BREATHE 2023
Cruise Report

IMR Cruise ID: 2023007008

Tromsø - Longyearbyen

11 – 30 May, 2023

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1. CRUISE OVERVIEW

This research cruise supports the scientific objectives of the Research Council of Norway's BREATHE (Bottom sea ice Respiration and nutrient Exchanges Assessed for THE Arctic) project (No. 325405) that is based at UiT The Arctic University of Norway. With a focus on the biogeochemical exchange processes occurring at ocean-sea ice interfaces, a suite of oceanographic, physical, chemical and microbiological measurements were collected from a single ice floe within Fram Strait. This work further supported the research of Sea Ice Deformation and Snow for an Arctic in Transition (SIDRIFT; RCN 287871), as well as several student projects from international institutions. An additional objective of the BREATHE cruise was to also train early-career scientists with research foci on sea ice, in turn contributing to outreach initiatives of both BREATHE and SIDRiFT projects. The field school brought together twenty international participants from M.Sc. student, Ph.D. candidate and postdoctoral research positions, who participated in a series of academic lectures, sampling excursions and activities for data analysis. Supporting the ECR training and cruise research objectives were an additional nine education and logistical personnel.

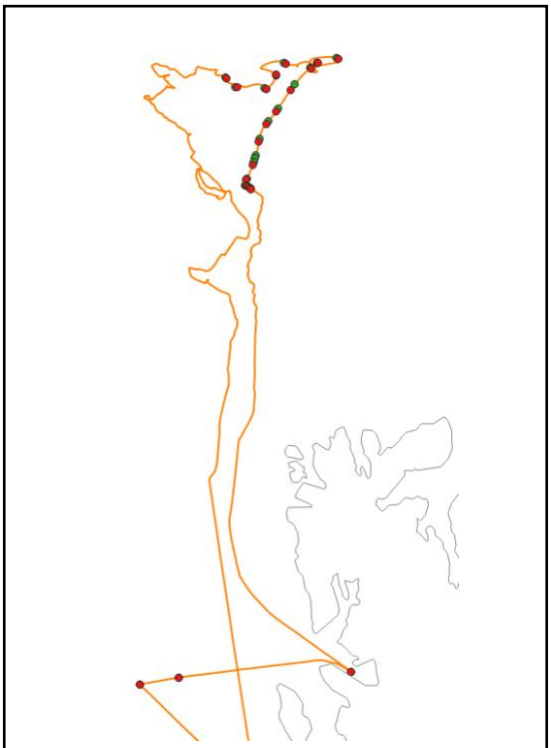

Figure 1.1. *Map of transit and sea ice drift during the study. Red points indicate locations of CTD deployment.*

The majority of scientific work was completed after establishing of a station on a sea ice floe approximately 2 x 2 km^2 in North of Svalbard and close to the Yarmak Plateau. For a period of 10 days the *Kronprins Haakon* remained anchored to this floe while a three-day rotation of activities was completed to sample the snow surface, sea ice and under-ice water. A triplicate of three-day sample cycles was completed. During the return transit from the study floe to Longyearbyen, an additional three CTD casts were completed at Arctic Distributed Biological Observatory (ADBO) stations V6, V10 and KB3 (contact Marit Reigstad, UiT for more information).

Table 1.1. Summary of station locations and depths completed during the field season.

ID	Date	Latitude Start	Longitude Start	Cast Depth
87	17/05 16:24	80.999935	9.475806	950
88	18/05 10:44	80.969672	9.667509	934
89	19/05 10:23	80.9664	10.244557	1025
90	20/05 10:29	81.005364	10.465758	1611
91	21/05 09:04	81.045226	10.623858	1939
92	22/05 10:30	81.02924	11.14689	2028
93	23/05 09:00	81.043906	11.282595	2072
94	24/05 09:00	81.059758	11.675845	2075
95	25/05 10:30	80.976634	10.837508	1853
96	25/05 17:30	80.902133	10.517442	1248
97	25/05 22:22	80.861234	10.313163	1148
98	26/05 05:26	80.805459	10.143383	1063
99	26/05 11:03	80.754698	10.069145	1127
100	26/05 12:00	80.744432	10.048444	1176
101	26/05 12:59	80.733988	10.027302	1233
102	26/05 20:01	80.67997	9.890936	1325
103	27/05 04:51	80.658665	9.85131	1356
104	27/05 09:26	80.653794	9.904088	1318
105	27/05 13:27	80.647532	9.9684	1305
106	28/05 09:32	78.954386	11.957284	343
107	28/05 16:04	78.932726	8.548457	291
108	28/05 17:27	78.906091	7.767263	1127

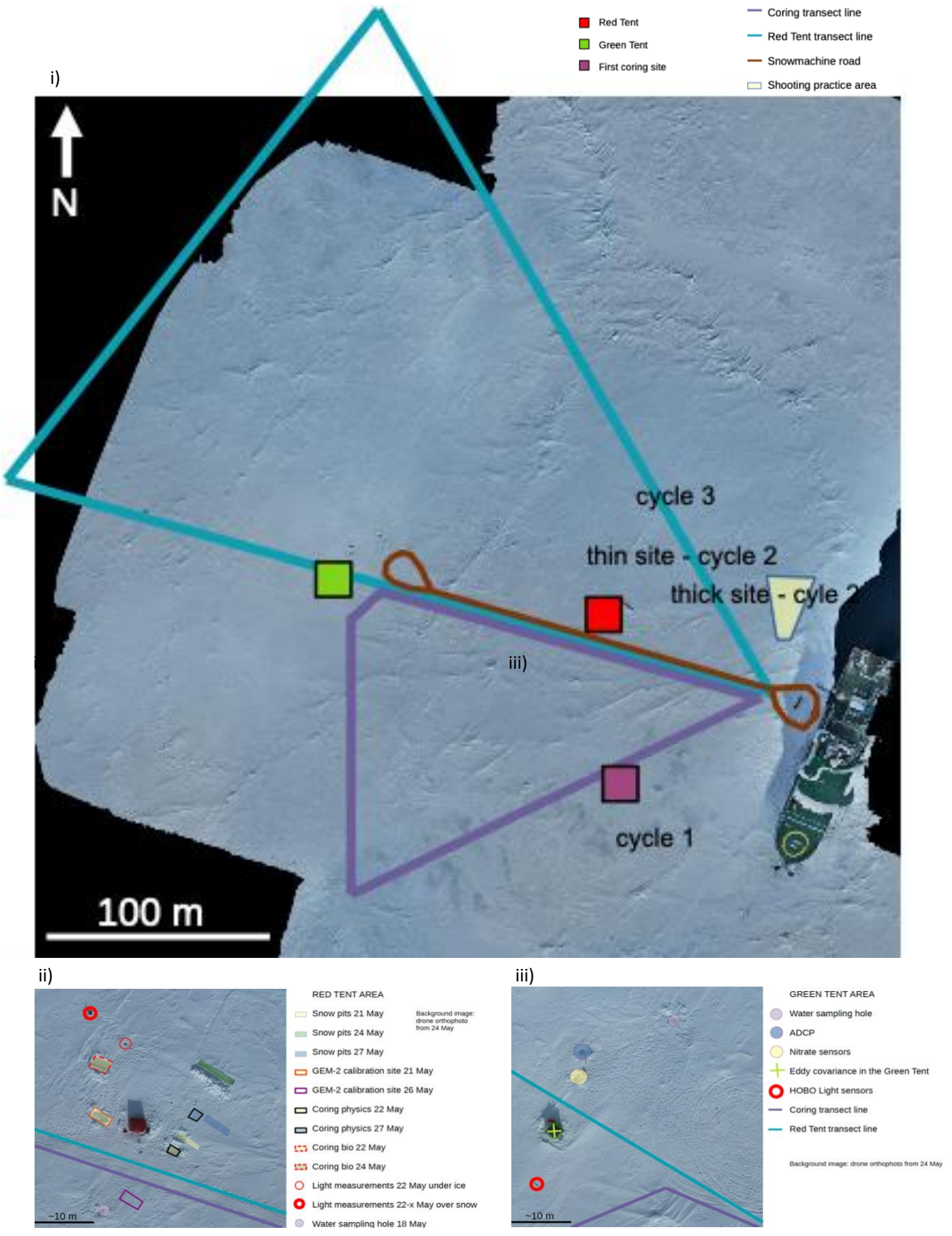

***Figure 1.2**. i) Map of sampling site distributions on the home sea ice floe. Location of temporarily constructed tents are also depicted, where the ii) Green Tent indicates location of underwater eddy covariance deployment and iii) the Red Tent the location of ROV use, as well as microprofiler casts. All background images are drone orthophotos from 24 May.*

2. DATA AVAILABILITY

All sea ice-ocean data from the cruise will be published with DOI on the Norwegian Polar Data Centre within two years of collection and will be linked together with common tag UiT-BREATHE-2023.

3. PARTICIPANTS

Organisation & Course Instruction			
Karley	Campbell	UiT	Cruise/course leader, ice biogeochemistry
Polona	Itkin	UiT	Cruise/course co-leader, snow & ice physics
Zoe	Koenig	UiT	Instructor, physical oceanography
Rosalie	McKay	UiT	Teaching assistant, ice microbial production
Christein	Leber	UiT	Teaching assistant, lab safety officer
Janina	Osanen	UiT	Teaching assistant, Blueeye ROV & ice optics
Technical & Safety			
Dmytro	Krasovsky	NPI	Ice & weather data products
Hana	Chelly	EIMS	Ice nutrients & gas sampling
Einar	Eliassen	NPI	Ice safety officer
Field School Participants			
Marja	Gatcher	UiT	Microbiology
Isolde	Glissenaar	U Bristol	Remote sensing
James	Van Niekerk	U Cape Town	Microbiology*
Esty	Wilcox	U Manitoba	Ammonia cycling*
Georges	Kanaan	U Washington	Bacteria*
Emma	Forss	UiT	Microbiology
Stine	Hagen	U Copenhagen	Microbiology
Antoine	Haddon	U Victoria	Biogeochemical modeling
Axelle	Brusselman	U Liege	Biogeochemistry ice & ocean
Eszter	Kovacs	U Leeds	Biogeochemistry & EPS
Julia	Steckling	U Hamburg	Ice physics
Franka	List	GEOMAR/Kiel University	Remote sensing
Amy	Swiggs	U of Leeds	Remote sensing
Nicolas	Michalezyk	Sorbonne Université	Biogeochemical modeling
Carmen	Nab	UCL	Remote sensing
Lu	Zhou	U Gothenburg	Remote sensing
Mareike	Bach	U Groningen	Biogeochemistry ice & ocean
Rebecca	Hardenbrook	U Utah	Numerical modeling snow
Michael	Sadler	U Washington	Virus & DNA*
Aline	Spera	U Texas	Microbiology

*Indicates sampling completed towards thesis in addition to attendance of field school

4. DAILY ACTIVITIES

4.1 CRUISE OVERVIEW

May 9	Introduction @ UiT
	ARCTOS-supported icebreaker activity @ Tromsdalen Lavvo
May 10	Flotation suit training for participants (NPI)
	Cruise preparations @ UiT Arnda
May 11 - 15	Depart Tromsø & transit
	Safety overview for KPH and field school activities
	Theory-based lectures & sampling preparations
May 17	Floe selection & deployment of ice-moored project
May 18	Physical sampling of ice floe via three-day cycle begins
May 27	Leave floe & transit to Longyearbyen
May 28	Kongsfjord CTD casts for ADBO
May 28 – 30	Data processing & final field school training activities
May 29	Group presentations on preliminary data & outreach projects
May 30	Disembark KPH in Longyearbyen

Photo of pre-cruise Lavvo gathering supported by ARCTOS

4.2 THEORY-BASED LEARNING

Participants engaged in lecture, laboratory and demonstrative activities before and after sampling of the sea ice floe. These activities are summarized below in Table 4.1. Each participant also provided a 5-10 minute presentation on their own research, which ranged from studying the genetic make-up of sea ice virus' to use of satellites to monitor snow-sea ice thickness in the Arctic.

Table 4.1. *Summary of field school activities to support safety training and theory-based learning*

Date	Activity type	Topic	Instructor
9 May	Lecture	Field school overview & welcome	KC, PI, ZK
12 May	Lecture	Introduction to snow sea ice physical properties	PI
	Lecture	Oceanography of the Arctic Ocean	ZK
		(5) Participant science presentations	-
13 May	Lecture	Studying the ocean at sea ice interfaces	ZK
	Lecture	Introduction to sea ice as a habitat	KC
	Lab	Tour of oceanographic sensors	ZK
	Lecture	Cold weather first aid & safety	EE
		(9) Participant science presentations	
14 May	Lecture	Introduction to sea ice remote sensing	PI
	Demonstration	Making ice observations	PI
		(5) Participant science presentations	
15 May	Lecture	Bear & ice safety training	EE
	Activity	Quiz: Testing your Norwegian knowledge	-
	Activity	First aid training & CPR	-
		(5) Participant science presentations	-
16 May	Demonstration	Using a Blueeye ROV for observing sea ice	JO
	Demonstration	Firearms theory & safety	EE
	Lecture	Sampling sea ice for microbiology	KC
	Lab	Safe work in ship laboratories	KC, RM
	Demonstration	Physical processing of sea ice samples	PI
	Lecture	The Yermack plateau's oceanography	ZK
		(5) Participant science presentations	-
ICE ACTIVITIES			
29 May	Lab	Microscopic study & preservation of ice algae	KC

4.3 SUMMARY OF ON-FLOE ACTIVITIES

Instructors meet at 7:00 on bridge each day before ice work. Daily 20:00 meetings with all participants continue throughout ice work. Ice work for the field school (divided into four groups) and BREATHE project sampling followed a three-day sampling cycle after selection of the home ice floe and deployment of moored instrumentation.

Day 0 (17.05.2023): PI and EE assessed selected floe for safety. Instruments deployed following instructor and crew rifle safety training. Only instructors and bear guard were on the ice for deployment of moored instrumentation. A 4 x 4 (10") auger hole was drilled for ROV deployment and covered with a (red) tent. A snowscooter track was marked out with bamboo, this track was also used for the on-ice parade for the 17 May celebration. The weather was good with clear sky and mild temperatures the entire day.

Day 1 (18.05.2023): Cycle 1 - Day 1 school and sampling begins, with sample and data processing in the evening. Snow pits were taken ~100 m south of the red tent (location latter know as 'the first coring site'). Snow and ice transects south of the snowmachine road were carried out by PI team. GEM-2 was calibrated. nder-ice water (UIW) sampling (from interface to 25m across six depths) took place adjacent to the red tent. A simultaneous rosette cast from 15m to the bottom was also taken through the ship's moon pool (water not collected). All water samples were filtered and processed as soon as possible after collection (by both BREATHE team and students). ROV were deployed for under-ice imaging. The afternoon activities were interrupted by a polar bear sighting, but continued after a short break. PI did a test flight with a drone to construct an orthophoto map of the area between the ship and halfway distance between the red and green tent.

Day 2 (19.05.2023): Cycle 1 - Day 2 school and sampling. Physical ice cores taken in the morning with PI´s group, this became the coring site for the day. Sac holes also started on the ice (drilled progressively deeper throughout the day). Oceanography MSS casts at red tent with ZK. After lunch, light measurements were taken for upwelling, downwelling, and transmittance at the biogeochemistry coring site. Following light measurements, biogeochemistry cores were taken for sampling, led by KC. Evening sessions for freezer lab ice coring were run by PI. Chlorophyll *a* (chl *a*) samples were read from the rosette and UIW samples of the previous day. This a was a very warm and sunny day.

Day 3 (20.05.2023): Cycle 1 - Day 3 school and lab work. PI lab for physical ice properties, structure and density in the morning. Student lab for processing the salinity and O^{18} core. Biogeochemistry student lab for filtering chl *a* and particulate organic carbon (POC) on ice samples and microscopy were held. BREATHE team carried out a variety of analyses and incubations on melted ice samples. Students looked at oceanography data processing with ZK. KC went to lead ridge site at 7 o'clock from the ship (~1 km distance) and collected lead ice algae sample with bucket, melted overnight. The sampling location was picked by observations of brown blocks of ice from the ship. On the way to the lead GEM-2 device was towed by snowmachine to record combined thickness of snow and sea ice. In the morning the weather started deteriorating and it remained cloudy until 27. May.

Day 4 (21.05.2023): Cycle 2 - Day 1. The chl *a* samples were read from melted ice samples. Processing of melted sample from the lead was done by BREATHE scientists. The main sampling activity in the ice camp is shifted to the red tent. This made the logistics in the windy weather with limited visibility easier. The ice there is thinner as at the coring location of Sample Cycle 1- Day 1. The transect loop on this day sampled the area north of the tents (snowmachine road). GEM-2 is calibrated at the red tent.

Day 5 (22.05.2023): Cycle 2 - Day 2. The coring site for all ice teams is at the red tent. New auger hole for water sampling was drilled at the green tent.

Day 6 (23.05.2023): Cycle 2 - Day 3. KC collected surface ridge algae samples with peristaltic pump, these were processed for all analyses by BREATHE team. The GEM-2 was again towed by snowmachine to record the total thickness of sea ice and snow. A short flight by done supplied an orthophoto map of the lead sampling area. The poor visibility shortened the lead sampling. Processing of physical and biogeochemical core samples collected on Day 2.

Day 7 (24.05.2023): Cycle 3 – Day 1. The chl *a* samples were read from melted ice samples. The transect by PI group is now extended to combine both previous loops. The GEM-2 field computer failed and no calibration was possible. This was a very warm day with partial overcast. PI did a complete drone survey of the camp.

Day 8 (25.05.2023): Morning meeting of all participants to discuss weather – poor visibility due wind and snow, no students on ice or unnecessary ice work. Forecast indicated that weather would not improve, so decision was made to retrieve deployed instruments with no sampling. Instrument retrieval from 8:30 to 10:30AM, instructors and bear guard only on ice due to wind and visibility. Two CTD casts were completed. Due to proximity to ice edge, it was possible to extend the stay on floe as the transit home will be shorter than originally planned.

Day 9 (26.05.2023): Low visibility. Ice work began at 15:00 to carry out GEM-2 camp grid transects by snowmachine and spatial chl *a* analysis. Diurnal study of MSS casts and destructive nutrient sampling begins at 19:00 with sampling every 4 hours.

Day 10 (27.05.2023): Cycle 3 – Day 2. Final day on ice floe. Diurnal sampling continues.

Day 11 (28.05.2023): Cycle 3 – Day 3. Sample processing and KPH in transit.

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5. SEA ICE IDENTIFICATION & NAVIGATIONAL TOOLS

Contact: *Polona Itkin*

5.1 RADARSAT-2 SAR IMAGES ACQUIRED DURING THE CRUISE

For the cruise we were allocated 5 RADARSAT-2 (RS-2) images though the BREATHE project partnership with the Norwegian Polar Institute. The start location was planned to be outside the normal coverage of Sentinel-1 (currently limited to south of 80N). The first RS-2 image was ordered to overview the sea ice conditions in the East Greenland Sea and the Fram Strait at about 81N on 9 May. Before the start of the cruise 3 other RS-2 images were ordered for the same area for 13, 14, 15 and 16 May. The images were sent to the ship via Vixed. By contract images can only be shared with the Norwegian partners and cannot be made public.

5.2 ICE OBSERVATIONS FROM THE BRIDGE USING ASSIST PROTOCOL

During transit to and from the base floe, regular visual shipboard sea ice observations were recorded by field school participants using the web-based platform Ice Watch (see https://cryo.met.no/en/icewatch). Ice Watch uses the Arctic Shipborne Sea Ice Standardization Tool (ASSIST) software to collect and archive data. All recorded data is stored and made publicly available on the Ice Watch web page https://icewatch.met.no.

Observations were made from the observation deck approximately every one to four hours between 07:00 and 22:00 while RV KPH was in ice/covered waters on May 15 and May 16 and between 17:00 and 19:00 on May 27th upon leaving the base ice floe. Several parameters were included in each observation, including sea ice type, floe size and thickness, snow cover, density of sea ice cover, etc., and were recorded alongside general ship data (e.g., coordinates, speed, and direction) and meteorological data (e.g., air and water temperature, wind speed and direction). No photos were taken during observations as observations can be supplemented by MonkeyTopFWD CCTV camera. The photos were recorded every 10 minutes. In total, 34 observations were made during the cruise while RV KPH was in the ice zone transiting to and from the base floe. Preliminary results below show changes in observed sea ice concentrations (top left panel) and sea ice thickness (top right panel) along the cruise track which suggest the ice observation survey captured the transition from the marginal ice zone into the more compact pack ice.

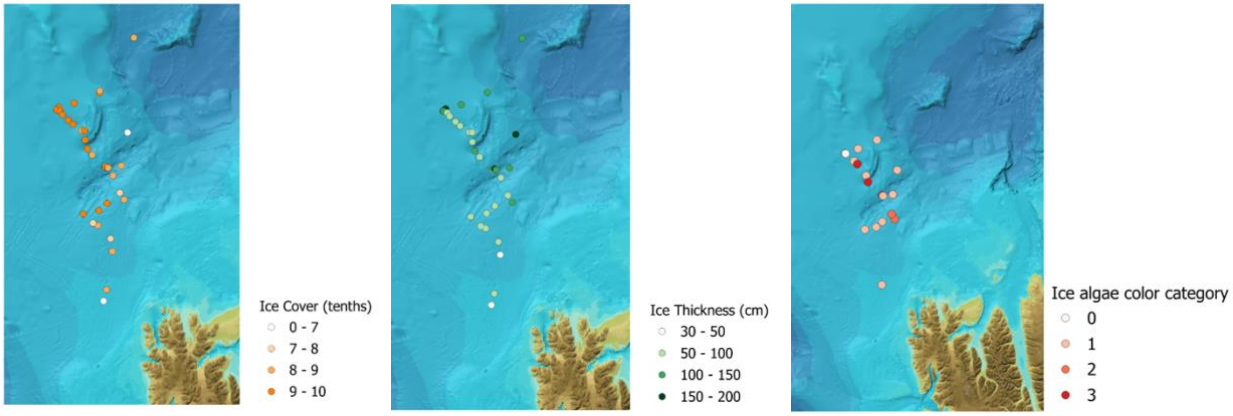

***Figure 5.1**. Ice concentration (left), ice thickness (mid), and ice algae density (right) of the 34 ice observations made during transit to and from the home floe.*

***Figure 5.2.** Photos of observed ice forms and ice observation activities.*

6. SEA ICE MEASUREMENTS & SAMPLING

6.1 MICROSTRUCTURE AND TURBULENCE MEASUREMENTS (MSS)

Contact: *Zoe Koenig*

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 047), a loosely-tethered free-fall instrument equipped with two airfoil probes aligned parallel to each other, a fast- tip thermistor (FP07), an acceleration sensor and a conventional CTD sensor for precision measurements. The shear probes used were SN067 (sensitivity 4.63e-04, SHE1) and SN068 (sensitivity 4.60e-04, SHE2).The sensors point downward when the instrument profiles vertically, and all sampled 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. In total 50 casts were done. The profiler is equipped with a sensor protection guard at the leading end.

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 (sea ice thickness: 1.30 m). The hole was ideally located approximately 130 m away from the ship, ensuring sampling of undisturbed waters. The propellers were turned down during most of the casts to insure the least disturbances. A manual winch was set up by the hole, 2 sets of 2 to 3 casts each were performed each day. See Table below for a total overview of the casts.

Table 6.1*. Summary of the MSS casts*

MSS cast	Day	Time (UTC)
2-3	18/05	15:15
4-6	19/05	08:30
7-8	19/05	14:15
9-11	20/05	14:20
12-14	21/05	07:30
15-17	21/05	14:30
18-20	22/05	08:00
21-23	22/05	14:30
24-26	23/05	08:30
27-29	23/05	14:30
30-32	24/05	07:15
33-36	24/05	14:45
37-38	26/05	14:15
39-40	26/05	17:30
41-42	26/05	21:15
43-44	27/05	01:15
45-46	27/05	05:15
47-48	27/05	13:00
49-50	27/05	13:00

6.2 DEPLOYED SENSORS FROM THE SEA ICE

Contact: *Zoe Koenig*

Under-ice acoustic Doppler current profiler (ADCP) measurements

A Signature 500 ADCP (SN100809) was deployed through a hole in the ice (thickness about 1.5m). The ADCP was mounted downward looking in a metal frame, hanging from two chains approximately 50 cm beneath the sea ice bottom. The instrument was configured to measure in ENU coordinates. The ADCP was configured with a concurrent plan measuring average currents in 0.5 m bins for 5 minutes every second minute and burst sampling with 5 beams as maximum sampling rate (600 samples, 2Hz) every 5 minutes. The ADCP was deployed on 17 May, 14:00 UTC and recovered on 25 May, 8:00 UTC.

Nitrate mooring

The TriOS Opus mooring consisted of two nitrate sensors tethered on a single rope under the ice (ice thickness 1.5m) @20cm (SN49227376) and @100cm (SN49227372). The TriOS Opus sensors were powered by an external power source consisting of a car battery and deck unit at the surface. The sensors were deployed on 17 May, 14:00 UTC and recovered on 25 May, 8:00 UTC.

Under-ice turbulence measurements from Eddy covariance mast

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 (ice thickness 1.5m). 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. The sensors were deployed on 17 May, 14:00 UTC and recovered on 25 May, 8:00 UTC.

Nitrate sensor profiling

A Seabird nitrate sensor (SUNA, 1125) was mounted on a frame with a RBR concerto (SN 201412) equipped with PAR and Chlorophyll a fluorescence sensor. The whole system was lowered down with a 50-m Kevlar rope in the hole used for the MSS. 2 profiles were performed on the morning of day 2 of the sampling cycle 1 and 2.

Fishing rod CTD

A CTD (SN 201412) was mounted on a fishing rod. This system was used to perform shallow cast in the upper layer of the ocean (upper 100m) through the MSS hole and through core barrels hole. Profiles were performed on the morning of day 2 of the sampling cycle 1, 2 and 3.

6.3 SEA ICE OPTICS

***Contact**: Janina Osanen*

Data on photosynthetically active radiation (PAR) were collected as nearly instantaneous measurements using Li-COR sensors with Li-COR datalogger. A Li-COR underwater quantum four-pi spherical sensor was deployed beneath the sea ice (i.e. below the ocean-ice interface), facing the direction of the sun, using a mechanical arm that allowed measurements from directly beneath the sea ice subsurface. Use of the arm positioned the under-ice sensor approximately 1 meter away from the augured hole of deployment. These integrated PAR measurements (µmol of photons m^{-2} s^{-1}) were completed immediately before ice sample collection at coring locations to ensure measurement under a pristine snow surface. Measurements of downwelling and upwelling irradiance were also collected with a two-pi sensor directly after or during the measurements of underwater transmitted irradiance at the same sample site. These were collected by positioning the same sensor on a 1-meter metal pole, held level via tripod. Height of the sensor for both upwelling and downwelling above the snow surface was approximately 0.6 meters.

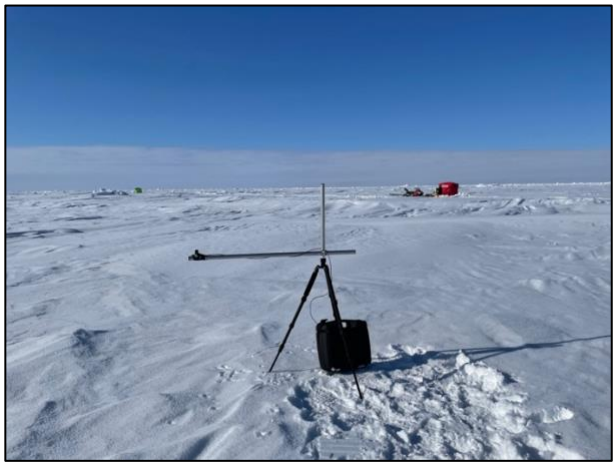

***Figure 6.1** Photo of tripod set-up used to measure albedo and log surface downwelling of PAR*

Leaving the two-pi sensor, Li-COR logger and tripod on the set-up on the ice, two times series sites were established for downwelling irradiance, measuring continuously for a minimum of 48 h next. This was done for the two coring locations of Cycle 1 and Cycle 2, starting on May 19th and May 22nd, respectively.

***Table 6.2.** Location, duration of deployment and file identification information for logged files on Li-COR*

Location	Start and end time (approximate)	Data file on logger
Biochem coring site 1	May 19th 16:00, May 22nd 13:30	BREATHE2
Biochem coring site 2 (red tent)	May 22nd 14:00, May 25th unknown time (data logger turned off in storm)	BREATHE4

Four self-logging HOBO sensors recording PAR and temperature were also deployed at the location of the TriOs nitrate tether, logging data at the ice-ocean interface, 20cm, 100cm and 200 cm. The sensors were deployed in around 1.50 m of ice in a 2-inch auger hole. At the recovery, the rope and chain were cut snapped, and the sensors were lost. The surface sensor placed on a pole 1 m above the snow ice surface was recovered.

6.4 SNOW PHYSICS

***Contact**: Polona Itkin*

Compaction and weather conditions cause development of layers in the snowpack. The characteristics of these layers can be studied in a snow pit - a trench exposing a flat vertical surface from the snow surface to the snow-ice interface. Snow pit measurements are taken using a standardized method, which allows for the easy inter-comparison of data from different sites. Characterizing the properties of snow allows us to understand the processes that govern these properties, as well as the spatial scales over which these properties vary. Additionally, understanding the characteristics of the snowpack improves our understanding of how snow cover affects and interacts with the atmosphere-sea ice-ocean-ecology system. This knowledge will help improve models and validate remote sensing methods, allowing us to estimate snow properties over larger spatial scales.

In total, four snow pits were made at two different sites. The sampling took place every 3 days. Snow pits 2, 3 and 4 were taken close to the red tent whereas snow pit 1 was taken closer to the ship next to the first coring site. Snow pit 2 was chosen deliberately to be in an area of thin snow whereas snow pit 3 was chosen to be in a snow dune. On the 24 to 25 of May there was a strong storm on our floe which altered the snow depths on our floe. For this reason, a fourth snow pit was taken after the storm in a new snow dune next to the red tent. In this last snow pit only one set of measurements was taken whereas the other snow pits were made by pairs of students working along a wide pit wall with about two-meter distance between each pair.
Bulk snow density was additionally measured snow water equivalent (SWE) probes at selected locations along the transects to calculate bulk snow density. Some of the SWE samples were kept for bulk salinity measurements.

At all the stations the following parameters were measured:

- Snow thickness
- Number and thickness of snow layers
- Snow grain sizes within the respective layers
- Salinity of the bottom part of the profile
- Density of the layers
- Temperature profile

Thickness and layer extent were measured using a ruler. Each layer was analysed for grain type, grain size, and hardness. The hardness of each layer was measured based on the levels, fist, fingers, finger, pencil, and knife. Snow grain size within each layer was analysed using a blue plastic crystal card with 2mm grid pattern. The snow grains were categorised into one or two of 5 categories: depth hoar, surface hoar, rounded grains, faceted crystals, participation particles and fragmented particles.

Snow salinity samples were collected in 3 cm increments starting from the bottom (0-3, 3-6, 6-9, 9-12). They were collected in melting cups and later analyzed for salinity using a WTW LF340-A. One set of density measurement was collected for every layer that was thick enough to allow for this. The density cutter used has a volume of 100 cm^3 and the scale used for the weighing was a digital scale with an accuracy of 0.1 g. The temperature was measured every 5 cm in the snowpack using a Hanna HI98501 thermometer. In addition, air/snow interface and snow/ice interface temperatures were measured.

Table 6.3. *List of detailed snow pit observations*

Date	Time (UTC)	Site name ID	Observer Responsible	Mean snow depth (cm)
18/05/2023	9:47	First coring site	Group 1	32
21/05/2023	7:25	Red tent	Group 2	28
24/05/2023	7:15	Red tent dune	Group 4	51
27/05/2023	10:40	Red tent dune after storm	Group 1	58

Preliminary findings: Snow stratigraphy

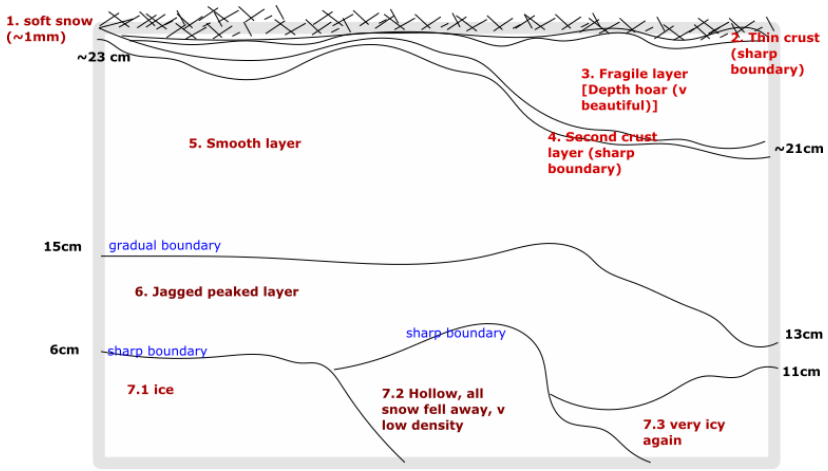

Figure 6.2. *Illustration of snow layers identified in snow pit No. 2 completed on 21 May.*

Figure 6.3*. Photos of snow layers found in the snow pits in Cycle 2 (first two photos from the left) and 3 (right), respectively. Multiple crusts at the surface and depth hoar in the lower layers were identified, labelled here with blue lines. Snow pit from Cycle 3 had a flooded snow-ice interface.*

Preliminary findings: Dye experiment

Dye experiments were carried out in the snow pits using food colouring. The purpose of the dye experiments was to visualise how melt water from the surface flows through the snow and to colour the layers and make them more visible. The depth to which the dye penetrated the snow was defined by the location of the hard ice crusts. The dye only trickled vertically to such layers and then spread horizontally. Only by breaking such layer (e.g. by sawing through it) enabled that the dye penetrated to the layer below.

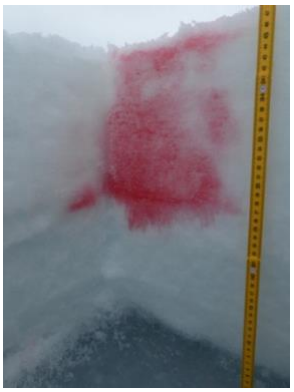

Photo dye experiment

Preliminary findings: Snow density measurements during transects

During the snow transects, salinity and density were measured at sites distributed within the entire ice camp. Salinities ranged between 0 and 0.4PSU with one outlier of 3.9PSU. In Cycle 1 bucket salinity samples were not taken because the activity was shorted due to a bear sighting in the vicinity of the camp. The bulk snow densities are plotted against time and against snow thickness in figure 3. The snow density increased with time until the storm due to melt in temperatures near 0°C after the first sample cycle. After the storm the density decreased again and snow thickness was quite high (only three samples taken in close proximity).

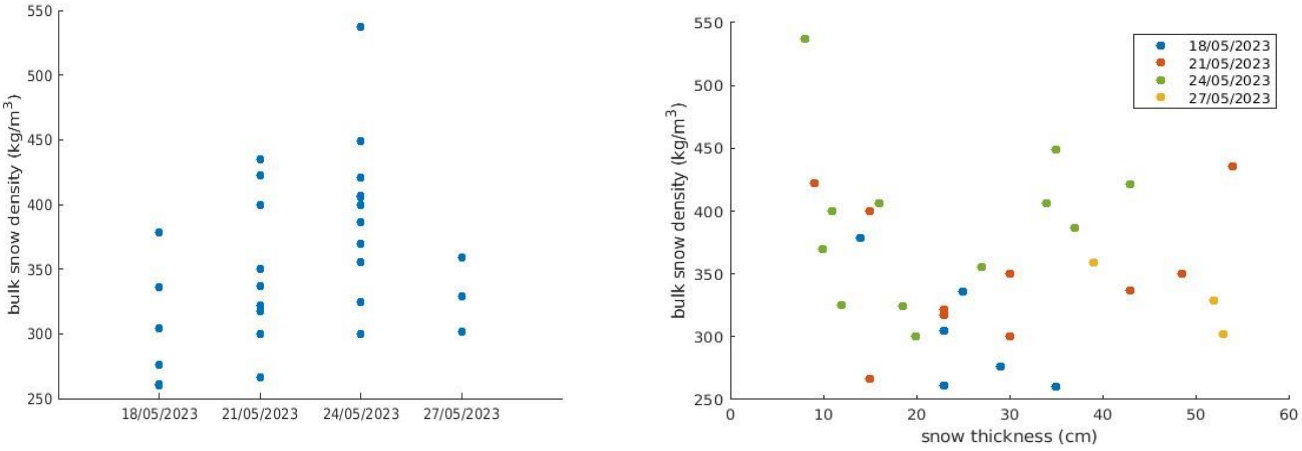

Figure 6.4. *Snow density measured during transects plotted against time (left) and against snow depth (right).*

6.5 SEA ICE PHYSICS CORES

***Contact**: Polona Itkin*

The aim of sea ice coring was to assess the history and highlight the heterogeneity of a sea ice floe during drift. Measurements of sea ice cores were made from 2 sample sites across 3 sampling days of varying snow, ice, and melt conditions. Parameters including temperature, salinity, density, ice thickness, 18O, snow depth and freeboard were measured. Snow depth, ice thickness, temperature, and salinity are particularly important variables as they constrain sea-atmosphere interactions and limit under ice biochemical cycling, and correspond to additional chlorophyll *a* and light measurements which aim to address under ice biological productivity.

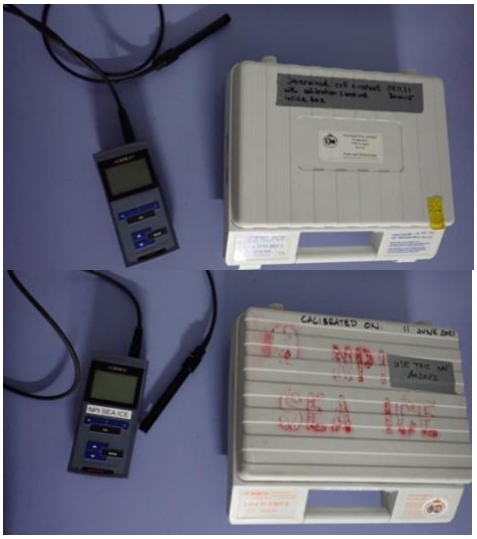

***Figure 6.5.** Photographs of the conductivity probes used in the lab measurements, including the (top) "Blue salinity meter" and (bottom) "Red salinity meter"*

Cores for snow and sea ice physics were taken at two sites:

- First coring site: about 100 m forward of the Red tent in the direction of the ship heading (approximately south)
- Red tent

The depths of the core were measured from the tops of the core (snow/ice interface), which is 0 cm. Measurements of snow depths were taken around the coring site to ensure homogenous snow cover on the whole site. Afterwards one set of sea ice physical cores was taken in every sampling cycle. The number and type of core was depending on sample cycle – whereas a temperature, a salinity and a density core were taken for all three-sampling cycle, archive cores were only taken once. A summary of all collected cores can be found in section 3 (List of collected data).

Temperature core

A temperature was measured immediately after core retrieval using a Testo 720 with robust stainless-steel probe. Temperature measurements were taken every 5 cm of the core. Additionally, measurement from the top and bottom were measured. After measurements the core was bagged and labelled in a core sleeve, transported back to the ship and used for processing for stratigraphy on the day after during the Ice Core Lab (see Section Ice Core Lab).

Salinity core (including ^{18}O sampling)

Immediately after retrieval the salinity core was cut into sections of 10 cm. The pieces were stored in melting cups (Nalgene 1 L screwcap cylinders) and taken to the ship. After melting o/n at RT the salinity was measured using either WTW Cond 3110 Set 1 ("Blue salinity meter") or WTW Cond 3110 Set 3 ("Red salinity meter") with a WTW TetraCon 325 probe (**Error! Reference source not found.**). When possible, it was noted down which probe was used to ensure comparability of data. An intercomparison of the two sets with values for one core as an example is summarised in Figure 6.9.

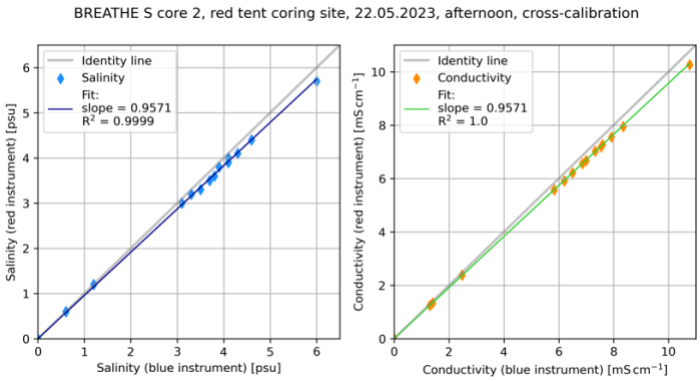

Figure 6.6. *Example of intercomparison of salinity probe sets used in the lab, conducted on sample cycle 2.*

In addition to salinity, samples for oxygen isotope analysis were taken and stored in bottles for later analysis. The ^{18}O samples were labelled according to the following template, where section refers to the melting cup label.

BR7008 Cycle X Salinity Core 2023/05/X
Depth: X Section: X

Density core

For density analysis one core was bagged and labelled in a core sleeve directly after retrieval and taken back on board the ship. The day after retrieval it was processed further to determine the density (see Section Ice Core Lab).

Archive core

Group 3 took two archive cores in addition to the general sampling. The entire cores were bagged and labelled in a core sleeve directly after retrieval. The cores were taken back to the ship, stored in the freezer storage at -20 °C. Photographs of all cores were taken for additional documentation.

Table 6.4. *List of collected data for physical sea ice coring program*

Date	**Time (UTC)**	**Site name (e.g. First Coring site, Red Tent)**	**Observers (group number)**	**List of cores taken**	**Mean snow depth (cm)**	**Mean sea ice thickness (cm)**
19-05-2023	09:28	First coring site 1 (80.97578°N 10.17059°E)	Group 4	Temperature/ Stratigraphy core	13.0	205.5
				Salinity core	13.0	209.0
				Density core	13.0	206.0
22-05-2023	10:00	Red tent coring site 2 (81.041°N 11.1377°E)	Group 3	Temperature/ Stratigraphy core	30.0	136.0
				Salinity core	30.0	137.0
				Archive core 4	30.0	136.0
				Archive core 5	30.0	136.0
27-05-2023	09:10	Red tent coring site 3 (80.65543°N 9.87629°E)	Group 1	Temperature/ Stratigraphy core	26.0	135.0
				Salinity core	26.0	135.0
				Density core	26.0	133.0

Laboratory Analyses of physical sea ice cores

Sea ice density is stratigraphy are along temperature and salinity key parameters that determine sea-ice porosity, brine volume, thermal diffusivity, and gas permeability. Finally, these properties come together to impact the biology of the system, such as the bacteria and algae present within the brines; as well as the accuracy of applied remote sensing techniques.

Density, Temperature, Stratigraphy & Temperature

Ice cores were drilled with a 9 cm Kovacs sea-ice core system. The density and temperature core were packed at the coring site, transported to the ship and stored at -20°C. After unpacking an initial visual assessment characterized the visibly different layers in the ice cores. We then noted the location of any breaks in the core, and whether there were any parts of the core that were visibly damaged or otherwise non-uniform. The temperature core was used for the stratigraphy analysis. Both cores were cut into 10 cm sections using a miter saw at -20°C. The pieces of the density core were individually weighed, and their length measured to determine the density of each section.

The top sections of the temperature core was selected for stratigraphic analysis. Sections of about 5mm were cut from the center of the core and placed atop a light table, photographed and described for the bubble and brine channel content. The sections were then thinned manually to about 2-4 mm thickness and observed on the light table between two polarizing filters under cross-polarized light, photographed and described for ice type (granular and columnar ice).

Table 6.5. *List of collected data from processing of physical sea ice cores*

Date of sampling	Date of analysis	Sampling site name	Observers	Core type
19/05/2023	19/05/2023	First coring site	Group 3	Density
22/05/2023	26/05/2023	Red tent	Group 2	Stratigraphy
22/05/2023	23/05/23	Red tent	Group 1	Density
22/05/2023	23/05/23	Red tent	Group 1	Stratigraphy
22/05/2023	26/05/2023	Red tent	Group 2	Density
27/05/2023	28/05/2023	Red tent	Group 4	Density

Preliminary findings: physical ice coring & analysis

The snow cover varied between 13 and 30 centimeters for the different sites. Ice thickness was between 133 and 209 centimeters, with a thicker and more hard ice at site 1. All the sites had positive freeboard except site 3 that had a -2cm freeboard. Three temperature cores were taken at three different locations (see table). The temperature profiles were taken directly on site. We can clearly see colder temperature for Site 1.

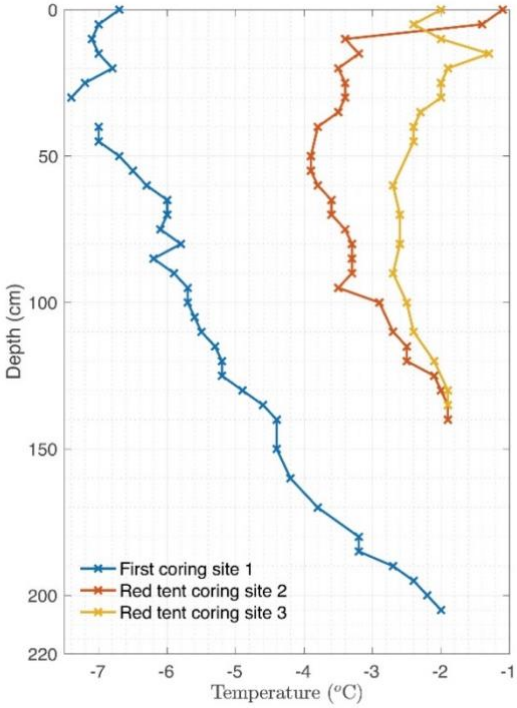

Figure 6.7. *Temperature profiles from the three sampling sites*

Conductivity and salinity were taken after 24 hours when the cores were melted.

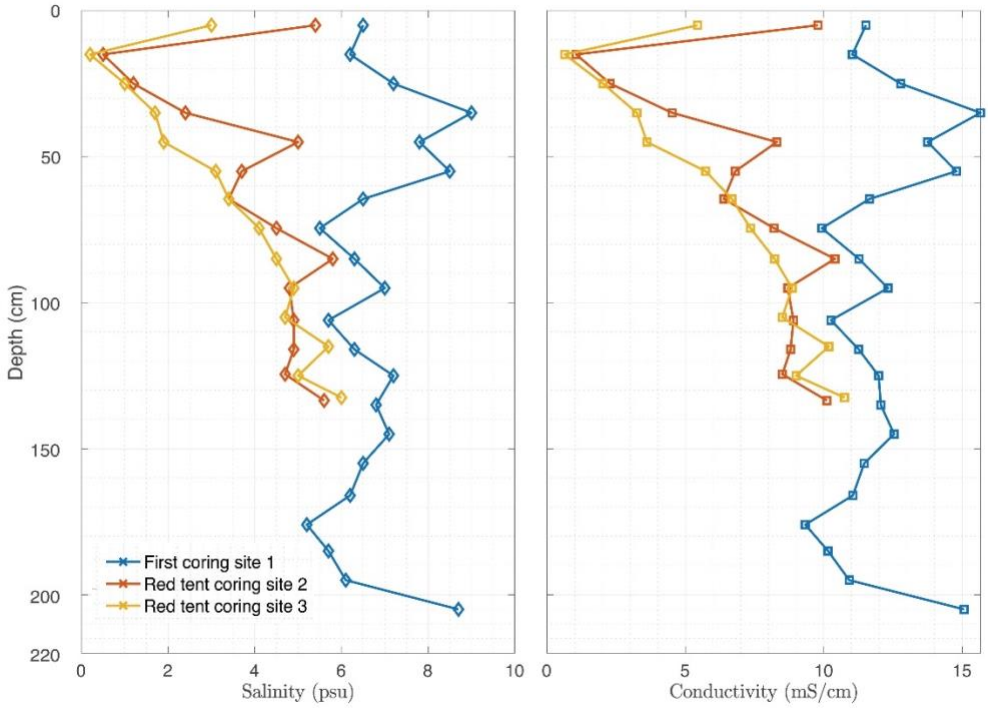

Figure 6.8. *Salinity and conductivity profiles for the three sample sites*

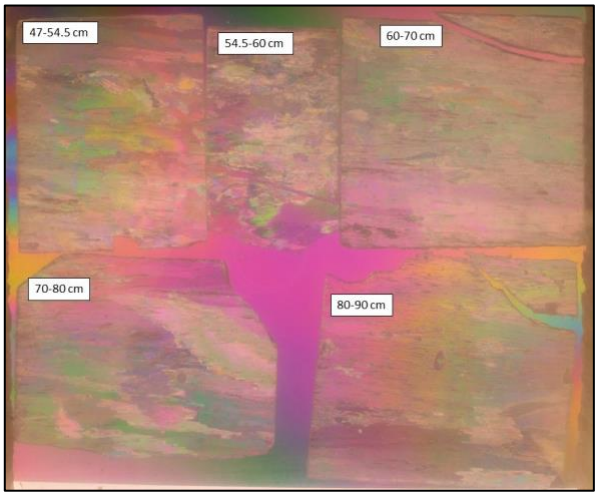

Figure 6.9. *Overview of thin ice sections for the 47-90 cm horizon of the stratigraphy analysis conducted on 26 May. Columnar ice crystals are visible in all sections.*

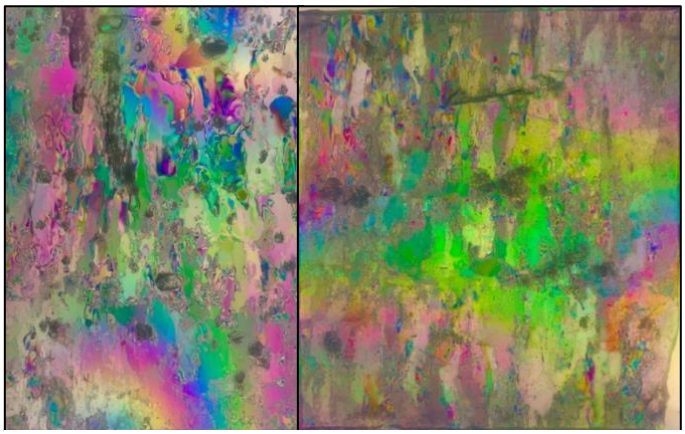

Figure 6.10. *(Left) A thin section from the top 10 cm of the stratigraphy analysis conducted on 23 May. (Right) A thin section from the same core at the 20 – 30 cm horizon.*

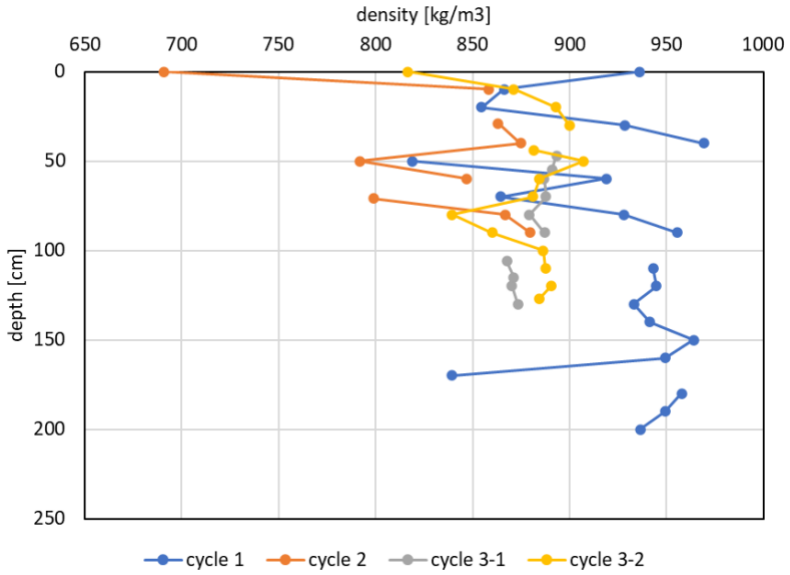

Figure 6.11. *Overview of ice densities (kg/m^3) for each density core taken per sample cycle. Breaks in lines point out breaks in the ice core itself.*

6.6 SNOW AND SEA ICE TRANSECT SAMPLING

***Contact**: Polona Itkin*

The main goal of the transects was the characterization of snow depth and ice thickness variations along profiles on the floe where the ice station was taking place.

The instruments used in transect surveys were:

- GEM-2 used to estimate total sea ice thickness by electromagnetic induction. Sea ice thickness can be derived if snow depth is subtracted. GEM-2 is sensitive to conductivity (including environmental temperature) and was calibrated after every transect or at least for every ice type.
- Magnaprobe used to estimate snow thickness. The Magnaprobe is an automated and GPS-enabled snow probe that logs the snow depth and position by manual operation (pushing a button after penetrating the snow).

***Figure 6.12.** Photos of methods used in transects, (top) GEM-2 being pulled across the floe, (bottom) Polona calibrating.*

***Table 6.6.** Summary of data collected for transect sampling. In total 4 combined Magnaprobe and GEM-2 transect surveys were carried out during the cruise. In addition, data were collected over longer transects by towing GEM-2 in a pulk behind a snowmachine.*

Station/ID number	Date	Time start (UTC)	Time end (UTC)	Transect name	Observers (group number)	Mean snow depth (cm)	Mean sea ice thickness (18kHz_i channel) (m)
	18-05-23	12:40	13:06	Coring Loop	Group 1	35.79	2.21
	20-05-23	12:03	13:20	Lead Trip 1	PI	No data	2.29
	21-05-23	12:51	14:11	Red Tent	Group 2	37.73	2.15
	23-05-23	11:47	11:57	Lead Trip	PI	No data	2.43
	24-05-23	12:37	13:59	Whole loop	Group 4	32.75	2.14
	26-05-23	13:22	14:34	Camp grid	PI	No data	2.20
	27-05-23	15:27	15:47	Red Tent	PI	42.26	2.55

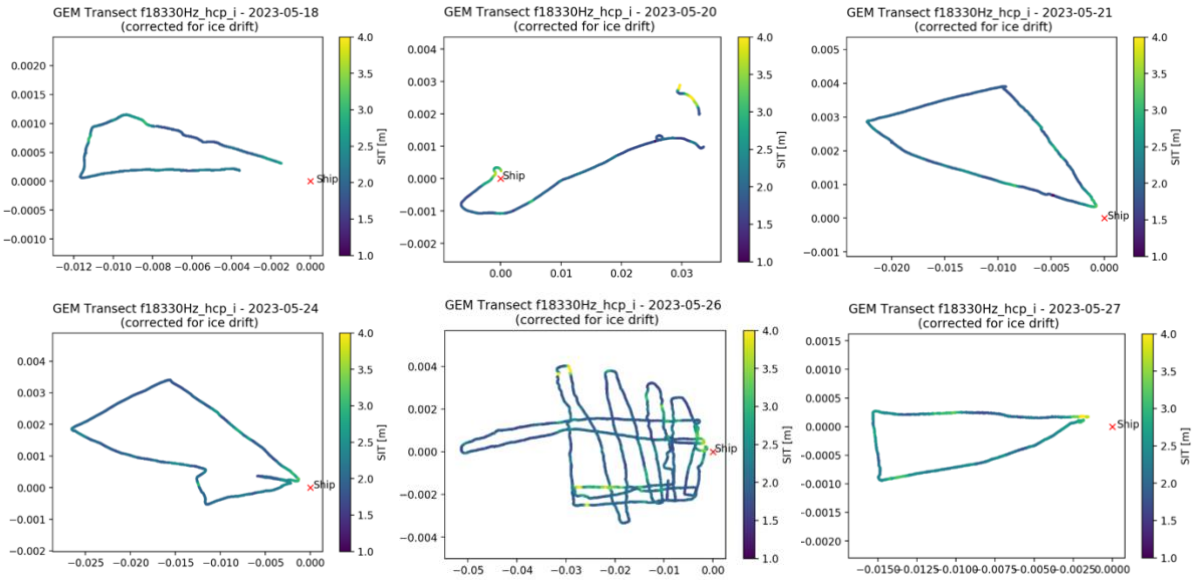

Figure 6.13. *Preliminary data from GEM surveys conducted. See subtitles for respective dates.*

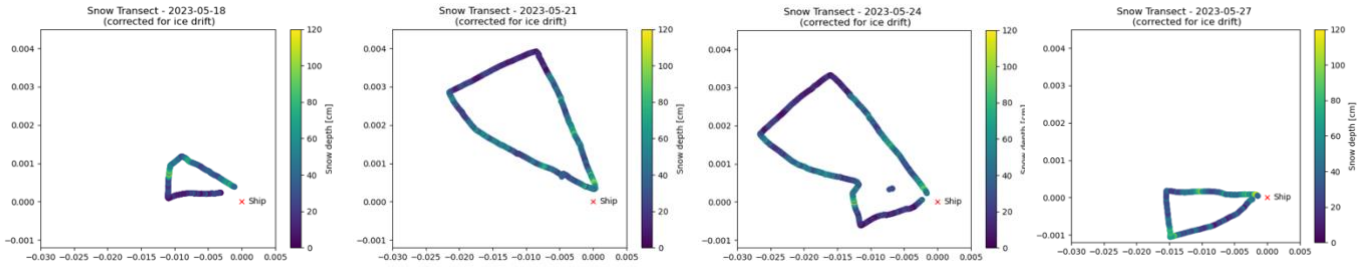

Figure 6.14. *Preliminary data from Mangaprobe snow surveys conducted. See subtitles for respective dates.*

6.7 DRONE OPERATIONS

***Contact**: Polona Itkin*

The drone flights were used for:

- mapping of the ice camp
- spatial characterization of the snow and ice surface

The drone DJI Mavic 3 was flying at 40 m elevation with camera in nadir view, taking a photo every 2 seconds. The flight lines were determined manually with the approximate mowing-the-lawn pattern. The test flight was operated from the ice (gangway), while the subsequent flights were made from the helideck of KPH. OpenDroneMap was used to compose an orthophoto image. The resulting orthophotos are available also in the cruise QGIS project. In addition, a smaller DJI Mavic 2 was tested from the ice and some photos of the area at the Red tent were taken on 27 May.

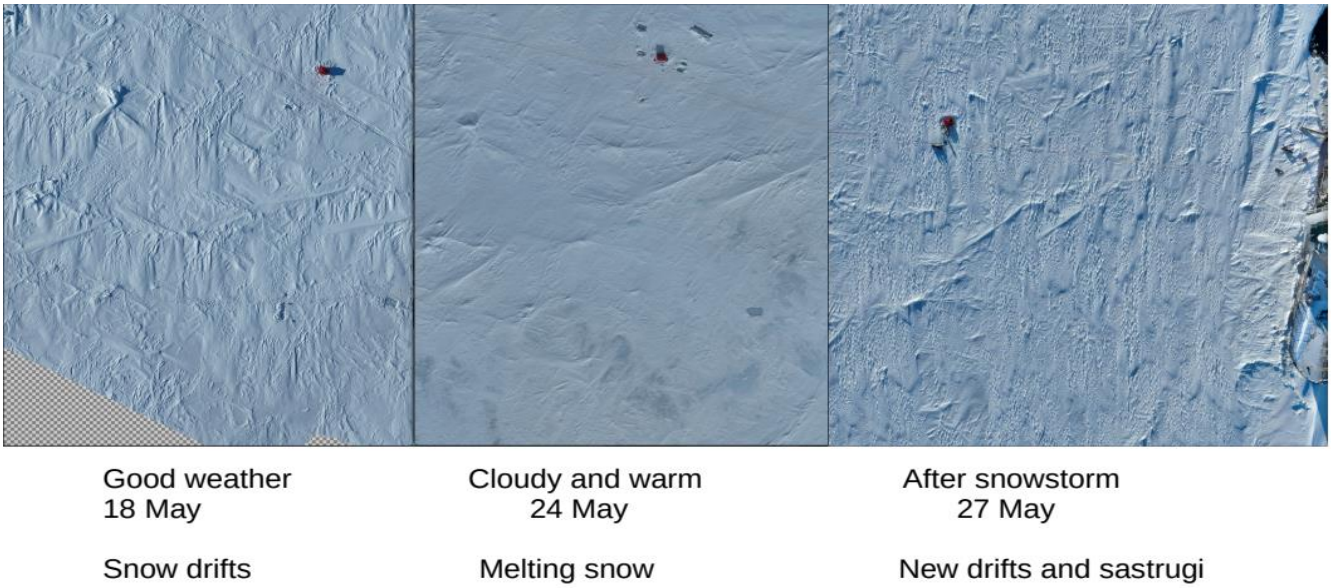

Figure 6.15. Sub-samples of done orthophotos (DJI Mavic 3) covering approximate same area on 18, 24 and 26 May.

Figure 6.16. An example of a single drone image (DJI Mavic 3) covering the lead sampling area

Table 6.7. *List of collected data from drone surveys*

Date	Time start (UTC)	Time end (UTC)	Start coordinates	Location/purpose	Comments
18-05-23	17:05	17:15	80.973940N 9.760926E	Test flight	Only 150 m by 150 m area off the ship, good quality
20-05-23	12:12	12:21	81.046081N 11.32442E	Lead flight	Low contrast, some blue and green water/ice blocks visible
24-05-23	10:25	10:45	81.057738N 11.696525E	Camp flight	Low contrast, visible all installations
26-05-23	21:29	21:55	80.673629N 9.868063E	Camp flight	After storm, good quality. Two flights (battery shift) – some uncovered area between the flights. Strong wind with gusts – several alarms. No drifting snow. Connection to drone lost several times, but re-stablished every time.

6.8 SEA ICE BIOGEOCHEM CORES & SAC HOLES: SPECIALIST CORES

Investigation of Transportation Systems

***Contact**: James van Niekerk*

The incubation of algal samples in liquid, solid and hybrid media was investigated. A cluster of five cores were taken during Sample Cycle 2 of the biogeochemistry coring on the 22 May 2023. 10 liters of interface water was collected from the coring site 21 May 2023 and filtered through 0.2 µm. This filtered sea water was then used for the diluted melt and in the hybrid tanks. The bottom 10cm of each core was collected as this section was anticipated to contain the highest biological density. The 10cm baseline core was sectioned into 4 2.5cm sections at the coring site and put into plastic containers, while the remaining 10cm cores for the 2 hybrid, solid and liquid systems were placed in full core bags (Table 6.7).

The solid core was placed in -20°C freezer for storage. The liquid and baseline cores were melted. The cores are melted in filtered sea water with a ratio of 3 parts water to 1 part ice. The melted liquid cores were placed in blacked out containers and stored in a 4°C cold room in the dark. The melted sections of the baseline core were decanted into 100 ml bottles and preserved with acidic Lugol's solution. The hybrid tanks were filled with filtered sea water before the hybrid cores were added to the tanks. The cooling coils of the tanks were turned on once the top section of the tank had frozen over and the core was secure in the system. The hybrid tank was stored at -10°C (Figure 6.17).

***Figure 6.17.** Experimental set up of Hybrid tank apparatus.*

The storage systems were incubated for approximately 6.5 days before the liquid system was preserved, and the hybrid and solid systems were melted and preserved. The preserved samples consisted of 100 ml from the specific storage system once melted with 1 ml of Lugol's solution. The remaining portion of each of the melted systems was the filtered through GFF. The GFF were placed into glass bottles and 10ml acetone was added. The filters were left in acetone for 16 hours to allow for the chlorophyll *a* to be extracted. The extracted chlorophyll *a* was placed into a fluorometer to measure the RFU values. The preserved samples will be analysed under an inverted microscope off ship.

Table 6.8. *Summary of data collection for transport system*

Date of collection	Sample type	Sample size/volume	Other information
21.05.23	Interface water	10 liters	Collected and filtered for melting and hybrid storage
22.05.23	1 ice cores	Bottom 10 cm of core	Solid core: stored at -20°C in dark
22.05.23	1 ice cores	Bottom 10 cm of core	Liquid core melted and stored at 4°C in dark
22.05.23	2 ice cores	Bottom 10 cm of each core	Hybrid cores: placed in hybrid tank and stored at -10°C

Ammonium halides, Total Alkalinity & $^{18}O/\delta_2H$

***Contact**: Esty Wilcox*

A full ice core was collected and sectioned in 10 cm segments for the analysis of stable water isotopes, total alkalinity, and on-board analysis of ammonium (Table 6.8). Additional opportunistic samples were obtained from snow and sac holes (Table 6.8). Some of the collected samples may be analysed using ion chromatography but this has not yet been approved.

Table 6.9. *Summary of samples collected for Ammonium halides, Total Alkalinity & $^{18}O/\delta_2H$ analysis*

Date of collection	Sample type	Description
19 May (Cycle 1)	Ice core	2.10 m core in 10 cm sections. Samples (x2) taken for TA, d18O/d2H. Salinity measured, processed for NH_4 using fluorometry
21 (Cycle 2)	Snow	x5 snow samples taken after group snow pit activity salinity was measured.
22 (Cycle 2)	Ice Core	1.4 m core in 10 cm sections. Samples (x3) taken for TA, $^{18}O/\delta_2H$. Salinity measured & NH_4 analysed
23 (Cycle 2)	Sackhole	Received 3 samples each of filtered and unfiltered sackhole brine. Sackhole depth was 160 cm depth for TA, $^{18}O/\delta_2H$ and on-site analysis of NH4. Taken Day 1 Cycle 2 (ice depth 205 cm but 3 sackholes pooled S = 95)
27 (Cycle 3)	Ice Core	1.6m core in 10 cm sections. Samples (x2) taken for TA, $^{18}O/\delta_2H$. Salinity measured & NH_4 analysed

Bacterial Meta-omics sampling

***Contact**:* Georges Kanaan

The goal of our work was to sample both ice cores and sackhole brines for metagenomic and metatranscriptomic analysis of the bacterial communities. Five sea-ice cores were sampled during biogeochemical coring of sample cycle 1 (Table 6.9). The cores were cut at 10 cm, 30 cm, 70 cm, and 160 cm from the top using a saw wiped with ethanol. The core sections were then individually bagged in sterile *Whirlpak* bags and kept out of the sun until their return to the ship. The cores were stored at 4°C for 1.5 hours. Appropriate volume of 286 ppt solution was then added to each bag to obtain an isohaline melt, the volume was calculated based on a reference temperature and salinity core. The bags were then allowed to melt for 48 hours at -1.5°C. Once melted, the ice cores were filtered using a *Sterivex* filter. The filter was then sealed using a luer lock seal and *Hemato-putty* before being flash frozen and stored at -80°C. An aliquot of the melted ice cores was fixed using Formaldehyde for bacterial counts, and another aliquot was taken to measure salinity of the final melt solution.

Seven Sackholes were cored for the same purpose (Table 6.9). In addition, we tested a new method of sackhole brine collection. We distinguish between 2 types of sackholes: full length and stepped. Full length sackholes were cored to a depth of 160 cm, and the brine collected once pooled into sufficient amounts. Three full length sackholes were cored on May 21st. Stepped sackholes were cored to depths of 40 cm, 70 cm, and 160 cm. We confirmed that no brine pooled at the 10 cm depth. We "stepped" the sackhole from one depth to the next only after that horizon was drained. We allowed the brine to pool for at least 1.5 hours, collected it and waited 30 minutes. We then checked the sackhole for brine accumulation, in which case it was drained and we waited again. This wait-collect cycle was repeated until no brine collected into the sackhole, at which point we considered that horizon drained. 4 stepped sackholes were taken, 1 during the sample cycle 1 biogeochemical coring event, and 3 on May 21st. All sackhole brines were immediately filtered at 1°C onto *Sterivex* filters. The filters were then flash frozen and stored at -80°C. Aliquots of each brine were fixed using Formaldehyde for counts, and used to measure salinity.

Sackhole step depths and core section depth were determined from a salinity core taken at the red tent site on May 16th. The salinity core collected was stored at -20°C for 24 hours and then cut into 10 cm sections and stored in Ziplock bags. The core sections were melted at high temperatures and the subsequent bulk salinity was measured (Figure 6.18).

Table 6.10. *Summary of data collection for bacterial meta-omics*

Date of collection	Sample type	Sample size/volume	Other information
19.05.2023	Ice core	5 whole cores	Cut at 10 cm, 30 cm, 70 cm and 160 cm. Isohaline melt then filtered.
19.05.2023	Sackhole Brine	1 stepped sackhole	Stepped at 40 cm, 70cm and 160 cm.
21.05.2023	Sackhole Brine	3 stepped sackholes	Stepped at 40 cm, 70cm and 160 cm.
21.05.2023	Sackhole Brine	3 full length sackholes	160 cm sackhole

Preliminary findings: Meta-omics

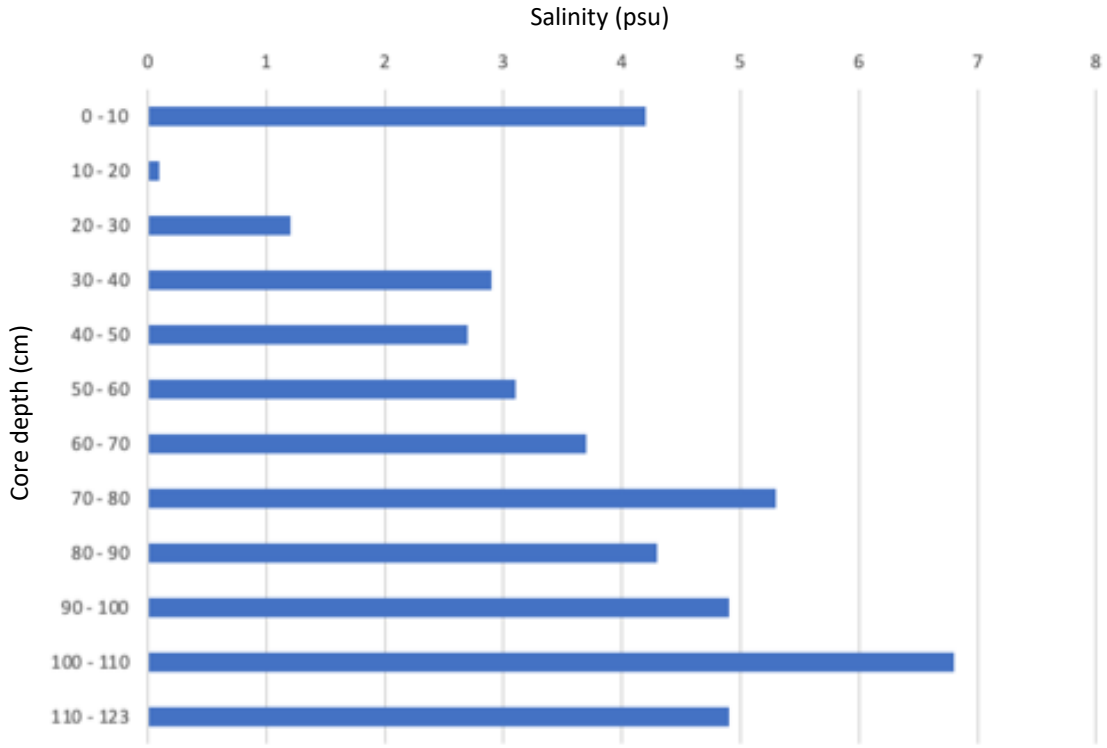

***Figure 6.18**. Bulk salinity from a core collected on 16 May near the red tent site.*

High Throughput Bacterial Culturing and Viral Concentrate

***Contact**: Mike Sadler*

Sea-ice brines were collected throughout the drift for bacterial and viral studies (Table 6.10). Glycerol stocks were made from each type of sample and stored at -80°C. These stocks will be used in a high throughput cell culturing experiment to culture new strains of Arctic bacteria, with a focus on strains from the SAR11 clade. We are interested in understanding what role prophages within the SAR11 genomes play in their adaptation to extreme environments. Thus, we have also sought to characterize the viral community present. To that end, concentrates of each sample were made using a Tangential Flow filter prepared according to the manufacturer's specifications. 2L samples were filtered at 5°C, until the sample was concentrated to approximately 40mL. The tangential flow filter was also used to make 5 L of sterile media from sea-ice brine and seawater which are to be used in the cultivation experiments. Virus stocks were also collected for future viral infection experiments against novel isolates by the preservation of 0.22um filtered samples.

10L of Sea ice brine were filtered using 0.2um sterivex filters for to obtain bacterial genomes. filters were flash frozen in liquid nitrogen after being sealed with a luer lock and hemato-putty. These filters will be used for the sequencing of bacterial metagenomes using long read oxford nanopore sequencing to address the role of prophage in the two distinct environments.

15L of sea ice brine were concentrated using a 30kDa tangential flow filter to collect viruses and screen for transduction by comparing the metavirome against metagenomes.

Table 6.11*. Summary of data collection for High Throughput Bacterial Culturing and Viral Concentrate*

Date of collection	Sample type	Sample size/volume	Intended purpose	Other information
21.05.2023	Sackhole Brines	4 L	Viral concentrate	Cored to 160 cm
27.05.2023	Sack hole	100 mL	Virus Stocks	-
27.05.2023	Sackhole Brine	4 L	Viral concentrate	Cored to 110 cm
21.05.2023	Stepped Sackhole brine	20 L	Bacterial glycerol stocks	5ml from each sackhole horizon

Aerosol production

Contact: *Eszter Kovacs*

Seawater from the air-sea interface was used in a water tank to generate aerosol. A plunging jet was created using a recirculating water pump with a flow rate of 1000L/h, which created bubbles that burst and formed aerosol. Particle-free air, cleaned using a 0.22 µm filter was pumped at a rate of 672L/h into the tank to prevent contamination by room air leaking into the tank. A suction pump with a flow rate of 400L/h pulled air through a 47mm nylon membrane filter with 0.1 µm pore size for aerosol collection. The aerosol filters were collected and replaced twice a day, and water samples were simultaneously taken (Tables 6.12 and 6.13).

Before seawater was added, the setup ran for one day with MQ water to clean all the components and collect control samples. The tank was then emptied, and seawater was added through a funnel with a mesh filter to separate the frozen seawater from the liquid seawater. The frozen part was then melted, and added into the tank 12 hours after the seawater. The experiment ran for 24 hours, then a 15 cm bottom section of ice core (diameter 9 cm) was added to the tank (Table 6.11).

The samples filtered for exopolymeric substances (EPS) were taken back to UiT (Table 6.14).

Table 6.12*. Summary of aerosol sampling events*

Date	Time	Event	Other information
2023.05.16	17:45	set up complete	control filter added
2023.05.17	13:25	MQ water added (5.5 L)	
2023.05.17	13:35	control wet filter added	
2023.05.18	18:15	seawater added	
2023.05.19	19:35	ice core added	
2023.05.19	20:57	ice core melted completely	exact melt rate unknown

***Table 6.13**. Summary of aerosol filter data collection for aerosol sampling*

Date of collection	Time of collection	Label	Sample type	Other information
2023.05.17	9:45	control dry	47 mm nylon 0.1 µm	no water in tank
2023.05.17	20:45	control wet	47 mm nylon 0.1 µm	5.5 L of MQ water
2023.05.19	08:45	SW1	47 mm nylon 0.1 µm	
2023.05.19	19:38	SW2	47 mm nylon 0.1 µm	melted ice added
2023.05.20	8:48	IW1	47 mm nylon 0.1 µm	ice core added
2023.05.20	19:48	IW2	47 mm nylon 0.1 µm	
2023.05.21	7:20	IW3	47 mm nylon 0.1 µm	
2023.05.21	18:20	IW4	47 mm nylon 0.1 µm	
2023.05.22	9:22	IW5	47 mm nylon 0.1 µm	
2023.05.22	18:03	IW6	47 mm nylon 0.1 µm	
2023.05.23	8:40	IW7	47 mm nylon 0.1 µm	vacuum pump was unplugged
2023.05.23	18:23	IW8	47 mm nylon 0.1 µm	
2023.05.24	9:29	IW9	47 mm nylon 0.1 µm	
2023.05.24	18:15	IW10	47 mm nylon 0.1 µm	
2023.05.25	7:25	IW11	47 mm nylon 0.1 µm	
2023.05.25	22:30	IW12	47 mm nylon 0.1 µm	
2023.05.26	8:42	IW13	47 mm nylon 0.1 µm	
2023.05.26	20:20	IW14	47 mm nylon 0.1 µm	
2023.05.27	18:09	IW15	47 mm nylon 0.1 µm	ran for a day

***Table 6.14**. Summary of seawater filter data collection*

Date of collection	Time of collection	Label	Sample type	Sample volume	Other information
2023.05.17	20:45	MQ	Water	10 mL	frozen at -10°C
2023.05.19	08:45	SW1	Water	10 mL	frozen at -10°C
2023.05.19	19:38	SW2	Water	10 mL	frozen at -10°C
2023.05.20	8:48	IW1	Water	10 mL	frozen at -10°C
2023.05.20	19:48	IW2	Water	10 mL	frozen at -10°C
2023.05.21	7:20	IW3	Water	10 mL	frozen at -10°C
2023.05.21	18:20	IW4	Water	10 mL	frozen at -10°C
2023.05.22	9:22	IW5	Water	10 mL	frozen at -10°C
2023.05.22	18:03	IW6	Water	10 mL	frozen at -10°C
2023.05.23	8:40	IW7	Water	10 mL	frozen at -10°C
2023.05.23	18:23	IW8	Water	10 mL	frozen at -10°C
2023.05.24	9:29	IW9	Water	10 mL	frozen at -10°C
2023.05.24	18:15	IW10	Water	10 mL	frozen at -10°C
2023.05.25	7:25	IW11	Water	10 mL	frozen at -10°C
2023.05.25	22:30	IW12	Water	10 mL	frozen at -10°C
2023.05.26	8:42	IW13	Water	10 mL	frozen at -10°C
2023.05.26	20:20	IW14	Water	10 mL	frozen at -10°C
2023.05.27	18:09	IW15	Water	10 mL	frozen at -10°C

***Table 6.15**. Summary of EPS data collection*

Date of collection	Sample type	Filter	Sample size/volume	Storage
2023.05.18	EPS	0.5 µm	150 mL	Frozen at -20°C
2023.05.19	EPS	0.5 µm	150 mL	Frozen at -20°C
2023.05.20	EPS	0.5 µm	150 mL	Frozen at -20°C
2023.05.21	EPS	0.5 µm	150 mL	Frozen at -20°C
2023.05.22	EPS	0.5 µm	150 mL	Frozen at -20°C
2023.05.23	EPS	0.5 µm	150 mL	Frozen at -20°C
2023.05.24	EPS	0.5 µm	150 mL	Frozen at -20°C

6.9 SEA ICE BIOGEOCHEM CORES: UNDILUTED CORE ANALYSES

Fine-scale nutrients & dissolved organic carbon (DOC)

Contact: *Karley Campbell*

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 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).

Fine-scale O2 & 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 $HgCl_2$. The DIC (duplicate) and O_2 (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.

6.10 SEA ICE BIOGEOCHEM CORES: DILUTED CORE ANALYSES

BREATHE-specific analyses

Contact: *Karley Campbell*

Cores were melted in darkness with the addition of 0.2 µm filtered seawater (collected on-site at the ice-ocean interface) for approximately 24h. Seawater for this dilution was collected the day prior to melt. 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.

Fine-scale chlorophyll a

The bottom 10 cm of an ice core was sectioned at 2.5 cm resolution, the remaining core was sectioned at 10 cm resolution. Following diluted melt in filtered seawater, samples were filtered for chl *a* in duplicate (GF/F & 10 ml acetone extraction for 24h at 4°C in darkness). Samples were run on board using a Turner Designs fluorometer.

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 minutes 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 µm 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

100 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.

Dissolved inorganic carbon (DIC)

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

Microbial Production

Three measurements of microbial production were completed on the diluted core sample. Refer to section Sea Ice Incubation Experiments (Chapter 6.12) for further information.

DMS(P) sampling of ice cores

Contact: *Mareike Bach*

Dimethylsulfoniopropionate (DMSP) is a secondary metabolite produced by a variety of marine microalgae. It is a precursor of the climate active gas dimethylsulfide (DMS) and provides sulfur flux from ocean to atmosphere. Potential physiological functions of DMSP in algae include e.g. cryoprotectant, antioxidant or sulfur overflow mechanism.

The objective of the sampling for this project was to quantify $DMS(P)_{t,d}$ and add the parameters to the biogeochemical characterisation of the ice floe. Samples were taken for the total fraction of DMS and DMSP content ($DMS(P)_t$) as well as dissolved fraction of DMS and DMSP ($DMS(P)_d$).

For $DMSP_t$ 10 mL of sample were pipetted into a glass vial. For $DMSP_d$ the remainder of the sample was filtered over a 4.7 cm GF/F filter in the Sartorius filter set-up. 10 ml of the filtrate were pipetted into a glass vial. 50 µL of a 2.3 µM D3-DMSP were added per vial as a standard to track storage loss. A pellet of NaOH was added and the vial closed and stored at -20°C.

In the home laboratory all samples will be analysed for DMS(P) using mass spectrometry (PTR-MS).

***Table 6.16**. Summary of $DMS(P)_{t,d}$ data collection from ice cores, under ice water and water from the CTD Rosette, $DMS(P)_t$ = total fraction of DMS and DMSP content, $DMS(P)_d$ = dissolved fraction of DMS and DMSP*

Date of collection	Date of processing	Sample type	Sample size/volume	Depths	Other information
19.05.2023	20.05.2023	Chl *a* core	10 ml	All sections of the core (24 sections)	$DMS(P)_t$ samples -Single sample
19.05.2023	20.05.2023	Pooled core	10 ml	bottom 5 cm (pooled)	$DMS(P)_t$ and $DMS(P)_d$ - Duplicates
22.05.2023	23.05.2023	Chl *a* core	10 ml	All sections of the core (19 sections)	$DMS(P)_t$ samples -Single sample
22.05.2023	23.05.2023	Pooled core (thick snow cover)	10 ml	bottom 5 cm (pooled)	$DMS(P)_t$ and $DMS(P)_d$ - Duplicates
22.05.2023	23.05.2023	Pooled core (thin snow cover)	10 ml	bottom 5 cm (pooled)	$DMS(P)_t$ and $DMS(P)_d$ - Duplicates
27.05.2023	28.05.2023	Chl *a* core	8.5 ml	All sections of the core (18 sections)	$DMS(P)_t$ samples -Single sample
27.05.2023	28.05.2023	Pooled core	8.5 ml	bottom 5 cm (pooled)	$DMS(P)_t$ and $DMS(P)_d$ - Duplicates

Isolation of heterotrophic marine bacteria

***Contact**: Marja Gächter*

Heterotrophic bacteria were isolated from the bottom 5 cm of the ice and the under-ice-water interface. Melted ice samples and water samples were collected into 50 mL sterile falcon tubes and filtered with a 10 µm pore size sterile filter to remove algae and bigger organisms. The filtrate was spread plated on marine agar plates with different dilutions to receive an ideal concentration of CFU (colony forming units) counts per plate. Additionally, filtrate was transferred to liquid marine broth for culturing. Plates and liquid cultures were incubated at room temperature (22°C) and at 4°C to check for the temperature effect on growth. Leftover filtrate was stored at 4°C for shipping back to Tromsø for further culturing at the home lab.

Table 6.17. Summary of collected under ice water and melted ice core samples for bacterial isolation

Date of collection	Sample type	Sample size/volume	Other information
18.05.2023	Under ice water, ice-water interface	100 mL	10 µm filtered before plating and cultivation
19.05.2023	Pooled ice cores, bottom 5 cm	100 mL	Melted in filtered sea water and 10 µm filtered before plating and cultivation
22.05.2023	Under ice water, ice-water interface	100 mL	10 µm filtered before plating and cultivation
23.05.2023	Pooled ice cores, bottom 5 cm	100 mL	Melted in filtered sea water and 10 µm filtered before plating and cultivation
24.05.2023	Under ice water, ice-water interface	100 mL	10 µm filtered before plating and cultivation
27.05.2023	Pooled ice cores, bottom 5 cm	100 mL	Melted in filtered sea water and 10 µm filtered before plating and cultivation

Preliminary Data: isolation of marine bacteria

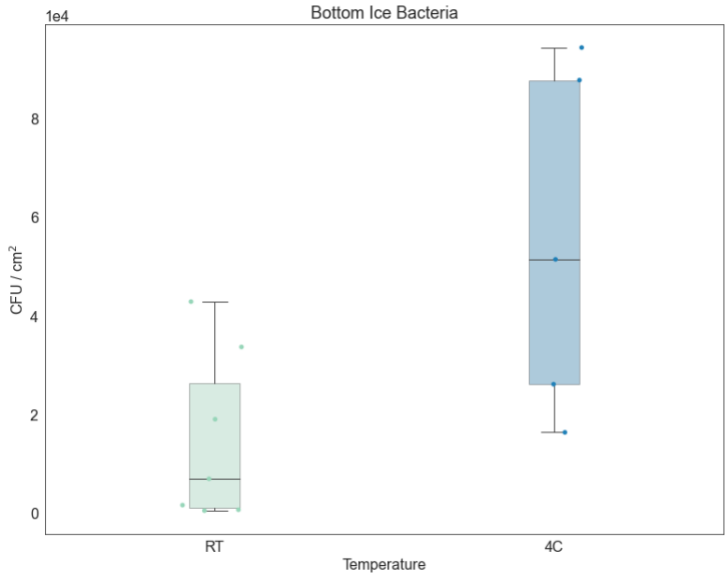

Figure 6.19*. Colony forming units (CFU) of marine bacteria per cm² of bottom sea ice. Bottom 5 cm of ice cores were melted and subsamples filtered through a 10 µm filter prior to spread plating on marine agar plates. Plates were incubated at room temperature (RT, 22°C) and 4°C (4C) for at least 9 days. Plates incubated at 4°C showed slower but more growth. Black line in the box represents the median, whiskers the minimum and maximum values. Dots show individual data points.*

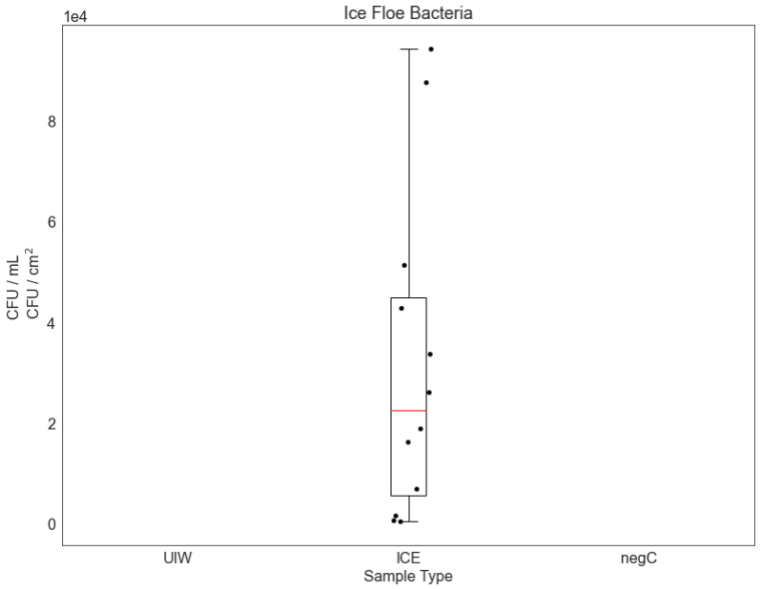

Figure 6.20. *Colony forming units (CFU) per mL under ice water (UIW) and cm² bottom ice (ICE). Bottom 5 cm of ice cores were melted and subsamples filtered through a 10 µm filter, while UIW samples were filtered directly prior to spread plating on marine agar plates. Plates were incubated at room temperature and 4°C for at least 9 days. Plates with 0.2 µm filtered sea water as well as empty ones were incubated at both temperatures as negative controls (negC). No growth was observed in UIW samples and negative controls. Red line in the box represents the median, whiskers the minimum and maximum values. Dots show individual data points.*

Mixotrophy transcriptomics

Contact(s): *Georges Kanaan & Mike Sadler*

Bottom ice melt from the pooled cores was filtered on behalf of Elaina Thomas. On 21 May, ocean-ice interface water was collected to produce sterile seawater. The seawater was filtered on behalf of Dr. Karley Campbell using a 0.2 µm filter, keeping the seawater in the dark, 7 hours after it was collected. The filter was collected and flash frozen before storage at -80°C. On 24 May ocean-ice interface seawater was again collected and filtered, with a 2h storage time. Finally, on 23 May, melted bottom ice from the pooled cores of sample cycle 2 was filtered immediately after melt.

Table 6.18. Summary of data collection for Mixotrophy analysis

Date of collection	Sample type	Sample size/volume	Other information
23.05.2023	Bottom ice pooled core	~500 mL	Filtered in the cold and dark immediately after melt.

RuBisCO Protein Sampling

Contact(s): *Georges Kanaan & Mike Sadler*

On 20 May and 23 May approximately 300 mL of pooled cores from the respective sample cycle were filtered onto a *Sterivex* filter, in duplicate. The filters were then stored at -80°C. The samples were kept in the dark during filtration. These samples were taken on behalf of Dr. Jodi Young for RuBisCO quantification.

Table 6.19*. Summary of data collection for RuBisCO*

Date of collection	Sample type	Sample size/volume	Other information
19.05.2023	Pooled core	300 mL	Duplicate filters were taken.
23.05.23	Pooled core	N/A	Duplicate filters were taken.

6.11 SPATIAL VARIABILITY OF CHLOROPHYLL A

Contact(s): Axelle Brusselman & Karley Campbell

Sea ice is an heterogenous environment regarding multiple parameters. The sampling strategy of sea ice often includes coring, which is a discrete method that doesn't always represent an entire floe. The idea is to sample a floe at different places but with a limited temporal difference (less than 24h). The strategy is to have two transects of 100 m each, with an increasing distance between the cores. One transect is aligned with the drift direction and the other is perpendicular, both are starting at the same point. Due to poor weather conditions the ice cores with ID 0 to 6 were collected on 26 May, while cores at 100 m distance were collected the following day on 27 May.

Only the bottom 5 cm of each core were placed into a sealed bag and kept in the dark. Each core was diluted with 955 ml of filtered sea water and then melted for 24h. The samples were processed and analysed exactly as all the samples collected for chlorophyll *a* during the BREATHE field school campaign.
Snow thickness was taken on both transects every 50 cm between 0 and 10 m. Ice thickness and freeboard were also taken for every core. During the sampling, strong winds were blowing on the floe for more than 24 hours. This impacted the snow cover forming a new one on the already existing snow.

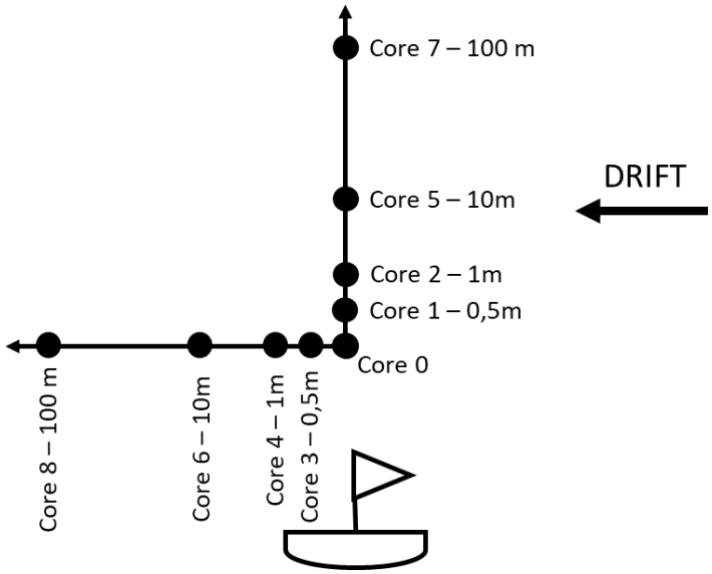

Figure 6.21. *Draft of the two sampling transects completed for spatial sampling of chl a*

Table 6.20*. Summary of data collection for the spatial variability of the chlorophyll a*

Date of collection	Core ID	Distance	Sample size/volume	Other information
26.05.23	Ice core 0	0 m	Bottom 5 cm	No visible coloration of the bottom of the core
26.05.23	Ice core 1	0.5 m perpendicular to the ship & drift	Bottom 5 cm	No visible coloration of the bottom of the core
26.05.23	Ice core 2	1 m perpendicular to the drift	Bottom 5 cm	No visible coloration of the bottom of the core
26.05.23	Ice core 3	0.5 m parallel to the drift	Bottom 5 cm	No visible coloration of the bottom of the core
26.05.23	Ice core 4	1 m parallel to the drift	Bottom 5 cm	No visible coloration of the bottom of the core
26.05.23	Ice core 5	10 m perpendicular to the drift	Bottom 5 cm	Visible brown coloration of the bottom
26.05.23	Ice core 6	10 m parallel to the drift	Bottom 5 cm	No visible coloration of the bottom of the core
27.05.23	Ice core 7	100 m perpendicular to the drift	Bottom 5 cm	No visible coloration of the bottom of the core
27.05.23	Ice core 8	100 m parallel to the drift	Bottom 5 cm	No visible coloration of the bottom of the core

Preliminary results: Spatial Chl a

The chlorophyll *a* was directly measured on board with a fluorometer. The transect perpendicular to the drift showed important variation of the chlorophyll *a*.

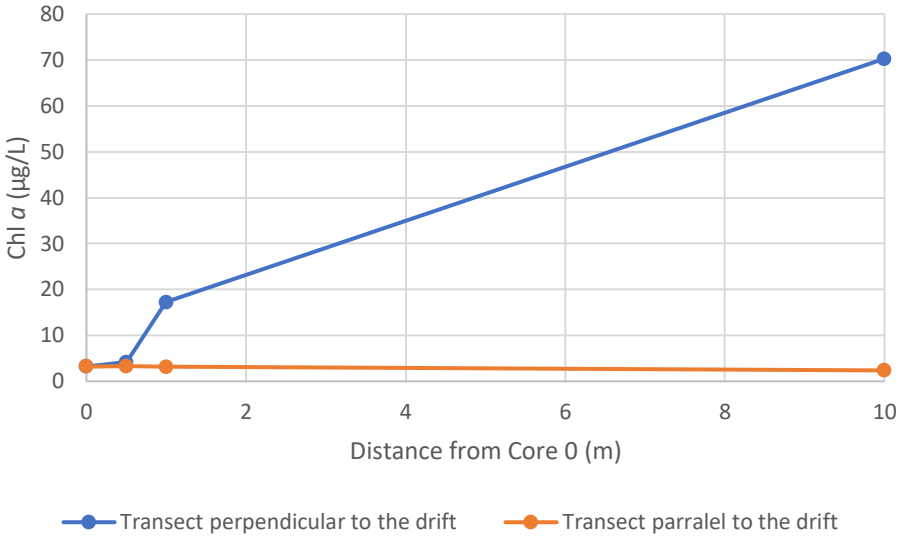

***Figure 6.22**. Spatial variability of chlorophyl a follow the two transects*

Variation of the snow cover due to the storm and the wind that was blowing for more than 24 hours were seen.

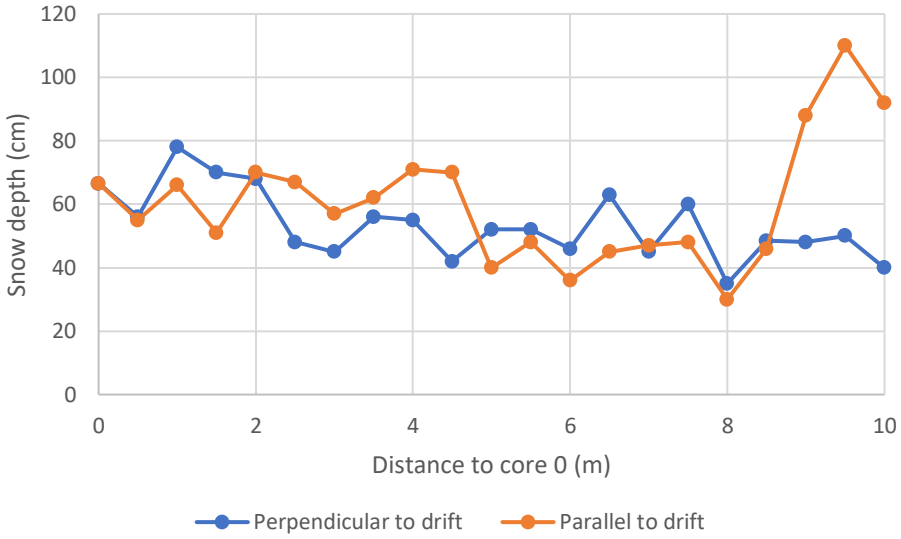

***Figure 6.23**. Snow transect perpendicular and parallel to the drift*

6.12 SEA ICE INCUBATION EXPERIMENTS

Contact: *Rosalie McKay*

Incubations were completed on the meltwater of five to six sea ice core sections (bottom 5 cm), unless otherwise specified. Three types of incubations were potentially completed on these pooled samples. See Table 6.21 for outline of incubations completed per ice station.

Table 6.21. *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.*

Cycle #	Site Description	Sample Description	GPP	BP	NCP
Cycle 1	Ice station 1 (near ship)	x6 pooled cores Bottom 5cm	Y	Y	Y
Cycle 2	Ice station 2 (thick snow cover near red tent)	x5 pooled cores Bottom 5cm	Y	Y	Y
Cycle 2	Ice station 2 (thin snow cover near red tent)	x5 pooled cores Bottom 5cm	Y	Y	Y
Cycle 2	Ridge site (lead)	Ice scooped up with bucket	Y	N	N
Cycle 2	Ridge site (ridge)	Algae sampled from ridge ice with peristaltic pump (liquid sample)	Y	N	Light and dark bottle

Gross primary production (GPP)

Twelve 60 ml Corning flasks (10 clear and two darkened) were incubated in a temperature-controlled chamber, held at -1.5°C. 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 ^{14}C (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, GF/F were dried (approximately 36h) 10 ml of Ecolume scintillation cocktail was added. Measurements of CPM were completed after an additional 48h extraction time. Measurements of GPP were completed at all biogeochemical ice coring stations, as well as opportunistically on ridge and lead algal samples.

Bacterial production (BP)

15 ml of sample were added to six 50 ml sterile falcon tubes and spiked with ^{3}H-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 -1.5°C, after which 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 48h extraction time. Measurements of BP were completed at all biogeochemical ice coring 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 all biogeochemical ice coring stations, as well as on the ridge algal sample.

7. UNDER-ICE WATER SAMPLING

Water collection

Contact: *Rosalie McKay*

Water samples were taken using the auger hole near the ROV tent or the ADCP hole. A 2 L (Hydrobios) water sampler was used for deeper depths (25 m, 5 m, 10 m). Whereas a peristaltic pump was used for the interface water, 20 cm and 1 m depths. Two casts (samplers) were taken per depth, Nalgene containers were rinsed 3x with the sampled water before filling. Samples were kept in a dark cooler for transport, then stored in the dark in a 4°C cooler until processing. Samples for POC, DOC, chl *a* and nutrients were taken for each depth. For the interface water, DIC, Winkler oxygen and flow cytometry were also taken. The chl *a* data was measured on a Turner Designs Trilogy fluorometer and recorded by students. Other samples were processed for storage until analysis at UiT.

High Throughput Bacterial Culturing and Viral Concentrate

Contact: *Mike Sadler*

Interface water were collected throughout the drift for bacterial and viral studies as described for sea ice brines. 10 L of sea ice brine and 10 L of under ice sweater were filtered using 0.2 μm sterivex filters for to obtain bacterial genomes. filters were flash frozen in liquid nitrogen after being sealed with a luer lock and hemato-putty. These filters will be used for the sequencing of bacterial metagenomes using long read oxford nanopore sequencing to address the role of prophage in the two distinct environments.

Table 7.1. *Summary of data collection for High Throughput Bacterial Culturing and Viral Concentrate on UIW*

Date of collection	Sample type	Sample size/volume	Intended purpose	Other information
27.05.2023	Interface water	100 mL	Virus Stocks	
21.05.2023	Interface Water	10 L	Interface water bacterial genomics	5 cm below the ice

Mixotrophy transcriptomics

Contact(s): *Georges Kanaan; Mike Sadler*

We filtered under ice interface water on behalf of Elaina Thomas. On May 21st, ocean-ice interface water was collected to produce sterile seawater. We filtered the seawater on behalf of Dr. Karley Campbell using a 0.2 μm Millipore filter, keeping the seawater in the dark, 7 hours after it was collected. We collected the filter and flash froze it before storage at -80°C. On May 24th ocean-ice interface seawater was again collected and filted, with a 2 h storage time.

***Table 7.2**. Summary of data collection for mixotrophy analysis*

Date of collection	Sample type	Sample size/volume	Other information
21.05.23	Interface water	~20L	Filtered in the cold and dark 7 hours after sampling.
24.05.2023	Interface water	~20L	Filtered in the cold and dark 2 hours after sampling.

CH_4 and N_2O survey

***Contact(s):** Axelle Brusselmann*

Collection of samples for the measurement of partial pressure of CH_4 and N_2O (pCH_4 and pN_2O) are carried out as a strategy for the Green feedback project. The idea is to allow us to derive a quasi-synoptic view of surface pCH_4 and pN_2O in the Arctic and related air-sea CH_4 and N_2O exchange over an extended area. All water collection followed the same protocol and will be measured at the same laboratory (University of Liège).

The method is to take duplicate samples for four vertical profiles with the rosette at 6 different depths (15m, depth maximum chlorophyl a or 25m if no maximum, 50m, 300m, 1000m and bottom minus 10m). To have an idea of the surface repartition of the gases, duplicates were also collected at the interface between ice and the water column. All samples were collected in 60ml clear glass vials avoiding making bubbles to limit the exchange with the atmosphere. The bottles were either directly spiked with $HgCl_2$ in the chemical room or stored in the fridge at 4°C in the dark until timing allowed us to spike them. The $HgCl_2$ stop all biological activities to keep the same amount of gases. The bottles were then crimped with an aluminum cap to avoid all contact with the atmosphere.

***Table 7.3**. Summary of data collection for CH_4 and N_2O samples for vertical profile (rosette samples) and interface samples*

Date of collection	Sample type	Sample size/volume	Depth	Other information
18.05.23	Rosette; Sea water	2 x 60ml	15m, DCM or 25m, 50m, 300m, 1000m, bottom – 10m	Collected and directly spiked with $HgCl_2$
18.05.23	Under-ice water	2 x 60ml	Interface	Collected and stored at 4°C in the dark and spiked with $HgCl_2$ after 2h
21.05.23	Rosette; Sea water	2 x 60ml	15m, DCM or 25m, 50m, 300m, 1000m, bottom – 10m	Collected and stored at 4°C in the dark and spiked with $HgCl_2$ after 2h
21.05.23	Under-ice water	2 x 60ml	Interface	Collected and stored at 4°C in the dark and spiked with $HgCl_2$ after 2h
24.05.23	Rosette; Sea water	2 x 60ml	15m, DCM or 25m, 50m, 300m, 1000m, bottom – 10m	Collected and stored at 4°C in the dark and spiked with $HgCl_2$ after 2h
24.05.23	Under-ice water	2 x 60ml	Interface	Collected and stored at 4°C in the dark and spiked with $HgCl_2$ after 2h
26.05.23	Rosette; Sea water	2 x 60ml 1 x 60ml	15m DCM or 25m, 50m, 300m, 1000m, bottom – 10m	Collected and stored at 4°C in the dark and spiked with $HgCl_2$ after 2h

DMS(P) sampling of ice cores, under ice water and water from the CTD Rosette

Contact(s): *Mareike Bach*

See DMSP sampling of sea ice for full description. For $DMSP_t$ 10 mL of sample were pipetted into a glass vial. For $DMSP_d$ the remainder of the sample was filtered over a 4.7 cm GFF filter in the Sartorius filter set-up. 10 ml of the filtrate were pipetted into a glass vial. 50 µL of a 2.3 µM D3-DMSP were added per vial as a standard to track storage loss. A pellet of NaOH was added and the vial closed and stored at -20°C.

In the home laboratory all samples will be analysed for DMS(P) using mass spectrometry (PTR-MS).

Table 7.4.*. Summary of $DMS(P)_{t,d}$ data collection from ice cores, under ice water and water from the CTD Rosette, $DMS(P)_t$ = total fraction of DMS and DMSP content, $DMS(P)_d$ = dissolved fraction of DMS and DMSP*

Date of collection	Date of processing	Sample type	Sample size/volume	Depths	Other information
18.05.2023	18.05.2023	Ice Interface water	10 ml	Interface, 20 cm below interface	$DMS(P)_t$ and $DMS(P)_d$ - Duplicates per depth
19.05.2023	20.05.2023	Sterile seawater background	10 ml	-	Background of sterile filtered seawater for core melting, triplicates
21.05.2023	21.05.2023	Ice Interface water	10 ml	Interface, 20 cm below interface	$DMS(P)_t$ and $DMS(P)_d$ - Duplicates per depth
22.05.2023	23.05.2023	Sterile seawater background	10 ml	-	Background of sterile filtered seawater for core melting, triplicates
24.05.2023	24.05.2023	Ice Interface water	8.5 ml	Interface, 20 cm below interface	$DMS(P)_t$ and $DMS(P)_d$ - Duplicates per depth
27.05.2023	27.05.2023	Sterile seawater background	8.5 ml	-	Background of sterile filtered seawater for core melting, triplicates

8. ROV OPERATIONS

Contact: *Janina Osanen*

One Blueye PRO (Trondheim, Norway) remotely operated vehicle (ROV) was used on this cruise. The ROV model is equipped with a depth sensor, light, compass and a tilting HD camera for still pictures and videos. The ROV is attached to a 300 + m long cable attached to surface unit. The battery life is estimated to last around 2 h, but the low temperatures affected it.

ROV operations were conducted on all three sample cycles on day 1. A roughly 60 cm by 1 m hole was made for the deployment and a tent was put up on top of the hole.

Sample cycle 1, 18.05.2023
The ROV was deployed for the first time to scan the topography of the sea ice. An area of around 200 m was scanned around the deployment hole, mainly in areas of smooth ice. The deployment lasted around 1.5 hours.

Sample cycle 2, 21.05.2023
The deployment of sample cycle 2 focused on nearby ridges and an attempt to have a look at oceanographic instruments deployed 150 m away from the ROV tent. The instrument inspection was unsuccessful due to a ridge in between the ROV deployment site and the instrument, leading to the entanglement of the ROV cable in ridge ice due to the buoyancy of the cable. The ROV was safely returned without damage. The deployment lasted around 2 hours.

Sample cycle 3, 21.05.2023
The deployment of sample cycle 3 focused on the ridges and flat areas in the vicinity of the ROV tent. Several scans were made around nearby coring sites and the ridge closest to the deployment hole. The ROV stayed close to the ice and close-ups of the ridged ice were captured on video and still images (**Fig. 8.1**). This deployment lasted around 1 h 45 min.

Figure 8.1. *Still image of the nearest ridge. Areas of algal biomass accumulation can be spotted in between the ridged ice.*

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9. SHIPBOARD OCEANOGRAPHIC MEASUREMENTS

Contact: *Zoe Koenig*

CTD

The main 24-bottle CTD was lowered though the moon pool. Note that the upper 10 m of profiles taken through the moonpool describes water trapped in the moon pool and not the natural environment.

The CTD was an SBE911+ unit. 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. A total of 22 casts were performed during the cruise (sta87 to sta108). The last 3 casts were taken in Kongsfjorden as part of the ABD observatory. Bottles were closed during some of the casts and a description of the water sampling can be found in the rest of the report.

***Table 9.1**. Sensor details installed on the CTD*

Sensor	SN	Calibration/Service date
Temperature	5884	14.10.2022
Conductivity	2860	18.10.2022
Pressure	141612	19.12.2017
Temperature, 2	6504	12.10.2022
Conductivity, 2	3123	18.10.2022
Oxygen, SBE 43	3785	29.11.2022
Altimeter, Benthos PSA-916	73084	24.12.2017
Fluorometer, Wet Labs ECO-AFL	6506	18.09.2020
Transmissiometer, Wet Labs C-	2003 DR	01.10.2019
Fluorometer, Wet Labs ECO	4885	15.08.2019
PAR/Irradiance,	70736	29.10.2018
SPAR, Biospherical/Licor	20568	27.11.2017
RDI WH300 L-ADCP, downward	24474	
RDI WH300 L-ADCP, upward	24472	

***Table 9.2**. Overview of the CTD and LADCP casts*

CTD	LADCP	Day	Time	Longitude	Latitude
Sta087	M0087000.000	17/05	16:24	9.4760	80.9998
Sta088	M0088000.000	18/05	10:44	9.6687	80.9695
Sta089	M0089000.000	19/05	10:23	10.2452	80.9662
Sta090	M0090000.000	20/05	10:29	10.4657	81.0053
Sta091	M0091000.000	21/05	09:04	10.6265	81.0450
Sta092	M0092000.000	22/05	10:30	11.1470	81.0290
Sta093	M0093000.000	23/05	09:00	11.2833	81.0438
Sta094	M0094000.000	24/05	09:00	11.6762	81.0597
Sta095	M0095000.000	25/05	10:30	10.8362	80.9763
Sta096	M0096000.000	25/05	17:30	10.5167	80.9018
Sta097	M0097000.000	25/05	22:22	10.3122	80.8610
Sta098	M0098000.000	26/05	05:26	10.1430	80.8052
Sta099	M0099000.000	26/05	11:03	10.0677	80.7540
Sta100	M0100000.000	26/05	12:00	10.0480	80.7442
Sta101	M0101000.000	26/05	12:59	10.0270	80.7338
Sta102	M0102000.000	26/05	20:01	9.8900	80.6797
Sta103	M0103000.000	27/05	04:51	9.8515	80.6585
Sta104	M0104000.000	27/05	09:26	9.9043	80.6537
Sta105	M0105000.000	27/05	13:27	9.9687	80.6473
Sta106	M0106000.000	28/05	09:32	11.9593	78.9542
Sta107	M0107000.000	28/05	16:04	8.5477	78.9327
Sta108	M0108000.000	28/05	17:27	7.7672	78.9060

Lowered acoustic Doppler current profilers (LADCPs)

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 the LADCP was checked on the sea ice during the cruise and was found to have an error of less than 10 degrees.

In total 22 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.

Vessel-mounted acoustic Doppler current profilers (VMADCP)

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.

R/V 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.

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10. NISKIN ROSETTE SAMPLING

For each of the three sampling cycles the rosette was used on Day 1 to collect sea water from the water column, with an additional cast in cycle 3 for a total of four water column samplings. Six standard depths were sampled at 15 m, deep chlorophyll maximum (DCM) or 25 m when no DCM present, 50 m, 300 m, 750 m and 10 meters from bottom. The following parameters were sampled from each depth of the rosette casts.

Chlorophyll a

Contact: *Karley Campbell*

Chlorophyll *a* (chl *a*) is a proxy for biomass of primary producing organisms. Seawater from the six standard depths was collected using a Niskin bottle rosette. A measured volume of water was filtered onto 25 mm Whatmann GF/F glass fiber filters and placed in 10 mL of acetone at 4˚ C in the dark for extraction. Immediately following an 18-24 hour extraction period, samples were analyzed onboard using a Turner Trilogy Flourometer.

Dissolved organic carbon (DOC)

Contact: *Karley Campbell*

Dissolved organic carbon (DOC) samples provide a quantification of bulk dissolved organic carbon concentrations (organic carbon that filters through a 450C-baked (6 h) 0.7 µm Whatmann GF/F filter and are used for understanding carbon biogeochemistry. Samples were immediately acidified to pH=2 with the addition of hydrochloric acid and stored in 4°C. The samples will be measured at UiT AMB using a Shimadzu TOC analyzer.

Nutrients

Contact: *Karley Campbell*

The parameter inorganic nutrients includes measurements of nitrate, nitrite, phosphate and silicate in seawater. Samples were collected for at all standard sampling depths. The samples were collected filtering through a baked 0.7 um Whatmann GF/F filter and freezing at -20C for post cruise analysis. All syringes, swinnex and vials used in this analysis were washed in 10% HCl for 24h prior to use. Processing was done wearing vinyl laboratory gloves.

Particulate organic carbon/nitrogen (POC/PON)

Contact: *Karley Campbell*

Particulate organic carbon/nitrogen (POC/PON) is a proxy for organic biomass in the water column. Seawater was collected from the six standard rosette sampling depths. A measured volume of water was filtered onto pre-combusted Whatmann glass fiber filters as described above. Filters were stored in baked aluminum pouches (45°C for 6h) and frozen at -20°C for further analysis at UiT.

Salinity

Contact: *Christien Laber*

Laboratory salinity measurements are used to validate and (if necessary) calibrate conductivity sensors on the CTD. Salinity samples were collected at the six standard depths from each CTD cast where rosette bottles were collected. Measurements were taken from seawater collected for chl *a* nd POC/PON sampling using a Cond 3110 SET salinometer (SN 1950 1082).

Nitrous Oxide and Methane

Contact: *Axelle Brusselman*

Nitrous Oxide and Methane gasses are both greenhouse gasses and significant contributors to biogeochemical cycling of nitrogen and carbon, respectively. These gasses were collected at all six standard depths from each rosette bottle sampling. Seawater was collected in glass containers without bubbles and preserved with 60 µl mercuric chloride and stored at room temperature in the dark until further processing. See section on under-ice water processing of these parameters for more information.

Total Alkalinity

Contact: *Esty Wilcox*

Total alkalinity is a measure of the buffer capacity of seawater to change in pH. Samples for these measurements were collected at all six standard depths from each rosette bottle sampling. Seawater was collected in glass containers without bubbles and stored at room temperature in the dark until further processing.

Dissolved Inorganic Carbon (DIC)

Contact: *Esty Wilcox*

Dissolved inorganic carbon (DIC) is a measure of the total amount of inorganic carbon dissolved in seawater. Samples for these measurements were collected at all six standard depths from each rosette bottle sampling event. Seawater was collected in glass exetainer vials without bubbles and preserved with 12 μl mercuric chloride and stored at room temperature for further processing.

Dimethylsulfide (DMS)

Contact: *Mareike Bach*

Dimethylsulfide is a gas produced by oceanic microbes enters the atmosphere influencing the nucleation of clouds. Samples were collected in glass vials slow filling without bubbles and stored preserved with Sodium hydroxide and internal DMSP standard and frozen at -20˚C in the dark until further processing.

See DMSP processing of sea ice for full description of method.

***Table 10.1**. Summary of $DMS(P)_{t,d}$ data collection from ice cores, under ice water and water from the CTD Rosette, $DMS(P)_t$ = total fraction of DMS and DMSP content, $DMS(P)_d$ = dissolved fraction of DMS and DMSP*

Date of collection	Date of processing	Sample type	Sample size/volume	Depths	Other information
18.05.2023	18.05.2023	CTD rosette	10 ml	15 m, 25 m, 50 m	$DMS(P)_t$ and $DMS(P)_d$ -Single sample per depth
19.05.2023	20.05.2023	Sterile seawater background	10 ml	-	Background of sterile filtered seawater for core melting, triplicates
21.05.2023	21.05.2023	CTD rosette	10 ml	15 m, 25 m, 50 m	$DMS(P)_t$ and $DMS(P)_d$ -Single sample per depth
22.05.2023	23.05.2023	Sterile seawater background	10 ml	-	Background of sterile filtered seawater for core melting, triplicates
24.05.2023	24.05.2023	CTD rosette	8.5 ml	15 m, 25 m, 50 m	$DMS(P)_t$ and $DMS(P)_d$ -Single sample per depth
24.05.2023	24.05.2023	Ice Interface water	8.5 ml	Interface, 20 cm below interface	$DMS(P)_t$ and $DMS(P)_d$ - Duplicates per depth
26.05.2023	26.05.2023	CTD rosette	8.5 ml	15 m, 25 m, 50 m	$DMS(P)_t$ and $DMS(P)_d$ -Single sample per depth
27.05.2023	27.05.2023	Sterile seawater background	8.5 ml	-	Background of sterile filtered seawater for core melting, triplicates

High Throughput Culture Collection

***Contact:** Mike Sadler*

Samples were collected in falcon tubes from each of the standard depths during the first two rosette casts for the isolation of bacteria/virus systems. Samples were preserved with glycerol and frozen at -20˚C until later processing.

50mL of seawater was collected from depths 25, 50, 300, and 1000m on May 24 on using a rosette equipped with Niskin bottles. The contents of the rosette were aliquoted into sterile falcon tubes and used to make eawater glycerol stocks for future cultivation preserved by flash freezing in liquid nitrogen and stored at -80C.