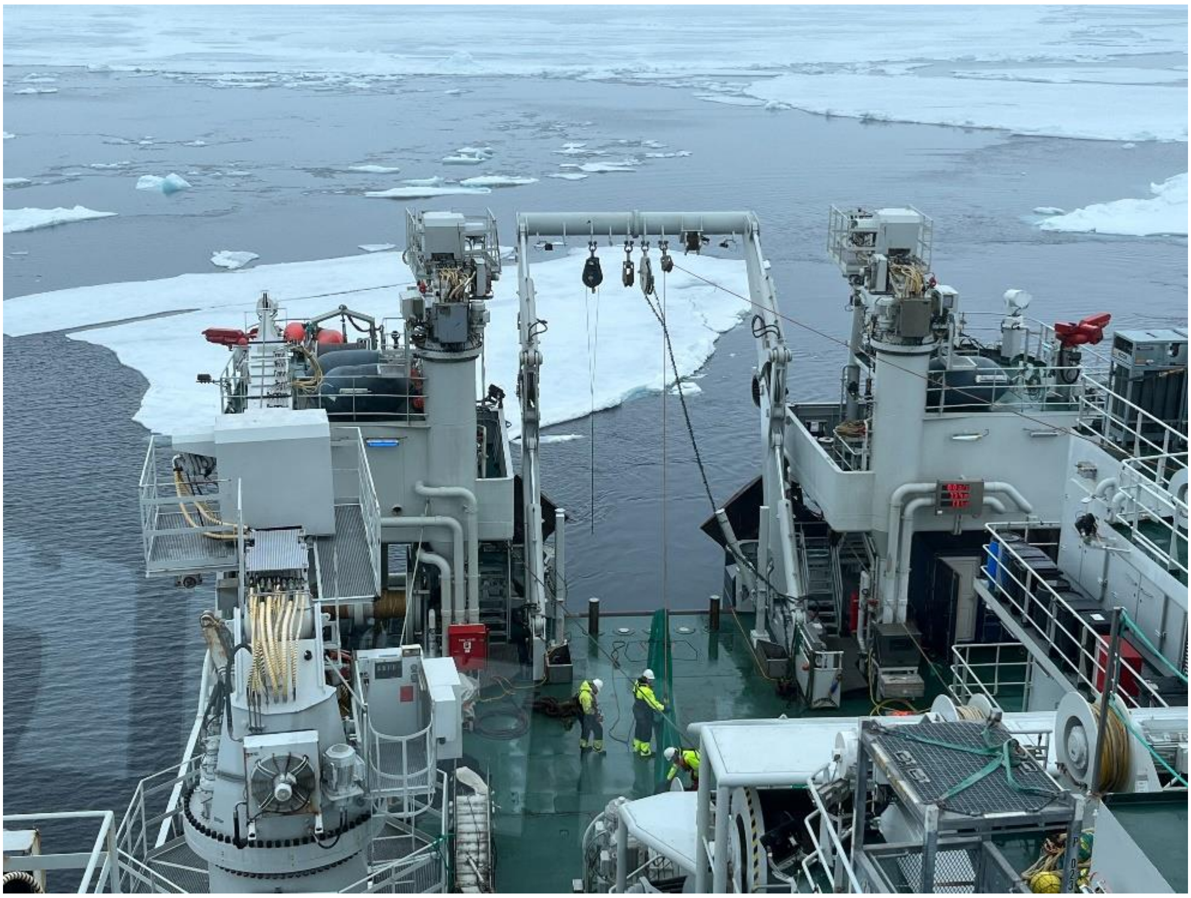


Figure 18. Shooting the Harstad pelagic trawl in an open lead at N89.82° W31.19°, station TR-5, 30 July 2022.

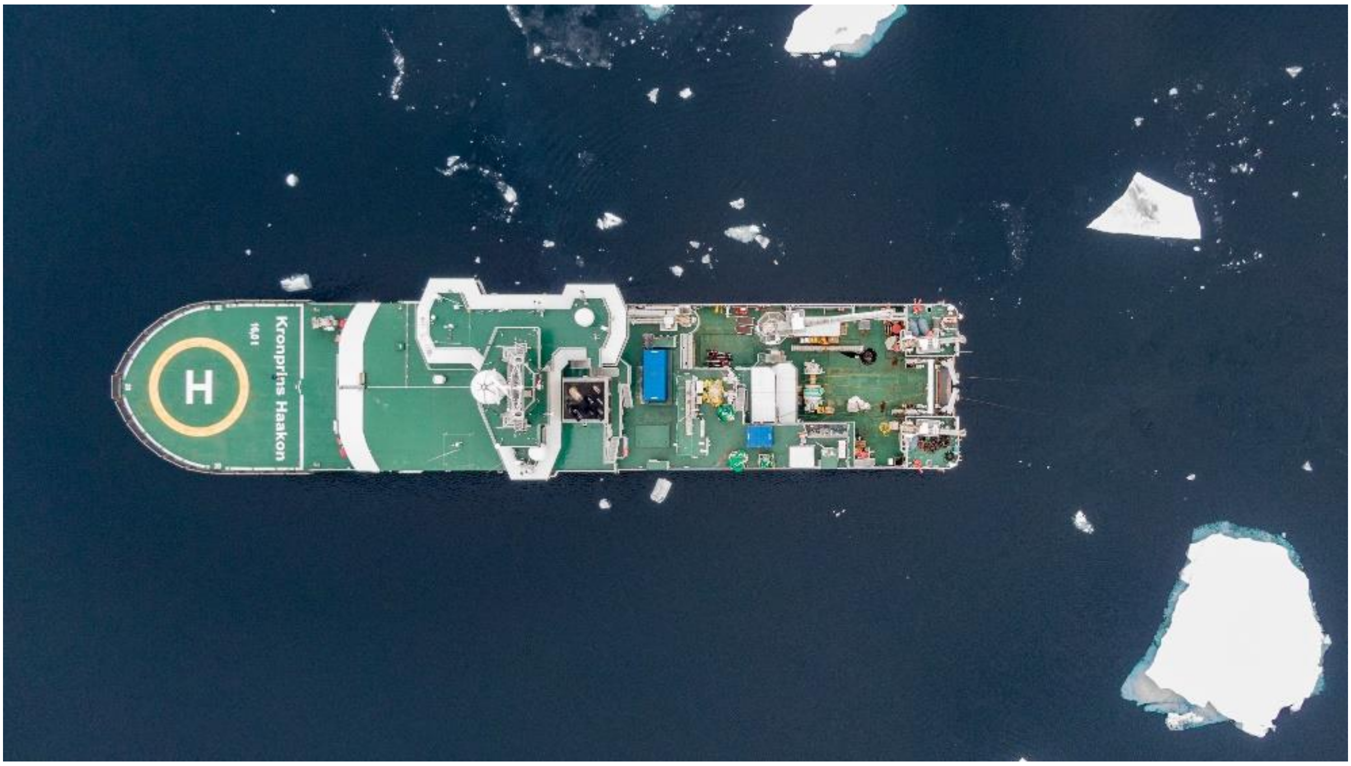


Figure 19. Drone photo of R/V "Kronprins Haakon" towing the Harstad pelagic trawl in an open lead with sporadic small ice floes at TR-6 at N87.70° W41.01°. The warps go through the lowered ice-gallows at the stern to prevent entangling of ice floes.

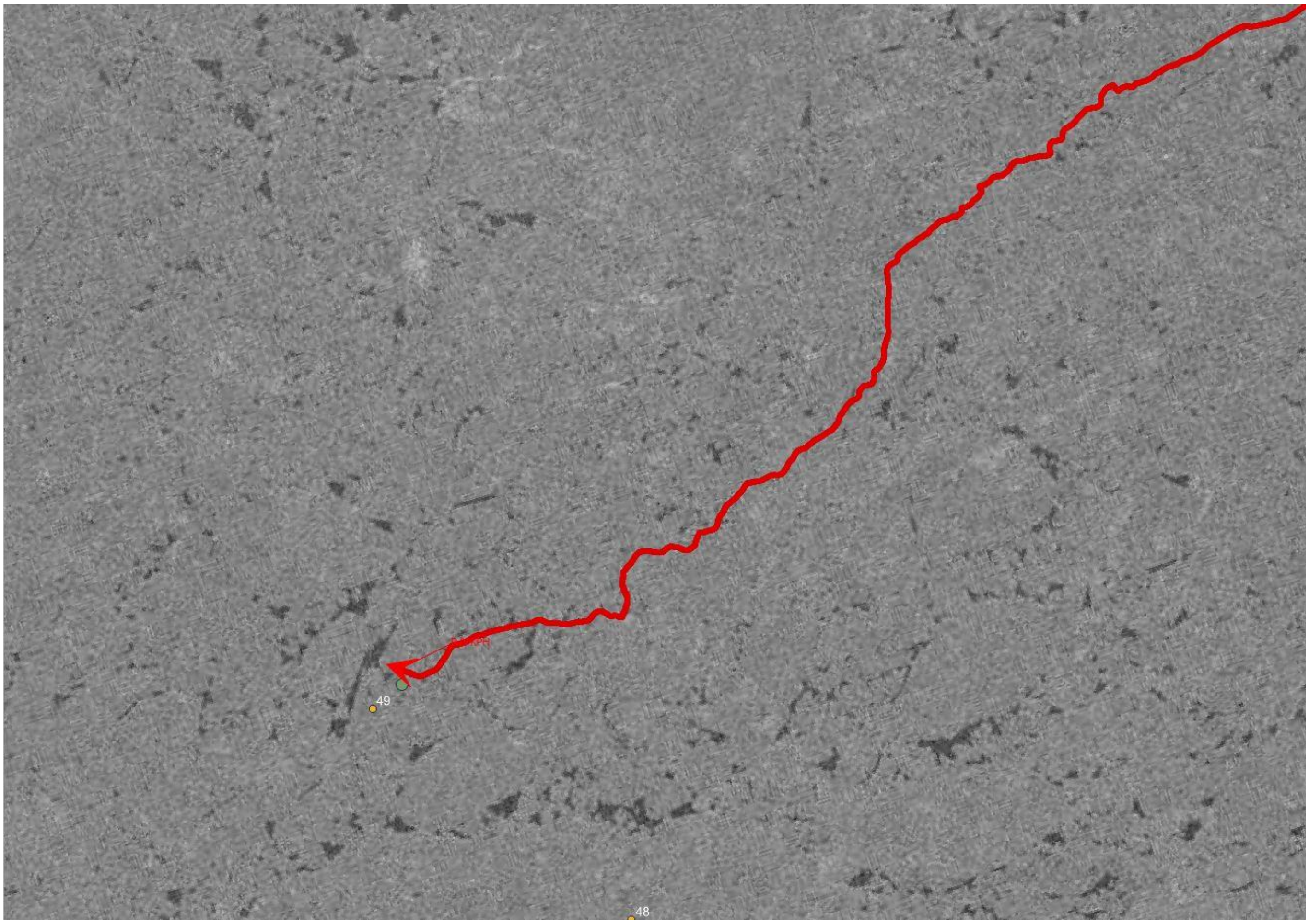


Figure 20. Radarsat image from 2. August 2022 covering the area where the hydrographic transect started. CTD stations 49 and 48 (136, 138) are visible. The red line is the cruise track of the vessel on the way south from the North Pole along W41° longitude. The arrow points to the about 3 nautical mile lead where TR-5 was carried out.

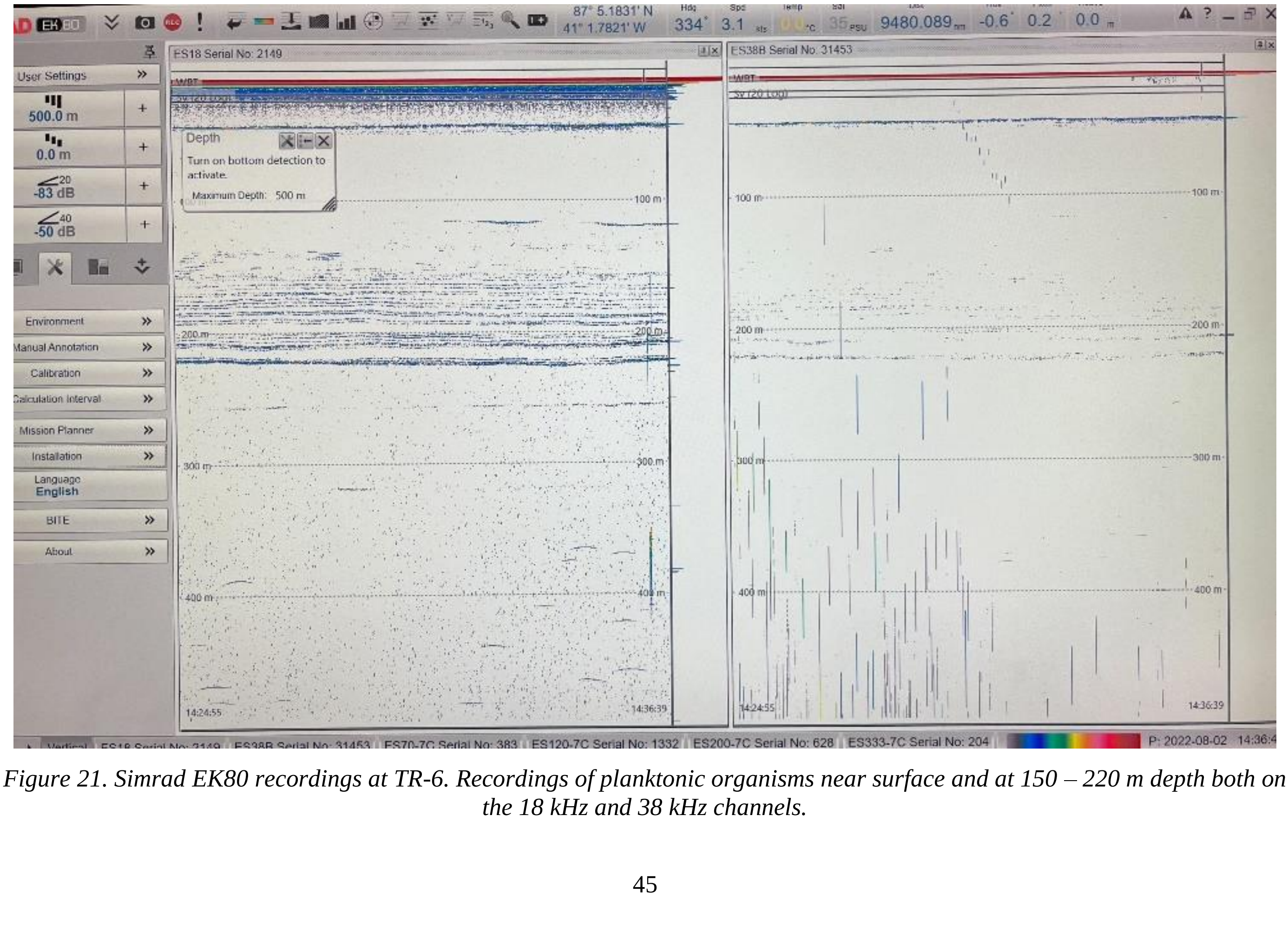


Figure 21. Simrad EK80 recordings at TR-6. Recordings of planktonic organisms near surface and at 150 – 220 m depth both on the 18 kHz and 38 kHz channels.

Mesozooplankton and macrozooplankton sampling

Contacts: Haakon Hop, Victoria Eggen and Vegar Stürzinger

Mammoth Multinet

Mesozooplankton are zooplankton in the medium size range, which are sampled with nets with mesh size of 180 μm. The large nets used on the AO-2022 cruise is Multinet Mammoth (1 m^2 opening, Figure 22), which consists of 9 nets that can be closed at different depths to get depth-stratified samples of zooplankton. In the deep basins, the following depths are used: Bottom-2500; 2500-2000, 2000-1500, 1500-1000, 1000-600, 600-200, 200-50, 50-20 and 20-0 m. Nets are towed at a speed of 0.5 m s^{-1}.

Net sampling in the entire water column is done two times. The first set of samples are filtrated and preserved in buffered 4% formaldehyde for mesoplankton abundance/taxonomy. They will later be identified by taxonomic experts at the Institute of Oceanology (IOPAN) in Sopot, Poland.
The second set of samples are filtrated and preserved in 96% EtOH. These samples will be used for genetic analyses, including barcoding of individuals to determine species based on analyses done at UNIS and IOPAN.

Identifying zooplankton based on their looks (i.e. morphologically) can be challenging. For instance, the three most important Calanus copepods are of different sizes but look very similar morphologically and their size ranges overlap. So, genetics is used to identify and separate them. There are also many little-known species in the deep Arctic Ocean, which are poorly described morphologically and therefore needs to be identified by barcoding. If they are completely unknown, the barcode will be sent to a barcode library.
Jelly plankton or gelatinous zooplankton, which includes ctenophores and medusas of Cnidaria are picked out from the samples and photographed before they are sorted and measured. Some are stored individually on EtOH for later genetic identification.

Typical species that are caught in the Mammoth net are Calanus copepods, of which Calanus hyperboreus constitute the largest component of the biomass, and secondly Calanus glacialis. Other species include amphipods (*Themisto libellula*, *T. abyssorum*, and some deep-water species), krill (*Thysanoessa* spp. And *Meganyctiphanes norvegica*), chaetognaths (*Parasagitta elegans*, *Eukrohnia hamata*) and pteropods (*Limacina helicina* and *Clione limacina*).

Figure 22. Mammoth net used for sampling of mesozooplankton.

MIK (method isaac kidd) net

Macrozooplankton are zooplankton of large size range, which are samples with MIK net with a 2-m diameter opening, 14 m long with main net bag of 1.2 mm mesh size, and the terminal 1.5-m part of 0.5 mm mesh size (Figure 23). The net is lowered to 1000 m depth and towed vertically at 1 m s^{-1}.

The net sampling is done two times. The first tow of samples is used for macrozooplankton abundance, biomass and genetics. The samples and weighed and split in two subsamples, where one is preserved in buffered 4% formaldehyde for abundance/taxonomy, and the other is preserved in EtOH for metabarcoding. The second tow of samples are used for samples of stable isotopes ($\delta^{13}C$, $\delta^{15}N$) to determine sources of carbon (stable carbon) and their trophic level in the food web (stable nitrogen). Zooplankton are sorted into taxa and frozen in zip-lock plastic bags at -80 C. Individuals of unknown or poorly known taxa are preserved individually in EtOH. Jellyplankton are removed and photographed as explained above.
Typical species caught in the MIK net are the largest copepods *Calanus hyperboreus*, and larger size classes of amphipods, krill and chaetognaths.

Figure 23. MIK net used for sampling of macrozooplankton.

Bongo net

The Bongo net (two nets of 60 cm dia./0.2827 m² opening, mesh size 180 µm) is used to get duplicate samples of mesozooplankton from the same depth (bottom-0 m/1000-0 m (Figure 24). Smaller zooplankton can alternatively be sampled with nets of finer mesh size (64 µm). The sample from one net is used morphology and preserved on formalin, whereas the sample from the other net is used for metabarcoding and preserved on EtOH. This net is operated from the side of the ship, which was not easy because of sea ice, which filled part of the net. Thus, only one sample was collected.

Figure 24. Bongo net towed in icy water.

Table 11. Sampling with Mammoth and MIK nets during the AO-2022 cruise (also see map in Figure 15).

Station	Date	Latitude	Longitude	Mammoth	MIK	Bongo
Ice station 1	2022-07-30	89.8062	-27.5515	2		
Ice station 1	2022-07-30	89.7726	-30.1057		2	
Ice station 2	2022-08-01	88.0007	-38.2286		2	
Ice station 6	2022-08-05	86.5209	-5.5924		2	
Ice station 6	2022-08-06	86.4974	-5.2126	2		
Ice station 6	2022-08-06	86.4853	-5.0456			1
Ice station 8	2022-08-12	83.9512	22.1628		2	
Ice station 8	2022-08-14	83.8496	21.7660			1
Ice station 10	2022-08-17	82.6921	27.5178	1		
Ice station 10	2022-08-17	82.7103	27.4152		1	
Totals:				**5**	**9**	**2**

Mooring deployments in the Amundsen and Nansen basins

Contacts: Arild Sundfjord and Paul Dodd (NPI)

Two moorings, Amundsen-1 and Nansen-1, with nearly identical instrumentation were deployed in the central Amundsen and Nansen basins. The deployment period is planned to be two years. The twin instrument set-up is intended to facilitate comparison between the two basin environments.

Most of the instruments were placed in the upper 500 meters to capture the characteristics of the upper water column, subject to the largest variability, but some sensors and a sediment trap were placed at greater depths, see the mooring diagrams in Figures 28 and 30. The parameters measured are thickness and transport of sea ice (IPS/ADCP), water temperature and salinity (CTD), ocean currents and circulation (ADCP), nitrate and carbon (CO_2) levels within the surface layer/photic zone (SBE16ECO/SUNA/ SAMI), and underwater noise (AURAL). Water samples are collected for analyses of eDNA and freshwater tracers (RAS), and for export of carbon and nitrate towards the seabed (Sediment trap). All the scientific instruments deployed are listed in Tables 12 and 13.

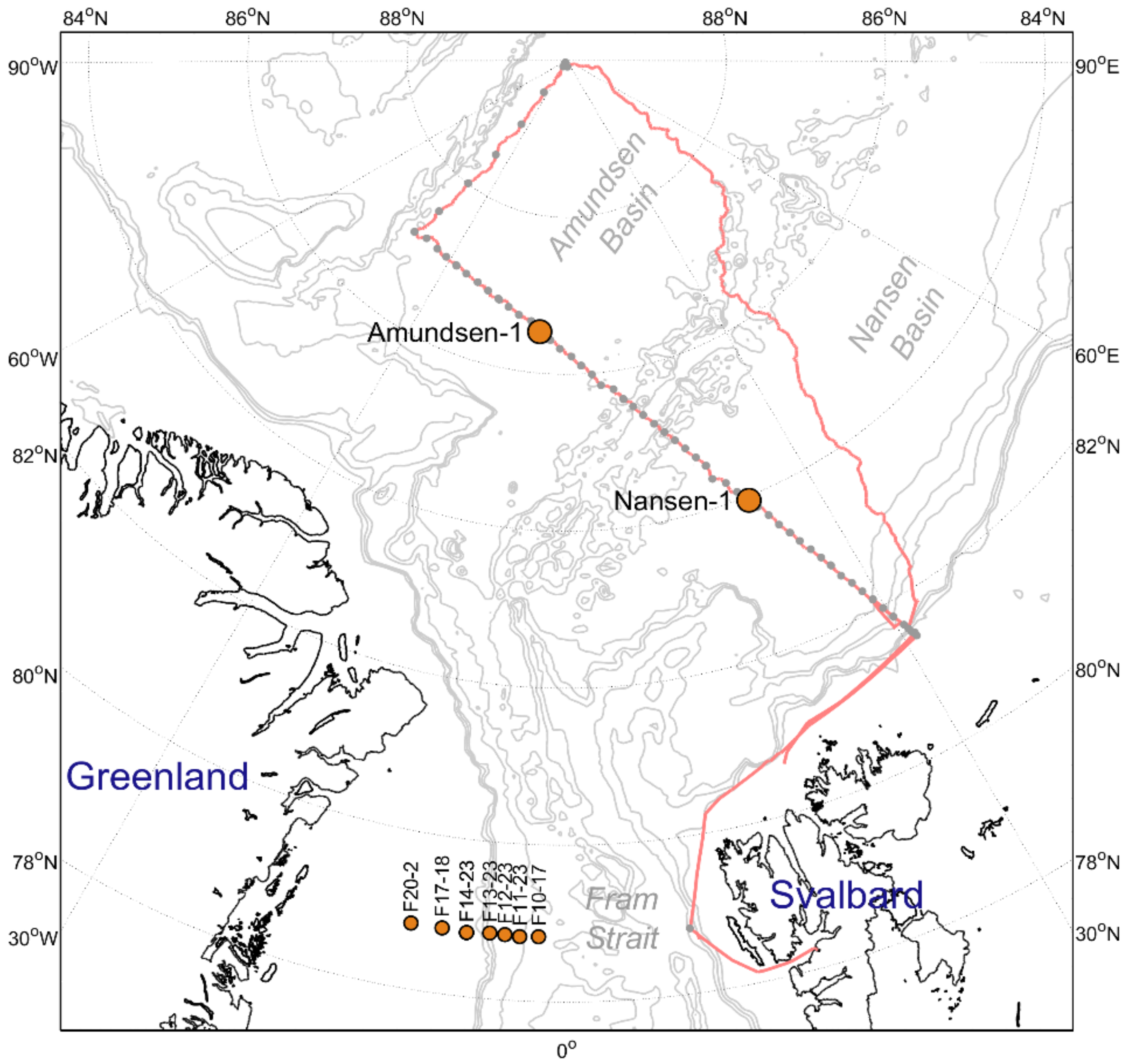


Figure 25. The location of the Amundsen-1 and Nansen-1 moorings deployed in the Central Arctic Ocean. The red line shows the ship track for the NPI AO-22 cruise, and the grey dots the CTD stations. The circles F10-F20 show the long-time NPI observatory in the western Fram Strait.

General approach

Prior to both deployments, a multibeam echo sounder survey was carried through to map the bottom characteristics (see p.58). Spooling of the Kevlar line and test deployments (with only parts of the anchor weight) to confirm the mooring length and bottom depth were done in parallel with ice station work 1-2 days before each deployment. Final assembly of instrumentation and preparation of sampling devices etc. was done during the mornings of the deployment days, with the actual deployment operation carried through in the afternoon. Both moorings were deployed from the starboard aft side, with anchor first (bottom-to-top order).

Deployment of Amundsen-1

A test of deployment depth/mooring length (depth of uppermost instrument) was carried out before the upper part of the mooring (above the RAS) was put into the water, by placing the mooring on the bottom (indicated by relaxed line tension) with help of a line marked into 5 m depth intervals. The test indicated a too shallow top location relative to the planned 45-50 m below the surface and the 40 m Kevlar line above the AURAL was replaced by a 20-meter line.
An approx. 1.5-hour drift was allowed (mooring hanging on the side) towards the desired deployment position before the top part of the mooring was deployed. The mooring was eventually released by help of an acoustic releaser at 15:35 UTC. A calibrated line indicated the releaser was at a depth of ca. 39 m just prior to the release (mooring still in a stretched state). Echograms collected after release showed a top location (IPS) of the released/relaxed mooring at 47 m depth (Figure 27).

Figure 26. The Signature55 ADCP going in the water by the Amundsen-1 site (Photo: Trine Lise Sviggum Helgerud/NPI).

Table 12. Scientific instrumentation for the Amundsen-1 mooring with serial numbers, estimated deployment depth, and programmed sampling interval. The deployment depths will be confirmed upon recovery with help of several pressure sensors.

Amundsen-1	**Latitude**	**Longitude**	**Anchor Depth (m)**	**Depl. time (UTC)**
Amundsen Basin	**86°31.582' N**	**005°36.575' W**	**4215**	**2022.08.07, 15:35**
Instrument	**Serial No.**	**Depl. depth (m)**	**Sampling Interval**	
ASL Env. Sci. IPS5	51064	48	Continuous w/ 2 sec ping period, in target detection mode	
RBR Concerto	60593	49	10 min	
NORTEK Signature250 ADCP, upward looking (narrow bandwidth)	103608	54	1 hr (ensembles of 20 pings over 1 min) NoCells=54;CellSize=2m;BlankDist=0.5m	
Seabird SBE16 w/ WetLabs ECO	50240	55	4 hrs	
Sunburst Sensors SAMI	209	56	2 hours	
Seabird SUNA V2 Nitrate Sensor	1909	57	4 hours (15 light frames, periodic mode)	
Remote Access Sampler (48 bottles)	ML12852-02	66	3x500 ml samples at irregular intervals (in total 16 sampling events, see p.55)	
Seabird SBE56	1225	88	5 min	
RBR Concerto	60599	118	10 min	
Seabird SBE56	1226	148	5 min	
Seabird SBE56	1227	188	5 min	
MTE AURAL-M3	MTEAU00Y YYLF313	208	10 min recording every 60 min	
RBR Concerto	204982	212	10 min	
Seabird SBE56	1228	232	5 min	
RBR Concerto	205985	262	10 min	
RBR Concerto	204986	382	10 min	
NORTEK Signature55 3-beam ADCP, upward looking (narrow bandwidth)	200181	512	1.5 hr (ensembles of 50 pings over 5 min); NoCells=70; CellSize=12m;BlankDist=2m	
RBR Concerto	201401	514	10 min	
RBR Concerto	201147	1595	10 min	
Seabird SBE37	8680	3114	15 min	
McLane ParFlux Sediment trap (PST21)	ML12289-02	3821	1x500 ml sample every 2-4th week (in total 21 sampling events, see p.56)	
RBR Duet	211709	3825	1 min	

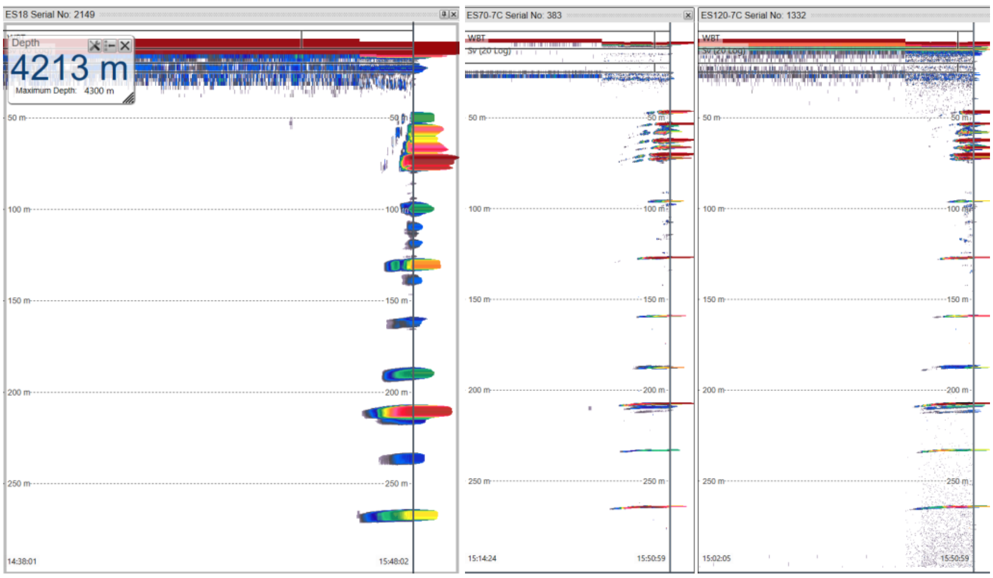
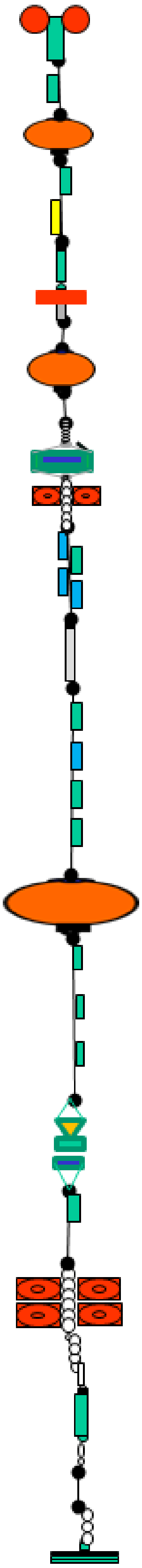


Figure 27. Echograms by the ship' sEK80 (at 18, 70 and 120 kHz) reflecting the location of the uppermost instruments of Amundsen-1

Amundsen-1 Deployed (yyyy.mm.dd) 2022.08.07 at 15:30UTC, Lat: 86°31.582 N, Lon: 005°36.575 W



		Depth (m)	Dist. from bottom (m)	Depl.time
IPS	Snr. 51064	48	4167	15:20
RBR Concerto	Snr. 60593	49	4166	15:20
5 m Kevlar				
Signature 250	Snr: 103608	54	4161	15:20
SBE16/ECO	Snr: 50240	55	4160	15:20
SAMI CO2	Snr: 209	56	4159	15:20
SUNA	Snr: 1909	57	4158	15:20
0,5m Kjetting Galv.				
2 m Kevlar				
AR861 R1	SNR: 0056	60	4155	15:20
Oppdrift med 100 m kevlartau				
2 m Kevlar				
Oppdriftskule		63	4152	
2 m Kevlar				
Vannprøvetaker	SNR: 12852-02	66	4149	15:08
0,5m Kjetting Galv.				
2 Glasskuler i 2 m galv. kjettinger				
SBE56	SNR: 1225	88	4127	14:43
RBR Concerto	SNR: 60599	118	4097	14:41
SBE56	SNR: 1226	148	4067	14:39
SBE56	SNR: 1227	178	4037	14:37
118 m Kevlar (108+20)				
AURAL	SNR: MTEAU00YYYLF 313	208	4007	12:20
2 m Kevlar				
0,5m Kjetting Galv.				
RBR Concerto	SNR: 204982	212	4003	12:20
SBE56	SNR: 1228	232	3983	12:13
RBR Concerto	SNR: 204985	252	3963	
RBR Concerto	SNR: 204986	382	3833	12:09
299 m (213 +43+43) Kevlar				
Signature 55	SNR: 200181	502	3713	12:00
0,5m Kjetting Galv.				
RBR Concerto	SNR: 201401	514	3711	12:00
RBR Concerto	SNR: 201147	1595	2620	11:42
SBE37	SNR: 8680	3114	1001	11:25
3293 m Kevlar (532+535+536+547+536+536+51+20)				
3 m Kevlar				
Sedimentfelle	SNR: ML12289-02	3821	394	
2 m Kevlar				
0,5m Kjetting Galv.				
RBR Duet	SNR: 211709	3825	390	11:12
377 m Kevlar (211+105+51+10)				
4 Glasskuler		4203	12	10:55
2 m Kjetting Galv.				
Svivel				
AR861	SNR. 3193			
5 m Kevlar				
2 m Kjetting				
ANKER 1000(850) kg		4215	0	

Figure 28. Configuration of the Amundsen-1 mooring.

Deployment of Nansen-1

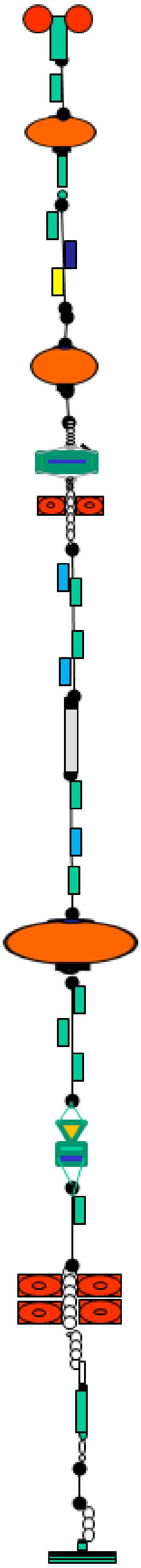
Ice conditions in Nansen basin were more difficult than in the Amundsen basin, with an ice floe of 4-6 nm diameter over the target deployment site and a more consolidated ice field with few naturally open areas suitable for deployment. The deployment was done from a lead within the ice flow created by the KPH. Due to the KPH's location within a large flow it was not easy to reposition before the deployment operation started.
A similar test of mooring length/deployment depth as for the Amundsen-1 was carried out between the AURAL and RAS, indicating a too shallow top location. The 40 m Kevlar line above the AURAL was replaced by a 10-meter line to target a top location around 45 meters.
The mooring was released by help of an acoustic releaser at 16:54 UTC. A calibrated line indicated the releaser was at a depth of 40 m just prior to release. Due to the dense ice conditions over the deployment site, it was not possible to manoeuvre the ship directly over the deployment position for the echo sounder survey and only instruments below 400 m could be identified. Assuming the same relaxation of the mooring line as for Amundsen-1, the top location (IPS) should be at 45-47 m depth.

Figure 29. The sediment trap going in the water by the Nansen-1 site (Photo: Trine Lise Sviggum Helgerud/NPI).

Table 13. Scientific instrumentation for the Amundsen-1 mooring with serial numbers, estimated deployment depth, and programmed sampling interval. The deployment depths will be confirmed upon recovery with help of several pressure sensors.

Nansen-1	**Latitude:**	**Longitude:**	**Anchor Depth (m)**	**Depl. time (UTC)**
Nansen Basin	**83°56.566' N**	**022°15.038' E**	**4025**	**2022.08.15, 16:54**
Instrument	**Serial No.**	**Depl. depth (m)**	**Sampling Interval**	
ASL Env. Sci. IPS5	51127	46	Continuous w/ 2 sec ping period, in target detection mode	
RBR Concerto	60596	47	10 min	
Teledyne RDI Workhorse Sentinel 300 4-beam ADCP, upward looking	24485	52	30 min (ensemble of 50 pings over 36 sec); NoCells=27; CellSize=4m; BlankDist=0.5m	
Seabird SBE16 w/ WetLabs ECO	50296	56	4 hrs	
Sunburst Sensors SAMI	210	57	2 hrs	
Seabird SUNA V2 Nitrate Sensor	1618	58	4 hrs (20 light frames, periodic mode)	
Remote Access Sampler (48 bottles)	ML12852-01	64	3x500 ml samples at irregular intervals (in total 16 sampling events, see p.55)	
Seabird SBE56	1230	88	5 min	
RBR Concerto	60590	118	10 min	
RBR Concerto	60594	148	10 min	
Seabird SBE56	1232	178	5 min	
MTE AURAL-M3	MTEAU00Y YYLF314	198	10 min recording every 60 min	
RBR Concerto	60601	202	10 min	
Seabird SBE56	1234	227	5 min	
RBR Concerto	204979	395	10 min	
NORTEK Signature55 3-beam ADCP, upward looking (narrow bandwidth)	200188	493	1.5 hr (ensemble of 50 pings over 5 min); NoCells=70; CellSize=12m; BlankDist=2m	
RBR Concerto	201407	494	10 min	
RBR Concerto	201146	1575	10 min	
Seabird SBE37	8761	3195	15 min	
McLane ParFlux Sediment trap (PST21)	ML14449-02	3796	One 500 ml sample every 2-4th week (in total 21 cups/events, see p.56)	
RBR Duet	211710	3798	1 min	

Nansen-1 Deployed (yyyy.mm.dd) 2022.08.15 at 16:54UTC, Lat: 83°56.566' N, Lon: 022°15.038' E



		Depth (m)	Dist. from bottom (m)	Depl.time
IPS	Snr. 51127	46	3979	16:50
RBR Concerto	Snr. 60596	47	3978	16:50
5 m Kevlar				
ADCP 300	SNR: 24485	52	3973	16:50
AR861 R1	SNR:0057			
0,5m Kjetting Galv.				
2 m Kevlar				
SBE16/ECO	Snr. 50296	56	3969	16:45
SAMI CO2	Snr. 210	57	3968	16:45
SUNA	Snr. 1618	58	3967	16:45
2 m Kevlar				
Oppdriftskule		61	3964	
2 m Kevlar				
Vannprøvetaker	Snr. 12852-01	64	3961	15:42
2 Glasskuler				
2,5m Kjetting Galv.				
SBE56	SNR: 1230	88	3937	15:12
RBR Concerto	SNR: 60590	118	3907	15:08
RBR Concerto	SNR: 60594	148	3877	15:05
SBE56	SNR: 1232	178	3847	14:55
139 m Kevlar (109+20)				
AURAL	SNR: MTEAU00YYYLF314	198	3827	14:47
2 m Kevlar				
0,5m Kjetting Galv.				
RBR Concerto	SNR: 60601	202	3823	14:47
SBE56	SNR: 1234	227	3798	14:42
RBR Concerto	SNR: 204979	395	3630	14:38
291 m Kevlar (229+52+10)				
Signature 55	SNR: 200188	493	3532	14:33
0,5m Kjetting Galv.				
RBR Concerto	SNR: 201407	494	3531	14:33
RBR Concerto	SNR: 201146	1575	2451	12:35
SBE37	SNR: 8761	3195	825	11:38
3302 m Kevlar (539+542+538+541+541+541+40+20)				
Sedimentfelle	SNR: ML14449-02	3796	229	11:22
0,5m Kjetting Galv.				
RBR Duett	SNR: 211710	3798	227	11:22
215 m Kevlar				
4 Glasskuler		4013	12	11:15
2 m Kjetting Galv.				
Svivel				
AR861	SNR. 3192			
5 m Kevlar				
2 m Kjetting				
ANKER 1000(850) kg		4025	0	

Figure 30. Configuration of the Nansen-1 mooring.

Moored water samplers (RAS)

Contact: Yannick Kern

Two McLane Remote Access Samplers (RAS) were deployed at a target depth of 60 m on the Amundsen-1 and Nansen-1 moorings (see p.49). For the preparation each of the 48 sampling tubes was primed with artificial seawater (Milli-Q water + NaCl) at a salinity of approximately 35 g/kg. A blank sample for eDNA of the priming water was taken for reference in later analysis. Each sample bag was prepared with 0.7 ml saturated $HgCl_2$ as a preservative. Post-sample flushing with acid was enabled and the acid bag was filled with 500 ml of 10% HCl acid. All communication during priming and deployment programming of the RAS via McLaneTerm was stored in form of capture file.

The sampling schedule plan and configuration of each RAS is summarised in tables 14 and 15 below. Three bags are filled at each sampling time to provide sufficient sample volume for all planned analyses. Note that times are planned to be concurrent with samples collected by similar samplers deployed in Fram Strait.

Table 14. Sampling schedule for moored water samplers

Fram Strait events	Nansen-1	Amundsen-1	Bag count
	16.08.2022	08.08.2022	3
30.08.2022	30.08.2022	30.08.2022	6
15.09.2022	15.09.2022	15.09.2022	9
01.10.2022	01.10.2022	01.10.2022	12
02.11.2022	02.11.2022	02.11.2022	15
04.12.2022	04.12.2022	04.12.2022	18
01.05.2023	05.01.2023	05.01.2023	21
06.02.2023	06.02.2023	06.02.2023	24
02.03.2023	02.03.2023	02.03.2023	27
03.04.2023	03.04.2023	03.04.2023	30
05.05.2023	05.05.2023	05.05.2023	33
21.05.2023	21.05.2023	21.05.2023	36
06.06.2023	06.06.2023	06.06.2023	39
22.06.2023	22.06.2023	22.06.2023	42
08.07.2023	08.07.2023	08.07.2023	45
24.07.2023	24.07.2023	24.07.2023	48

Table 15. Configuration summary for moored water samplers

	Nansen-01	Ammundsen-01
Frame	12852-01	12852-02
Model	RAS 3-48-500	RAS 3-48-500
Casing	ML 12852-01	ML 12852-02
Valve	12852-02	12852-01
Pump	12852-02	12852-01
Pump head	1168170006	1125433003
Pump model	GA-V21.C8FT.C	GA-V21.CFS.C
Capture priming	2022-08-13_nansen _priming.txt	2022-08-04_amundsen _priming_[a-c].txt
Capture deployment	2022-08-14_nansen _deployment.txt	2022-08-06_amundsen _deployment.txt

Potential problems with water samplers deployed: Some of the plastic sample tubes showed minor leaks at the lower ends where the outer body of the tube is joined to the plastic disc at the bottom. Note that the sample itself is contained in a sample bag and that these leaks concern the fluid on the outside of the sample bag. However, it is possible leakages here could lead to lower than planned sample volumes being collected. The lower multi-way valve of the sampler deployed at Nansen-1 also showed minor leakage. This issue concerns the fluid on the outside of the sample bag and not the sample itself but could also lead to lower than planned sample volumes being collected. Potential problems with the two samplers are summarised in below

Nansen-1

- Leaking tubes around sealing at bottom:
  - replaced tube 40
- Multivalve not watertight and should be replaced. Potential chance of only sampling around 350ml instead of 500ml per bag.

Ammundsen-1

- Leaking sample tubes:
  - replaced tubes 23,33 and 48
  - tubes 7, 10, 12 and 31 could not be replaced due to a shortage of spare tubes.

Moored sediment traps

Contact: Janne Søreide (UNIS) and Daniel Vogedes (UiT)

Both the Amundsen-1 and Nansen-1 moorings deployed during the cruise (see p.49), were equipped with sequential automated McLane ParFlux 21-cups sediment trap (PST21) deployed at deeper depth to collect down-falling particles through the water column.
The scheduled sampling intervals vary between 2-4 weeks and correspond to the intervals for the moored water samplers; see p.55) and the monthly sediment trap intervals used in Svalbard with finer resolution during the productive season (see KROP – Mare Incognitum). The sediment trap sample cups collect everything that settles during the time interval set (integrative sampling), while the RAS samples water at the date programmed (snapshot sampling).

Pre-deployment preparation procedure: Both traps are powered by internal battery packs. New batteries were loaded (14 alkaline c-cell batteries). After the change of batteries, the date was set according to US-date format (mm/dd/yy, 24-hour format, UTC). A diagnostics test was run to confirm battery voltage, temperature, and rotator alignment, see Table 16. The sampling schedule was set according to Table 17 and 18, respectively, with sampling taking place every 2-4 weeks.

Each cup/bottle (500 ml) was rinsed with mili-Q water, air-dried, and filled with formaldehyde-filtered sea water fixative solution (a mixture of mili-Q, formalin, and salt), with help of the MotoCrossML software. Start position for the turntable was set to zero port, under the funnel. The bottles were marked with ID #1-#21, see Tables 17 and 18. At each sampling, one 500 ml bottle will rotate into place underneath the funnel to collect depositing particles integratively until the next bottle rotation.

The final deployment depth for the sediment traps was estimated to 3821 m (Amundsen-1; Ser.No ML12289-02) and 3796 m (Nansen-1; Ser.No ML14449-02) but will be finally determined at recovery with help of pressure sensors attached along the mooring line.

Table 16. System status prior to deployment for the Amundsen-1 sediment trap (SerNo: ML12289-02; left panel) and Nansen-1 sediment trap (SerNo: ML14449-02; right panel).

Configuration: PST-21 CF2 V3_16 McLane Research Laboratories, Inc. ParFlux Sediment Trap ML12289-02 System status: Battery Internal Date Time Voltage Temp.(C) Rotator 08/06/22 17:56:11 20.5 3.8 aligned	Configuration: PST-21 CF2 V3_16 McLane Research Laboratories, Inc. ParFlux Sediment Trap ML14449-02 System status: Battery Internal Date Time Voltage Temp.(C) Rotator 08/14/22 14:27:03 20.1 9.8 aligned

Table 17. Sampling schedule of the Amundsen-1 sediment trap (SerNo: ML12289-02). The photo shows the trap and the RBR Duet attached underneath, on one of the lines.

Amundsen-1 Sediment trap sampling schedule		
Lat: 86°31.582’ N	Lon: 5°36.575’ W	Depth: 3821 m
Rotation of turntable	Start of sampling period (mm/dd/yy hh:mm UTC)	Sample bottle ID
Event 1*	08/09/22 12:00	Amund #1
Event 2	09/01/22 12:00	Amund #2
Event 3	09/15/22 12:00	Amund #3
Event 4	10/01/22 12:00	Amund #4
Event 5	11/01/22 12:00	Amund #5
Event 6	12/01/22 12:00	Amund #6
Event 7	01/01/23 12:00	Amund #7
Event 8	02/01/23 12:00	Amund #8
Event 9	03/01/23 12:00	Amund #9
Event 10	04/01/23 12:00	Amund #10
Event 11	05/01/23 12:00	Amund #11
Event 12	06/01/23 12:00	Amund #12
Event 13	06/21/23 12:00	Amund #13
Event 14	07/05/23 12:00	Amund #14
Event 15	07/19/23 12:00	Amund #15
Event 16	08/09/23 12:00	Amund #16
Event 17	09/01/23 12:00	Amund #17
Event 18	01/01/24 12:00	Amund #18
Event 19	05/01/24 12:00	Amund #19
Event 20	06/21/24 12:00	Amund #20
Event 21	09/01/24 12:00	Amund #21
Event 22**	10/01/24 12:00	Amund #22

* rotation from open hole (zero port) to first bottle
** rotation from last bottle to open hole (zero port)

Table 18. Sampling schedule of the Nansen-1 sediment trap (Ser.No: ML14449-02). The photo shows the trap and the RBR Duet attached underneath, on one of the lines.

Nansen-1 Sediment trap sampling schedule		
Lat: 83°56.866’ N	Lon: 22°15.038’ W	Depth: 3796 m
Rotation of turntable	Start of sampling period (mm/dd/yy hh:mm; UTC)	Sample bottle ID
Event 1*	08/15/22 12:00	Nansen #1
Event 2	09/01/22 12:00	Nansen #2
Event 3	09/15/22 12:00	Nansen #3
Event 4	10/01/22 12:00	Nansen #4
Event 5	11/01/22 12:00	Nansen #5
Event 6	12/01/22 12:00	Nansen #6
Event 7	01/01/23 12:00	Nansen #7
Event 8	02/01/23 12:00	Nansen #8
Event 9	03/01/23 12:00	Nansen #9
Event 10	04/01/23 12:00	Nansen #10
Event 11	05/01/23 12:00	Nansen #11
Event 12	06/01/23 12:00	Nansen #12
Event 13	06/21/23 12:00	Nansen #13
Event 14	07/05/23 12:00	Nansen #14
Event 15	07/19/23 12:00	Nansen #15
Event 16	08/09/23 12:00	Nansen #16
Event 17	09/01/23 12:00	Nansen #17
Event 18	01/01/24 12:00	Nansen #18
Event 19	05/01/24 12:00	Nansen #19
Event 20	06/21/24 12:00	Nansen #20
Event 21	09/01/24 12:00	Nansen #21
Event 22**	10/01/24 12:00	Nansen #22

* rotation from open hole (zero port) to first bottle
** rotation from last bottle to open hole (zero port)

Multibeam surveys prior to mooring deployments

Contacts: Paul Dodd, Roy Robertsen

Before the deep mooring deployments, surveys with the ship's EM303 multibeam echosounder were carried out to map the bottom characteristics of the target deployment sites. The echosounder was calibrated for the current hydrographic conditions (sound velocity) with help of a full-depth CTD cast just prior to each multibeam survey (CTD 151 for the Amundsen Site and CTD 178 for the Nansen site). The location of the mooring sites and the extent of each survey is outlined in Figure 31a,b. Both sites had level bathymetry with depths varying by less than +/- 5 m within the areas surveyed. Typical depths were 4206 m for the Amundsen site and 4010 at the Nansen site.

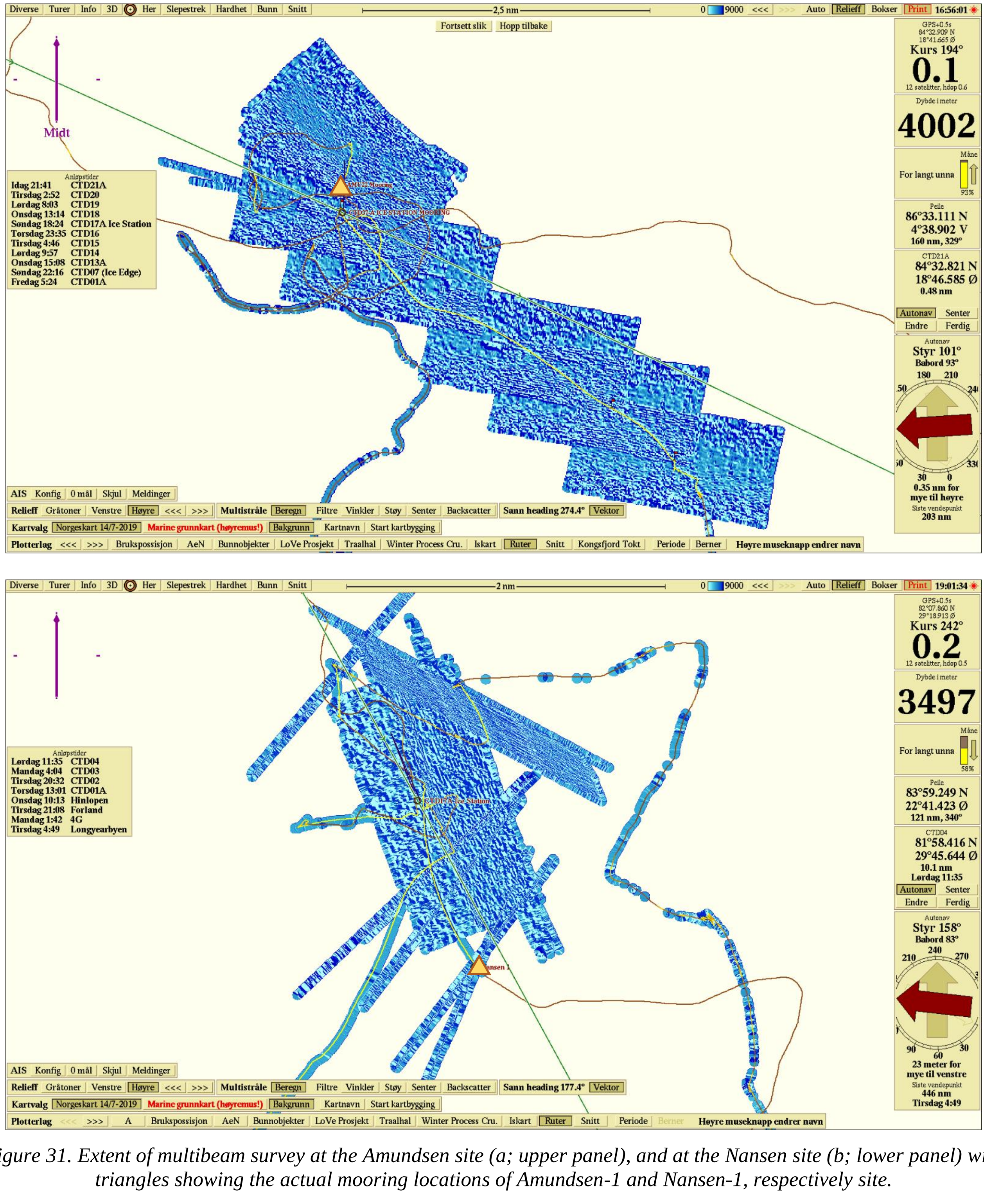


Figure 31. Extent of multibeam survey at the Amundsen site (a; upper panel), and at the Nansen site (b; lower panel) with triangles showing the actual mooring locations of Amundsen-1 and Nansen-1, respectively site.

Sea ice stations

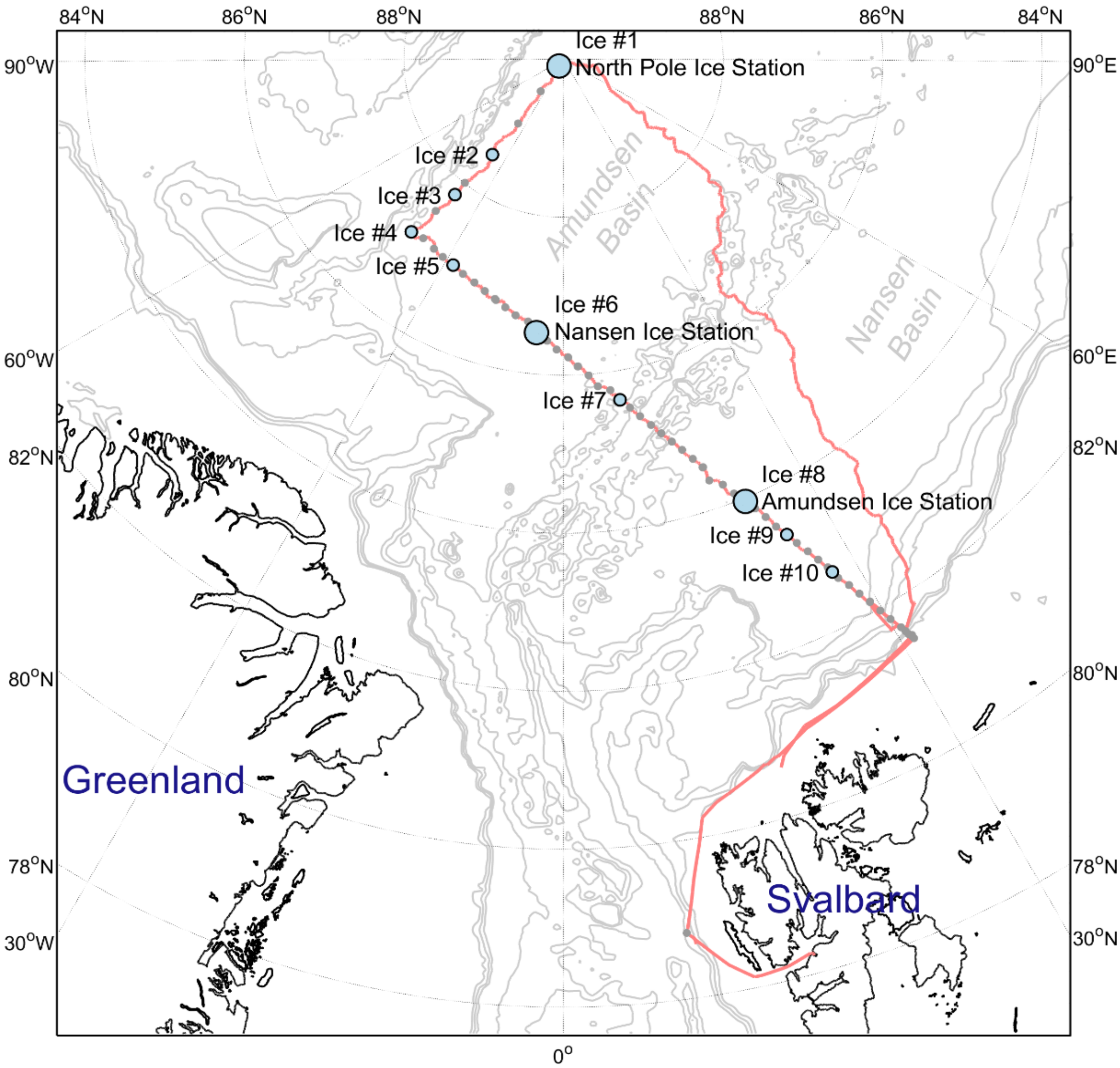


Figure 32. The locations of the AO-22 ice stations. Larger symbols mark the major, longer ice stations while smaller symbols are used for shorter ice-stations/visits, e.g. for deployment of ice buoys or brief sampling.

Table 19. Start time and location of all sea ice stations. Ice station #1, #6 and #8 were the major ones.

Sea Ice Station #	Start time	Start position
#1 (North Pole)	29-Jul-2022 07:10 UTC	N 89° 53.916’ W 033° 50.814’
#2 (Basket)	31-Jul-2022 17:00 UTC	N 88° 30’ W 036° 28’
#3 (Basket)	01-Aug-2022 12:15 UTC	N 87° 48.729’, W 038° 29.040’
#4 (Basket)	02-Aug-2022 13:15 UTC	N 87° 05.999, W 041° 10.363
#5 (Basket)	03-Aug-2022 06:26 UTC	N 87° 03 N, W 028° 00’
#6 (Amundsen Basin)	05-Aug-2022 06:50 UTC	N 86° 31.382’, W 005° 36.514’
#7 (Basket)	09-Aug-2022 10:19 UTC	N 85° 37.847’, E 009° 20.601’
#8 (Nansen Basin)	12-Aug-2022 14:10 UTC	N 83° 57.450’ E 22° 13.200’
#9 (Basket)	16-Aug-2022 06:50 UTC	N 83° 21.884’ E 25° 01.615’
#10 (Marginal Ice Zone)	17-Aug-2022 07:50 UTC	N 82° 41.349’ E 027° 32.079’

Ice Station #1 (North Pole)

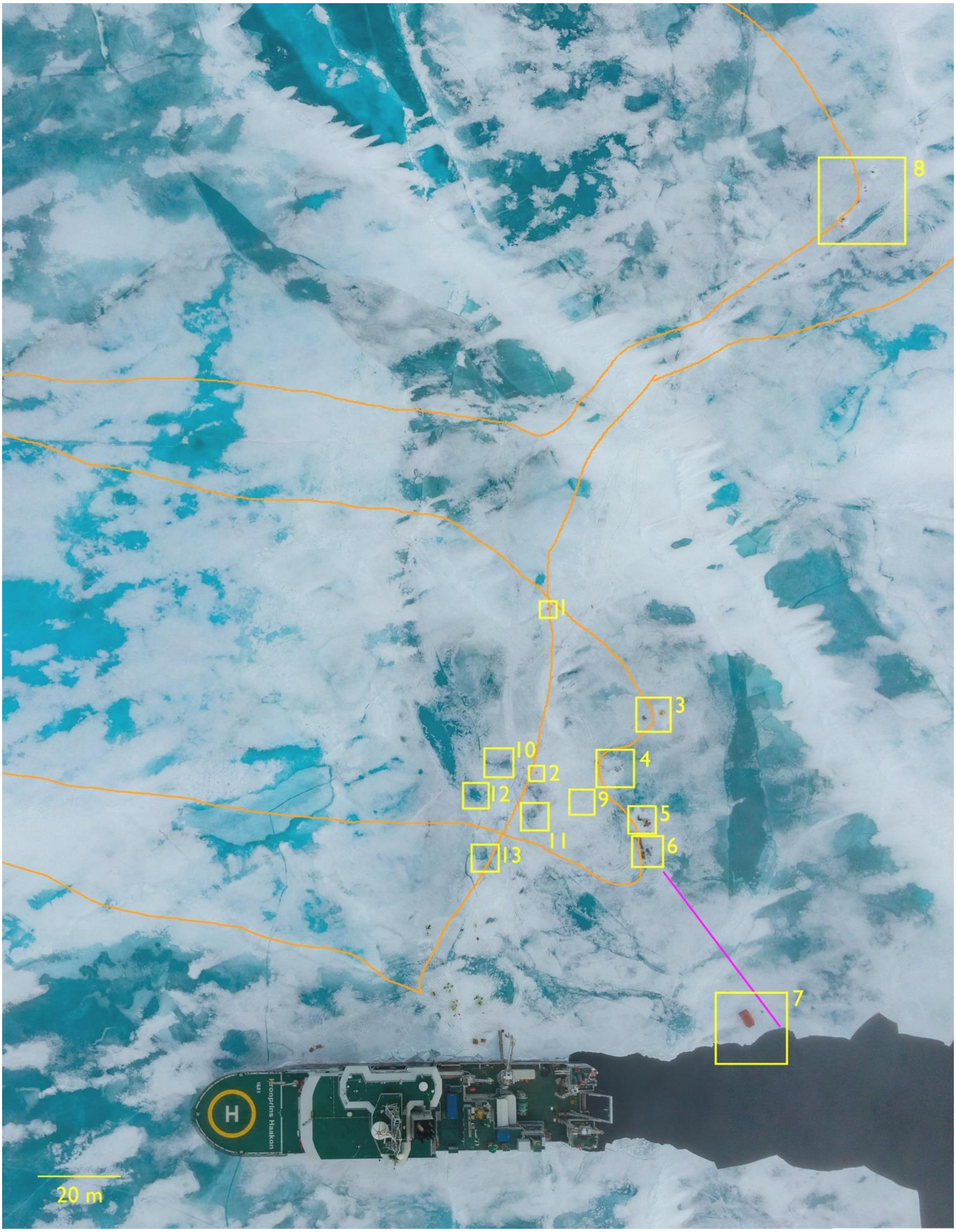


Figure 33. Mosaic of arial images showing the work area on at North Pole ice station. Yellow boxes: work sites, orange line: EM and snow transect. Pink line ROV transect. Images provided by Vegard Stürzinger.

Table 20. Metadata for Ice station #1

	Site	Date	Time	Configuration
Equipment Installed and left behind				
AZFP-ITO (UiT)	3	29-July	16:30	
SIMBA-UIT0202 (UiT)	2	29-July	16:30	(IMEI 300234065765510)
SIMBA-UIT0204 (UiT)	1	29-July	16:30	(IMEI 300234065863280)
LT-ITO1 (UiT)	1	29-July	16:30	
LT-ITO1 (UiT)	2	29-July	16:30	
Weather Station (UiT)	3	29-July	16:30	
Equipment installed temporarily				
ADCP-signiture 500	8	29-July	10:40	30 cm below ice/water interface down-looking
SUNA(SN1618)	8	29-July	11:00	10 m below ice/water interface
RBR CTD (SN201408)	8	29-July	11:00	10 m below ice/water interface
Nitrate TriOS Opus (49227375)	8	29-July	11:00	20 cm below ice/water interface
Nitrate TriOS Opus (49227376)	8	29-July	11:00	1 m below ice/water interface
Nitrate TriOS Opus (49227372)	8	29-July	11:00	5 m below ice/water interface
Nortek vector (4990)	8	29-July	12:45	20 cm below ice/water interface
Rockland microsquid	8	29-July	12:45	20 cm below ice/water interface
Hobo light sensor (21349878)	8	29-July	08:55	1 m above ice/water interface
Hobo light sensor (21349883)	8	29-July	11:00	20 cm below ice/water interface
Hobo light sensor (21349882)	8	29-July	11:00	1m below ice/water interface
Ramses irradiance (NPI-1)	4	29-July	12:24	25 cm below ice/water interface uplooking
Ramses irradiance (NPI-2)	4	29-July	12:24	25 cm below ice/water interface downlooking
Ramses irradiance (NPI-3)	4	29-July	12:24	2 m over ice surface uplooking
LICOR PAR (2pi)	4	29-July	12:24	1 m over ice surface uplooking
LICOR PAR (4pi)	4	29-July	12:24	25 cm below ice/water interface uplooking
Ramses irradiance (NPI-1)	4	29-July	15:15	25 cm below ice/water interface uplooking
Ramses irradiance (NPI-2)	4	29-July	15:15	25 cm below ice/water interface downlooking
Ramses irradiance (NPI-3)	4	29-July	15:15	2 m over ice surface uplooking
LICOR PAR (2pi)	4	29-July	15:15	1 m over ice surface uplooking
LICOR PAR (4pi)	4	29-July	15:15	25 cm below ice/water interface uplooking
Profiling instruments cast from ice				
MSS session 1	5	29-July	13:00	1 cast to 200 m (1)
MSS session 2	5	29-July	16:00	3 casts to 200 m (2-4)
MSS session 3	5	29-July	21:00	2 casts to 200 m (5-6)
MSS session 4	5	30-July	04:00	3 cast to 200 m (7-9)
MSS session 5	5	30-July	07:00	4 casts to 200 m (10-13)
MSS session 6	5	30-July	12:00	5 casts to 200 m (14-18)
Wetlabs ACS (NPI, SN 311)	5	29-July	18:30	1 cast to 95 m (Optics-003)
Seabird Microcat (NPI, SN 20177)	5	29-July	18:30	1 cast to 95 m (Optics-003)
Seabird Chl-A fluorometer (NPI, SN 725)	5	29-July	18:30	1 cast to 95 m (Optics-003)
Seabird FDOM fluorometer (DTU, SN 7470)	5	29-July	18:30	1 cast to 95 m (Optics-003)
Sequoia LISST-VSF (UIB, SN 1667)	5	30-July	07:30	Stopped at depths of 2 & 5 m below water surface (LISST-003)
Cast-Away CTD	4	29-July	19:00	1 cast to 25 m
Plankton Net	5	30-July	06:30	1 cast to 25 m
Cameras / Imagers				
UHI (NPI)	4	29-July	13:30	1 m below ice/water interface uplooking 180° 1m ø swath
UHI (NPI)	6	30-July	12:00	1 m below ice/water interface uplooking 180° 1m ø swath
ROV Video	7	30-July	12:00	Video camera line from ice edge to site 6 (pink line on map)
Ice cores				
Bacteria core 1	4	29-July	17:00	
Bacteria core 2	4	29-July	17:00	
Microplastic core 1	4	29-July	17:00	
CDOM core 1	4	29-July	17:00	
CDOM core 2	4	29-July	17:00	
CDOM core 3	4	29-July	17:00	
CDOM core 4	4	29-July	17:00	
HPLC core 1	4	29-July	13:45	
HPLC core 2	4	29-July	13:45	
HPLC core 3	4	29-July	13:45	
HPLC core 4	4	29-July	13:45	
Nutrient/DIC/DOC core 1	4	29-July	13:45	
Nutrient/DIC/DOC core 2	4	29-July	13:45	
Production incubation 4 cores pooled	4	29-July	13:45	
Production incubation 4 cores pooled	6	30-July	12:15	
POC & chlorophyll core 1	4	29-July	13:45	
POC & chlorophyll core 2	4	29-July	13:45	
POC & chlorophyll core 3	4	29-July	13:45	
Intracellular nutrients core	4	29-July	13:45	
Chlorophyll core bottom	4	29-July	13:45	
Salinity & d18O core	4	29-July	14:00	
DIC, nutrients & d18o core	4	29-July	14:00	

Temperature core	4	29-July	14:00	
Archive core	4	29-July	14:00	
Stratigraphy core	4	29-July	14:00	
Density core	4	29-July	14:00	
HPLC core 1	6	30-July	12:15	
HPLC core 2	6	30-July	12:15	
HPLC core 3	6	30-July	12:15	
HPLC core 4	6	30-July	12:15	
Transects				
Ice and snow thickness survey	n/a	30-July	08:00	(orange line on map)
Water Samples				
Melt Pond Water	10	29-July	12:30	1 sample (1000) for alkalinity, pH, nuts, d18o)
Melt Pond Water	11	29-July	12:30	1 sample (1001) for alkalinity, pH, nuts, d18o)
Melt Pond Water	12	29-July	12:30	1 sample (1002) for alkalinity, pH, nuts, d18o)
Melt Pond Water	13	29-July	12:30	1 sample (1003) for alkalinity, pH, nuts, d18o)
Underice water samples	4	29-July	17:00	Ice/water interface
Underice water samples	4	29-July	17:00	20 cm below Ice/water interface
Underice water samples	4	29-July	17:00	1 m below Ice/water interface
Underice water samples	4	29-July	17:00	5 m below Ice/water interface
Underice water samples	4	29-July	17:00	10 m below Ice/water interface
Underice water samples	4	29-July	17:00	25 m below Ice/water interface
** under ice water samples analysed for: DIC, nutrients, d18O, Chl-A, POC, flow cytometry & taxonomy*				
Snow				
Snowpit	9	30-July	11:30	
Snow Sample	9	30-July	08:50	1 sample (1009) of 6 cm snow-pack for alkal., pH, nuts, d18O

Ice Station #2 (N 88° 30', W 036° 28')

Figure 34. Deployment site for SIMBA buoy NPI 0802

Table 21. Metadata for Ice station #2

	Site	Date	Time	Configuration
Ice thickness Drilling	1	31-Aug	19:00	
SIMBA buoy NPI 0802	1	31-Aug	19:21	IMEI (300534061788840)

Ice Station #3 (N 87° 48’, W 038° 29’)

Figure 35. Deployment site for SIMBA buoy LOCEAN 0702

Table 22. Metadata for Ice station #3

	Site	Date	Time	Configuration
Ice thickness Drilling	1	01-Aug	12:30	
SIMBA buoy (LOCEAN 0702)	1	01-Aug	12:30	IMEI (300 234 065 173 780)

Ice Station #4 (N 87° 06’, W 041° 10’)

Figure 36. Deployment site for SIMBA buoy LOCEAN 0701.

Table 23. Metadata for Ice station #4

	Site	Date	Time	Configuration
Ice thickness Drilling	1	02-Aug	13:15	
SIMBA buoy LOCEAN 0701	1	02-Aug	13:38	IMEI (300 234 065 176 790)

Ice Station #5 (N 87° 03, W 028° 00')

Figure 37. Image showing the work area on sea ice station 5. Yellow boxes: work sites

Table 24. Metadata for Ice station #5

	Site	Date	Time	Configuration
Ice thickness Drilling	1	03-Aug	09:00	
Pooled Incubation Core 1	1	03-Aug	09:00	Core bottom only 5 cm
Pooled Incubation Core 2	1	03-Aug	09:00	Core bottom only 5 cm
Nutrients Core 3	1	03-Aug	09:00	Core bottom only 10 cm
Chla Core 4	1	03-Aug	10:30	Full core
Salinity & Temp Core	1	03-Aug	11:00	Full core
Water sample	1	03-Aug	10:00	Ocean/ice interface
Cast-away CTD	2	03-Aug	08:50	Cast to 25 m depth

Ice Station #6 (Amundsen Basin - N 86° 31, W 005° 36')

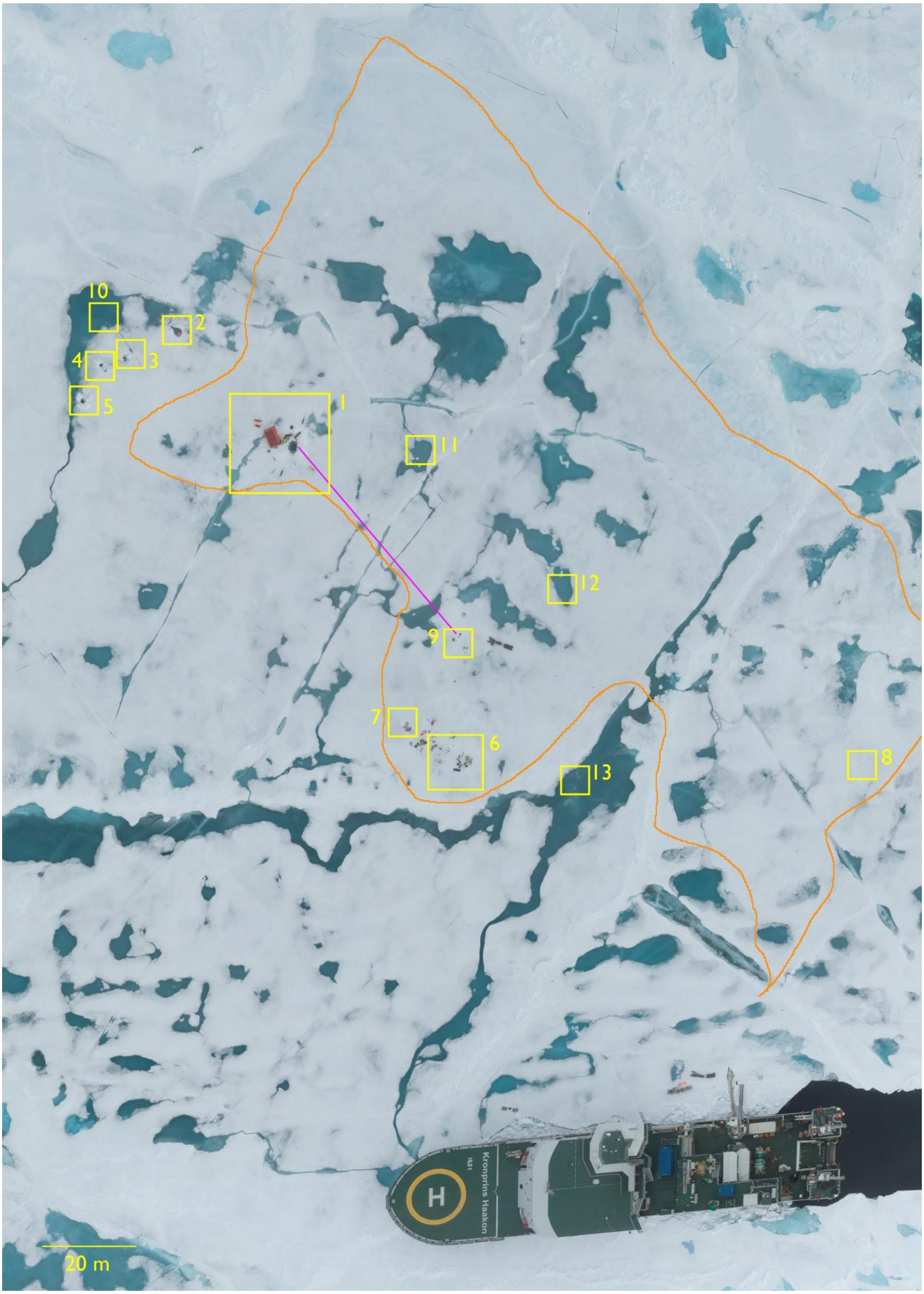


Figure 38. Mosaic of ariel images showing the work area on at Amundsen Basin ice station (#6). Yellow boxes: work sites, orange line: EM and snow transect. Pink line ROV transect. Images provided by Vegard Stürzinger.

Table 25. Metadata for Ice station #6

	Site	Date	Time	Configuration
Equipment Installed and left behind				
SIMBA buoy NPI 0803	1	06-Aug	10:40	IMEI (300534061784880)
Equipment installed temporarily				
ADCP-signature 500	5	05-Aug	09:30	30 cm below ice/water interface down-looking
SUNA(SN1618)	3	05-Aug	09:40	10 m below ice/water interface
RBR CTD (SN201408)	3	05-Aug	09:40	10 m below ice/water interface
Nitrate TriOS Opus (49227375)	4	05-Aug	11:00	20 cm below ice/water interface
Nitrate TriOS Opus (49227376)	4	05-Aug	11:00	1 m below ice/water interface
Nitrate TriOS Opus (49227372)	4	05-Aug	11:00	5 m below ice/water interface
Nortek vector (4990)	2	05-Aug	12:27	20 cm below ice/water interface
Rockland microsquid	2	05-Aug	12:27	20 cm below ice/water interface
Hobo light sensor (21349878)	4	05-Aug	10:15	1 m above ice/water interface
Hobo light sensor (21349883)	4	05-Aug	09:30	20 cm below ice/water interface
Hobo light sensor (21349882)	4	05-Aug	09:30	1m below ice/water interface
Ramses irradiance (NPI-1)	6	05-Aug	11:00	25 cm below ice/water interface uplooking (instantaneous)
Ramses irradiance (NPI-2)	6	05-Aug	11:00	25 cm below ice/water interface downlooking (instantaneous)
Ramses irradiance (NPI-3)	6	05-Aug	11:00	2 m over ice surface uplooking (instantaneous)
LICOR PAR (2pi)	6	05-Aug	11:00	1 m over ice surface uplooking (instantaneous)
LICOR PAR (4pi)	6	05-Aug	11:00	25 cm below ice/water interface uplooking (instantaneous)
Ramses irradiance (NPI-1)	7	05-Aug	12:00	25 cm below ice/water interface uplooking (24h time series)
Ramses irradiance (NPI-2)	7	05-Aug	12:00	25 cm below ice/water interface downlooking (24h time series)
Ramses irradiance (NPI-3)	7	05-Aug	12:00	2 m over ice surface uplooking (24h time series)
LICOR PAR (2pi)	7	05-Aug	12:00	1 m over ice surface uplooking (24h time series)
LICOR PAR (4pi)	7	05-Aug	12:00	25 cm below ice/water interface uplooking (24h time series)
Profiling instruments cast from ice				
MSS session 1	1	05-Aug	13:10	3 cast to 200 m (31-33)
MSS session 2	1	05-Aug	15:10	3 casts to 200 m (34-36)
MSS session 3	1	05-Aug	18:40	2 casts to 200 m (37-38)
MSS session 4	1	06-Aug	04:50	3 cast to 200 m (39-41)
MSS session 5	1	06-Aug	09:10	3 casts to 200 m (42-44)
MSS session 6	1	06-Aug	13:20	2 casts to 200 m (45-46)
Wetlabs ACS (NPI, SN 311)	1	05-Aug	16:55	1 cast to 73 m (Optics-009)
Seabird Microcat (NPI, SN 20177)	1	05-Aug	16:55	1 cast to 73 m (Optics-009)
Seabird Chl-A fluorometer (NPI, SN 725)	1	05-Aug	16:55	1 cast to 73 m (Optics-009)
Seabird FDOM fluorometer (DTU, SN 7470)	1	05-Aug	16:55	1 cast to 73 m (Optics-009)
Sequoia LISST-VSF (UIB, SN 1667)	1	05-Aug	17:39	Stopped at depths of 2 & 5 m below water surface (LISST-009)
Cast-Away CTD	6	05-Aug	17:00	1 cast to 25 m
Plankton Net	1	06-Aug	06:50	1 cast to 25 m
Cameras / Imagers				
UHI (NPI)	6	05-Aug	12:00	1 m below ice/water interface uplooking 360° 1m ø swath
UHI (NPI)	9	06-Aug	09:00	1 m below ice/water interface uplooking 360° 1m ø swath
UHI (NPI)	9	06-Aug	14:00	1 m below ice/water interface uplooking 360° 1m ø swath
UHI (NPI)	9	06-Aug	14:00	1 m below ice/water interface uplooking 360° 1m ø swath
ROV UHI	Tr	05-Aug	17:00	Pink Line (3m depth)
ROV UHI	Tr	06-Aug	14:00	Pink Line (3m depth)
ROV UHI	Tr	06-Aug	14:00	Pink Line(3m depth)
Ice cores				
Bacteria core 1	6	05-Aug	17:00	
Bacteria core 2	6	05-Aug	17:00	
Microplastic core 1	6	05-Aug	17:00	
CDOM core 1	6	05-Aug	16:00	
CDOM core 2	6	05-Aug	16:00	
CDOM core 3	6	05-Aug	16:00	
CDOM core 4	6	05-Aug	16:00	
HPLC core 1	6	05-Aug	13:00	
HPLC core 2	6	05-Aug	13:00	
HPLC core 3	6	05-Aug	13:00	
HPLC core 4	6	05-Aug	13:00	
Nutrient/DIC/DOC/O2 core 1	6	05-Aug	13:00	
Nutrient/DIC/DOC/O2 core 2	6	05-Aug	13:00	
Production incubation 4 cores pooled	6	05-Aug	13:00	
POC & chlorophyll core 1	6	05-Aug	13:00	
POC & chlorophyll core 2	6	05-Aug	13:00	
POC & chlorophyll core 3	6	05-Aug	13:00	
Intracellular nutrients core	6	05-Aug	13:00	
Chlorophyll core bottom	6	05-Aug	13:00	
Salinity & d18O core	6	05.Aug	13:15	
DIC, nutrients & d18o core	6	05.Aug	13:15	
Temperature core	6	05.Aug	13:15	

Archive core	6	05.Aug	13:15	
Stratigraphy core	6	05.Aug	13:15	
Density core	6	05.Aug	13:15	
HPLC core 1	9	06-Aug	08:00	
HPLC core 2	9	06-Aug	08:00	
HPLC core 3	9	06-Aug	08:00	
HPLC core 4	9	06-Aug	08:00	
Production incubation 4 cores pooled	9	06-Aug	08:00	
Transects				
Ice and snow thickness survey	n/a	06-Aug	13:15	(orange line on map)
Water Samples				
Melt Pond Water	10	05-Aug	07:45	1 sample (1027) for alkalinity, pH, nuts, d18o)
Melt Pond Water	11	05-Aug	07:45	1 sample (1028) for alkalinity, pH, nuts, d18o)
Melt Pond Water	12	05-Aug	07:45	1 sample (1029) for alkalinity, pH, nuts, d18o)
Melt Pond Water	13	05-Aug	07:45	1 sample (1030) for alkalinity, pH, nuts, d18o)
Underice water samples	6	05-Aug	15:00	Ice/water interface for DIC, nuts, d18o, chl-a,o2,nutrients,POC
Underice water samples	6	05-Aug	15:00	20 cm below Ice/water interface, chl-a,o2,nutrients,POC
Underice water samples	6	05-Aug	15:00	1 m below Ice/water interface for DIC, nuts, d18o, chl-a, nutrients, POC
Underice water samples	6	05-Aug	15:00	5 m below Ice/water interface for DIC, nuts, d18o, chl-a, ,nutrients, POC
Underice water samples	6	05-Aug	15:00	10 m below Ice/water interface for DIC, nuts, d18o, chl-a, nutrients, POC
Underice water samples	6	05-Aug	15:00	25 m below Ice/water interface for DIC, nuts, d18o, chl-a, ,nutrients, POC
Underice water samples	2	05-Aug	09:40	At ice/water interface 02, nutrients
Underice water samples	5	06-Aug	07:00	At ice/water interface 02, nutrients
Underice water samples	5	06-Aug	17:30	At ice/water interface 02, nutrients
Snow				
Snowpit	6	00-Aug	07:30	
Snow Sample	6	06-Aug	07:30	2 samples (1036, 1037) of 7 cm snow-pack for alkalinity, pH, nuts, d18O

Ice Station #7 (N 85° 38', E 009° 21')

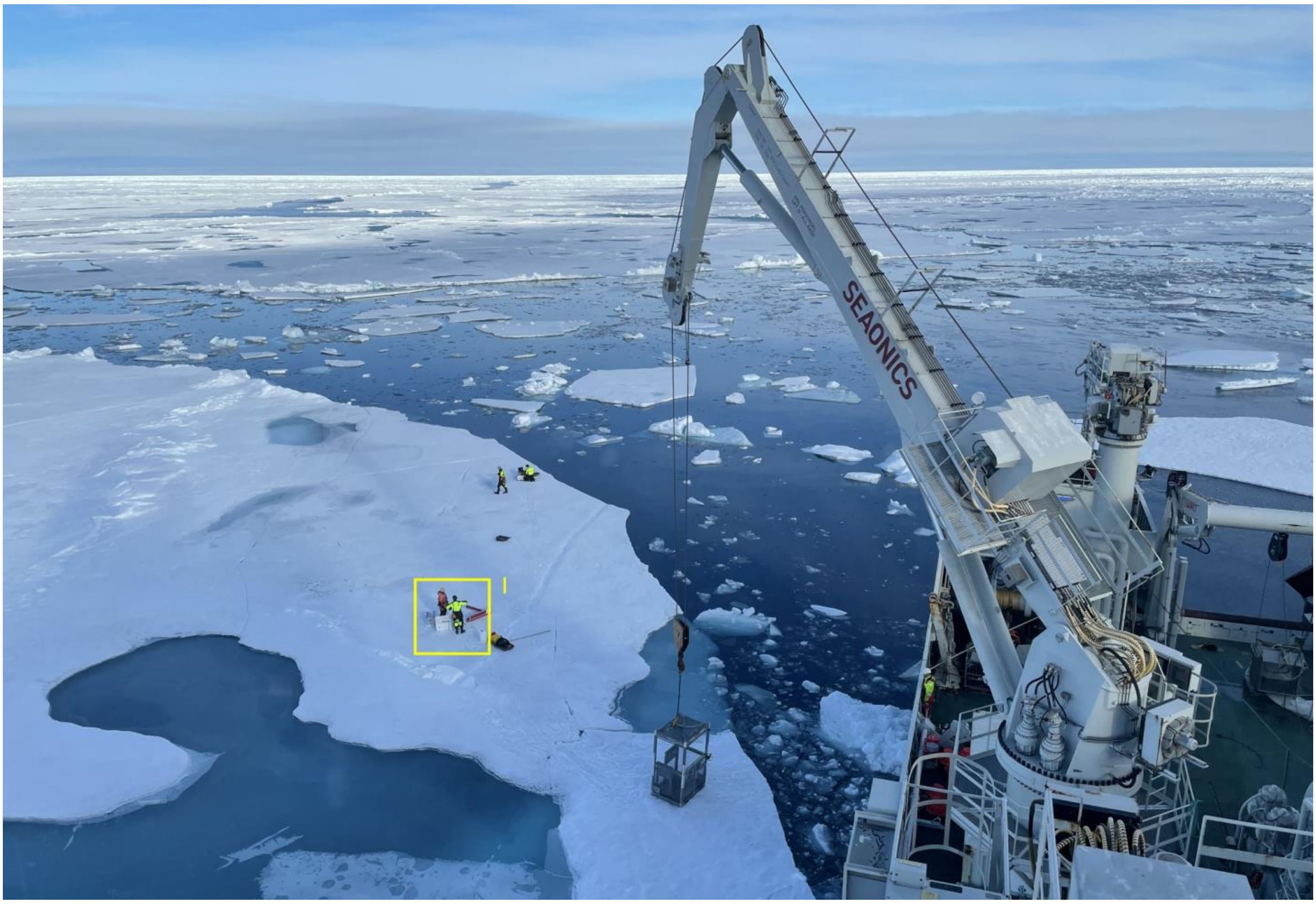


Figure 39. Image showing the work area (yellow box) on sea ice station 7.

Table 26. Metadata for Ice station #7

	Site	Date	Time	Configuration
Cameras / Imagers				
ROV Alga collection test	2	09-Aug	11:30	Pink Line (3m depth)
Ice thickness Drilling	1	09-Aug	09:00	
Pooled Incubation Core	1	09-Aug	09:00	Core bottom only 5 cm
Pooled Incubation Core	1	09-Aug	09:00	Core bottom only 5 cm
Nutrients Core	1	09-Aug	09:00	Core bottom only 10 cm
Chlorophyll A Core	1	09-Aug	10:30	Full core
Salinity & Temp Core	1	09-Aug	11:00	Full core
Water sample	1	09-Aug	10:00	Ocean/ice interface
Cast-away CTD	1	09-Aug	13:00	Cast to 25 m depth

Ice Station #8 (Nansen Basin - N 83° 57.450' E 22° 13.200')

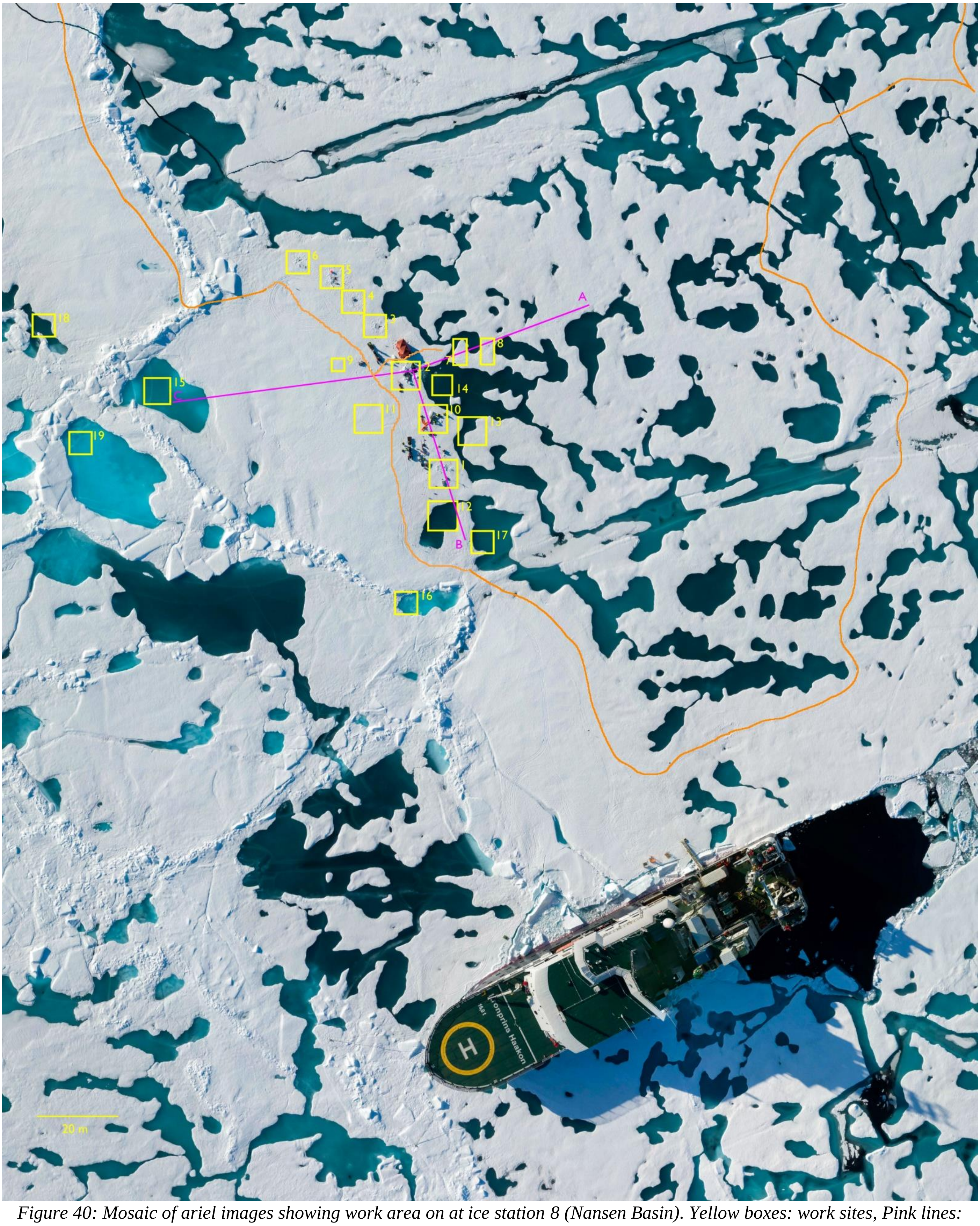


Figure 40: Mosaic of ariel images showing work area on at ice station 8 (Nansen Basin). Yellow boxes: work sites, Pink lines: ROV transects, Orange Line, sea ice and snow thickness transect. Images provided by Vegard Stürzinger.

Table 27. Metadata for Ice station #8

	Site	Date	Time	Configuration
Equipment installed temporarily				
ADCP-signature 500	3	12-Aug	18:30	30 cm below ice/water interface down-looking
SUNA(SN1618)	6	12-Aug	18:30	10 m below ice/water interface
RBR CTD (SN201408)	6	12-Aug	18:30	10 m below ice/water interface
Nitrate TriOS Opus (49227375)	4	12-Aug	18:30	20 cm below ice/water interface
Nitrate TriOS Opus (49227376)	4	12-Aug	18:30	1 m below ice/water interface
Nitrate TriOS Opus (49227372)	4	12-Aug	18:30	5 m below ice/water interface
Nortek vector (4990)	5	12-Aug	18:30	20 cm below ice/water interface
Rockland microsquid	5	12-Aug	18:30	20 cm below ice/water interface
Hobo light sensor (10608018)	4	12-Aug	18:30	1 m above ice/water interface
Hobo light sensor (21349883)	4	12-Aug	18:30	20 cm below ice/water interface
Hobo light sensor (21349882)	4	12-Aug	18:30	1m below ice/water interface
Ramses irradiance (NPI-1)	1	13-Aug	08:00	25 cm below ice/water interface uplooking (Point measurements)
Ramses irradiance (NPI-2)	1	13-Aug	08:00	25 cm below ice/water interface downlooking
Ramses irradiance (NPI-3)	1	13-Aug	08:00	2 m over ice surface uplooking
LICOR PAR (2pi)	1	13-Aug	08:00	1 m over ice surface uplooking
LICOR PAR (4pi)	1	13-Aug	08:00	25 cm below ice/water interface uplooking
Ramses irradiance (NPI-1)	1	13-Aug	09:00	25 cm below ice/water interface uplooking (Timeseries)
Ramses irradiance (NPI-2)	1	13-Aug	09:00	25 cm below ice/water interface downlooking
Ramses irradiance (NPI-3)	1	13-Aug	09:00	2 m over ice surface uplooking
LICOR PAR (2pi)	1	13-Aug	09:00	1 m over ice surface uplooking
LICOR PAR (4pi)	1	13-Aug	09:00	25 cm below ice/water interface uplooking
Profiling instruments cast from ice				
MSS session 1	2	13-Aug	07:30	3 cast to 200 m (67-69)
MSS session 2	2	13-Aug	10:20	4 casts to 200 m (70-73)
MSS session 3	2	13-Aug	13:20	3 casts to 200 m (74-76)
MSS session 4	2	13-Aug	16:40	3 cast to 200 m (77-79)
MSS session 5	2	13-Aug	21:00	2 cast to 200 m (80 & 81)
MSS session 6	2	14-Aug	04:50	3 casts to 200 m (82-84)
MSS session 7	2	14-Aug	08:30	4 casts to 200 m (85-88)
MSS session 8	2	14-Aug	12:20	3 cast to 200 m (89-91)
MSS session 9	2	14-Aug	16:50	3 cast to 200 m (92-94)
Wetlabs ACS (NPI, SN 311)	2	13-Aug	13:40	1 cast to 95 m (Optics-015)
Seabird Microcat (NPI, SN 20177)	2	13-Aug	13:40	1 cast to 95 m (Optics-015)
Seabird Chl-A fluorometer (NPI, SN 725)	2	13-Aug	13:40	1 cast to 95 m (Optics-015)
Seabird FDOM fluorometer (DTU, SN 7470)	2	13-Aug	13:40	1 cast to 95 m (Optics-015)
Sequoia LISST-VSF (UIB, SN 1667)	2	13-Aug	14:02	Stopped at 1.5, 2 & 5 m below water surface (LISST-015)
Cast-Away CTD	1	13-Aug	13:30	1 cast to 25 m
Plankton Net	2	14-July	07:00	1 cast to 25 m
Cameras / Imagers				
UHI (NPI)	1	13-Aug	08:00	1 m below ice/water interface uplooking 360° 1m ø swath
ROV mounted UHI transect	B	13-Aug	11:00	2 transects ROV line along pink lines on map
ROV mounted UHI transect	A	13- Aug	11:30	3 transects ROV line along pink lines on map
ROV mounted UHI transect	C	13- Aug	12:00	2 transects ROV line along pink lines on map
UHI (NPI)	7	13-Aug	14:30	1 m below ice/water interface uplooking 360° 1m ø swath
UHI (NPI)	7	14-Aug	07:00	1 m below ice/water interface uplooking 360° 1m ø swath
UHI (NPI)	8	14-Aug	11:00	1 m below ice/water interface uplooking 360° 1m ø swath
ROV & algae pumping operations	9	13-Aug	09:30	Sample collection at 2 m for ridge incubation.
ROV & algae pumping operations	7	13-Aug	15:00	Sample collection from underside of ice
ROV & algae pumping operations	7	14-Aug	08:00	Sample collection from underside of ice
ROV & algae pumping operations	8	14-Aug	12:00	Sample collection from underside of ice
Ice cores				
Salinity & d18O core	10	13.Aug	10:30	
DIC, nutrients & d18o core	10	13.Aug	10:30	
Temperature core	10	13.Aug	10:30	
Archive core	10	13.Aug	10:30	
Stratigraphy core	10	13.Aug	10:30	
Density core	10	13.Aug	10:30	
Bacteria core 1	10	13-Aug	17:00	
Bacteria core 2	10	13-Aug	17:00	
Microplastic core 1	10	13-Aug	17:00	
CDOM core 1	10	13-July	17:00	
CDOM core 2	10	13-July	17:00	
CDOM core 3	10	13-July	17:00	
CDOM core 4	10	13-July	17:00	

HPLC core 1	1	13-Aug	09:45	
HPLC core 2	1	13-Aug	09:45	
HPLC core 3	1	13-Aug	09:45	
HPLC core 4	1	13-Aug	09:45	
Nutrient/DIC/DOC core 1	1	13-Aug	10:30	
Nutrient/DIC/DOC core 2	1	13- Aug	10:30	
Production incubation 4 cores pooled	1	13- Aug	10:30	
POC & chlorophyll core 1	1	13- Aug	10:30	
POC & chlorophyll core 2	1	13- Aug	10:30	
POC & chlorophyll core 3	1	13- Aug	10:30	
Intracellular nutrients core	1	13- Aug	10:30	
Chlorophyll core bottom	1	13- Aug	10:30	
Transects				
Ice and snow thickness survey	n/a	13-Aug	06:40	(orange line on map)
Snow				
Snowpit	11	13-Aug	12:15	
Snow Sample	11	13-Aug	16:50	0-3 cm** (Alkalinity pH, d18O, nuts sample 1063)
Snow Sample	11	13-Aug	16:50	3-6 cm** (Alkalinity, pH, d18O, nuts sample 1062)
SWE measurements	11	14-Aug	12:15	
Transects				
Ice and snow thickness survey	n/a	30-July	08:00	(orange line on map)
Melt pond work				
Melt Pond Thickness & Freeboard	12	14-Aug	17:30	
Melt Pond Thickness & Freeboard	13	14-Aug	17:30	
Melt Pond Thickness & Freeboard	14	14-Aug	17:30	
Melt Pond Thickness & Freeboard	15	14-Aug	17:30	
Melt pond water sample 1	16	14-Aug	06:50	Alkalinity, pH, d18O, nutrients (1076)
Melt pond water sample 2	17	14-Aug	06:50	Alkalinity, pH, d18O, nutrients (1077)
Melt pond water sample 3	18	14-Aug	06:50	Alkalinity, pH, d18O, nutrients (1078)
Melt pond water sample 4	19	14-Aug	06:50	Alkalinity, pH, d18O, nutrients (1079)
Melt pond water sample 5	15	14-Aug	06:50	Alkalinity, pH, d18O, nutrients (1080)
Underice water samples	1	13-Aug	12:30	At Ice/water interface (DIC, d18O, nutrients sample 1057)
Underice water samples	1	13-Aug	12:30	20 cm below Ice/water interface
Underice water samples	1	13-Aug	12:30	1 m below Ice/water interface (DIC, d18O, nuts sample 1058)
Underice water samples	1	13-Aug	12:30	5 m below Ice/water interface (DIC, d18O, nuts sample 1059)
Underice water samples	1	13-Aug	12:30	10 m below Ice/water interface (DIC, d18O, nuts sample 1060)
Underice water samples	1	13-Aug	12:30	25 m below Ice/water interface (DIC, d18O, nuts sample 1061)

** under ice water samples analysed for: DIC, nutrients, d18O, Chl-A, POC, flow cytometry & taxonomy*
*** 0 is the ice-snow interface*

Times and dates are UTC 'start' times when equipment began logging or transects / casts were started. See the flow map (Figure X) for site locations. Absolute positions may be extracted from the KPH's position log using deployment start times.

Ice Station #9 (N 83° 21.884’, E 25° 01.615’)

Figure 41. Image showing the work site (yellow box) on sea ice station 9.

Table 28. Metadata for Ice station #9

	Site	Date	Time	Configuration
Cameras / Imagers				
Ice thickness Drilling	1	16-Aug	07:00	
Pooled Incubation Core 1	1	09-Aug	07:00	Core bottom only 5 cm
Pooled Incubation Core 2	1	09-Aug	07:00	Core bottom only 5 cm
Nutrients Core 3	1	09-Aug	07:00	Core bottom only 10 cm
Chla Core 4	1	09-Aug	07:00	Full core
Salinity & Temp Core	1	09-Aug	07:00	Full core
Water sample	1	09-Aug	07:00	Ocean/ice interface
Cast-away CTD	1	09-Aug	08:00	Cast to 25 m depth

Ice Station #10 (Marginal Ice Zone - N 82° 41.349’ E 027° 32.079’)

Figure 42. Mosaic of ariel images showing work area on at ice station 10 (Marginal Ice Zone). Yellow boxes: work sites, Pink lines: ROV transects. Images provided by Vegard Stürzinger.

Table 29. Metadata for Ice station #10

	Site	Date	Time	Configuration
Profiling instruments cast from ice				
MSS session 1	5	17-Aug	09:00	3 casts to 200 m (105-107)
MSS session 2	5	17-Aug	11:00	2 casts to 200 m (108-109)
Cast-Away CTD	5	17-Aug	10:15	1 cast to 25 m
Cameras / Imagers				
ROV mounted UHI transect	A	17-Aug	10:00	Transect along line A (repeated twice)
ROV mounted UHI transect	B	17- Aug	10:15	Transect along line B (repeated twice)
LICOR PAR (4pi)	1	17-Aug	08:45	25 cm below ice/water interface uplooking (at coring site)
LICOR PAR (2pi)	1	17-Aug	08:45	1 m above ice/air interface uplooking & downlooking (at coring site)
Ice cores				
Salinity & d18O core	2	17.Aug	08:30	
DIC, nutrients & d18o core	2	17.Aug	08:30	
Temperature core	2	17.Aug	08:30	
Archive core	2	17.Aug	08:30	
Stratigraphy core	2	17.Aug	08:30	
Density core	2	17.Aug	08:30	
Nutrient/DIC/DOC core 1	4	17-Aug	09:30	
Nutrient/DIC/DOC core 2	4	17- Aug	09:30	
Production incubation 4 cores pooled	4	17- Aug	09:30	
POC & chlorophyll core 1	4	17- Aug	09:30	
POC & chlorophyll core 2	4	17- Aug	09:30	
POC & chlorophyll core 3	4	17- Aug	09:30	
Snow				
Snowpit	2	17-Aug	09:00	At ice coring site
Snow Sample	2	17-Aug	11:00	0-3 cm (0 is ice-snow interface) (Alkalinity, pH, d18O, nutrients sample 1084)
Melt pond work				
Melt pond water sample 1	1	17-Aug	10:40	Alkalinity, pH, d18O, nutrients (1081) close to MSS
Melt pond water sample 2	3	17-Aug	10:40	Alkalinity, pH, d18O, nutrients (1082) close to gangway
Underice water samples	4	17-Aug	10:40	At Ice/water interface (DIC, d18O, nutrients sample 1083 + Chl-A, POC)
Underice water samples	4	17-Aug	10:40	1 m below Ice/water interface (nutrients, Chl-A, POC)
Underice water samples	4	17-Aug	10:40	10 m below Ice/water interface *nutrients, Chl-A, POC)

Under-ice acoustic Doppler current profiler (ADCP) measurements

Contacts: Morven Muilwijk and Zoe Koenig

A Signature 500 ADCP (SN100809) was deployed through a hole in the ice (5 overlapping auger holes) at three ice stations (#1 North Pole, #6 Amundsen Basin, and #8 Nansen Basin). The ADCP was mounted downward looking in a metal frame, hanging from two chains approximately 30 cm beneath the sea ice bottom. The instrument was configured to measure in XYX coordinates with the x-coordinate aligned with the ship's heading. Given the proximity to the geographic and magnetic north pole, the compass is expected to be less trustworthy, and the ship's navigational data should therefore be used as reference frame. The ship was moored to the ice floe during the whole deployment period. The ADCP was configured with a concurrent plan measuring average currents in 0.5 m bins for one minute every second minute and burst sampling with 5 beams as maximum sampling rate (600 samples, 2Hz) every 5 minutes. Deployment file: AO2022_ice.deploy. Deployment times are provided in the ice station overview (p. 59). At ice stations #1 and #6 the instrument logged for approximately 24 hours and at ice station #8 it logged for approximately 48 hours.

Overview of deployments

At ice station #1 (North Pole), the instrument was deployed at SITE 8 (Figure 33), approximately 230 m away from ship, straight to starboard side of the vessel. The site was characterized by thick (1.8 m) level ice with thin layer of slushy snow. Some cracks and small ridges within 50 m of the site. Upon recovery at the Nort Pole Station it was noted that the ADCP was hanging slightly titled in the hole. One of the chains was caught on a corner of the ice hole. The instrument had a tilt of approximately 60 degrees with the hole partly covering some of the transducers. It is unclear when this happened but could have happened during final adjustments of the direction when the instrument was deployed. The team was called back to the ship with a red alarm and had no time to properly check the deployed sensors.

At Ice station #6 (Amundsen Basin), the instrument was deployed at Site 5 (Figure 38), approximately 150 m away from the ship. The site was characterized by level ice (1.6 m) covered with multiple melt ponds and surrounded by multiple ridges in all directions. The landscape was very deformed with multiple large ridge "gardens" and leads. The ice was soft and mushy. Approximately 30 m away from Site 3 was a large ridge with a 3 m sail.

During ice station #8 (Nansen Basin), the instrument was deployed under level ice (1.4 m) at Site 3 (Figure 40), 170 m away from the ship. Within 50 m radius there were multiple ridges and ROV surveys revealed several locations of rafted ice in the vicinity.

Ice-tethered nitrate measurements

Contacts: Morven Muilwijk, Zoe Koenig and Karley Campbell

Two separate ice-tethered nitrate moorings were deployed at ice station #1, #6 and #8 (North Pole, Amundsen Basin and Nansen Basin sea ice stations). One mooring consisted of a single SUNA sensor and the other consisted of three TriOS Opus sensors. Details on the time of the deployment can be found in the overview of the sea ice stations (p. 59).

SUNA mooring: A SUNA nitrate sensor (SN 1618) was mounted on a frame with a Concerto RBR CTD (SN 201408) and an external battery pack. The SUNA was configured for periodic sampling every 10 minutes during the North Pole ice station, and 2 minutes for the next ice stations (Amundsen and Nansen Basin ice station). The CTD sampled every 2 minutes for all three ice stations (North Pole, Amundsen and Nansen basin ice stations). This setup was moored on a Kevlar rope at 10m depth under the sea ice.

TriOS Opus mooring: The TriOS Opus mooring consisted of three nitrate sensors tethered on a single rope under the ice (@20cm (SN49227375), @100cm (SN49227376) & @500cm (SN49227372)). Two Hobos light sensors were attached @20cm (SN21349883) and @100cm (SN21349882). The TriOS Opus sensors were powered by an external power source consisting of a car battery and deck unit at the surface.

Overview of deployments

At ice station #1 (North Pole), the instruments were deployed at SITE 8 (Figure 33), approximately 230 m away from ship, straight to starboard side of the vessel. The site was characterized by thick (1.8 m) level ice with thin layer of slushy snow. Some cracks and small ridges within 50 m of the site.

At Ice station #6 (Amundsen Basin), the instruments were deployed at Site 3 and 4 (Figure 38), approximately 150 m away from the ship. The site was characterized by level ice (1.6 m) covered with multiple melt ponds and surrounded by multiple ridges in all directions. The landscape was very deformed with multiple large ridge “gardens” and leads. The ice was soft and mushy. Approximately 30 m away from Site 3 was a large ridge with a 3 m sail.

During ice station #8 (Nansen Basin), the instruments were deployed under level ice (1.4 m) at Site 6 and 4 (Figure 40), approximately 180 m away from the ship. Within 50 m radius there were multiple ridges and ROV surveys revealed several locations of rafted ice in the vicinity.

Under-ice turbulence measurements from Eddy covariance mast

Contacts: Zoe Koenig, Morven Muilwijk and Karley Campbell

An eddy covariance system was deployed at ice station #1, #6 and #8 (North Pole, Amundsen Basin and Nansen Basin sea ice stations). The system was located at site 8 in ice station #1, site 3 in ice station #6 and site 5 in ice station #8. For further deployment details, site maps and site characteristics see Ice Station section (p.59).

The system was composed of a Nortek Vector turbulence sensor (SN4990) and Micro-squid from Rockland Scientific (SN 1744). The Micro-squid was composed of a micro-T sensor (SN T745), a micro-C sensor (SN C167) and an oxygen sensor (SN 12170703). The vector was setup to sample continuously at 64 Hz. Clocks between the Micro-squid and the Vector were synchronized before the deployment. The two instruments were mounted on a pole through the ice, and the length of the pole was adjusted so that the sensors were located 20 cm under the sea ice. The Micro-squid and Vector were connected to a datalogger under the ice, which was in turn connected to a deck unit and a car battery on the surface.

Underwater hyperspectral imager measurements using under ice arm

Contacts: Benjamin A. Lange, Janina Osanen and Karley Campbell

Under-ice hyperspectral surveys were conducted using a Underwater Hyperspectral Imager (Ecotone UHI-4, SN: 4-10, Ecotone AS, Trondheim, Norway) with a manufacturer radiometric calibration (October 2020). The UHI has a 60 º field-of-view (FOV) with 968 spatial across-track pixels, and 214 wavelength bins between 380-750 nm with a spectral resolution of ~1.7 nm. The UHI was attached to an under-ice arm deployed through a 25 cm auger hole (Figure 43a). The arm allowed for positioning the UHI in an upward facing direction (ie., pointed at the ice bottom) at a horizontal distance of 1.1 m from the deployment hole and a target distance to the sea ice bottom of ~ 1m. UHI surveys were conducted over a 180º swath ('Arch' configuration, Figure 43b) keeping the position of the survey in the direction of the sun and keeping the surface undisturbed before sampling (ie., coring or algae sampling. Surveys were also conducted over a 360º swath ('Doughnut' configuration, Figure 43c and d). Surveys were conducted before sampling, keeping the sampling locations undisturbed as best as possible, and repeat surveys of the same area were conducted after sampling. Repeat surveys after sampling were done to accurately align the sampling locations with the undisturbed, pre-sampling surveys so that spectra could be extracted from the exact location as samples were extracted from. UHI surveys were also conducted along the ROV-UHI transect lines at stations 06 and 08 for intercomparability and bio-optical algorithm compatibility.

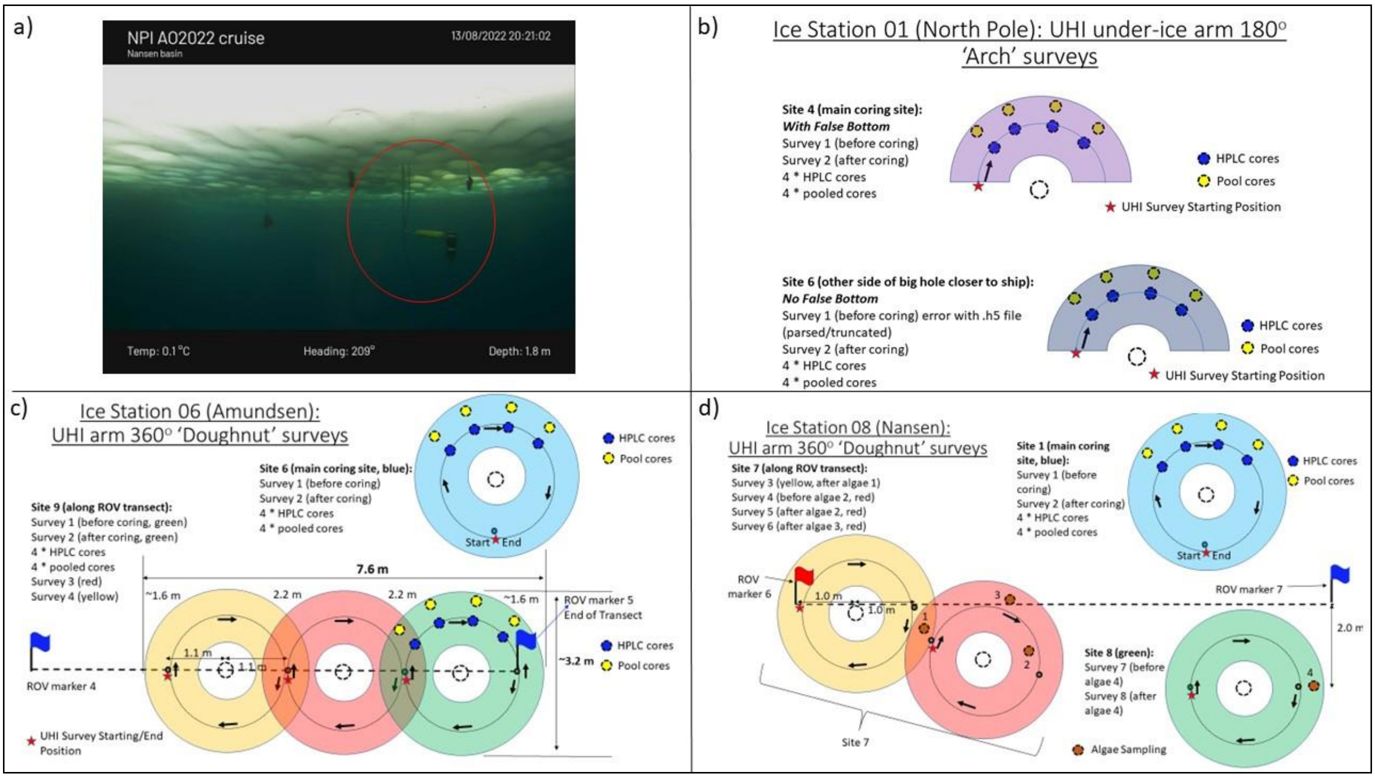


Figure 43. a) under ice picture of the under-ice arm with mounted UHI system (taken from the ROV single blueye, P. De La Torre, NTNU). Diagrams showing the UHI survey design and associated sampling and ROV transects for: b) ice station #1 (North Pole); c) ice station 06 (Amundsen); and ice station 08 (Nansen).

Sea ice optics

Karley Campbell, Benjamin A. Lange, Janina Osanen

Data on photosynthetically active radiation (PAR) and hyperspectral radiation were collected as instantaneous (Table 30) or time series (Table 31) measurements using Li-COR sensors with Li-COR datalogger, and three TriOS RAMSES hyperspectral radiometers (wavelength range 350-920 nm, 3.3 nm resolution) with a Trios Tribox datalogger. Sensors were deployed beneath the sea ice (i.e. below the ocean-ice interface) via a mechanical arm, or above the air-ice interface. Instantaneous measurements were completed immediately prior to ice sample collection at coring locations. The time series site was established proximal to the coring location, and sensors logged for the duration of the ice station. Self-logging HOBO sensors recording PAR and temperature were also deployed at the location of the TriOs nitrate tether and time series site described above. Deployment of these sensors is outlined in Table 32.

Table 30. Summary of sensors used for instantaneous measurements

Sensor ID	Serial No	Location of sensor	Description
NPI-1 (SAMIP_501C ACC-2 VIS)	010-05-501C	Below ice (upward looking)	Transmitted downwelling irradiance (10 sec sampling interval, usually over 2 minutes)
NPI-2 (SAMIP_5027 ACC-2 VIS)	010-05-5027	Below ice (downward looking)	Transmitted upwelling irradiance (10 sec sampling interval, usually over 2 minutes)
NPI-3 (SAMIP_5029 ACC-2 VIS)	010-06-5029	Above ice (upward looking)	Downwelling irradiance (ie., incoming irradiance) (10 sec sampling interval, usually over 2 minutes)

Table 31. Summary of sensors used for time series measurements

Sensor ID	Serial No	Location of sensor	Description
NPI-1 (SAMIP_501C ACC-2 VIS)	010-05-501C	Below ice (upward looking)	Transmitted downwelling irradiance (10-minute sampling interval)
NPI-2 (SAMIP_5027 ACC-2 VIS)	010-05-5027	Below ice (downward looking)	Transmitted upwelling irradiance (10-minute sampling interval)
NPI-3 (SAMIP_5029 ACC-2 VIS)	010-06-5029	Above ice (upward looking)	Downwelling irradiance (ie., incoming irradiance) (10-minute sampling interval)

Table 32. Summary of HOBO sensors logging at nitrate tether location

Serial No	Site	Location of sensor
21349878	Nitrate tether	1 m above ice-air interface
21349883	Nitrate tether	20 cm below ocean-ice interface
21349882	Nitrate tether	1 m below ice-air interface
10473169	Time series site; arm positions sensor 1 meter away from deployment hole	20 cm below ocean-ice interface

Sea ice incubation experiments

Contact: Karley Campbell

Incubations were completed on the meltwater of two to four sea ice core sections (bottom 5 cm), unless otherwise specified. Cores were melted in darkness with the addition of 0.2 um filtered seawater (collected on-site at the ice-ocean interface) for approximately 24 h. The filtered seawater was added at a ratio of three parts water to one-part ice. Total volume and volume of seawater were recorded for all cores to correct subsequent measurements for dilution. Three types of incubations were potentially completed on these pooled samples. See Table 33 for outline of incubations completed per ice station.

Table 33. Summary of gross primary production (GPP), bacterial production (BP) and net community production (NCP) incubations completed for cruise ice stations. (Y) indicates completion of incubation.

Station #	Site Description	Sample Description	GPP	BP	NCP
1	Ice Station 1 (North Pole)	x4 pooled cores bottom 5 cm; Site A	Y	Y	Y
		x4 pooled cores bottom 5 cm; Site B	Y	Y	Y
5	N 87° 2.7665 W 027° 59.1615	x2 pooled cores bottom 5 cm	Y	Y	-
6	Ice Station 6 (Amundsen Basin)	x4 pooled cores bottom 5 cm; Site A	Y	Y	Y
		x4 pooled cores bottom 5 cm; Site B	Y	Y	Y
7	N 85° 37.8128 W 009° 18.9656	x2 pooled cores bottom 5 cm	Y	Y	-
		Floating aggregate	Y	-	Y
8	Ice Station 8 (Nansen Basin)	x4 pooled cores bottom 5 cm; Site A	Y	-	Y
		Aggregate sample #1	Y	Y	Y
		Aggregate sample #3	Y	-	Y
		Ridge sample	Y	-	-
9	N 83° 21.9489 E 024° 59.9824	x2 pooled cores bottom 5 cm	Y	-	-
10	N 82° 45.1953 E 027° 20.4063	x4 pooled cores bottom 5 cm	Y	-	-

Gross primary production (GPP). Twelve-60 ml Corning flasks (10 clear and two darkened) were incubated in temperature-controlled chamber, held at -1.5C. The chamber permitted incubation of samples over a range of light intensities that were measured using Walz 4-pie microsensor, from which a photosynthesis-irradiance curve could be constructed. Prior to incubations each bottle was spiked with 1 ml 14C (4uCi ml^{-1}) solution. Subsamples of initial activity were completed before bottles were placed in the incubator for 3h. Sample bottles were then each filtered onto GF/F before acidification with HCl. Once filtered were dried (approximately 24h) 10 ml of Ecolume scintillation cocktail was added. Measurements of CPM were completed after an additional 24h extraction time. Measurements of GPP were completed at all ice stations.

Bacterial production (BP). 15 ml of sample were added to six-50 ml sterile falcon tubes and spiked with 3H-Leucine for a final concentration of 10 nM. Three were immediately killed with 50% trichloroacetic acid solution (1.5 ml). Samples were then incubated in darkness for 6h at -1.5C, after which time the remaining three samples were killed with the TCA solution. Filtration was then completed onto cellulose acetate filters. Filters were allowed to dry for 24h before dissolution using ethyl acetate and the addition of 10 ml of Ecolume scintillation cocktail. Measurements of CPM were completed after an additional 24h extraction time. Measurements of BP were completed at all ice stations.

Net community production (NCP). The NCP of pooled ice samples was determined using oxygen optodes. Samples were transferred to glass bottles via peristaltic pump and incubated in a temperature-controlled photosynthesis-irradiance chamber similar to GPP described above. Each bottle was equipped with a Pyroscience robust O_2 optode that logged data at two-minute intervals. Incubations were run for approximately 72h. Measurements of NCP were completed at multi-day ice stations at the North Pole, Amundsen Basin and Nansen Basin, as well as opportunistically on aggregate algal samples.

Supporting parameters

Intracellular nutrients. Approximately 1 cm of the bottom ice from one ice core was removed using a stainless-steel blade. The ice as placed into a Nalgene containing 1L of 0.2 um filtered sea water. Immediately upon return to the ship this sample was filtered through GF/F. The filter was then exposed to boiling MQ water and the filtrate collected for post-field analysis of intracellular nutrients. A MQ blank is taken for each measurement. Chlorophyll *a* (in duplicate) was also filtered from this sample (GF/F & 5 ml methanol extraction for 24h at 4°C in darkness). Samples were stored at -20°C for later analysis at UiT (Seal analytical autoanalyzer). Completed at multi-day ice stations at the North Pole, Amundsen Basin and Nansen Basin.

Fine-scale chlorophyll *a*. The bottom 10 cm of an ice core was sectioned at 2.5 cm resolution. Following diluted melt in filtered seawater, samples were filtered for chl *a* in duplicate (GF/F & 5 ml methanol extraction for 24h at 4°C in darkness). Samples were run on board using a Turner Designs fluorometer. Completed Stations 1, 6, 7, 8 and 9. A full profile of chl *a* was also completed at all ice stations sampled following the method described by M Lens in this report.

Fine-scale nutrients & dissolved organic carbon (DOC). The bottom 10 cm of an ice core was sectioned at 2.5 cm resolution. Following undiluted melt, pseudo-duplicate samples were filtered through burnt GF/F (450°C for 6h) into acid washed vials. The DOC the vials were also pre-combusted (450C for 6h) and the sample acidified with 2N HCl prior to storage at 4°C. Nutrient samples were stored at -20°C and DOC at 4°C for later analysis at UiT (Seal analytical – nutrients; Shimadzu TOC analyser DOC). Completed at all stations.

Fine-scale O_2 & Dissolved inorganic carbon (DIC). The bottom 10 cm of an ice core was sectioned at 2.5 cm resolution. Core sections were placed into vacuum bags that were sealed immediately on the ice using a commercial bag sealer. Samples were melted in darkness at room temperature before the meltwater was transferred into 15 ml exetainers (without headspace) via glass syringe. Samples were spiked with HgCl2. The DIC (duplicate) and O2 (triplicate) will be analysed at UiT using Shimadzu TOC analyser and winkler titration, respectively. Salinity was measured using conductivity probe on all samples. The DIC concentration of pooled core meltwater was also sampled. Completed Stations 1, 6, and 8.

Flow cytometry. To determine the number of cells within incubations, a flow cytometry sample was collected from the pooled ice sample. This was done in duplicate by adding 5 ml of samples to cyrovials before fixing with 25% glutaraldehyde. Samples sat at room temperature for 10 m before storage at -80°C and future analysis at UiT. Completed at all stations.

Exopolymeric Substances (EPS). The pooled ice sample was filtered through 0.4 um polycarbonate filter for later determination of EPS concentration via phenol extraction at UiT. Samples were stored at -20C after filtration. Completed on all ice stations.

Species composition. 50 ml of pooled ice sample was placed into a glass bottle and spike with acidic lugol. Samples were stored in darkness at 4°C for later analysis on a light microscope. Completed on all ice stations sampled.

Particulate organic carbon (POC). The pooled ice sample was filtered through burnt GF/F (450°C for 6h). A blank of filtered seawater on burnt GF/F was also taken. These samples were stored in pre-combusted aluminium foil at -20°C for later analysis at UiT. A full profile of POC was also completed following the method described by M Lens in this report. Analyses were completed on all ice stations.

Parameters measured from sea ice cores

Salinity

Contacts: Dmitry V. Divine, Mats Granskog, Bonnie Raffel

At each coring event during ice station work, a dedicated ice core was collected to obtain the ice salinity profile using a 9 cm diameter Kovacs ice corer. Recovered cores were sectioned on site at 5-cm vertical resolution on Ice stations 1, 6 and 10. At short ice stations 5 and 7 cores were packed on the ice and brought onboard for cutting. Sectioning of the cores was carried out relative to both the ice surface and ice bottom to better capture the processes at the surface and bottom interfaces. Bulk salinity of melted sections was also measured from the carbon chemistry core, which was bagged on the ice and cut into 10 cm sections onboard. Each core section was vacuumed packed in Tedlar bags to avoid gas exchange with the environment before sampling. Onboard, bulk salinity of melted sections were measured using a conductivity meter Cond 3110 SET3 S/N 11400491. Salinity is reported on the practical salinity scale (dimensionless). Oxygen isotope ratio samples were collected from the same cores.

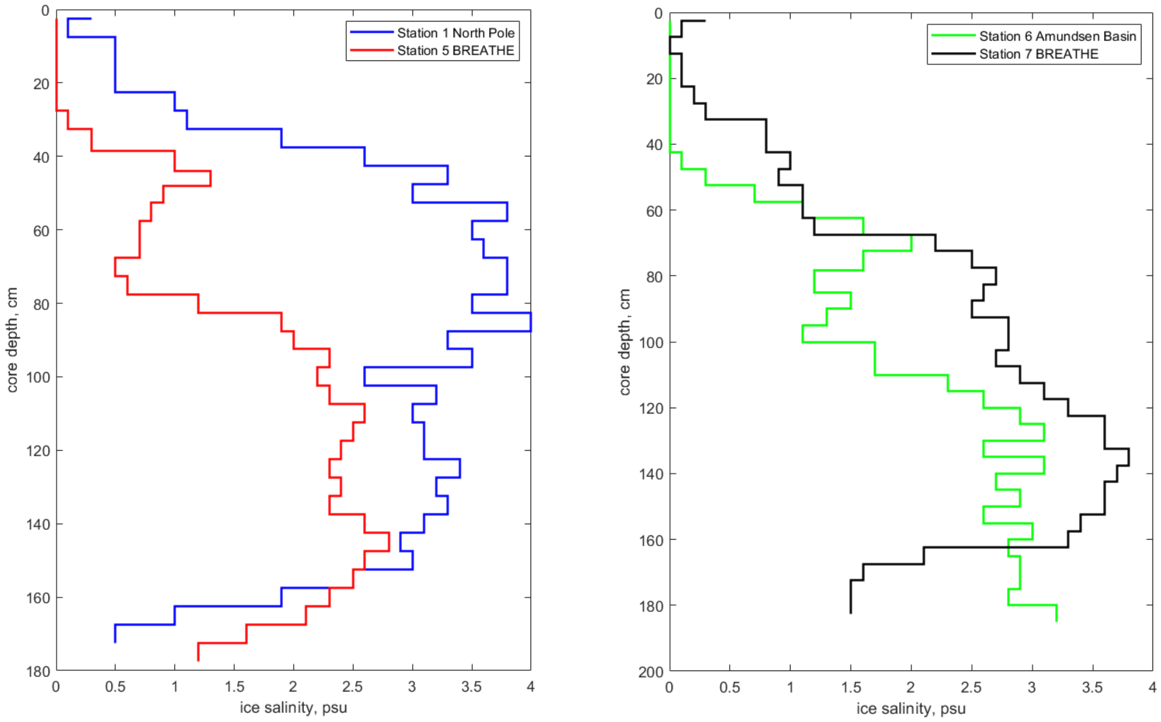


Figure 44. Measured salinity profiles of sea ice cores recovered on ice stations 1, 5, 6, and 7.

Salinity profile from ice core from Ice station 1 North Pole (blue line, left figure) is indicative of first year ice of Ice station 1 ice floe. Profiles from ice stations 5 and 6 can with a higher certainty be associated with older ice types, which in present day Arctic most likely would be a second-year ice (SYI). Data from station 7 requires additional analysis, in particular for stable water isotopes to infer the age of the ice that was sampled.

Temperature

Contact: Dmitry V. Divine

At each coring event during ice station work, sea ice temperature profiles were measured on one recovered ice core within a few minutes from core extraction. The measurements were made using a thermistor probe Testo-720 from holes drilled into the ice core at 10 cm spacing.

Bacterial community composition using Meta-OMICS techniques

Contacts: Venkatachalam Siddarthan and Ahammed Shereef

Two sea-ice cores were collected on each ice stations of North-Pole (Ice station #1), Amundsan basin (Ice station #6) and Nansen basin (Ice station #8). The sea-ice cores collected from North-Pole, Amundsan basin were divided into three 60 CM sections (Top, Middle, Bottom), while cores from the Nansen basin was divided into three 40CM sections and melted in the dark room at 4º C. The melt water was filtered into 0.22 µm membrane filters (Merck-Millipore) to retain microbial biomass. The filters were frozen at -80º C and will be further analyzed for deciphering bacterial community composition by metagenomics and meta-transcriptomics techniques at the Polar Biology laboratory, National Centre for Polar and Ocean Research, India.

Oxygen isotope ratios

Contacts: Mats Granskog and Bonnie Raffel

The parameter $\delta^{18}O$ describes the ratio of ^{18}O to ^{16}O isotopes in the H_2O molecule. $\delta^{18}O$ is a tracer for water which has at some point evaporated. Sea ice $\delta^{18}O$ samples will be measured ashore. This will help to identify ice layers that have contributions from snow to the mass balance or ice of different origin. The samples are collected from the salinity (sectioned at 5 cm intervals) and carbonate chemistry cores (sectioned at 10 cm). In addition, samples were collected of snow, melt pond water and under ice water at the ice-water interface, 1 m, 5 m, 10 m and 25 m depth at the ice stations 1, 6, 8 and 10.

Dissolved Inorganic Carbon

Contact: Bonnie Raffel

The parameter Dissolved inorganic carbon (DIC) describes the sum of dissolved CO_2, carbonic acid, bicarbonate- and carbonate ions in seawater. It is used to investigate carbon chemistry to study ocean acidification. The focus on the cruise was not only seawater but also sea ice and its environment. At Ice station 1, 6, 8 and 10 one sea-ice core, meltpond water and snow were collected and analysed on board. The ice core was bagged on ice and cut onboard in 10 cm sections. To avoid gas exchange with the environment before sampling the sea-ice core sections and the snow sample were vacuumed packed in Tedlar bags. The melted sea ice core, snow and meltpond water were analysed for pH first, using a spectrophotometer with a pH sensitive dye and second for Alkalinity using a potentiometric titration with HCl and a pH sensitive electrode. Using a chemical equilibrium model (f.e. CO2SYS) DIC can be calculated from the pH and Alkalinity value.

Nutrients

Contact: Bonnie Raffel

The parameter inorganic nutrients is the sum of nitrate, nitrite, phosphate and silicate in the seawater. The focus on the cruise was not only seawater but also sea ice and its environment. At Ice station 1, 6, 8 and 10 one sea-ice core, meltpond water and snow were collected. The ice core was bagged on ice and cut onboard in 10 cm sections. To avoid gas exchange with the environment before sampling the sea-ice core sections and the snow sample were vacuumed packed in Tedlar bags. The melted sea ice core, snow and meltpond water was filled in vials, preserved with 250 µl Chloroform and kept cool and dark for further post cruise analysis.

Chlorophyll-a

Contact: Megan Lenss

Chlorophyll *a* (chl *a*) is a proxy for algal biomass in sea ice. Ice cores for chl *a* were collected using a 9 cm core barrel at all ice stations. One profile core with sectioning 0-5cm, 5-10cm, 10-20cm and 20 cm sections thereafter was taken at each location in addition to 2 other cores sectioned only 0-5cm and 5-10 cm. Cores were brought onboard and melted with a 3:1 filtered seawater buffer at room temperature in the dark. Once melted, a measured volume of water was filtered onto 25 mm Whatmann glass fiber filters and placed in 5 mL of methanol for extraction. Immediately following an 18-24 hour extraction period, samples were analyzed onboard using a Turner Trilogy Flourometer.

Particulate organic carbon/nitrogen (POC/PON)

Contact: Megan Lenss

POC/PON is a proxy for organic biomass in sea ice. Ice cores for POC/PON were collected using a 9 cm core barrel at all ice stations. One profile core with sectioning 0-5cm, 5-10cm, 10-20cm and 20 cm sections thereafter was taken at each location in addition to 2 other cores sectioned only 0-5cm and 5-10 cm. Cores were brought onboard and melted with a 3:1 filtered seawater buffer at room temperature in the dark. Once melted a measured volume of water was filtered onto pre-combusted Whatmann glass fiber filters. Filters were dried at 60˚C for approx. 24 hours and packed for further analysis ashore.

Sea ice flow cytometry

Contact: Megan Lenss

Flow cytometry provides information on the abundance and size distribution of microorganisms. Ice cores for flow cytometry were collected using a 9 cm core barrel at ice stations 1 (North Pole), 6 (Amundsen Basin) and 8 (Nansen Basin). One profile core with sectioning 0-5cm, 5-10cm, 10-20cm and 20 cm sections thereafter was taken at each location in addition to 2 other cores sectioned only 0-5cm and 5-10 cm. Cores were brought onboard and melted with a 3:1 filtered seawater buffer at room temperature in the dark. Once melted, 1.8mL of sample was fixed with 25% glutaraldehyde for 2 hours at +4˚C before flash freezing at -80˚C. Samples will be further analyzed ashore.

Sea ice algae taxonomy

Contact: Megan Lenss

Samples for sea ice algae taxonomy are taken to understand the community composition of ice alga. Ice cores for taxonomy were collected using a 9 cm core barrel at the ice stations 1 (North Pole), 6 (Amundsen Basin) and 8 (Nansen Basin). One profile core with sectioning 0-5cm, 5-10cm, 10-20cm and 20 cm sections thereafter was taken at each location in addition to 2 other cores sectioned only 0-5cm and 5-10 cm. Cores were brought onboard and melted with a 3:1 filtered seawater buffer at room temperature in the dark. Once melted, 190 mL of sample was spiked with 0.8 mL of 25% glutaraldehyde and 20% hexamine-buffered formaldehyde for fixation and stored at +4˚C. Once ashore, fixed samples will be shipped to IO PAN for further identification and analysis.

Pigment composition

Contacts: Karley Campbell Benjamin A. Lange and Janina Osanen

To calibrate measurements of the underwater hyperspectral imager (UHI), the bottom 5 cm of four individual sea ice cores were collected between a first and second UHI survey of a given sample location. Following collection sea ice cores were melted in 0.2 um filtered seawater that was added at a ratio of three parts water to one part ice, for a period of approximately 24h. The total meltwater volume was measured to account for dilution before filtration onto GF/F for later analysis of algal pigments via high performance liquid chromatography (HPLC). Filters were stored at -80°C. A duplicate subsample of chlorophyll *a* was also taken from each core (GF/F filtration, 5 ml methanol extraction for 24h, measurement on Turner Designs fluorometer before and after 5% HCl acidification).

Snow measurements and sampling

Contact: Dmitry V. Divine

The overarching goal of the snow measurements was to characterize the structure of snow cover on sea ice studied during the cruise. Snow pits were made in locations next to the coring sites or sites with snow cover representative for the station flow. Each snow pit included the snow temperature and density profiles; bulk snow samples were taken for analysis of salinity. Snow grain size and geometry were analysed and registered following the existing classification scheme.

Radarsat II SAR images acquired during the cruise

Contact: Paul A. Dodd

25 Radarsat II ScanSAR images were ordered to coincide with the times and positions of planned activities, to put in-situ ice and snow measurements into a broader context as listed in the table X. Figure X illustrates the areas covered by each image. Images were processed at NPI in Tromsø and sent to the KPH via an iridium-based email link within a few hours of acquisition so that they could also be used for navigation.

Table 34. List of Radarsat II images acquired during the cruise.

			Corner 1		Corner 2		Corner 3		Corner 4	
Date	**Acquisition Time (UTC)**	**Mode**	**Lon.**	**Lat.**	**Lon.**	**Lat.**	**Lon.**	**Lat.**	**Lon.**	**Lat.**
22/07/2022	06:17:32	STD	29.448	81.576	34.581	80.980	38.643	81.662	33.351	82.308
23/07/2022	05:48:20	STD	29.420	81.487	34.966	80.990	38.449	81.740	32.570	82.282
25/07/2022	13:11:56	WIDE	-77.316	86.976	-40.729	83.215	-1.185	83.486	32.019	87.631
27/07/2022	13:53:49	WIDE	-84.112	87.264	-48.446	83.342	-8.769	83.383	26.404	87.363
29/07/2022	12:55:09	WIDE	-73.390	86.952	-36.751	83.204	2.769	83.493	35.771	87.652
31/07/2022	05:12:30	HI	327.879	89.498	54.973	89.506	145.291	89.538	240.028	89.529
01/08/2022	13:06:58	STD	-57.843	88.778	-41.979	88.114	-13.461	88.293	-10.856	89.075
02/08/2022	10:56:11	WIDE	-37.296	87.436	-2.566	83.406	37.149	83.300	73.152	87.178
02/08/2022	14:18:15	STD	-18.608	88.559	-1.383	89.283	-60.008	89.333	-46.185	88.583
03/08/2022	08:46:47	WIDE	-23.993	85.042	10.660	82.137	45.792	83.732	37.831	88.425
03/08/2022	13:48:05	STD	-45.803	88.365	-38.841	87.415	-18.569	87.441	-13.415	88.406
04/08/2022	13:18:09	WIDE	19.921	81.944	53.891	84.751	2.250	88.332	-13.908	83.703
04/08/2022	13:19:03	STD	-12.798	83.965	19.166	81.405	50.067	83.577	20.346	87.896
05/08/2022	07:48:20	WIDE	-25.748	85.375	9.662	82.349	45.845	83.742	47.263	88.453
06/08/2022	08:59:17	WIDE	-21.975	84.424	11.153	81.728	43.897	83.669	21.095	88.186
07/08/2022	08:30:11	WIDE	-15.466	84.140	16.944	81.530	48.534	83.616	21.048	88.014
08/08/2022	08:00:53	WIDE	-29.324	85.281	5.884	82.291	41.644	83.742	39.942	88.453
09/08/2022	09:11:55	WIDE	-24.058	84.749	9.889	81.948	43.964	83.714	28.298	88.342
10/08/2022	08:42:41	WIDE	3.043	82.571	31.588	80.357	56.959	83.108	20.097	86.750
11/08/2022	06:31:11	WIDE	-13.595	83.189	16.427	80.833	44.200	83.350	8.718	87.289
12/08/2022	07:44:22	WIDE	-5.999	83.311	24.338	80.925	52.519	83.388	17.502	87.384
13/08/2022	07:14:57	WIDE	0.011	82.641	28.729	80.411	54.277	83.133	17.447	86.803
14/08/2022	06:45:45	WIDE	-15.653	83.674	15.589	81.195	45.342	83.503	12.742	87.685
15/08/2022	07:56:49	WIDE	15.293	80.864	45.441	83.235	22.728	87.319	-12.582	83.357
16/08/2022	14:09:05	WIDE	15.2724	80.8761	45.4063	83.2459	22.6549	87.3171	-12.494	83.3578

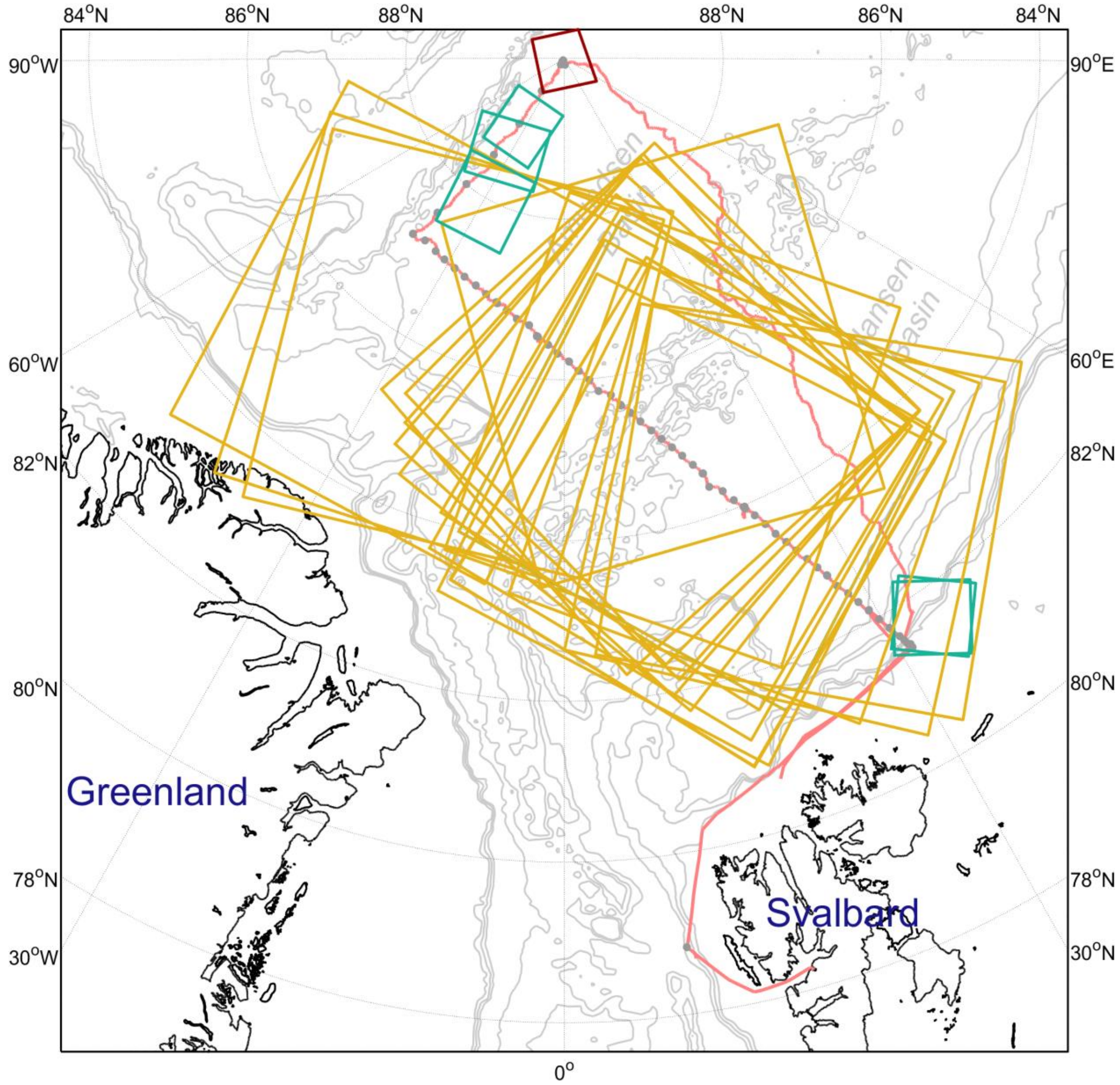


Figure 45. Areas covered by Radarsat II images acquired during the cruise. Yellow: ScanSAR wide mode, Green: ScanSAR standard mode, Red: ScanSAR High latitude mode

Ice observations from the bridge using ASSIST protocol

Contact: Dmitry V. Divine

Regular sea ice observations using ASSIST protocol (see https://cryo.met.no/en/icewatch) were made by D.V. Divine, B. Lange, M. Granskog, M. Muilwijk and Z. Koenig with contributions from J. Osanen, P. de la Torre, H. Sandven and P. Kupiszewski while RV KPH was in the ice/covered waters.

Sea ice conditions were observed every one to three hours, except for the night-time between midnight and 7:00, from the observation deck of RV KPH. Various sea ice parameters including sea ice types, floe sizes, snow cover, ridges, rafting etc. were recorded along with ship data (position, speed, and heading) and meteorological data (air and water temperature, air pressure, wind speed and direction, and humidity). Digital photos were taken with each observation (3 photos, looking out towards port, bow, and starboard. In total 125 observations were made during the cruise while RV KPH was in the ice zone.

Preliminary results below show changes in observed sea ice thickness (upper panel) and sea ice concentrations (lower panel) along the cruise track suggesting heavier ice conditions with thicker ice to be accompanied by less consolidated ice cover with ice concentrations about 8-9.

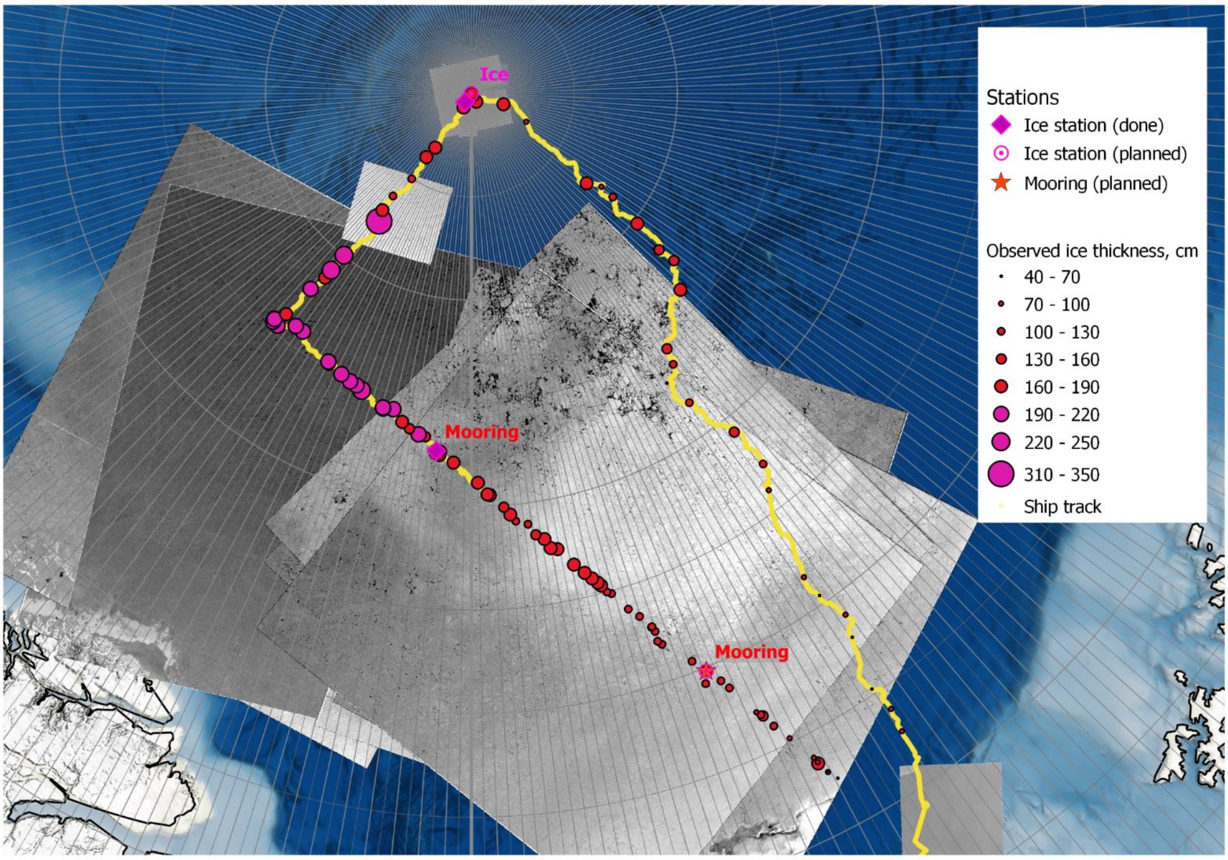


Figure 46. Estimates of sea ice thicnkess made from the vessel while underway.

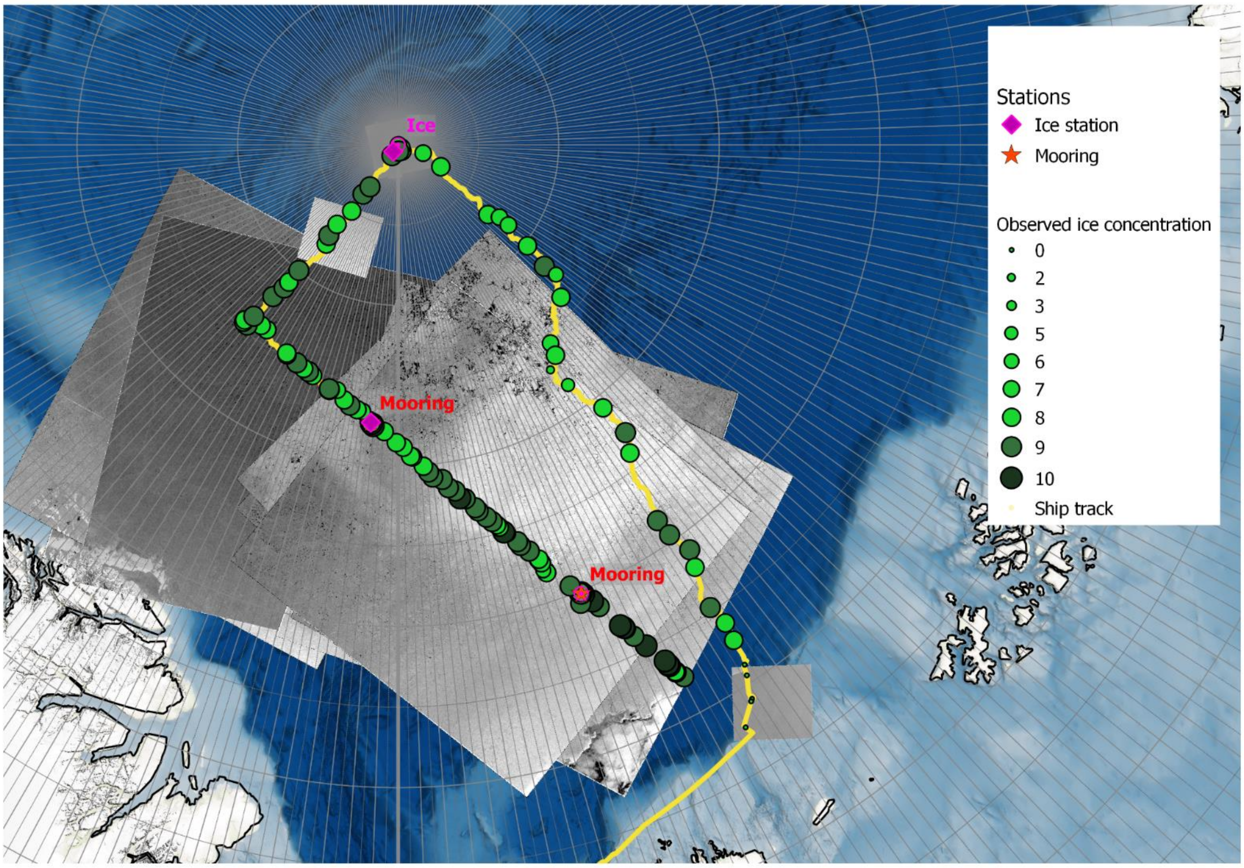


Figure 47. Estimates of sea ice concentratoin made from the vessel while underway.

Marine mammal observations

Contacts: Haakon Hop and Ole Arve Misund

Marine mammals were recorded from the bridge on a form paper log sheet. Adult bears, females with cubs and seals, mostly ringed seals, were recorded. The results are summarised in the map below (Figure 48).

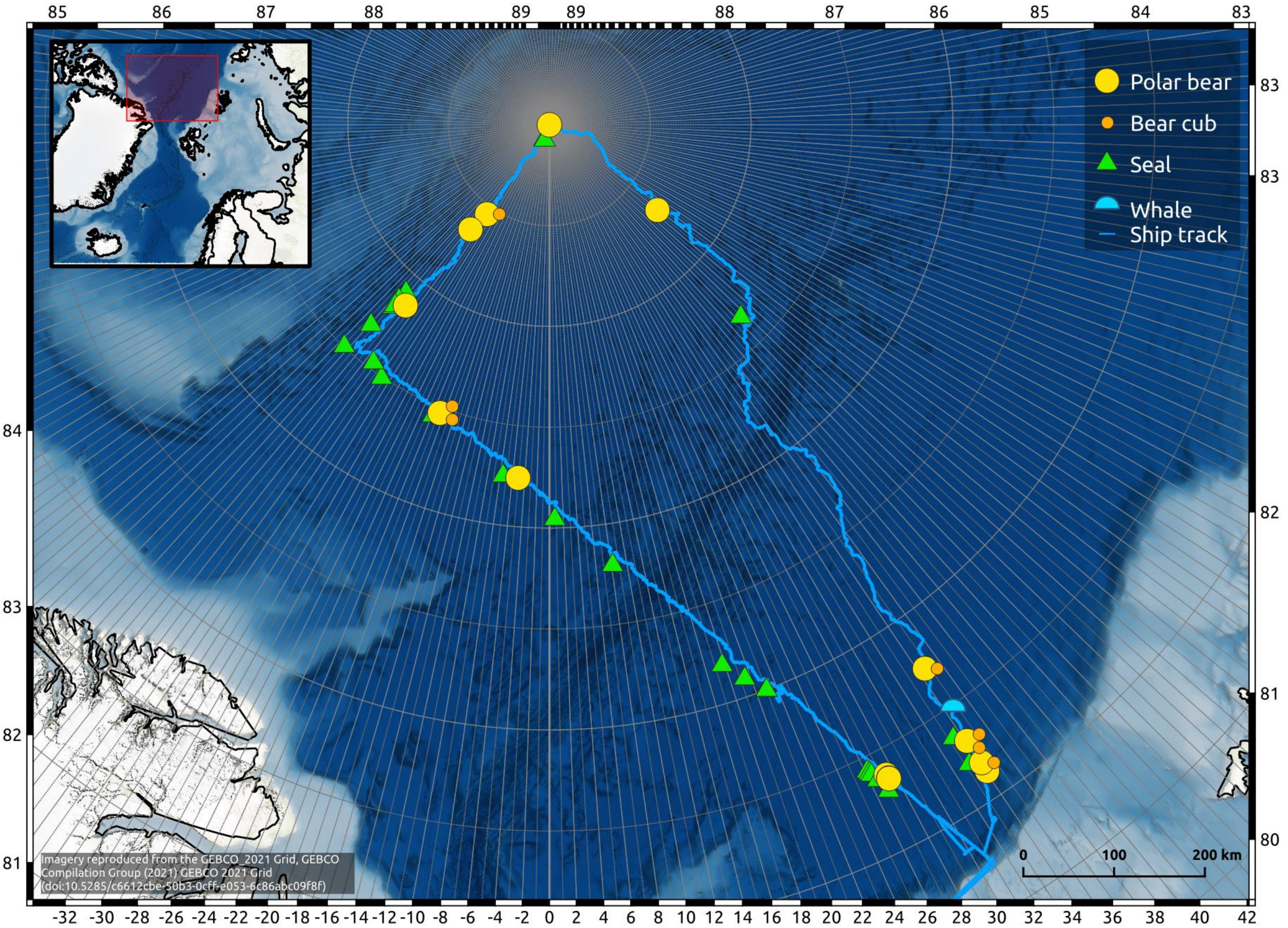


Figure 48. Marine mammal observations along the AO-2022 cruise track.

Drifting instruments deployed on the sea ice

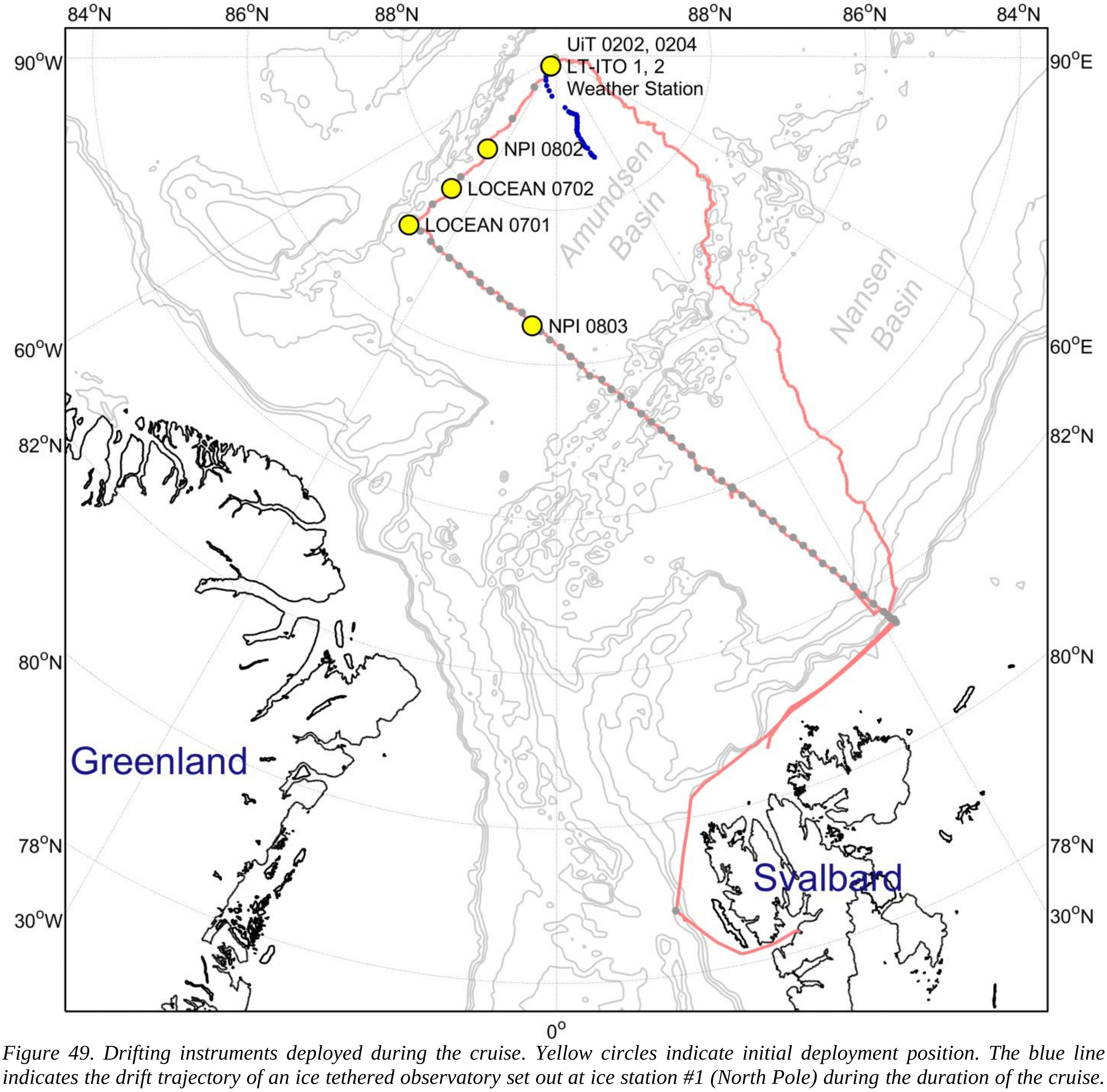


Figure 49. Drifting instruments deployed during the cruise. Yellow circles indicate initial deployment position. The blue line indicates the drift trajectory of an ice tethered observatory set out at ice station #1 (North Pole) during the duration of the cruise. UiT0202, UiT0204, NPI 0802, LOCEAN 0702, LOCEAN 0701 and NPI 0803 are SIMBA buoys. LT-ITO 1 & 2 are light and temperature ice tethered observatories. An Acoustic zooplankton & fish profiler ice tethered observatory (AZFP-ITO), equipped with an automatic weather station was also deployed at the North Pole.

SIMBA buoys

Contacts: Mats Granskog, Zoe Koenig, Dmitry Divine, Marius Bratrein and Pedro de la Torre

SIMBA buoys or more generally sea ice mass balance buoys measure snow and sea ice thickness. SIMBA buoys (manufactured by SAMS Enterprises) specifically use a thermistor string with heating units to measure the temperature at 2 cm intervals. During a daily heating cycle the rate of temperature change is measured, which provides a mean to estimate whether a thermistor is in air, snow, ice or water due to differences of thermal conductivity of the media. Data is transmitted in near real-time to the SAMS data portal (accessible to the owners of the buoys only, unless shared publicly).

Table 35. SIMBA buoys deployed during the AO2022 cruise.

SIMBA ID	IMEI	DEPLOY-MENT DATE	TIME UTC	LATITUDE	LONGITUDE	REMARKS	ICE THICK-NESS	SNOW DEPTH	FREE-BOARD
UIT 0202	300 234 065 765 510	29 July 2022	17:00	89.847173 N	29.41888 W	Ice Station 1 (North Pole), Arctic ABC and Arctic PASSION	1.64 m	0.105 m	0.1 m
UIT 0204	300 234 065 863 280	29 July 2022	16:00	89.850613 N	29.11359 W	Ice Station 1 (North Pole), Arctic ABC and Arctic PASSION	1.63m	0.055 m	0.09 m
NPI 0802	300 534 061 788 840	31 July 2022	19:21	88.503273 N	36.4878873 W	Ice Station 2 H2020 Arctic Passion, data on meereis portal (buoy 2022T95)	3.50 m	0.03 m	0.50 m
LOCEAN 0702	300 234 065 173 780	1 Aug 2022	12:30	87.812833 N	38.3433333 W	Ice Station 3 H2020 Arctic Passion	1.77 m	0	0.15 m
LOCEAN 0701	300 234 065 176 790	2 Aug 2022	13:38	87.0985 N	41.1366666 W	Ice Station 4 H2020 Arctic Passion	1.91m	0.07 m	0.18 m
NPI 0803	300 534 061 784 880	6 Aug 2022	10:38	86.49380 N	05.14619 W	Ice Station 6 (Amundsen Basin) H2020 Arctic Passion, data on meereis portal (buoy 2022T97).	1.745 m	0.19	0.055 m

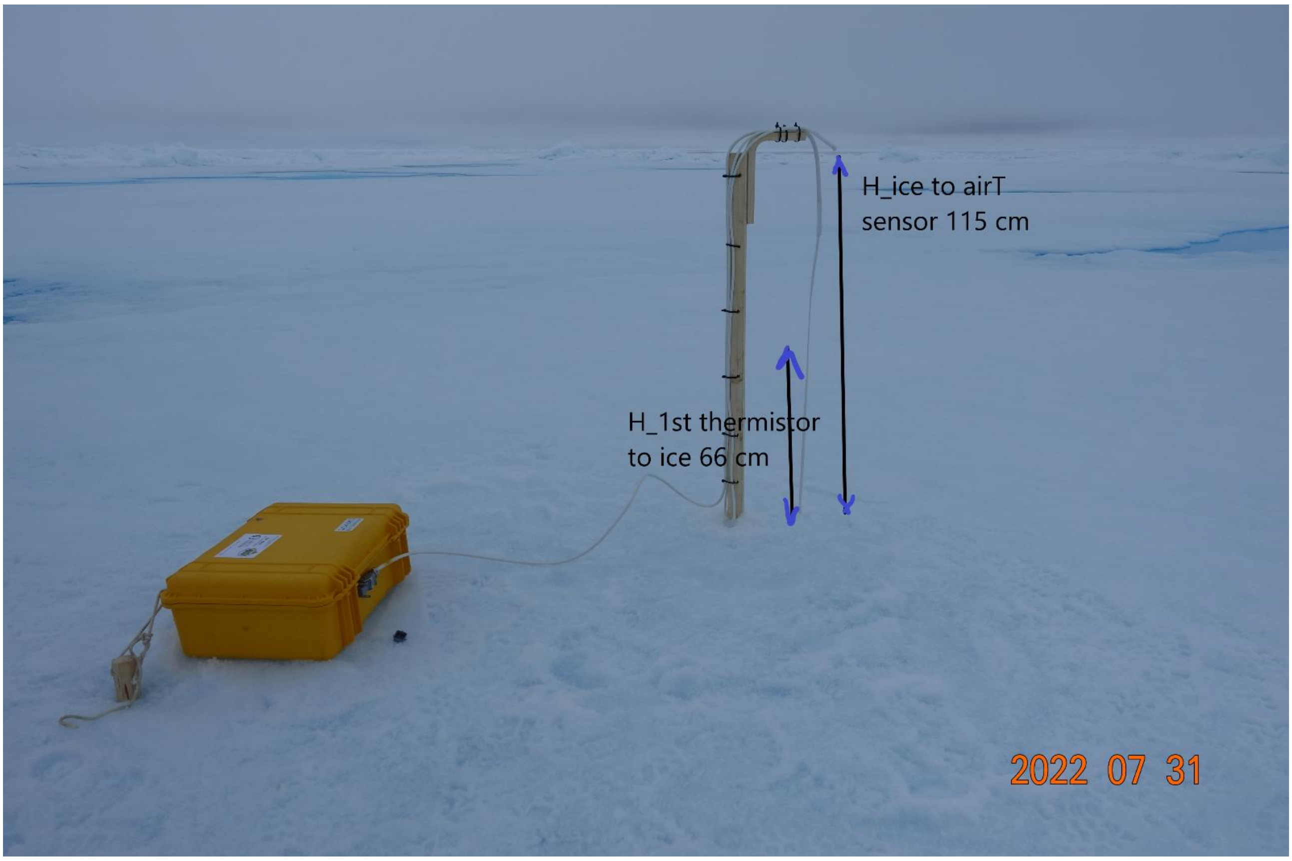


Figure 50. Photo of SIMBA NPOL 08 02 after deployment. Photo: Dmitry Divine

Acoustic zooplankton & fish profiler ice tethered observatory (ITO)

Contact: Pedro De La Torre

The Acoustic zooplankton and fish profiler (AZFP) is a scientific echosounder produced by ASL Environmental (Canada). It operates at 4 frequencies, 38, 125, 200 and 455 kHz, with 1ms long, narrow-band pulses. For this deployment, the unit transmits one pulse every 15s. The AZFP has its own battery and memory storage, and it is connected through a cable to the topside unit. All the equipment together is referred to as an ice tethered observatory (ITO). The task of the ITO is to download the data from the echosounder subsea and make it available at the surface. The data can then be transferred wirelessly through radio. This specific buoy is equipped with Kongsberg's (Norway) maritime broadband radio (MBR). This enables the buoy to transfer large amounts of data to a recipient with a similar radio, for example, RV Kronprins Håkon or the Dornier airplane from Lufttransport with its Radionor radio.

In the transit between Svalbard and the sea ice front, The ITO was deployed in open waters to do an inter calibration with the ships echosounders. Both instruments were operating in the vicinity, but without interfering with each other's measurements. This was done by placing the echosounder in water while the ship navigated a circle with at least a nautical mile radius around it. On July 24th 2022, the deployment happened at 13:22:08, 8149.876884 N, 03237.239829 E and the retrieval at 16:12:57, 8150.039495 N, 03233.420798 E (Figure 51).

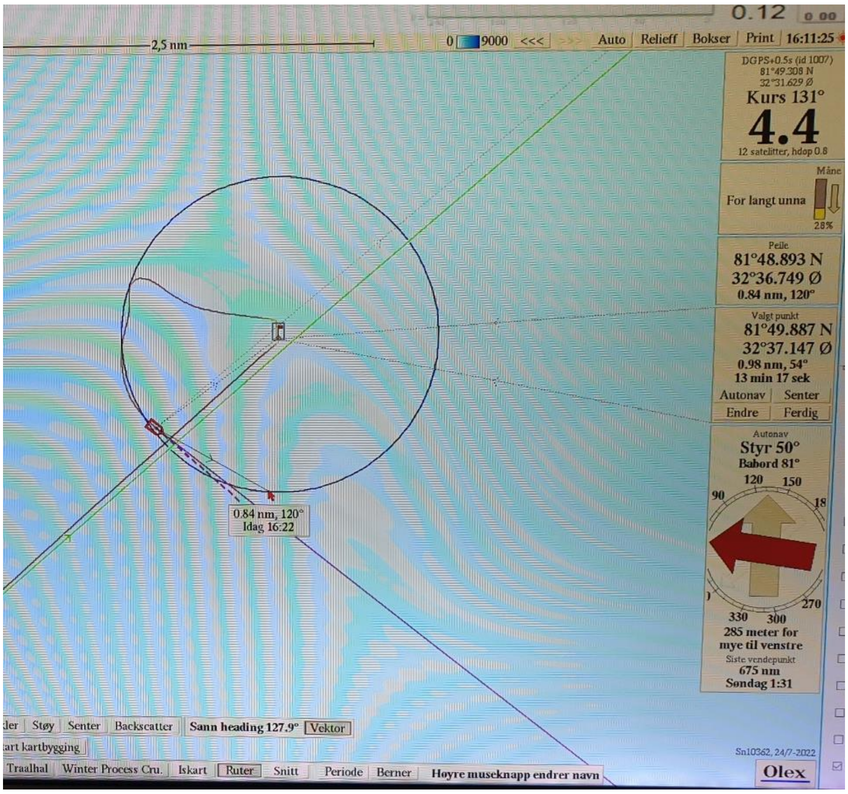


Figure 51. The AZFPITO was tested in open water to have a comparison data set to the echosounders 38 kHz and 120 kHz on board RV Kronprins Håkon. The echosounder hangs 5 m under the top side unit. It was left on the sea while the ship sailed a 1nm circle around it.

AZFP-ITO serial number 310 with AZFP 55135 was permanently deployed as planned during the North Pole sea ice station #1 at Site 3 (Figure 52). The deployment was completed on July 29th 2022 at 16:30 UTC and reported its position on July 30th at 0100 UTC as N89 48.90’, W26 16.90’. A 60x60x180cm hole was made in the ice floe for the deployment. The AZFP was deployed through, and the topside unit covered the hole. One day later the data that had been generated so far was downloaded from an MBR radio mounted on RV KPH. The instrument was left to drift with the floe.

Figure 52. The deployment team from left to right Piotr, Mats, Dima, Pedro and Marius celebrates the installation of the heavy equipment through the ice. Photo: Trine Lise Sviggum Helgerud/Norwegian Polar Institute.

Light and temperature ice tethered observatory (ITO)

Contact: Pedro De La Torre

The LT-ITOs consist of a 50 m long chain of sensors that record the photosynthetic active region (PAR) of the light spectrum at discrete depths. These are 1, 2, 3, 4, 5, 7, 9, 14, 21, 32 and 50 m. Measurements are performed on an hourly basis. A float on the top of the chain keeps the GPS and the Iridium antennas exposed to the sky and is also equipped with a PAR sensor. Data is sent through Iridium. Both units were deployed through a 25cm hole.

Two LT ITOs were deployed in the North Pole sea ice station (#1) at Sites 1 and 2 (Table 36). Each LT-ITO was deployed together with a SIMBA ice mass balance buoy and within a 50 m radius away from the AZFP ITO. Deployment was completed on 29 July 2022 at 16:30 UTC. Their position reported after deployment are in the following table.

Table 36. Light and temperature ice tethered observatories deployed at the North Pole

LT ITO number	IMEI	dtm	Latitude	Longitude
1	300234068038810	2022-07-31 03:00:31	N89.7254048	W28.2045831
2	300234068660490	2022-07-31 03:00:03	89.7246381	W28.2769982

*Figure 53. Marius Bratrein, Pedro De La Torre and Mats Granskog place carefully the long sensor chain through 1.6m thick ice. The PAR sensor, GPS and Iridium antennas on the top of the floating buoy are shown. A SIMBA is placed next to the instrument and left to drift together. (*Photo: Trine Lise Sviggum Helgerud/Norwegian Polar Institute*)*

ROV operations

Contact: Pedro De La Torre

Two different remotely operated vehicles (ROVs) were used during AO-2022 (Figure 54).

- A PRO by Blueye (Norway), hereon referred to as BE, is a portable vehicle with a tilt-enabled camera, compass, depth sensor and light.
- A “double Blueye”, hereon referred to as DBE, is built by joining two single Blueye units with an aluminium frame. This allows an underwater hyperspectral imaging camera (UHI) to be transported in between the vehicles. The camera is mounted looking upwards to see the bottom of the ice.

ROV operations were performed from the ice edge, through a hole on the ice. A tent protected the topside units from weather.

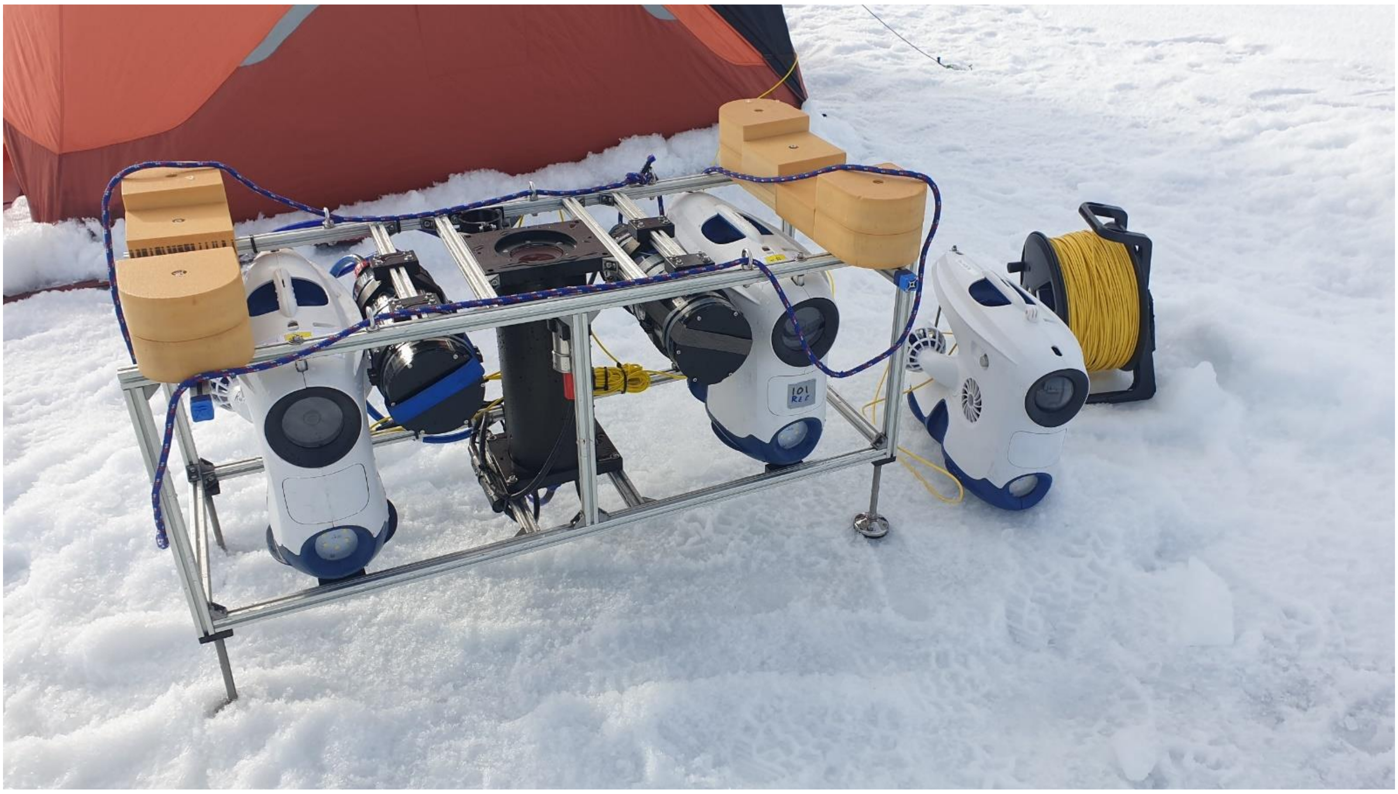


Figure 54. On the left, the double Blueye and on the right the Blueye are ready to be deployed in the water. The tent on the back served as control room for the vehicles.

Deployment at ice station #1 (North Pole)

At the North Pole, the chosen deployment site had strong current from the vessel’s propellers. The double Blueye could not navigate in the current and therefore no scientific data were recorded. However, video of the bottom of the ice along a transect between the deployment site 6 and the thorough-ice UHI site 7 (Figure 33) was taken with the single blueye.

Deployment at ice station #6 (Amundsen Basin)

A roughly 2 by 1.5 m hole was made for the DBE (Figure 55). Poles with flags were installed through the ice to aid with navigation through a 50 m long transect towards the UHI coring station. The DBE completed three transects with the UHI camera on it. The BE was also deployed through the hole. A dive to 150 m was accomplished as well as a scan of the ridge in the neighbourhood of the hole. All the operations with this vehicle at this site were interrupted either due to bad weather, forced returns for meal breaks and evacuation due to polar bear.

Figure 55. The DBE was the largest device on the cruise that needed to be deployed through the ice. Building a hole for ice was time consuming and required several people.

Deployment through the moonpool

On August 6th 2022 at 2100UTC, with the help of the crew and with the ships propellers off, the BE was deployed with a C - node attached to it. The goal was to test the Hipap positioning system of the vessel to have it ready for whenever the vehicle could be deployed. Three transects each exceeding 100 m were made. One towards the starboard, the following towards the port and a final towards the bow were ran. The setup increased the ROV’s navigation safety and comfort. No entanglements happened with the tether due to the relatively straight lines that could be flown and even the ship could be inspected without major risk (Figure 56).

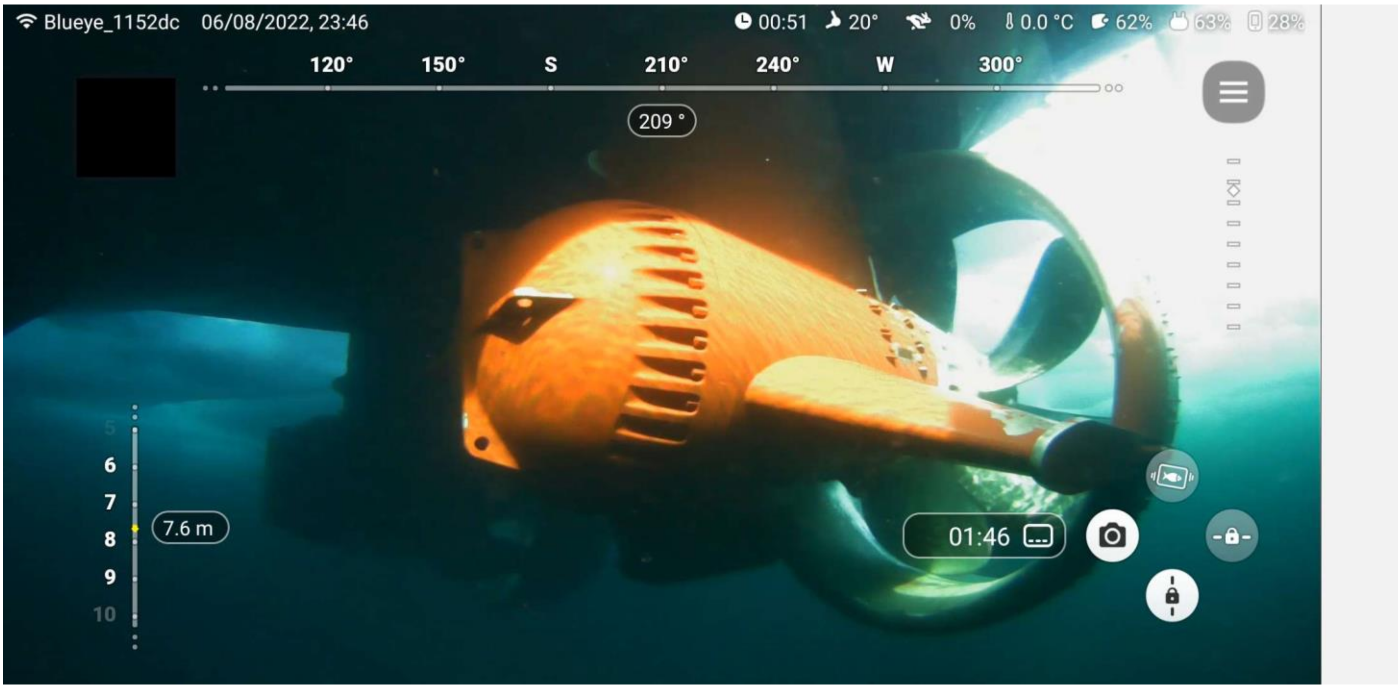


Figure 56. Before retrieving the vehicle, and because navigation with the Hipap system was reliable, the was used to inspect the propellers at the aft of the vessel.

Deployment at ice station #7

August 9th 2022 1030UTC. A sieve was mounted on top of the BE. The plan was to pick algae from the bottom of the ice. During approximately one hour and thirty minutes BE navigated under an ice floe looking for specimens to collect. They were found and several attempts were made to collect them. The position of the sieve was also adjusted as well as buoyancy to make easier sampling. In the end, a sample was taken but it was lost on the trip back to the ice edge. The method proved useful but the tool to sample needs to be improved.

Trial from the starboard side of the ship algae sieves 2 and 3

On August 11th 2022, during deep CTD cast from 1100UTC to 1300UTC, the ROV was deployed from the starboard side of the ship. Sieves 2 and 3 (as shown in Figure 57) were tested. The results were unsuccessful in that they were not good enough to collect algae aggregates and bring them back complete on board. Also, a Blue Robotics ROV was tested (Figure 58). He had prepared a net and a metal blade for scooping the algae out. In addition to the design not being able to catch the sample, the positively buoyant tether of the vehicle got stuck several times in ice with relatively low topography. None of the four samplers was successful in collecting a sample due to the quality of the filter or the capacity for them to get the sample into the device and holding it in place.

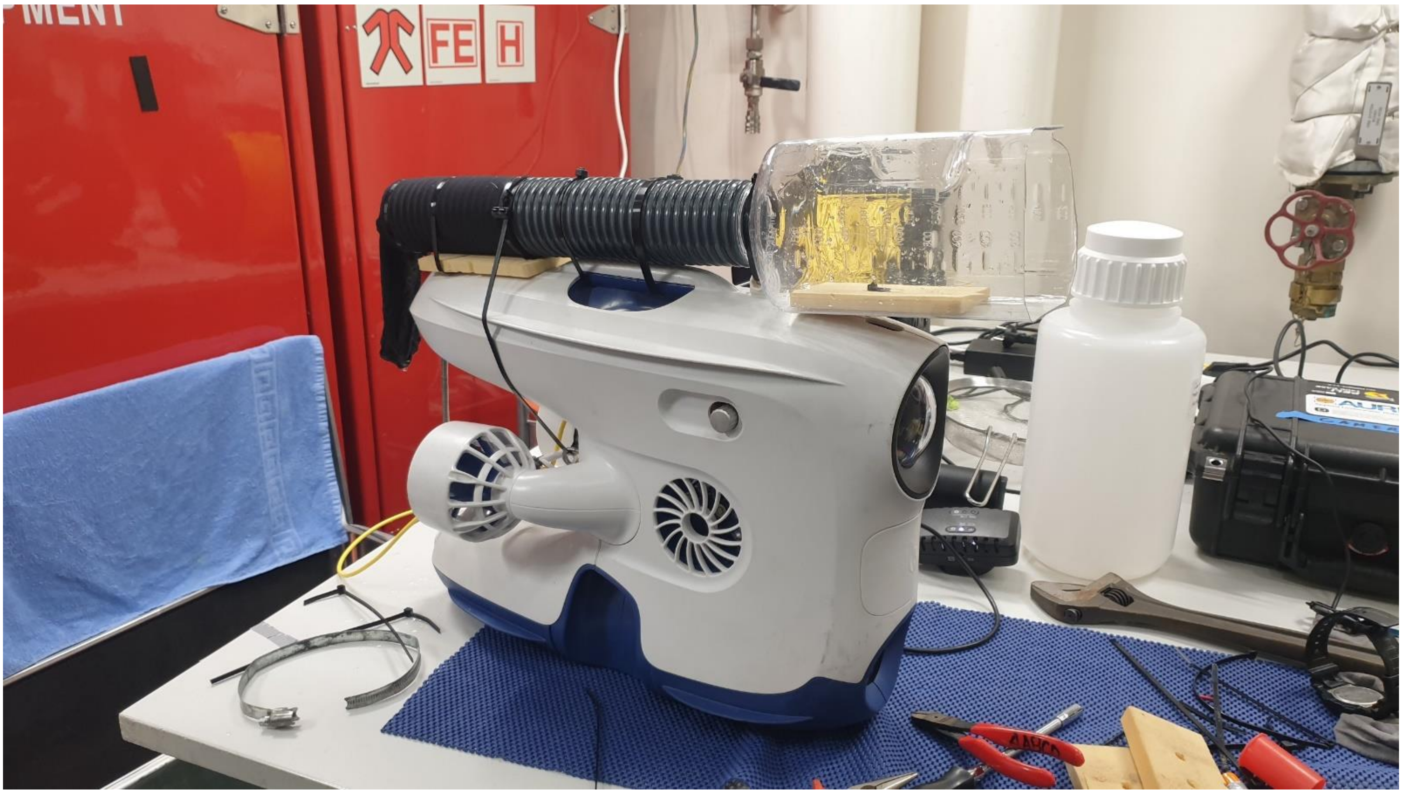


Figure 57. The Blueye was equipped with an improvised sampling mechanism with the hope that it could collect algae samples. The one shown is the 2nd of four different devices built in total.

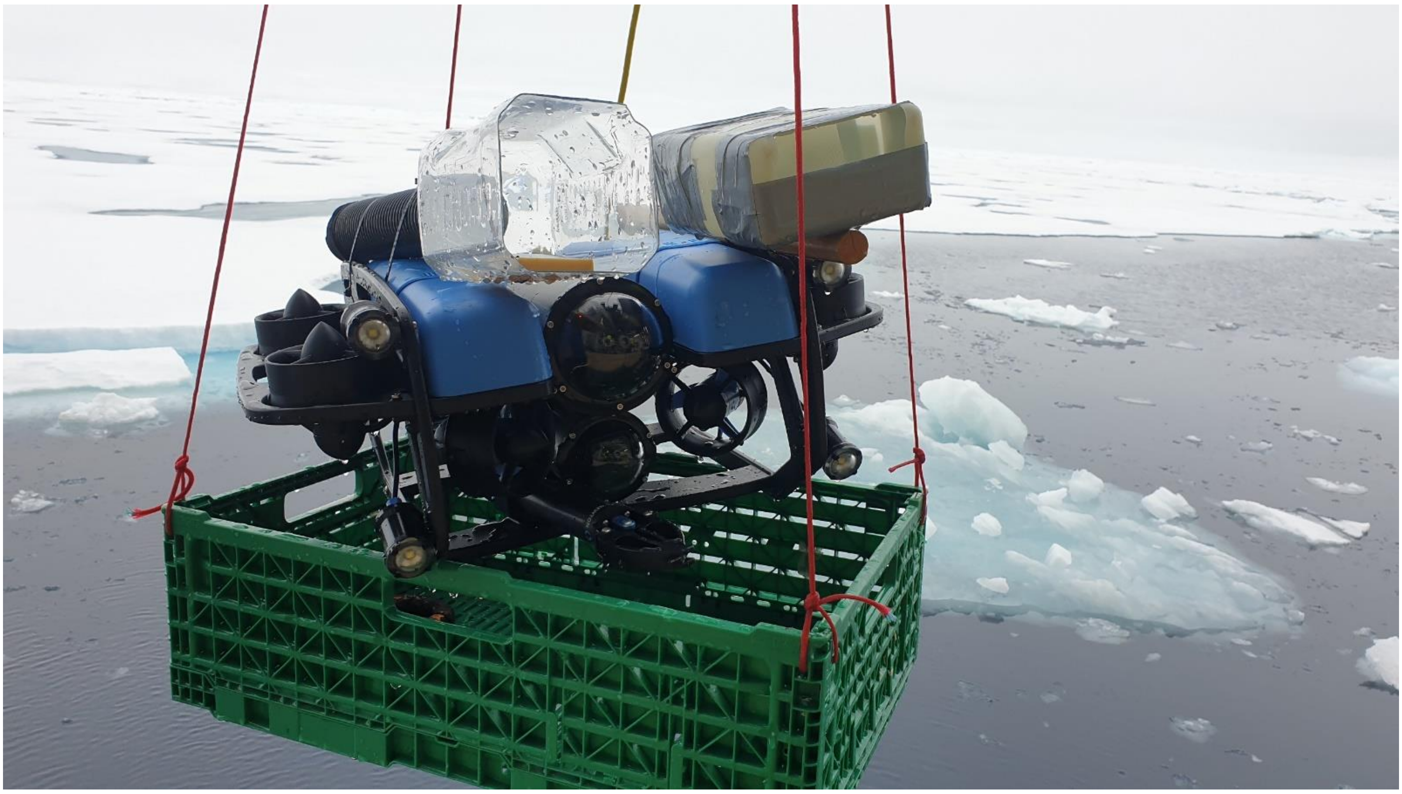


Figure 58. Blue Robotics ROV tested with sampling devices 2 and 3 at the same time. In this case the difference in hydrodynamics and buoyancy between the designs made the vehicle difficult to manoeuvre and to have a constant roll.

Deployment at ice station 8 (Nansen Basin)

August 13th 2022. ROV activities during this station combined both, surveys with the BE and transects with the DBE. Once the hole was made and the tent was set up, the BE dove looking for algae. BE found quickly massive algae gardens on rafted ice at depths which varied between the transition of the ice and water and 5m. 3 different transects were made with the UHI on the DBE and these were aligned with the K Campbell's algae coring sites and the B Langes UHI surveys. Each transect measured 50m long at least and was marked with bamboo flags placed at 10m intervals to assist with navigation.
The BE proved to be a useful tool to discover algae on the sea-ice bottom. The vehicle was used to discover algae aggregates under the ice. They usually hide in small crevices that make them difficult to spot and at they are randomly scattered. Trial-and-error coring from the surface was assisted with the ROV until the core, or the auger hit the right spot. Several pumping techniques were tried which resulted in sampling complete aggregations. The vehicle was used also to position the UHI survey sites (the circular ones) so that the instrument measured confirmed algae aggregations.

Deployment ice station 10 (Marginal Ice Zone)

August 17th 2022. 0700 to 1100 UTC. With a minimal setup, which included a single Zarges box for placement of the navigation computers and power, both ROVs were deployed through a crack on the ice. First and inspection dive with the BE was made while Morven's MSS casts were made. Once the site was understood a transect was marked with flags by B Lange. Immediately afterwards, the DBE was launched and the 50m long line was run twice. Each line took about 10min to be covered. Due to the limited amount of time, a second transect line was made, but this was only based on the topography of the site. There were no physical markers, but instead, references like bubbles, air pockets and the ice formations were useful in creating a relatively straight path. Time was used in this case to create a roughly 50m long transect also. When the activity was concluded, the DBE was brought closed to the ice opening. The BE was launch simultaneously to film the DBE to be able to describe the methodology in later publications. Limited time was available to survey the area with the BE due to the approach of a polar bear, which made it necessary to leave the work site.

Appendix – Scanned images of paper log sheets completed during CTD casts and niskin bottle sampling