Cruise report 2022

15 October–19 November

About this report

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Septentrio Reports (3) 2026
https://doi.org/10.7557/7.8786

Forord

Norge fikk i 2009 støtte fra Kontinentalsokkelkommisjonen i FN i kravet om nye store sokkelområder nord for Svalbard. Kunnskapen om sokkelen er liten på norsk side. Andre land har de senere år vært langt mer aktive i Polhavet enn Norge.

GoNorth skal gjennom mobilisering av de fremste kunnskapsmiljøene bringe Norge i front på kunnskap om, for og i Polhavet, slik at vi kan stå frem som den fremste forvalter av miljøet og naturressursene. Vi vil samarbeide med internasjonale fagmiljøer som deler våre interesser og ambisjoner, og som er innstilt på samarbeid om forskning, fartøyer og finansiering.

Det første GoNorth-toktet gikk fra Longyearbyen 15. oktober 2022 med kurs for Nordmarginen av Svalbard, Nansen-bassenget og Knipovich-ryggen vest av Svalbard. Denne toktrapporten summerer opp toktet på vegne av partnerskapet. Jan Sverre Laberg, professor ved UiT Norges arktiske universitet, var toktleder om bord og har også hatt redaktøransvaret for rapporten.

GoNorth vil gjerne takke Nærings- og fiskeridepartementet, Utenriksdepartementet og Kunnskapsdepartementet for økonomisk støtte til å gjennomføre toktet til Nordmarginen. Vi vil også takke universitetene i Bergen og Tromsø for at de bidro med finansierte toktdøgn om bord på det isgående forskningsfartøyet Kronprins Haakon, og Oljedirektoratet for at vi klarte å kombinere GoNorths vitenskapelige mål med ODs ambisjoner om å kartlegge mineralressurser på norsk sokkel. Dette ble et vinn-vinn-samarbeid som tjente begge parter godt.

Vi vil også gjerne takke kapteiner og mannskap om bord på Kronprins Haakon for godt samarbeid underveis. Dette var et krevende tokt under vanskelige forhold (toktet gikk i oktober–november), som alt tatt i betraktning ble faglig og praktisk sett vellykket.

Sist, men ikke minst vil vi takke partnerskapet i GoNorth, og spesielt prosjektets vitenskapelige kjernegruppe, for god planlegging og koordinering av ulike interesser over mange år. GoNorth har vært et usedvanlig krevende prosjekt som til slutt ble kronet med et godt første tokt i 2022.

Trondheim 15. mars 2023

Gunnar Sand, prosjektleder for GoNorth og prosjektdirektør i SINTEF

Sammendrag

Den norske del av Arktis, Svalbard inkludert, opplever i dag store klimatiske endringer. Disse endringene vil påvirke både havet, livet der, og sjøisen. Vi vet imidlertid lite om hvordan dette vil bli påvirket, fordi vi mangler kunnskap, særlig gjelder dette i selve Polhavet. Området ligger langt mot nord og er vanskelig tilgjengelig, noe som krever spesialbygde, isgående forskningsfartøy med avansert utstyr for å drive forskning. Går vi lengre tilbake i tid er dette også et område som har vært gjennom store geologiske endringer. Polhavet har utviklet seg fra å være et isolert basseng, i en periode dominert av ferskvann, til å bli en integrert del av verdenshavene og den naturlige utvekslingen av vann og varme som skjer der. Når og hvordan dette skjedde er fortsatt dårlig forstått, først og fremst på grunn av mangel på geologiske og geofysiske data.

I GoNorth-prosjektet er hovedformålet å bøte på denne mangelen på kunnskap ved å arrangere tre tokt med FF *Kronprins Haakon* i perioden 2022–2024, og disse toktene skal også kunne gjennomføres utenom den normale toktsesongen. Toktene skal være multidisiplinære, det vil si at ulike faggrupper deltar med sine prosjekter. Synergien i å organisere forskningen på denne måten ligger i at de samme dataene kan gi grunnlag for ulike typer studier, men også motivere til samarbeidsprosjekter i etterkant av toktet. Videre er også forskerutdanning en viktig del av arbeidet med disse dataene.

Det første toktet fant sted i perioden 14.10–19.11 i 2022 og bestod av to deler. Den første delen gikk fra Longyearbyen 14. oktober, med avslutning samme sted 3.november. På dette toktet deltok 29 forskere og forskningsingeniører fra ni ulike institusjoner, og arbeidsområdet var lokalisert nord for Nordaustlandet og Kvitøya, fra kontinentalhylla og videre nordover til selve Nansenbassenget (Polhavet), der vanndypet er nesten 4000 meter. Her ble det samlet inn geofysiske data (totalt 539 km med seismiske data), for å studere den geologiske utviklingen av denne delen av Polhavet. Noen av disse innsamlingsmetodene involverte bruk av havbunnsnoder satt ut med undervannsrobot, noe som ikke har vært gjort tidligere i dette området. Det ble også samlet inn prøver av sedimentene på havbunnen, der noen av faggruppene etter toktet analyserer disse med tanke på dagens havbunnsmiljø, mens andre går bakover i tid for å studere utviklingen over et lengre tidsrom. I tillegg ble det gjort målinger og tatt prøver av havvannet og sjøisen der blant annet organismer ble identifisert og analysert, noe som vil gi innblikk i det unike økosystemet knyttet til sjøisen. Det ble gjort målinger av ising på fartøyet, og geo-refererte bilder ble også samlet inn mens båten gikk i isen. Kontinuerlige målinger av den potente klimagassen metan ble gjort gjennom hele toktet. Ny teknologi ble også prøvd ut gjennom en havbunnsrigg og en selvgående, flytende og drivende farkost som begge gjorde målinger i havet i den perioden det første toktet varte.

Del to av toktet (4.–19.11 2022) gikk til Knipovichryggen, en del av den midt-oseaniske spredningsryggen som ligger i dyphavet vest for Svalbard. Her deltok 23 forskere og forskningsingeniører. Denne del av toktet hadde to formål; 1) å lokalisere, kartlegge og ta prøver av hydrotermale mineralavsetninger, og 2) kartlegge og ta prøver av områder på havbunnen med manganskorpe.

I denne rapporten presenteres de som deltok på toktet og arbeidet som ble gjort. Dette vil danne grunnlag for videre arbeid i årene som kommer, inkludert utdanning av nye forskere med nødvendig kompetanse på denne viktige delen av kongeriket Norge.

Contents

LEG 1

1. Introduction

The first GoNorth cruise (Institute of Marine Research Cruise number 2022713), using the Norwegian Research Vessel *Kronprins Haakon*, was divided into two parts, Leg 1 and Leg 2. Leg 1 focused on the continental margin north of Svalbard (Figure 1) and took place 14.10–3.11 2022. Most of the work was done north of Nordaustlandet and Kvitøya; on the continental shelf, the slope and in the deep sea to a water depth of nearly 4000 m. Here we did one refraction seismic line using 19 Ocean Bottom Seismometers (OBS) from GEUS and five from the University of Bergen, two reflection seismic lines, and we had fifteen stations were several scientific disciplines acquired data (also called "Superstations"), and finally one ROV dive for sea floor filming (Figure 1, see also Appendix 1–8 for details). The activity at the stations included seawater measurements and sampling (using the CTD of the ship), sediment sampling (using Multi corer, Box corer, Gravity corer or Grab), plankton sampling (small Plankton, WP3, and MIK nets), and sea ice studies (including sampling). In addition, we deployed a lander and a glider at the start of Leg 1, which were recovered before returning to Longyearbyen.

The study area was partly covered by sea ice, and due to a strong northerly wind, the sea ice zone expanded nearly 50 km south during a 2-day-period of Leg 1. The sea ice included both newly formed (first year) as well as second-year ice (thickness up to about 1 m). No older ice was seen.

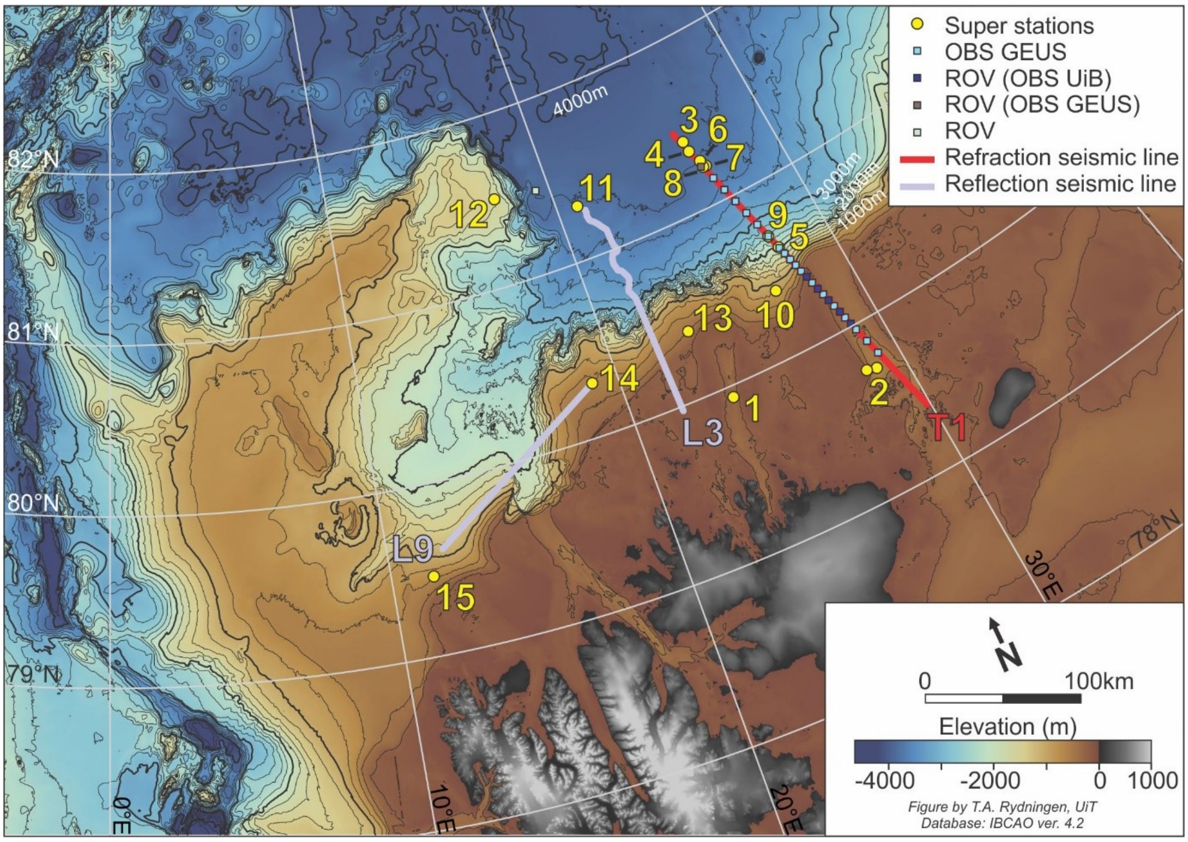

Figure 1. Bathymetric map of the study area (IBCAO 4.2; Jakobsson et al. 2020). The location of the reflection and refraction seismic lines, OBS locations, Superstations, and ROV dive is indicated. Image by T. A. Rydningen, UiT.

2. Participants

For Leg 1 of the GoNorth cruise we had the following 29 participants (Table 1):

Table 1. Participants of GoNorth Leg 1. UiT = UiT The Arctic University of Norway (Tromsø), UiB = University of Bergen, IMR = Institute of Marine Research, GEUS = Geological Survey of Denmark and Greenland, UiO = University of Oslo, DWS = Deep Water Services, BSA = BSA Offshore AS.

No.	Name	Institution	Role
1	Jan Sverre Laberg	UiT	Cruise leader, scientist
2	Tom Arne Rydningen	UiT	Co-chief/ HSE-responsible, scientist
3	Max Weber	UiT	PhD student
4	Orlando Martinez Bautista	UiT	PhD student
5	Truls Holm	UiT	Science engineer
6	Franck Andersen	UiB	Science engineer
7	Bent Ole Ruud	UiB	Science engineer
8	William Skjold	IMR	ROV pilot (Ægir6000)
9	Bjørn Løfquist	Saga Subsea	ROV pilot (Ægir6000)
10	Kai Roger Loven	DWS	ROV pilot (Ægir6000)
11	Andreas Storebø	BSA	ROV pilot (Ægir6000)
12	Frode Evensen	BSA	ROV pilot (Ægir6000)
13	Johan Skøld	Saga Subsea	ROV pilot (Ægir6000)
14	Per Trinhammer	Aarhus Universitet (GEUS)	Science engineer
15	Lars Rasmussen	Consultant (GEUS)	Science engineer
16	Thomas Funck	GEUS	Scientist
17	Alexander Minakov	UiO	Co-chief, scientist
18	Juan Camilo Meza Cala	UiO	PhD student
19	Jon Thomassen Hestetun	NORCE	Scientist
20	Stijn De Schepper	NORCE	Scientist
21	Sabine Cochrane	Akvaplan niva	Chem. Responsible, scientist
22	Sondre Pedersen	Akvaplan niva	Science engineer
23	Frode Leirvik	SINTEF Ocean	Science engineer
24	Thor-Arne Pettersen	SINTEF Ocean	Science engineer
25	Vegard Hornnes	NTNU	PhD student
26	Evgenii Salganik	NTNU	Scientist
27	Nabil Panchi	NTNU	PhD student
28	Paul Rubsamen-von Døhren	NTNU	PhD student
29	Daniel Albert	SINTEF	Journalist, communication

3. Cruise diary

Below is a day-to-day summary of the Leg 1 activities (some additional water sampling was done underway):

October 12: arrival in Longyearbyen for most of the science part of Leg 1, safety training (Group 1) at UNIS 14:00–16:30 (local time, here and below).

October 13: UNIS safety training for personnel on sea ice and polar bear guards (9:00–16:00).

October 14: science party entering the ship at 08:00. Safety training (Group 2) at UNIS 09:00–11:30. Pick up of Regatta outdoor working suites, rifles, and other equipment for working on sea ice at UNIS 12:00. Loading of science equipment for RV Kronprins Haakon.

October 15: continued loading of science equipment, testing of ROV Ægir 6000 (UiB), seismic compressors (GEUS) and airguns (UiB). Final tests completed, leaving Longyearbyen at midnight.

October 16: sailing for station 1. ROV sea test at 10:00. Safety drill for all personnel onboard at 17:00.

October 17: starting at station 1 at 06:00, here we did a CTD, water sampling, and multi corer. Then deployment of a Lander slightly before (west of) station 2. Station 2: deployment of a glider. There were some issues with one of the sensors of the glider, so it had to be recovered, and the sensor was fixed, and the glider re-launched. Multi corer at station 2: first cast was ok, second not, third try ok. Then we sailed for the first OBS deployment, GEUS 1 OBS successfully deployed (free fall deployment). UiB and GEUS OBS deployment continued according to plan (24 in total).

October 18: OBS deployment ongoing, final UiB OBS deployed by ROV, continuing with GEUS OBS (free fall deployment). OBS deployment done by 17:00, the final one had to be deployed by ROV to be able to locate precisely when recovering from under the sea ice. Following this, we had to stop our activities due to the weather, as strong northerly winds were expected until Thursday morning (October 19). No coring or other activities possible due to the sea ice drift, up to 1 knot/hour from the combined effects of winds and currents. The glider returning signals as expected, located south of the ship, in waters free of sea ice.

October 19: planning for the first sea ice station, but due to snow showers and low visibility this was not possible. Final decision to terminate this plan due to safety concerns was taken at 16:00. Then we began planning for refraction seismic line T1 to be started in the morning next day, pending weather. While sailing north to the start of T1 during the night, a polar bear was seen, moving away from the ship.

October 20: start of T1 in sea ice covered water using the GEUS airguns. After some issues with air leakage and some damage to one of the cables being hit by ice, we were doing fine, and proceeded southwards. Nice drone photos of the ship were taken.

October 21: we reached ice free waters at about 03:00 and terminated the first part of T1 using the GEUS airguns. Then we did a CTD and a multi corer before deploying the UIB airguns and continued T1. We were back on T1 moving south at about 11:30. Now we were using 3 out of 4 airguns and only one of the two compressors of RV Kronprins Haakon (see below). More drone photos of the ship were taken. For the airguns, there were problems with the cables from deck to the instrument room, that is why we could only use 3 out of 4 airguns. Tuning of signals and overall quality of data was good. It also turned out that one of two ship compressors stopped after half an hour of operation, and restart was not successful. This compressor was not available for the rest of the cruise.

October 22: the second compressor stopped around midnight, restarted successfully at 01:30. The end of the T1 line was reached at about 10:30. Then the airguns were recovered, and we headed for the recovery of GEUS 1 OBS. This one was on deck at about 16:30 and we sailed for GEUS 2.

October 23: continuing the OBS recovery, next was GEUS 10 (07:00). Continued to station GEUS 15, then ROV had to be deployed as the rest (northernmost) of the OBSs now were in sea ice covered water. OBS 15 was located NE of its release position. A lot of organisms (plankton) in the water column as well as on the sea floor (observed from the ROV).

October 24: finished OBS GEUS 16 during the night (OBS located W of the release position), then we took a break from this activity, sailing north for the first sea ice station. Started preparing for deployment of the sea ice party, they entered the sea ice at about 10:00 and kept on working for four hours. Excellent weather condition except for low air temperature (-21ºC), collection of sea ice samples and in situ measurements according to plan. Then we restarted the recovery of OBS, and GEUS 19 was successfully recovered. Here we also did 2 push cores for sediment sampling.

October 25: recovered GEUS OBS 18 during the night, sea ice drift too high for push core samples at this site. GEUS 17, the final OBS, recovered during the morning. Then we started with Superstation 9 where we did CTD and water sampling, three different plankton nets, and multi corer. This site was located at the edge of the sea ice zone, still low air temperature.

October 26: continued doing box corer and gravity corer. Heat flow was measured by the gravity corer, it was not possible to use the heat flow lance through the ship's Hangar as there was too much equipment on deck already. Then we sailed to Superstation 5 (where we already did some work) to do plankton net (MIK net), gravity corer (returned empty) and box corer. Slightly higher air temperature here, but still very cold outside. Then we moved on to Superstation 10 were CTD, water sampling, MIK net and multi corer was done.

October 27: heading for start of reflection seismic line 3, started at about 07:00. Good weather conditions. We met with the sea ice in the afternoon, but were able to progress due to mostly thin, newly formed ice. Indeed, we progressed northwards way beyond expectations.

October 28: at about 04:00 we met with a thin zone of heavy ice. When passing this zone, the sea ice just behind the ship interfered with our airguns and streamer, lifting the airguns out of the water and the streamer was detached from the rest of the cable. We turned the ship to look for the streamer, it was not found and is considered lost. A bit ahead of where this happened, an area of open water allowed for deploying the multi corer, CTD, and to do water sampling. The multi coring was partly successful, another try was not possible here due to increasing ice drift. As predicted, the wind was increasing, we stayed in the area until wind speeds came down.

October 29: for a period, wind was coming down and sea ice drift was 0.6 knots/hour, allowing for a ROV dive to film the sea floor and macrofauna at the end of Line 3. Good quality results, then wind and sea ice drift were increasing, causing the filming to be terminated.

October 30: the wind dropped to acceptable values, and we did sea ice station #2 in the morning, the position was west of the area of ROV filming due to the overnight sea ice drift. Ice thickness this time was 30–35 cm of ice formed this year; the work was efficiently done according to plan, and we left the area at about 12:00 for the next multi core station on the way to pick up the lander.

October 31: the sea was too rough for multi coring, then we sailed for the position of the lander which was successfully recovered. Next, we did a CTD followed by water sampling, two times MIK net and two small plankton net. For one of the MIK nets, the sample was lost. Then we did four grab samples before we started the process of recovering the glider. An updated position led us to it, and it was successfully recovered. Then we sailed to our next multi corer station, located on the way to the start of seismic line L9B.

November 1: the multi corer (Superstation 15) was done at about 04:00, the next multi corer was at the start of L9B, and we reached this position at 08:00. The coring returned a sample of good quality. Then we started deploying the seismic equipment, and acquisition of seismic data started at 11:00. Seismic data acquisition continued throughout the day, evening, and night.

November 2: seismic line L9B was ended at 05:00, and the equipment was recovered at 05:30. We then sailed for the final multi corer station that was successfully done 06:30. Following this, we started sailing back to Longyearbyen.

November 3: arrived in Longyearbyen in the early morning, end of Leg 1.

4. Daily reports – a summary

A summary of our daily reports, produced by Daniel Albert during the cruise, is included below. The link will take you to the full version of these reports (in Norwegian):

- Read the daily reports from the GoNorth expedition here (in Norwegian).

Norway is a bit more acquainted with its own backyard because of the first leg of the very first GoNorth polar expedition. Seismic surveys were carried out in areas we knew very little about until now. Data was acquired in a range of topics, from life in the Arctic Ocean to pollution from afar, via the sea ice of the past—and of the present. The data will be analysed by scientists for many years to come.

We now have better data than ever to ascertain where the limit of the European continental crust in the Arctic is located, says Alexander Minakov (UiO), who was one of the expedition's co-chiefs. He adds that more answers will emerge as the data gets analysed.

4.1 Geological and geophysical studies

RV Kronprins Haakon (Figure 2) carried out seismic profiles along three lines (Figure 3). This work involved UiO (Alexander Minakov and Juan Meza Cala), UiT (Tom Arne Rydningen, Orlando Martinez Bautista, Truls Holm and Max Weber), UiB (Franck Andersen and Bernt Ole Ruud) and GEUS (Per Trinhammer, Lars Rasmussen and Thomas Funck). The T1 line (Figure 3) was the subject of a seismic refraction survey, a time-consuming process. First, ocean bottom seismometers are placed on the sea floor, along the whole line. Then, the ship sails along the line while an airgun sends sound and pressure waves to the sea floor.

Figure 2. RV Kronprins Haakon. Photo by Daniel Albert, SINTEF/GoNorth.

The seismic waves travel far below the seafloor, and the echo that comes back gets recorded by the seismometers. After that, the ship sails along the line one more time to pick up the seismometers; this needs to be done because they have no transmission capabilities.

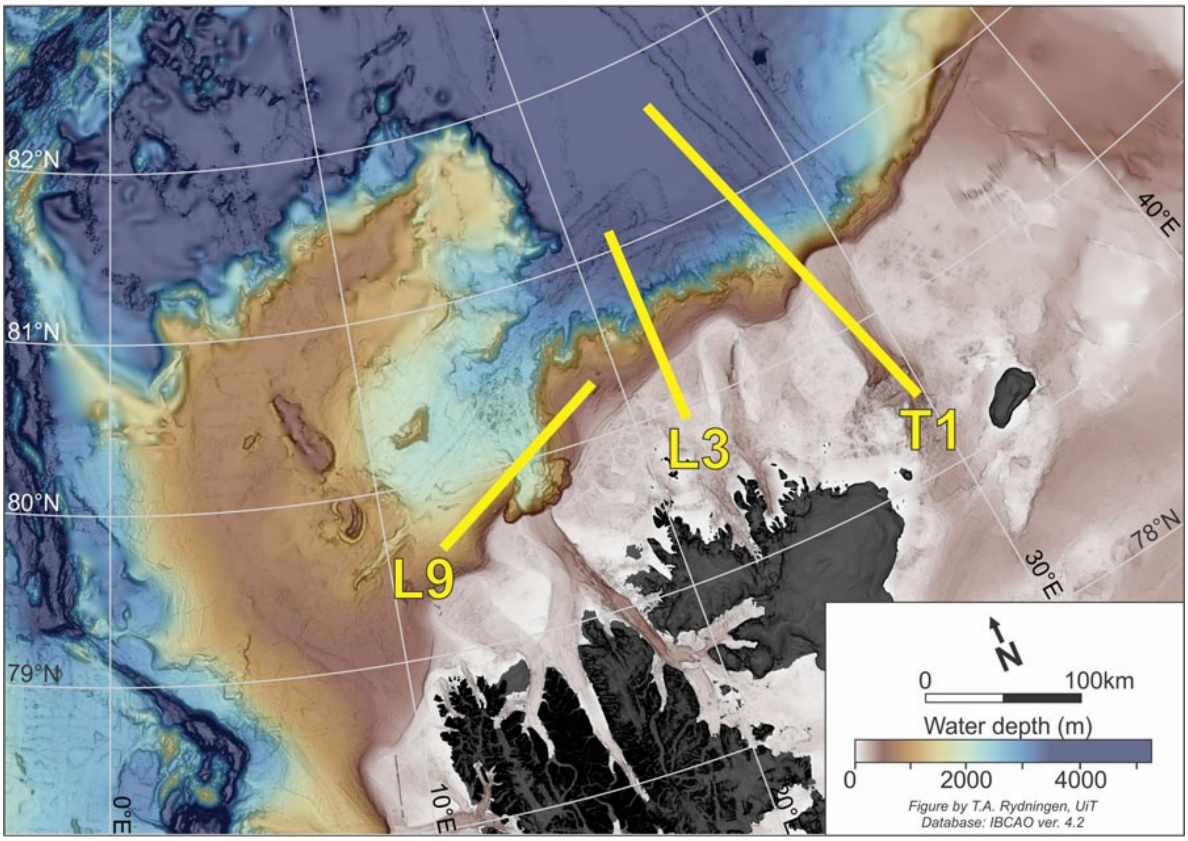

Figure 3. Bathymetric map of the study area (IBCAO 4.2; Jakobsson et al. 2020). The location of the refraction (T1) and reflection seismic lines (L3, L9) is indicated. Image by T. A. Rydningen, UiT.

Such an operation is especially difficult to carry out in the Nansen basin, where ice on the surface can damage the airguns, and water depths of over 4000 m increase the odds of losing seismometers. A remotely operated submersible vehicle, UiB’s Ægir 6000, was used to place and pick up several seismometers. The operation takes a long time, but the results are worth the effort. Seismic refraction profiles reveal information about the whole crust, all the way down to the mantle.

The L3 and L9 lines on the map (Figure 3) were investigated with seismic reflection profiles. This process is comparatively simpler: both the airguns and the receivers are fixed to a cable, towed behind the ship. The data acquired in such a way only sheds light on the upper layers of the seafloor but has a better resolution than that of seismic refraction.

Seismic surveys require a lot of work. Scientists and engineers from UiO, UiB, UiT and Denmark’s GEUS contributed with their work during the expedition. The same institutions, plus NORSAR, will analyse the data after the expedition. The data will also provide the foundation to educate the next generation of polar researchers in the field. Two PhD candidates from UiT and one from UiO participated in the trip and will be involved in the data analysis.

4.2 Biological survey

Akvaplan-niva sent a scientist and an engineer to gather data about life in ocean floor sediments, in the water column above and in the ice. In addition to gathering sediment, water, and ice samples, they collected data using high-tech solutions.

A lander equipped with oceanographic and biological sensors (Figure 4) was lowered to the seafloor at the beginning of the expedition and gathered data for two whole weeks. An ocean glider travelled along the T1 line. This is a torpedo-shaped, autonomous submersible drone, also equipped with an array of sensors.

Figure 4. Akvaplan-niva's lander is hoisted back up on board after spending 14 days on the seafloor. Photo by Daniel Albert, SINTEF/GoNorth.

4.3 Traces of pharmaceuticals in the Arctic

Frode Leirvik and Thor-Arne Pettersen, from SINTEF, were looking for pollution in the Arctic Ocean; traces of pharmaceutical and personal care products (Figure 5). The pair collected water samples from 14 locations and depths—600 L each time. They filtered the water and ran it through a device designed to accumulate any traces of pharmaceuticals. In addition, they gathered plankton and sediments to be analysed for the same compounds.

Figure 5. Thor-Arne Pettersen and Frode Leirvik (SINTEF) handled many such buckets of seawater during the expedition. Photo by Daniel Albert, SINTEF/GoNorth.

4.4 Clues from the past

Two scientists from NORCE were working to use ancient DNA to paint a picture of historical sea ice conditions. The first step in this project is to establish a database of sediment DNA from many areas with different sea ice conditions. During the expedition, Jon Hestetun and Stijn De Schepper gathered samples from 10 different areas (Figure 6).

Figure 6. Jon Hestetun and Stijn De Schepper (NORCE) transfer sediments from the top layer of the seafloor to a small container, for later analysis. Photo by Daniel Albert, SINTEF/GoNorth.

4.5 The sea ice's properties

Three PhD students and one postdoc from NTNU worked on various projects. Vegard Hornnes (Figure 7) and Evgenii Salganik went on the ice twice to measure its thickness, density, salinity, and mechanical strength. These measurements will be used as a basis for simulations that will help calculate the likelihood of icebergs and sea ice in the southwestern Barents Sea.

PhD student Nabil Panchi worked on automated systems that can interpret pictures of sea ice taken by passing ships. He gathered thousands of pictures during the trip. Paul Rübsamen-von Döhren, also a PhD student, was not so lucky. He participated in the expedition to study a phenomenon called marine icing—when sea spray freezes on ships or structures. Unfortunately, the weather conditions during the trip were such that there was no marine icing to observe during the trip.

Figure 7. Vegard Hornnes (NTNU) measures the sea ice's mechanical strength with a device called a borehole jack. Photo by Daniel Albert, SINTEF/GoNorth.

4.6 An enormous task

Expedition chief Jan Sverre Laberg (UiT) spent months planning this trip. He was up at all hours of the day during the expedition. Ship time is expensive and to avoid idle time, more activities must be planned than can be carried out. This ensures activities can continue in case something has to be cancelled due to bad weather or equipment breakdowns.

The result is that not all on board get to do everything they planned. This is because of the complexity of the cruise, and the fact that some of the activities had never been done before onboard Kronprins Haakon, which meant that extra time had to be allowed for the ship's crew and the science party to familiarise themselves with the routines. There were also weather constraints, and working under sea ice conditions involves delays due to safety measures. Nevertheless, all participating institutions got some data out of the trip. In addition, everyone got the experience of working on such a multidisciplinary expedition; experience that will be useful when planning the next GoNorth expeditions.

―All participants worked incredibly hard for their own and their colleagues' projects. Add to that a dedicated crew and all the pieces were in place for us to feel really satisfied with the results of this first leg of the first GoNorth expedition―says expedition chief Jan Sverre Laberg.

5. Results

5.1 Geophysics

5.1.1. Introduction

by A. Minakov & T. Funck

The acquisition of seismic, gravity and heat flow data were performed in the context of the DYPOLE research project (UiO, UiB, UiT, NORSAR) to obtain an understanding of the interplay between the various tectonic, magmatic, and sedimentary processes that have shaped the northern Barents Sea-Svalbard margin, caused continental breakup, and controlled the variation in spatial and temporal oceanic accretion in the Eurasia Basin. The project also aims to establish links between the tectono-magmatic history of the Cenozoic Arctic and oceanographic and climatic changes. The new deep seismic refraction data provide control on seismic velocities, that combined with seismic reflection, gravity and magnetic data can be used to determine the crustal and upper mantle structure of the northern Barents Sea continental margin and the character of the continent-ocean transition zone. New seismic reflection data jointly interpreted with existent data will help to identify faults, mass transport deposits, seismic stratal terminations and sedimentation characteristics that may point to either tectonic or climatic events. The acquisition was carried out from the Norwegian research vessel Kronprins Haakon that has ice classification.

For the acquisition of seismic refraction/wide-angle reflection data (R/WAR) along the 242-km-long line T1 of the GoNorth 2022 expedition, a total of 24 seismic receivers were deployed (Figure 8). Nineteen of those receivers were ocean bottom seismometers (OBS) provided by the national Danish seismometer pool DanSeis, while the remaining five OBS came from the University of Bergen (UiB).

Seismic reflection data were collected along Line 3 and Line 9 (see Table 2). Seismic reflection Line 3 is roughly parallel (with an azimuth of about 330°) to the refraction line T1 about 100 km to the west. Line 3 provides an image of the sedimentary structure of the northern Barents Sea shelf, the continental ocean transition, and the western part of the Nansen Basin. Line 9 runs from the northeast to southwest and located with the southern flank of the Sophia Basin and northwest Svalbard continental margin.

Table 2. Location of seismic profiles.

Line	Start of Line Latitude	Start of Line Longitude	End of Line Latitude	End of Line Longitude
T1 (OBS)	82.4769°N	26.0045°E	80.3860°N	29.8585°E
L3 (MCS)	80.9789°N	21.8422°E	82.2739°N	21.1318°E
L9B (MCS)	81.2892°N	18.7103°E	80.6097°N	11.9681°E

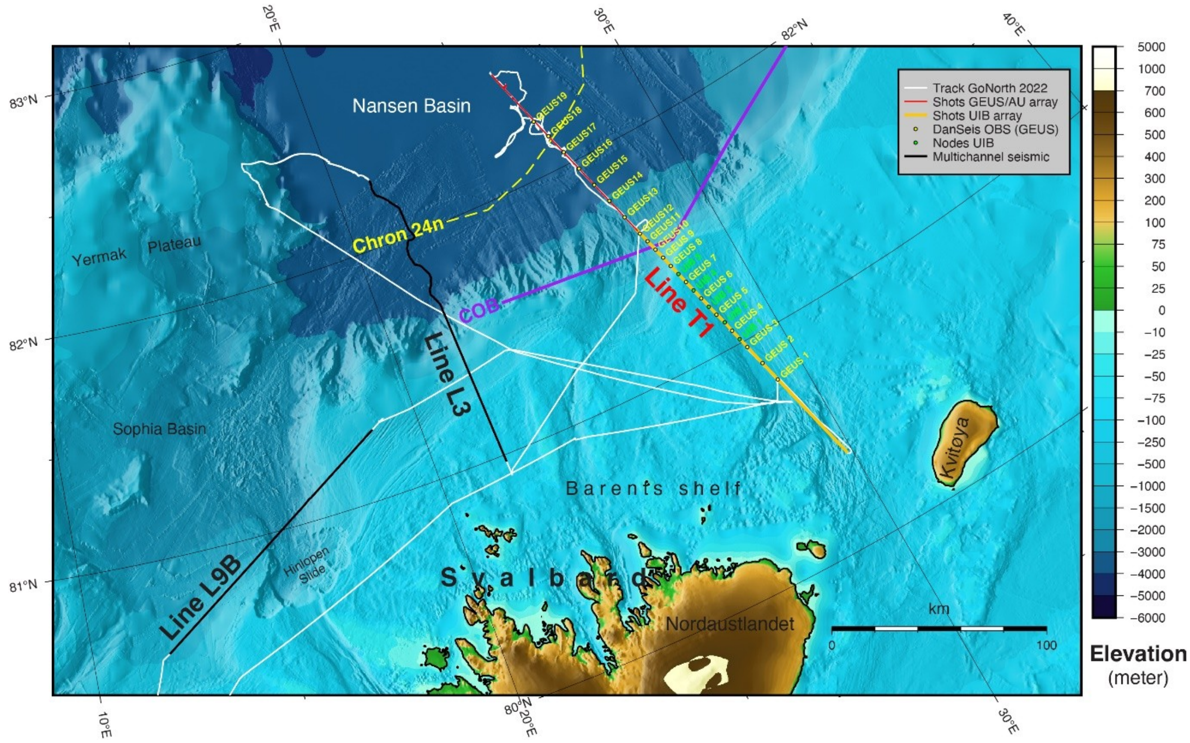

Figure 8. Bathymetric map (IBCAO 4 grid; Jakobsson et al. 2020) of the study area indicating the location of seismic receivers and airgun shots. COB – approximate boundary between continental and oceanic crust. Chron 24n – location of seafloor spreading magnetic anomaly C24 (~53 Ma).

5.1.2. Ocean Bottom Seismometers

by T. Funck, B.O. Ruud & A. Minakov

The 4-component OBS available from the Danish seismometer pool DanSeis are of the type Sercel MicrOBS_Plus housed in a 17-in glass sphere (Figure 9, left). Acquisition electronics, geophone and hydrophone are identical with the original Sercel MicrOBS while the disk space was enlarged to 8 GB resulting in a deployment length of up to 31 days with 24 days of recording at a sampling rate of 4 ms (250 Hz). The lightweight instruments are of 36 kg with an anchor used for the deployment weighing 28 kg.

The “Trilobit” ocean bottom seismometers were manufactured by Seabed Geosolution and provided by University of Bergen (UiB). The UiB OBS included three sensors SM-6 O/B, mounted in Galperin configuration and a hydrophone. Geophones have a natural frequency of 14 Hz and a damping of 0.70. The instrument response is -3 dB at 14 Hz (low cut), with the slope of -12 dB/oct, and hydrophone response (low cut) -3 dB at 3.6 Hz, with the slope of -6 dB/oct, and it is flat towards higher frequencies. The dynamic range of the “Trilobit” OBS at 2 ms recording is 116 dB. The anti-aliasing filter is 3 dB down at 206 Hz and at least 90 dB down at the Nyquist frequency (250 Hz). A pair of OBSs were deployed at each of the 5 deployment positions to increase data quality by repeated measurements. In addition, portative AmpSeis 4C seismometers were used at the locations UiB OBS 04 and UiB OBS 05 to provide complementary seismic records.

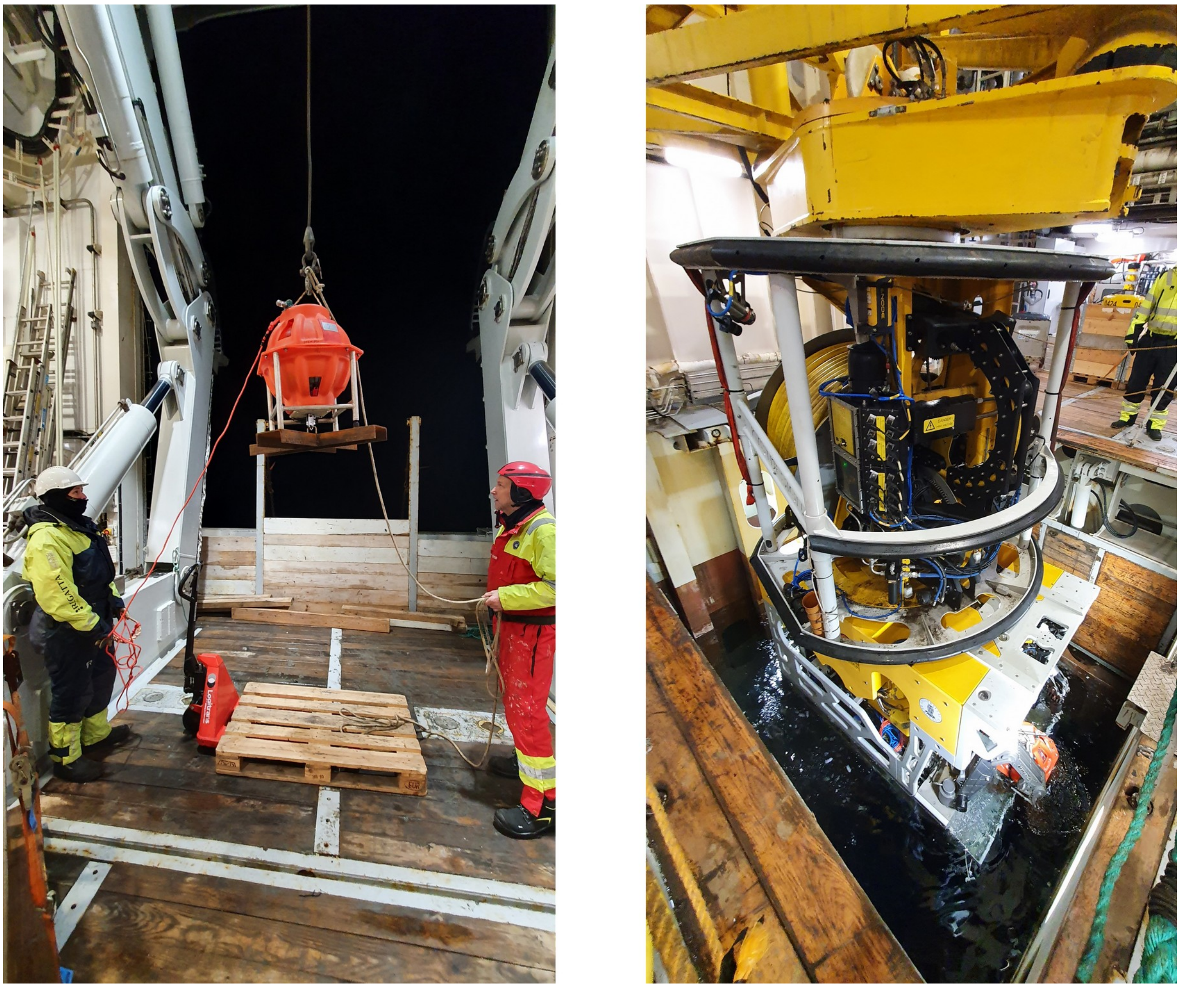

Figure 9. Deployment of Sercel MicrOBS Plus through the A-frame in the main hangar used at the OBS stations GEUS 1–18 (left), and the UiB Ægir6000 remotely operated vehicle (ROV) used for OBS deployment at the station UiB1–5 and GEUS 19 (right). Photos by Thomas Funck, GEUS.

5.1.3. Seismic sources

by T. Funck, B.O. Ruud & A. Minakov

Along the northernmost part of line T1, the GEUS (Geological Survey of Denmark and Greenland)/AU (Aarhus University) ice array was used as seismic source as this area was ice-covered and therefore not suited for the larger UiB source.

The GEUS/AU cluster consisted of two G-Guns with a volume of 520 in^3 each (total volume of 1040 in^3 or 17 L). The cluster was operated at a nominal pressure of 180 bar and a nominal survey speed between 3.5 and 4.5 knot depending on the variable ice conditions. No float was attached to the G-gun cluster to minimise the risk of damage by sea ice. Since the cluster was not equipped with a depth sensor, no information on its depth is available and varies in first order with the speed of the ship. The cluster was towed along the centre line of the ship, about 15 m behind the stern (see Sect. 5.1.6. **Seismic Reflection Data** section for geometry of the airgun setup). The average depth is estimated to be 15 m. During earlier experiments in ice with a depth sensor, the depth varied between 6 and 20 m. The shot interval was 45 seconds. However, at the start of the shooting and after two breaks for repairs, shorter shot intervals of as little as 8 s were chosen to synchronise the firing of the two G-guns.

Along the southern segment of line T1, the UiB array was used consisting of three Bolt LL 1500 guns with a volume of 1200 in^3 each (total volume of 3600 in^3 or 59 L). The depth of the array was 8 m below the surface and was maintained by floats attached to the guns. The shot interval was 100 m, and the nominal pressure was 130 bar. The UiB airguns were deployed from the 3rd deck and are positioned about 40 m from the stern of the ship hanging from floats.

The ship's Eiva NaviPac software was used to trigger and control the seismic source. The fire orders are sent to the Eiva Seismic Trigger unit over a serial line. NaviPac was configured to generate an event log for each shot, including gravity. The airguns are fired by a RTS HotShot4 unit. The HotShot Controller software generates a log file with the time of every shot including information about any irregularities. The shot times in the log are taken from the PC system time and are not accurate enough to be used for the OBS recording. Therefore, a separate unit is used for time stamping of the shots. The GPS Synchroniser unit receives a Clock Time Break (TTL pulse) from the HotShot unit and generates a time stamp to nearest microsecond in UTC. The time stamps are saved in internal memory during shooting and are downloaded to a PC after the line is completed.

5.1.4. Acquisition of OBS data

by T. Funck, B.O. Ruud & A. Minakov

The DanSeis/GEUS and UiB seismic instruments were deployed from south to north working from the Barents Sea shelf into the Nansen Basin (Figure 8). The UiB nodes were deployed using the UiB remotely operated vehicle (ROV) Ægir6000 that was operated from the moonpool of RV Kronprins Haakon. The DanSeis/GEUS OBS were prepared in the OBS container on the starboard side of deck 3, from where they were transported to the hangar for deployment by the A-frame on the starboard side (Figure 9, left). At the location of GEUS 18, the first sea ice was encountered. At the position of GEUS 19, the OBS could have still been deployed over the side of the vessel but recovery by releasing the instrument from the seafloor would have not been possible due to the size of the ice floes and nine to ten tenth ice cover. To avoid a search by ROV over a large area for recovery, the OBS was deployed by ROV and an exact position at the seafloor was obtained (Figures 9 to Figure 11). To avoid entanglement with the thrusters of the ROV, the 6-m-long recovery rope of the OBS was removed prior to deployment. The deployment was accompanied by the strong ice drift with a speed of about 1 knot which complicated the exact positioning of ROV. Therefore, OBS 19 was dropped about 700 m southeast of the planned deployment location.

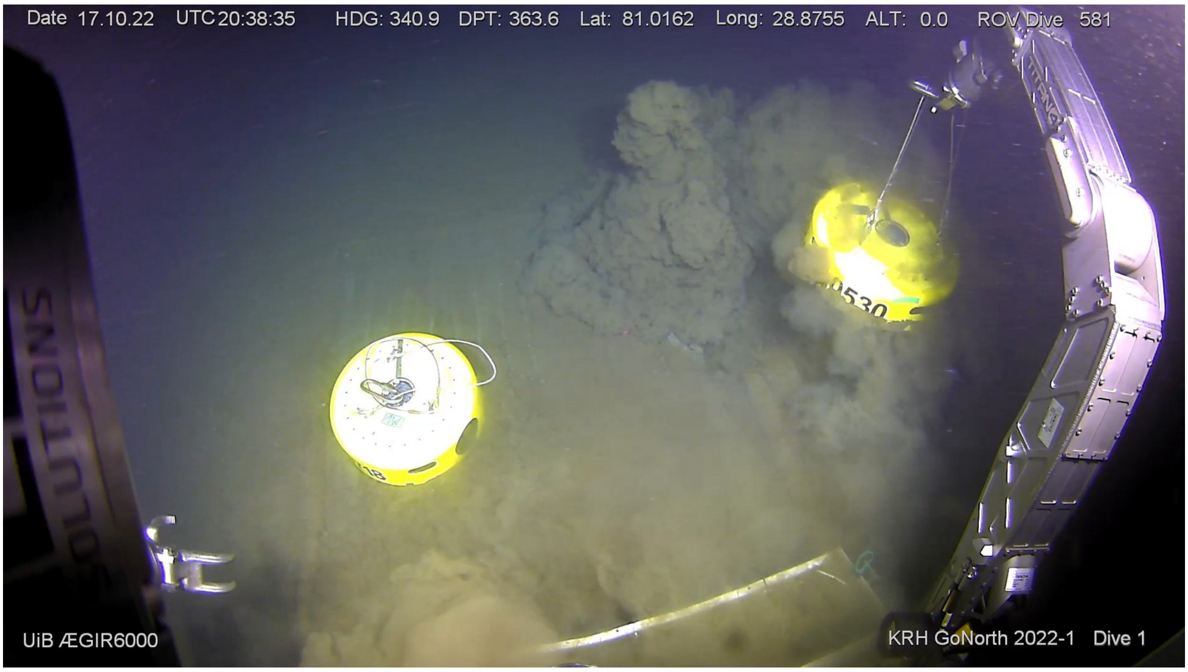

Figure 10. Deployment of University of Bergen's Ocean Bottom Seismometers (OBS) UiB1E and UiB1W using remotely operated vehicle (water depth 364 m). Photo by Ægir 6000/NORMAR.

After deployment of the last OBS (GEUS 19), the ship started the airgun shooting 29 km to the north. In the ice, the GEUS/AU array was used and had to be pulled in twice for repairs. The first repair was necessary due to air leakage of a gun related to freezing. This problem was fixed by swapping the G-gun cluster with the spare cluster. Later, the guns stopped triggering due to damage of the cables between the ice-strengthened umbilical and the cluster. This problem was fixed by swapping the entire cable string using the intact section of the other cluster. Once the ship was out of the ice, the source was changed to the UiB array and there was a 1-km-long overlap between the two arrays. A 150-m streamer (48 channels) was connected and used for acquisition of collocated seismic reflection data. The planned 10 km overlap between GEUS and UiB airgun systems has been reduced to about 1 km because of rapidly advancing ice front. The shooting of the UiB stopped for three hours due to a problem with the compressors on the vessel. The shooting stopped 47 km to the SSE of the southernmost OBS (GEUS 1). At the start of shooting, a soft start of the guns was performed starting with one gun operated at 100 bar until the full array was used at nominal pressure after 15 minutes.

The recovery of instruments started in the south with GEUS 1. Problems with the transducer delayed the recovery by two hours. The error was located in the modulator unit of the transducer. After switching to the spare modulator, the system worked flawless. OBS at positions GEUS 1 through 14 were recovered by releasing them from the seafloor by sending an acoustic signal with the transducer that was lowered into the water from the starboard side of the ship. All instruments released on the first set of signals that was sent to them. The ascent time to the surface was within the typical range for the OBS (13 minutes for the burnwire to break and 0.86 m/s ascent rate). The storm after deployment of the OBS moved the sea ice to the south, and the OBS at sites GEUS 15 through 19 had to be recovered by ROV. Since the position at the seafloor was not known for OBS 15 through 18, a time-consuming search pattern had to be followed by the ROV that lasted up to 4 hours, using a line spacing of 40 m. Since the optical visibility is poor (around 5 m), the main tool for the search was the forward-looking sonar of the ROV with a maximum range of 50 m. Rocks at the seafloor or sand ripples occasionally produced targets on the sonar and complicated the search.

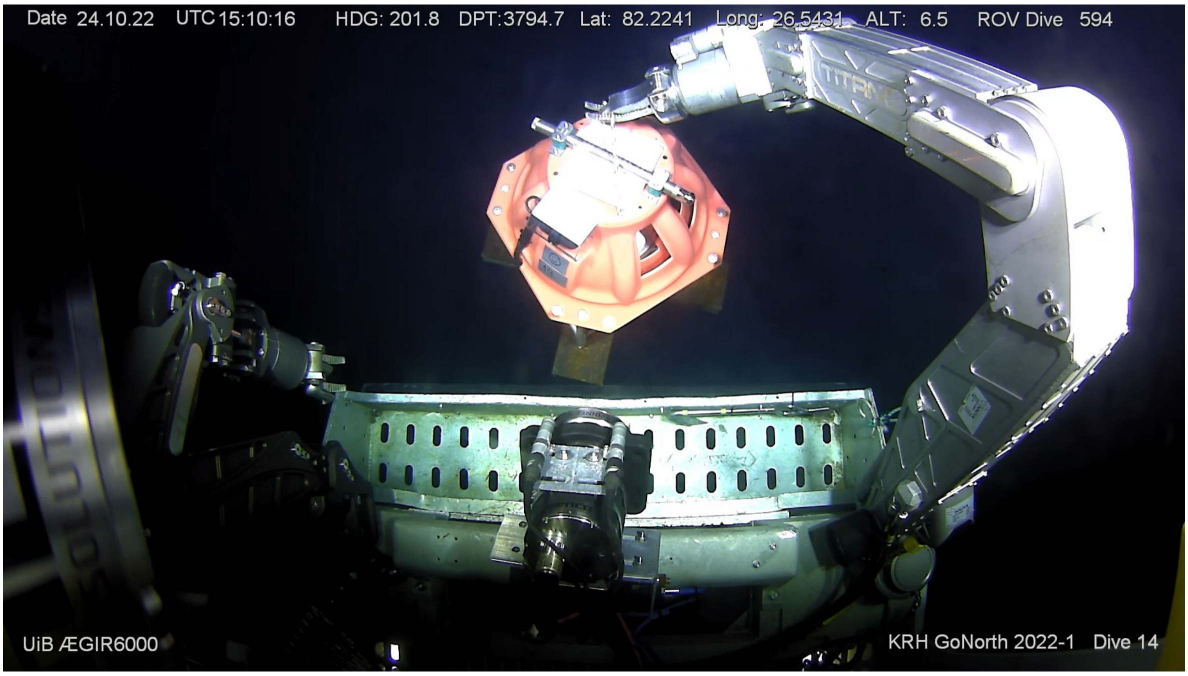

Figure 11. Recovery of GEUS OBS 19 using remotely operated vehicle (water depth 3794 m). Photo by Ægir 6000/NORMAR.

Estimates of the OBS stations drift by ocean currents were used from previous stations, to determine possible direction of drift from the deployment position. The search occurred first to the east and then along a grid of W-E profiles. The maximum speed of ROV was about 0.8 knots and the search radius was about 300 m. The station GEUS 15 was found in about 186 m east of the deployment position. The recovery rope of the OBS caused some trouble as it potentially could have gotten into the thruster of the ROV. To avoid pollution, cutting the rope was not an option. Instead, the rope was winded around one of the two gripper arms of the ROV, while the other arm grabbed the aluminium frame of the OBS. The operation took about 3.5–4 hours. The search of station GEUS 16 was more time consuming, about 5–6 hours. The station was expected in the east of deployment position but was found about 100 m west of deployment position. GEUS 17 was successfully recovered about 70 m west of the deployment point after a search along WE oriented profiles with a length of 300 m starting from the north. Two ROV dives had to be made to recover GEUS 18 due to a strong southward ice drift of about 0.6 knots. The boat had to drift for about 3.5 hours while the ROV was descending. As the force of the arm can only be poorly controlled, the two frames of GEUS OBS 15 and 16 were bent by the gripper. For the last three OBS (17 through 19), the OBS was grabbed at the carriage rope at the top of the OBS.

Table 3 shows the deployment and recovery positions of the GEUS OBS. Positions were marked as waypoints on the handheld GPS device that are noted on the OBS deployment sheets and were downloaded and stored electronically. For deployment, the waypoints were taken next to the A-frame when the recovery rope was thrown into the water. For recovery, the waypoints were taken when the recovery rope was attached to the hook of the crane. The recovery position for GEUS 15 to GEUS 19 were taken from the ROV video recordings corresponding to the time when ROV was first in contact with OBS. For OBS 2, the coordinates were erroneous and therefore substituted with data from the ship’s navigation system. Water depths were taken from the centre beam of the EM302 multibeam echosounder.

Table 3. Deployment and recovery information for the DanSeis/GEUS OBS.

OBS GEUS	Deployment Date and Time (UTC)	Deploy. Latitude (deg. N)	Deploy. Longitude (deg. E)	Depth (m)	Recovery Latitude (deg. N)	Recovery Longitude (deg. E)	Recovery Date	Time Re-leased (UTC)	Time At Surface (UTC)	Time On Deck (UTC)	Distance and Azimuth from Deployment to Recovery Position
1	2022-10-17 17:39:35	80.79079	29.23744	458	80.78969	29.22820	2022-10-22	13:55	14:15	14:26	205 m - 263°
2	2022-10-17 18:32:31	80.88190	29.09317	412	80.88056	29.08436	2022-10-22	15:08	15:24	15:35	215 m - 261°
3	2022-10-17 19:41:31	80.97208	28.94752	387	80.97185	28.94103	2022-10-22	16:18	16:34	16:42	116 m - 268°
4	2022-10-17 21:38:41	81.06261	28.79828	327	81.06235	28.79159	2022-10-22	18:20	18:43	18:53	119 m - 268°
5	2022-10-17 23:31:12	81.15308	28.64487	253	81.15211	28.64277	2022-10-22	20:31	20:49	20:57	114 m - 245°
6	2022-10-18 01:17:39	81.24318	28.49099	192	81.24171	28.49014	2022-10-22	23:32	23:45	23:53	164 m - 210°
7	2022-10-18 03:03:20	81.33332	28.33253	157	81.33205	28.32414	2022-10-23	01:27	01:44	01:54	199 m - 261°
8	2022-10-18 04:49:44	81.42350	28.17069	374	81.42535	28.18366	2022-10-23	03:25	03:48	04:55	298 m - 82°
9	2022-10-18 05:21:15	81.46911	28.08960	870	81.47324	28.12150	2022-10-23	04:29	05:00	05:14	698 m - 83°
10	2022-10-18 05:57:07	81.51360	28.00563	1285	81.51628	28.04298	2022-10-23	05:39	06:07	06:28	681 m - 86°
11	2022-10-18 06:22:44	81.55959	27.92147	1670	81.56065	27.94386	2022-10-23	06:53	07:32	07:40	384 m - 87°
12	2022-10-18 06:46:16	81.60341	27.83638	2013	81.60294	27.85752	2022-10-23	08:04	08:54	08:59	347 m - 91°
13	2022-10-18 07:29:50	81.69338	27.66398	2536	81.69185	27.67954	2022-10-23	09:41	10:36	10:45	302 m - 96°
14	2022-10-18 08:13:04	81.78326	27.48886	2899	81.78258	27.51034	2022-10-23	11:30	12:37	12:46	350 m - 92°
15*	2022-10-18 08:52:29	81.87301	27.30815	3134	81.8738	27.3186	2022-10-23	16:57⊗			186 m - 86°
16*	2022-10-18 09:31:14	81.96264	27.12702	3380	81.9630	27.1211	2022-10-24	01:42⊗			100 m - 274°
17*	2022-10-18 10:13:27	82.05236	26.93855	3560	82.0529	26.9368	2022-10-25	07:23⊗			66 m - 287°
18*	2022-10-18 10:57:50	82.14177	26.74584	3678	82.1421	26.7443	2022-10-25	00:48⊗			44 m - 282°
19**	2022-10-18 14:56:27	82.22415	26.54341	3797	82.2241	26.5432	2022-10-24	15:01⊗			6 m - 256°

* Recovery by ROV; ** Recovery and deployment by ROV; ⊗ Time of first contact between OBS and ROV

The UiB "Trilobit" OBS were deployed during the evening of October 17 and the following night. They were recovered during the evening of October 22 and the following night. In both cases, starting from site UiB1, see Table 4. Two Trilobit OBS were deployed by ROV at each site (West and East) with about 2 m separation.

Table 4. Deployment/recovery and clock synchronisation information for the UiB ocean bottom seismometers. The TSN and EDR are serial number which identifies the OBS.

Site	Lat. (deg. N)	Lon. (deg. E)	Water Depth (m)	TSN	EDR	Start Time*	Stop Time**	Clock Drift (ms)	Volt. at Start (V)	Volt. at Stop (V)
UiB1W	81.01618	28.87586	366	0718	2778	10:43:45	09:16:40	-4.028	10.6	9.4
UiB1E	81.01618	28.87586	366	0530	1024	12:13:45	09:29:26	-1.241	10.6	9.1
UiB2W	81.10776	28.73567	304	0877	2475	12:08:22	08:50:55	-5.509	10.6	9.2
UiB2E	81.10776	28.73567	304	0749	1057	11:39:17	09:05:04	+2.492	10.6	9.4
UiB3W	81.19744	28.56993	218	0967	2812	12:01:18	08:21:18	-26.977	10.7	9.3
UiB3E	81.19744	28.56993	218	0576	2155	11:30:01	08:04:38	-3.559	10.6	9.3
UiB4W	81.28742	28.41355	177	0972	2082	11:54:45	08:36:39	+1.931	10.6	9.4
UiB4E	81.28742	28.41355	177	0861	2694	11:14:45	07:46:13	-0.104	10.6	9.3
UiB5W	81.37883	28.25011	155	0848	1004	11:07:55	06:59:09	+10.228	10.7	9.3
UiB5E	81.37883	28.25011	155	0588	2130	11:46:20	07:27:49	-4.176	10.7	9.2

*Date of start time is 16.10.2022; **Date of stop time is 23.10.2022.

A mini streamer was additionally deployed as a receiver during shooting of the OBS profile. The streamer is a Geometrics MicroEel solid analogue hydrophone streamer with 24 channels (one for each hydrophone group consisting of three hydrophones), group interval 6.25 m, and a total length of the active section of 150 m. The distance from the source to the nearest hydrophone group is about 40 m. In the seismic lab, the mini-streamer recording was controlled by a Windows laptop running the Geometrics Seismic Controller software. The Mini-streamer data were saved in SEG-Y format with 2 ms sampling and 8.0 s recording length (Figure 12).

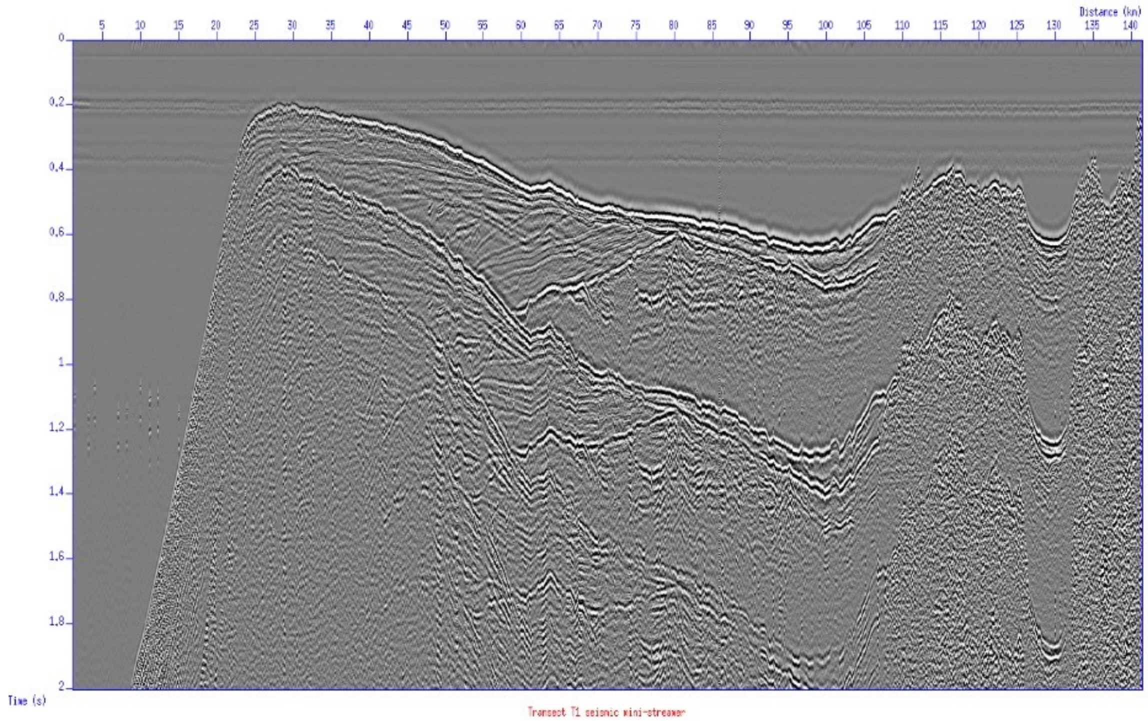

Figure 12. Mini-streamer data collected along wide-angle reflection and refraction Profile T1.

5.1.5. OBS data processing and archiving

by T. Funck, B.O. Ruud & A. Minakov

The seismograms corresponding to each data channel were cut into traces using compiled shot-time tables. For the shots fired by the GEUS/AU cluster, trigger times accurate to milliseconds were logged by the time tagging device from UiB. A delay of 50 ms was applied for the gun delay, at which the peak of the first pulse occurred. Shot navigation was obtained from the NAVIPAC system, that recorded the position of the GPS antenna (4.11 m to the starboard of the centre line and 21.1 m from the stern). The coordinates of the gun position 15 m behind the ship were then calculated by using the gyro course and the geometry. A total of 1661 shots (shot numbers 0 through 1661) were recorded on the tagging device, no cleaning for missed shots was done to this table. The trigger times of the UiB array were logged by the same time tagging device but included already the gun delay of 50 ms. The navigation was likewise obtained by a NAVIPAC system that provided the true gun position. Trigger times without a corresponding entry in the navigation file were deleted and vice versa. After correlation with the log file, a total of 1451 shots remained (shot numbers 1662 through 3112). The shot file is stored as shots-GEUS-UIB.txt.

After recovery of an instrument, the raw data files (internal format used by Sercel) were extracted from the OBS and subsequently merged and converted to pseudo-SEGY format with one continuous record for each of the four channels of the OBS: 1) hydrophone, 2) vertical geophone, 3) and 4) horizontal geophone components.

The raw data files are stored on the data disk together with the XML file that contains meta data for a particular OBS. The pseudo-SEGY files are also stored on the data disk and the file names use the following nomenclature: s[1][01-19]-[1-4].pseg where the first parameter is the OBS line (1 for T1), the second variable is the GEUS OBS number (01 through 19), and the last parameter is the channel number. The file names are listed in Table 5.

Table 5. OBS clock synchronisation before and after deployment.

OBS GEUS	Serial No.	Synchronisation Start (UTC)	Synchronisation End (UTC)	Skew (ms)	Datafiles (SEGY)	Data Files (Pseudo-SEGY)
1	200-122	2022-10-16 19:40:00	2022-10-22 17:17:59	-33	s101ch[1-4].sgy	s101-[1-4].pseg
2	200-130	2022-10-17 08:08:00	2022-10-22 17:39:59	-85	s102ch[1-4].sgy	s102-[1-4].pseg
3	200-143	2022-10-17 08:47:00	2022-10-22 18:10:59	-26	s103ch[1-4].sgy	s103-[1-4].pseg
4	200-124	2022-10-17 10:56:00	2022-10-22 21:04:59	-44	s104ch[1-4].sgy	s104-[1-4].pseg
5	200-148	2022-10-17 11:40:00	2022-10-23 01:42:00	56	s105ch[1-4].sgy	s105-[1-4].pseg
6	200-132	2022-10-17 12:07:00	2022-10-23 01:48:59	-39	s106ch[1-4].sgy	s106-[1-4].pseg
7	200-133	2022-10-17 12:30:00	2022-10-23 04:21:59	-80	s107ch[1-4].sgy	s107-[1-4].pseg
8	200-131	2022-10-17 13:12:00	2022-10-23 05:32:59	-87	s108ch[1-4].sgy	s108-[1-4].pseg
9	200-145	2022-10-17 13:36:00	2022-10-23 06:39:59	-37	s109ch[1-4].sgy	s109-[1-4].pseg
10	200-150	2022-10-17 14:01:00	2022-10-23 07:54:59	21	s110ch[1-4].sgy	s110-[1-4].pseg
11	200-149	2022-10-17 14:55:00	2022-10-23 09:55:59	-12	s111ch[1-4].sgy	s111-[1-4].pseg
12	200-128	2022-10-17 14:45:00	2022-10-23 10:58:59	-89	s112ch[1-4].sgy	s112-[1-4].pseg
13	200-117	2022-10-17 18:03:00	2022-10-23 13:18:59	-71	s113ch[1-4].sgy	s113-[1-4].pseg
14	200-147	2022-10-17 18:41:00	2022-10-23 18:17:59	-8	s114ch[1-4].sgy	s114-[1-4].pseg
15	200-146	2022-10-17 19:08:00	2022-10-24 02:18:59	-26	s115ch[1-4].sgy	s115-[1-4].pseg
16	200-129	2022-10-17 19:37:00	2022-10-24 06:24:59	-8	s116ch[1-4].sgy	s116-[1-4].pseg
17	200-144	2022-10-17 20:01:00	2022-10-25 11:10:59	41	s117ch[1-4].sgy	s117-[1-4].pseg
18	200-125	2022-10-17 20:25:00	2022-10-25 03:59:59	-123	s118ch[1-4].sgy	s118-[1-4].pseg
19	200-134	2022-10-17 21:01:00	2022-10-24 18:51:59	-296	s119ch[1-4].sgy	s119-[1-4].pseg

Before deployment and after recovery, the recorders are synchronised with the GPS time signal to determine the time drift (skew time) during the experiments. The drift of the OBS clock is assumed to be linear and the skew time is then applied to correct the data for this drift. Then a resampling of the data is carried out. The drift correction is applied when the raw data are converted to pseudo-SEGY format using the *micrOBS* software by Sercel. The shot and OBS coordinates are added to the SEGY headers, and offsets (shot-receiver distance) were written into the SEGY headers. The following naming convention is used for the SEGY files: s[1][01-19]ch[1-4].sgy, where the first parameter is the OBS line (1 for T1), the second variable the GEUS OBS number (01 through 19), and the last parameter the channel number. The file names are listed in Table 5 and all SEGY files and shot tables are stored on the hard disk. Offsets written into the SEGY headers are negative and positive signs for shots to the north and south of the OBS, respectively.

For an initial quality check, record sections were inspected for all OBS and all components. All OBS and all channels recorded data. The hydrophone data has a generally better data quality than the vertical geophone component. Record sections examples for channels 1 (hydrophone) and 2 (vertical geophone) are shown in Figure 13 and Figure 14.

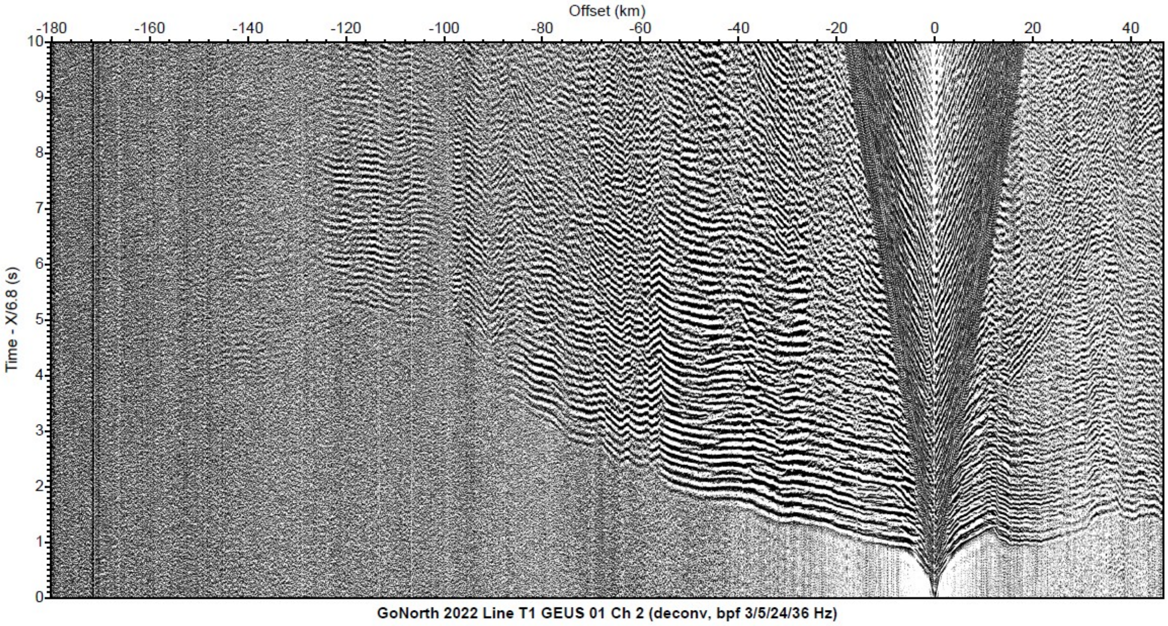

Figure 13. Record section of vertical geophone component of OBS GEUS 1. The data are plotted using reduction velocity of 6.8 km/s for the time axis.

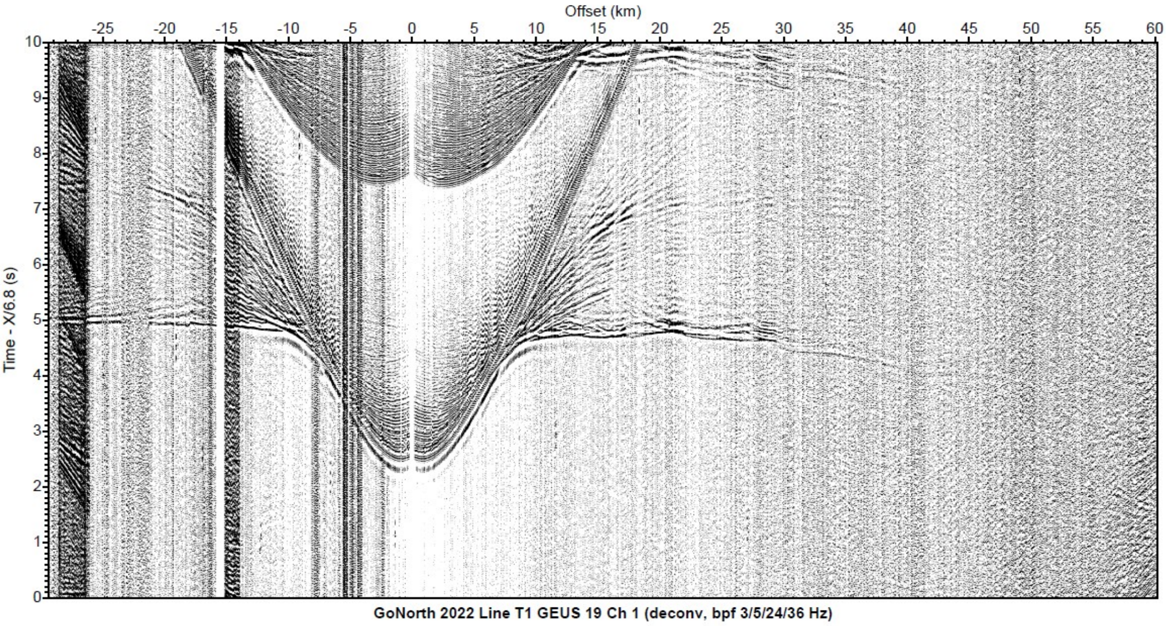

Figure 14. Record section of hydrophone component of OBS GEUS 19. The data are plotted using reduction velocity of 6.8 km/s for the time axis.

The Trilobit data recording units are synchronised to GPS time and the recording parameters (e.g., sampling interval, gain) must be set before deployment. The Trilobits are programmed from a PC which communicates through a cable via an inductive coil ("puck") which is placed on top of the "Trilobit". After the OBS was recovered, the clock was again synchronised to GPS, the recording stopped, and the batteries disconnected. The instruments were programmed to record with 2 ms sampling intervals. The data are downloaded through an USB cable to a PC as a “raw” file which contains data for all components in a lossless compressed format. The “raw” data are then decoded by software provided by Seabed Geosolutions into separate continuous, uncompressed data for each component (hydrophone, three geophones, and auxiliary data). The auxiliary data are battery voltage, temperature, and three tilt components sampled once a minute. The SEG-Y records are produced from the continuous data using a file with shot times and coordinates and a file with the OBS information and contains the receiver coordinates (see Figure 15 for data example). The clock drift correction was applied after the recovery.

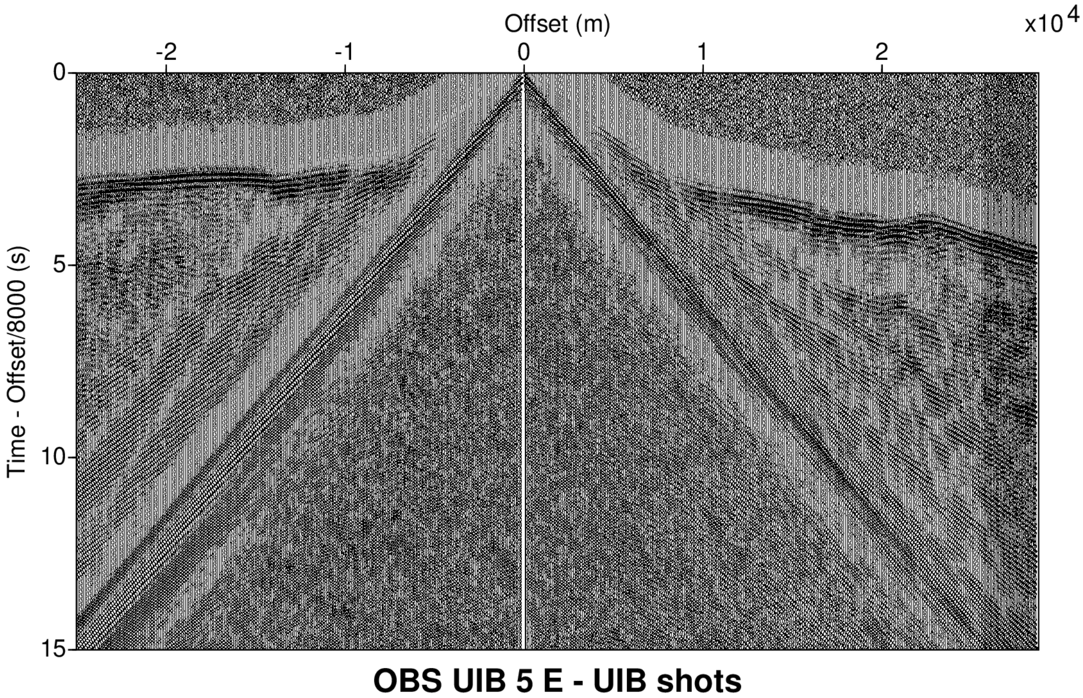

Figure 15. Record section of hydrophone component of OBS UiB 05. The data are plotted using reduction velocity of 8 km/s for the time axis.

The extracted record length for the SEG-Y files is 60 s. Thus, there is some overlap between records since the shooting interval was about 45 s. Files with names containing "h1" are the hydrophone component. The geophones in the Trilobit OBS have a Galperin configuration (symmetric triaxial). The vertical and horizontal components were calculated as linear combinations of the three geophones. The average amplitude has been removed from each record. Files with names containing "gx", "gy" or "gz" are geophone components (gx=inline, gy=crossline, gz=vertical). The GEUS shots are numbered 1 - 1661 (1127 shots) and UiB shots are numbered 2052 - 3491 (1439 shots). Bad shots and shots fired out of line (due to technical problems) were removed, thus some shot numbers are not present. Two OBSs were deployed at each station (West and East). The shot numbers are in trace header bytes 17-19 (ep). Trace header bytes 9-12 (fldr) contains the station number: for example: 101 for UiB1W (TSN 0718), 102 for UiB1E (TSN 0530). The TSN number is a serial number which identifies the OBS. Shot coordinates and shot numbers are taken from EIVA Navipac. Receiver coordinates are taken from the ROV. Coordinates are in arcsec (multiplied with the horizontal scaler), so that the longitude and latitude are obtained dividing by 3600 (or 360000 if the horizontal scaler is not automatically applied). Sampling interval was 2 ms and record length 60000 ms.

5.1.6. Seismic reflection data: method and preliminary results

by J. Meza, O. Martinez & A. Minakov

Two 2D multi-channel seismic (MCS) profiles were acquired during the GoNorth-1/KPH22 expedition. The seismic dataset includes profile L3 and L9B. Seismic profile L3 is roughly parallel (with an azimuth of about 330°) to the refraction transect T1 about 100 km to the west, located in the western Nansen Basin under partially covered sea ice-drift areas. Seismic profile L9B runs from the northeast to southwest, located at the southern flank of the Sophia Basin and northwest Svalbard continental margin, under free sea ice-drift conditions. In addition, a Mini-streamer survey was acquired on the northern Svalbard/Barents Sea shelf along seismic refraction transect T1, under free sea ice-drift conditions (Figure 8). The acquired profiles provide valuable image of the sedimentary structure of the northern Barents Sea shelf, the continental ocean transition, and the western part of the Nansen Basin.

The utilised MCS reflection system operated by GEUS consisted of a two-gun array (2 x Sercel G-Guns) mounted on a single frame. The airgun setup had in one end an umbilical cable with a connection to the ship, and the other one was connected to the set of streamer cables, depending on the geometry setup. The far-field source signature and frequency spectrum are illustrated in Figure 16.

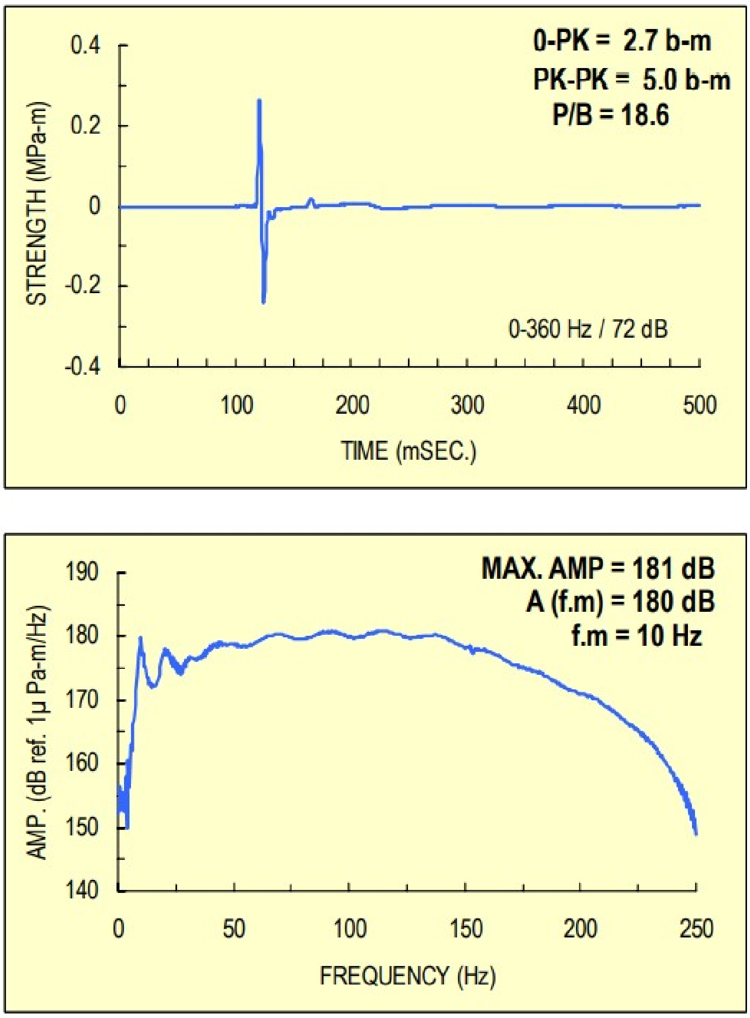

Figure 16. Far-field signature (upper plot) and frequency spectrum (lower plot) of the GI-Gun at the pressure of 2,000 psi and the depth of 3.0 m.

The seismic setup and geometry of the source-receiver system was designed for either sea-ice covered areas (Figures 17 and Figure 18), or open water conditions (Figure 19 and Figure 20) within the surveyed areas of the Arctic Ocean. An ice array operation was used for seismic sampling along the profile L3, with an offset between the airgun array and ship of 22.3 m, and an offset between the streamer Channel 1 and the airgun array of 9.5 m (Figure 17). The depth of the seismic equipment for the ice array operation was set at 20 m below sea level, as it was necessary to protect the tools from sea-ice drift (Figure 18). In contrast, an open water operation setup was used for seismic sampling along the profile L9B, with an offset between the airgun array and ship of 22.7 m, and an offset between the streamer Channel 1 and the ship of 60-40 m (Figure 19). The depth of the seismic equipment for the open water operation was set at 8 m below sea level (Figure 20). Both ice and open water operations surveyed at a ship speed of approximately 4 knots.

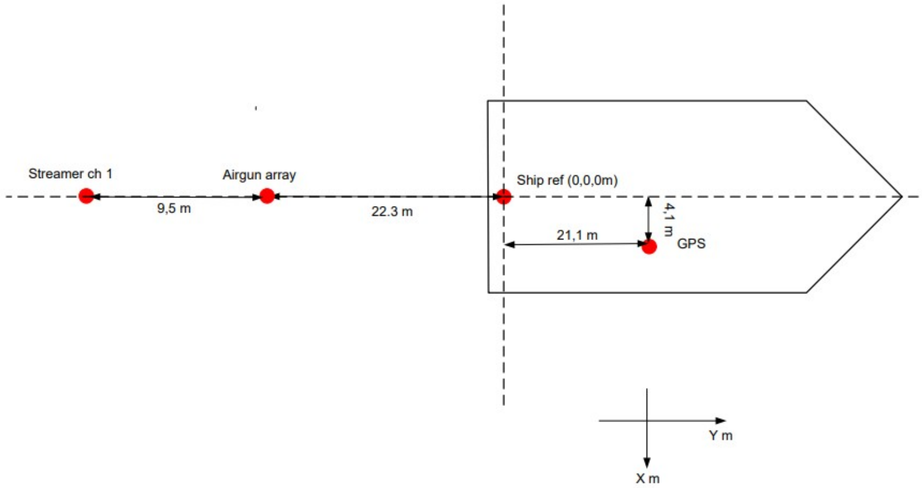

Figure 17. Seismic setup GoNorth/KPH2022. Ice array operation. Figure by Per Trinhammer, Aarhus Universitet (GEUS).

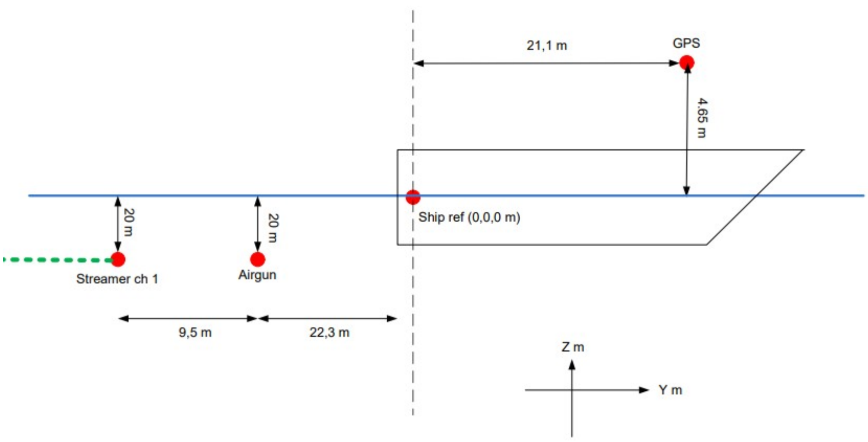

Figure 18. Seismic setup GoNorth/KPH2022. Ice array operation. Figure by Per Trinhammer, Aarhus Universitet (GEUS).

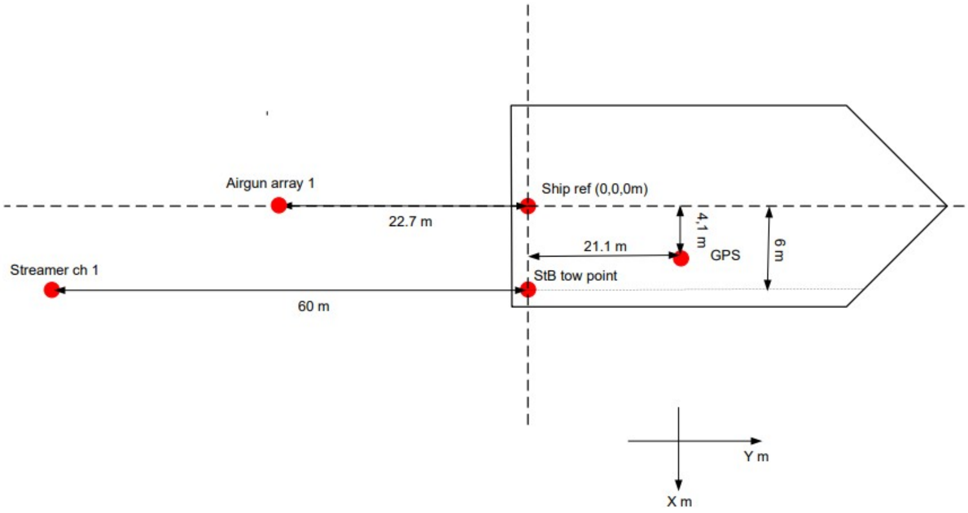

Figure 19. Seismic setup GoNorth/KPH2022. Open water operation. Figure by Per Trinhammer, Aarhus Universitet (GEUS).

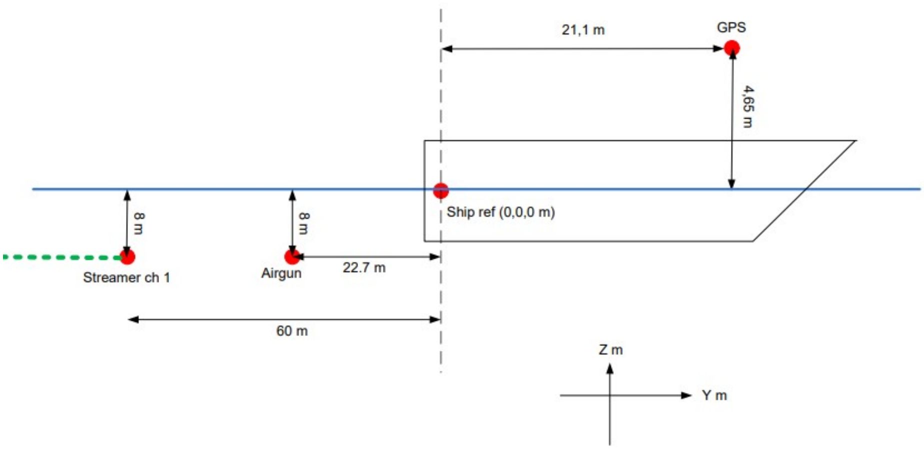

Figure 20. Seismic setup GoNorth/KPH2022. Open water operation-vertical view. Figure by Per Trinhammer, Aarhus Universitet (GEUS).

During the acquisition of seismic reflection Line 3 (L3), the air pressure ranged between 110-120 bar, with a shot interval of 15 s. The deployed streamer contained six sections with 8 channels each with a total length of about 300 m and 48 channels (6 section with 50 channels for each section). The airguns and the ice streamer of GEUS were deployed at 8:00 UTC on Thursday October 27, in south to north sailing direction within the ice-covered area. The last section contained noisy channels indicated with a small leakage on the streamer controller unit. The shooting was halted at 4:30 UTC on Friday October 28, due to the loss of entire streamer sections jammed in the ice. The files are saved in SEG-D format for each shot gather. Initial real-time processing was performed during the data acquisition and included NMO-correction and stacking traces with laterally variable velocity-depth profiles. The stacked data are saved in SEG-Y format (Figure 21).

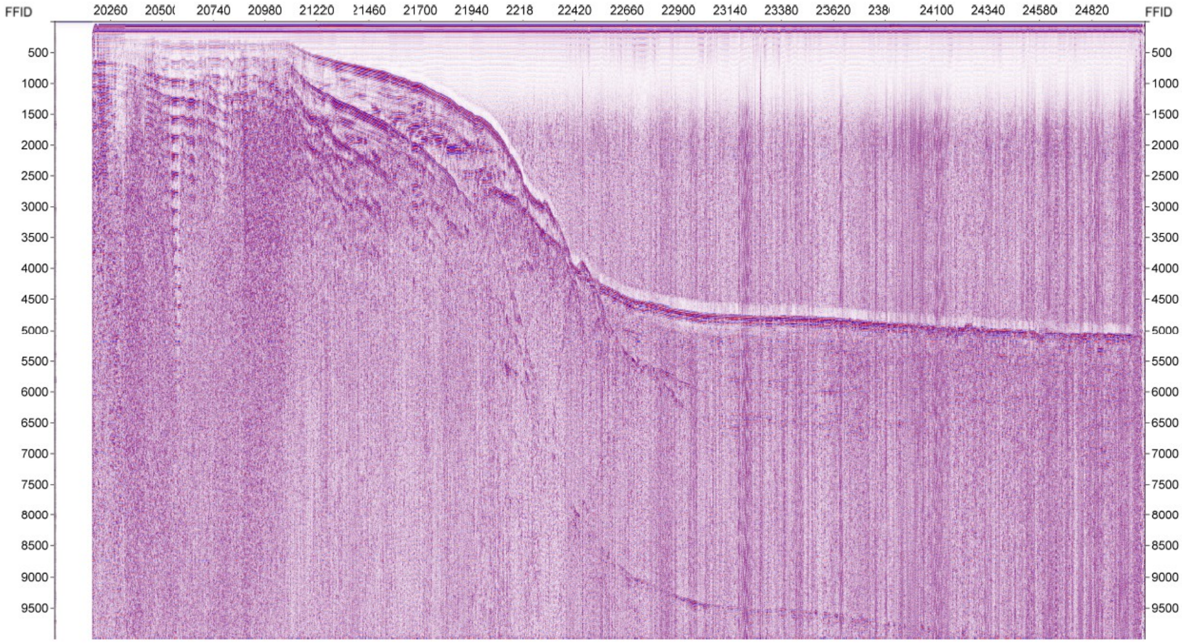

Figure 21. Brute stack of seismic reflection data along profile L3.

During the acquisition of seismic reflection data along Line 9, the air pressure ranged between 170-180 bar (GEUS + one of the onboard air compressors), with a shot interval of 15 s. A streamer of 550 m length with 88 channels (11 section with 8 channels for each section). The airguns and streamer of GEUS were deployed at 9:54 UTC on Tuesday November 1, in northeast to southwest sailing direction in open water. The shooting was terminated at 4:47 UTC on Wednesday November 2.

The files are saved in SEG-D format for each shot gather. Initial real-time processing was performed during the data acquisition and included bandpass filtering, NMO-correction and stacking traces with laterally variable velocity-depth profiles. The stacked data are saved in SEG-Y format (Figure 22).

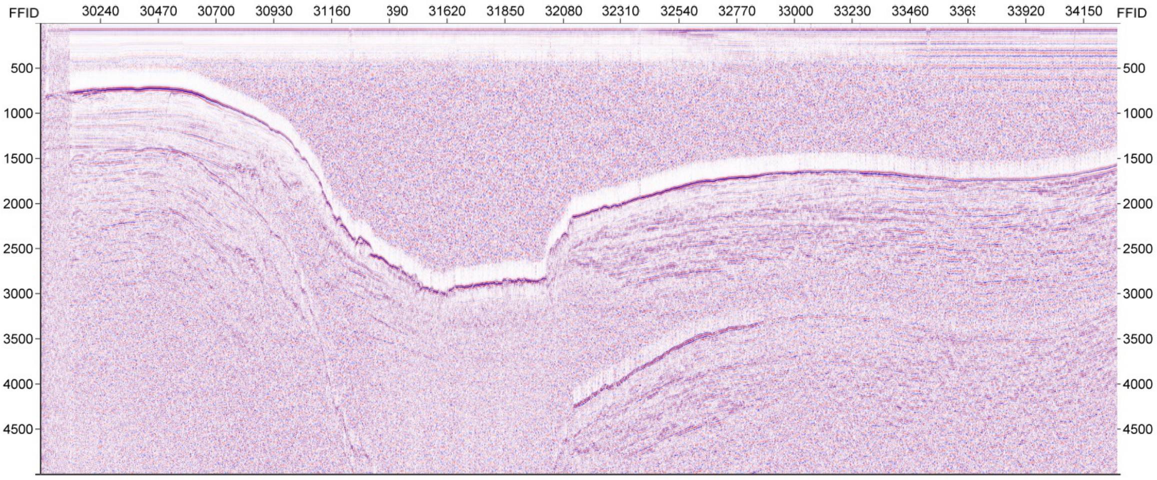

Figure 22. Brute stack of seismic reflection data along profile L9.

5.1.7. Heat flow measurements

by A. Minakov

Surface heat flow data provide constraints into the tectonic structure of the lithosphere and is useful for assessing hydrocarbon and methane hydrate distribution. Such measurements in the Arctic Ocean are still sparse, and any opportunity to enhance the existent database of heat flow measurements will contribute to construct or ground-truth regional thermal models.

Miniature temperature probes of ~15 cm in length by 1.5 cm diameter (ANTARES), are used to collect in situ temperature data at a resolution of 0.001°C and nominal accuracy of 0.1°C. Multiple probes spaced about 1 m apart were attached to the outside of the gravity core barrel. To avoid effects from frictional heating related to core penetration, the probes were placed inside holders within steel fins (secured with a steel pin or similar) located 10 cm away from the core barrel. The corer remains in the sediment for about 10 min to allow for thermal equilibration within the sediments.

The distance at which sensors are placed on the barrel is measured relative to a fixed point (distance from the lead weight) before deployment and after recovery of the corer, to calculate the temperature gradient with depth. The data are recorded as time series synchronised to computer time (in UTC; Figure 23). The “plateau” in the temperature curves means that the temperature system has equilibrated between the sensor and the host rock.

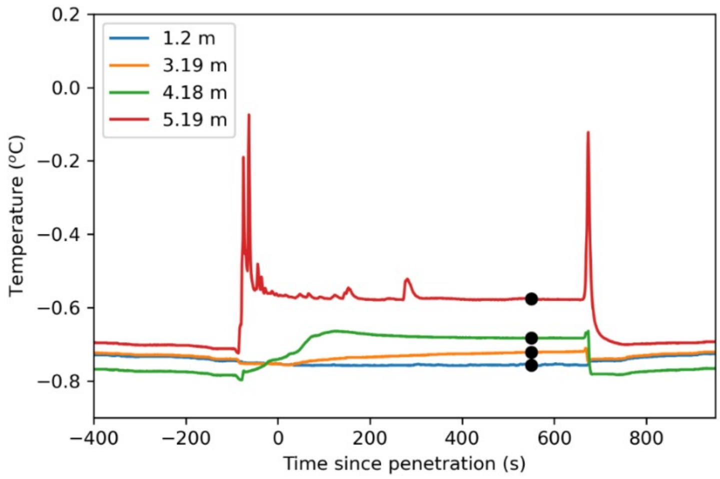

Figure 23: Time series of temperature measurements performed at the different depths below the seafloor at GoNorth-1 Superstation 10.

Heat flow measurements were performed on Tuesday October 25 and Wednesday October 26 together with gravity coring at Superstations 10 and Superstation 5. Five temperature sensors were mounted on the 6-m-long gravity core barrel at about 1 m interval (Station 10). The first core recovered 50% sediments and showed disturbance of the upper 3 temperature measurements (Figure 24). The second core (Station 05) had zero penetration and randomly distributed temperatures were observed.

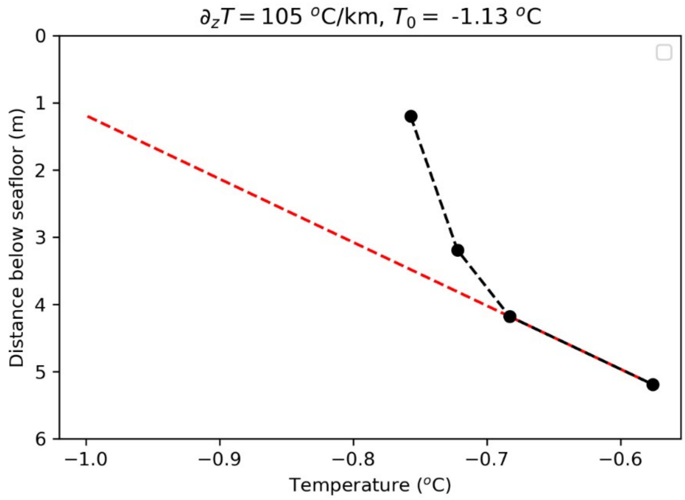

Figure 24. Temperature vs. depth (distance below the seafloor). The measurements were performed at GoNorth-1 Superstation 10.

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5.1.8. Gravity measurements

by B.O. Ruud

The LaCost & Romberg dynamic gravity meter sea gravimeter installed in a dedicated room near the ship's centre of mass, which is right below the ship's GPS antenna (positions logged by NaviPac) was used for underway acquisition of gravity data. The gravity meter system includes a gyro platform and dynamic control system. The gravimeter is controlled by the UltraSys software running on a PC where all data are continuously logged at 10-s intervals. In addition, the filtered digital gravity data is sent over a serial line to the Eiva NaviPac PC where it is included in the event log when shooting seismic lines.

The marine gravimeter measures a relative gravity acceleration which means that the measurements must be tied to a point with known gravity in order to obtain the absolute gravity values. For this cruise, we used a point at the harbor in Longyearbyen where we have estimated the absolute gravity during previous cruises. The difference in gravity between a point at the quay near the ship and the point of known gravity is measured by a land gravimeter at the beginning and end of the cruise so that the drift of the sea gravimeter can be corrected for.

An example of raw gravity data logged along the seismic line T1 is shown in Figure 25. The gravity low at the beginning of the line (north end) is due to the large water depth. The gravity is seen to fall towards the south for the shallow part of the line.

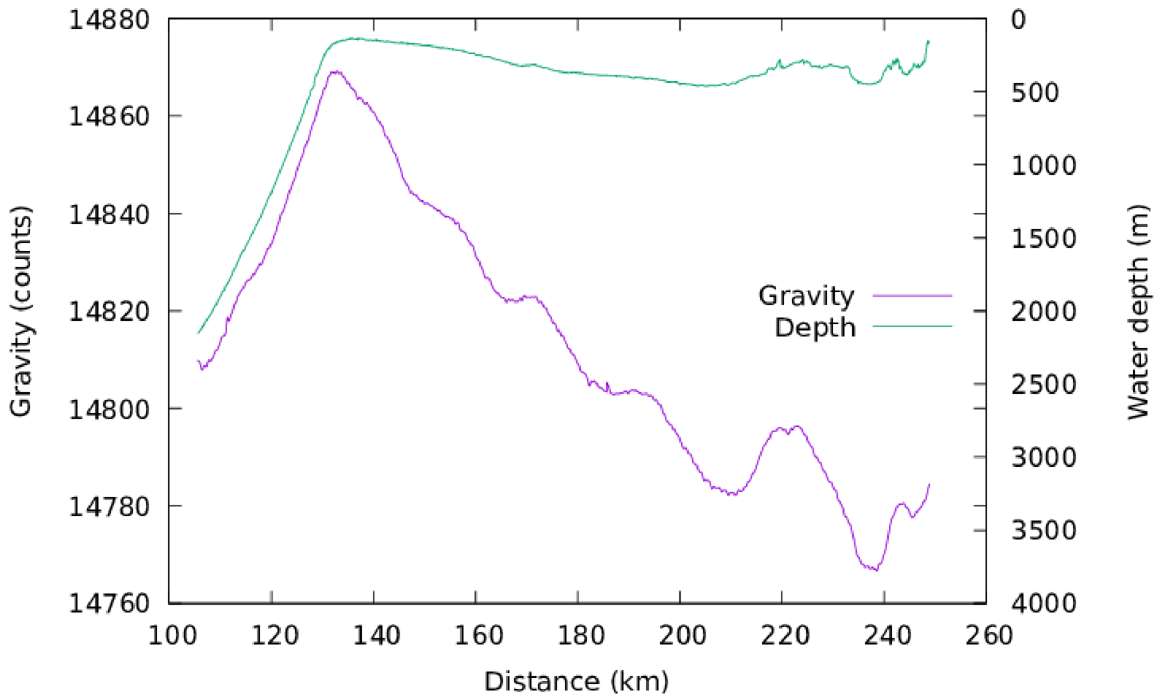

Figure 25. Gravity measurements and bathymetry profile along the OBS seismic line T1. One count is approximately 1 mGal.

5.2 Sea water, sea ice, sediments, biology, and gas

Our data acquisition also included sea water sampling, sea ice studies (both in situ measurements, and sampling, marine icing on RV Kronprins Haakon, and data collection for AI systems), sediment sampling, sampling of plankton and benthos, and measurements of methane and CO_2. Lander and Seaglider operations were also done. The aim of this work and some preliminary results is detailed below.

5.2.1. Sea water sampling and climate gas measurements

by T.-A. Pettersen and F. Leirvik

Two Engineers from SINTEF, Thor-Arne Pettersen and Frode Leirvik participated in the first leg of the GoNorth 2022 cruise. Work has been done on two projects: The Pharmarine project investigating transport of pharmaceuticals with ocean currents, and the OceanClimateLab project that involves mapping of methane concentrations. Ida Beate Øverjordet at SINTEF is project manager for both projects

5.2.1.1. Pharmarine Project

As part of the Pharmarine project a Polish research vessel has sampled seawater all the way from the Baltic Sea to the southeastern side of Svalbard. In continuation of this work, and as part of the GoNorth initiative SINTEF has extended the sampling scheme to the north of Svalbard and into the Polar basin. In addition to seawater sampling/processing, samples have been taken of seabed sediments and of zooplankton. Sampling positions are shown in Figure 26 and Table 6 below. Some surface water samples have been taken outside the defined cruise sampling stations. These are shown in the map as SSW, but not listed in the table (see also Appendix 4 for details).

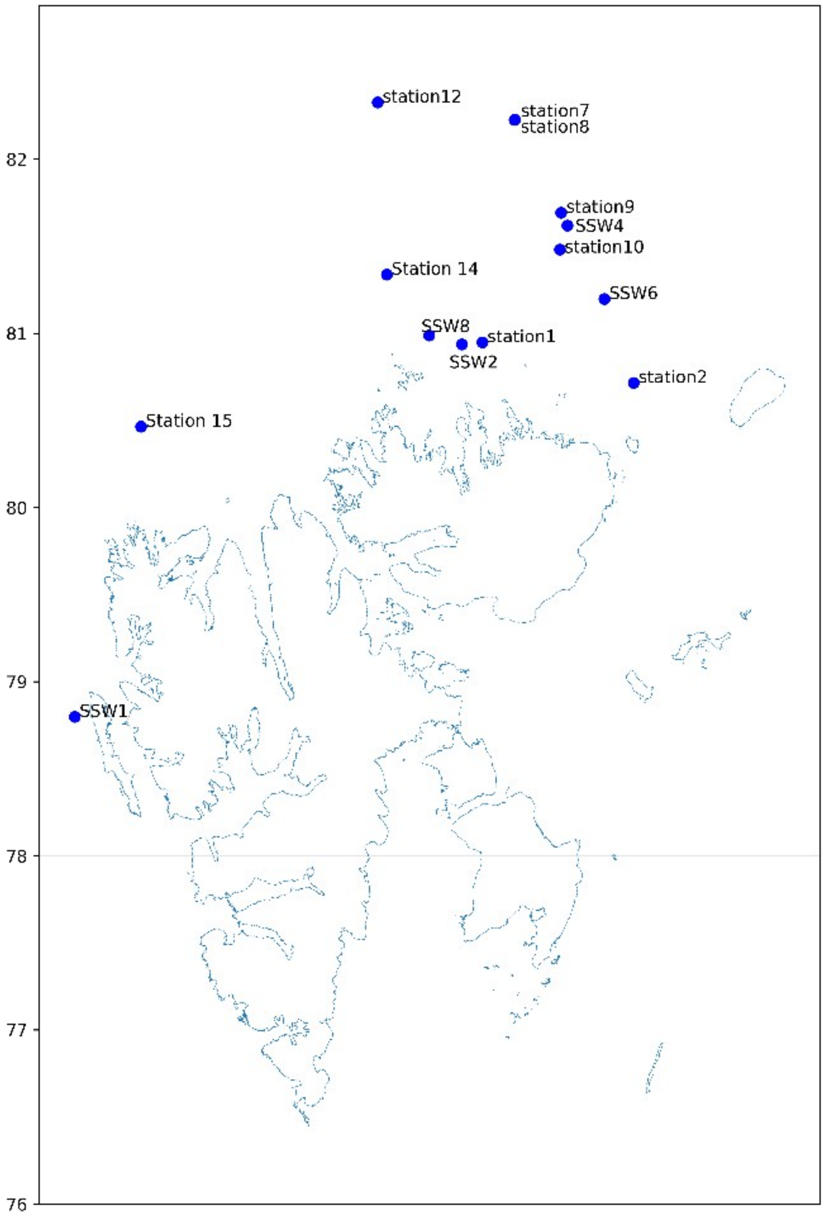

Figure 26. Sea water sampling positions for the Pharmarine project.

Table 6: Pharmarine sampling done at the stations shown in Figure 26.

Sampling position	**Surface Seawater**	**Atlantic Seawater**	**Top Sediment**	**Sliced Sediment**	**eDNA Sediment**	**Plankton**
1	1	1	2	1	1	
2	1	1	1			1
5			1	1	1	
7			1	1		
9	1	1	4	1	2	1
10	1	1	1	1		1
11		1				
12		1				
14			1			
15			1			

The objective of the project has been to investigate transport of pharmaceuticals from Europe and into the arctic. It was therefore important to sample water at a depth where it was most likely to find Atlantic water transported from the Norwegian coast. A water sampling rosette/CTD were used to target water from the Atlantic currents. Samples were also taken of surface water through the ships water sampling pumps. As concentrations are suspected to be low, water samples were typically 600 L. Water samples were extracted on board by pumping water through a Solid Phase Extraction (SPE) Column at rates of 0.5-1 L/min. This means one sample took approximately 12 hours to process. The SPE columns along with sediments and zooplankton will be brought back to SINTEF laboratories for analysis using LC-MS. Sediment samples have been taken from multi-corer, box corer and with push cores taken with the ROV. Plankton has been sampled using WP3 and MIC-net.

5.2.1.2. OceanClimateLab project

The OceanClimateLab project is a strategic SINTEF project to use an instrumentation buoy as a platform for measurements of climate gas. The GoNorth cruise was used as an opportunity to extend the scope of the project. Measurements of methane and CO_2 has been running continuously in the three weeks of the cruise. Measurements of methane and CO_2 was performed using the Picarro gas analyser. The room was situated relatively high on the 7th deck of the ship, and above the heli-hangar (Figure 27).

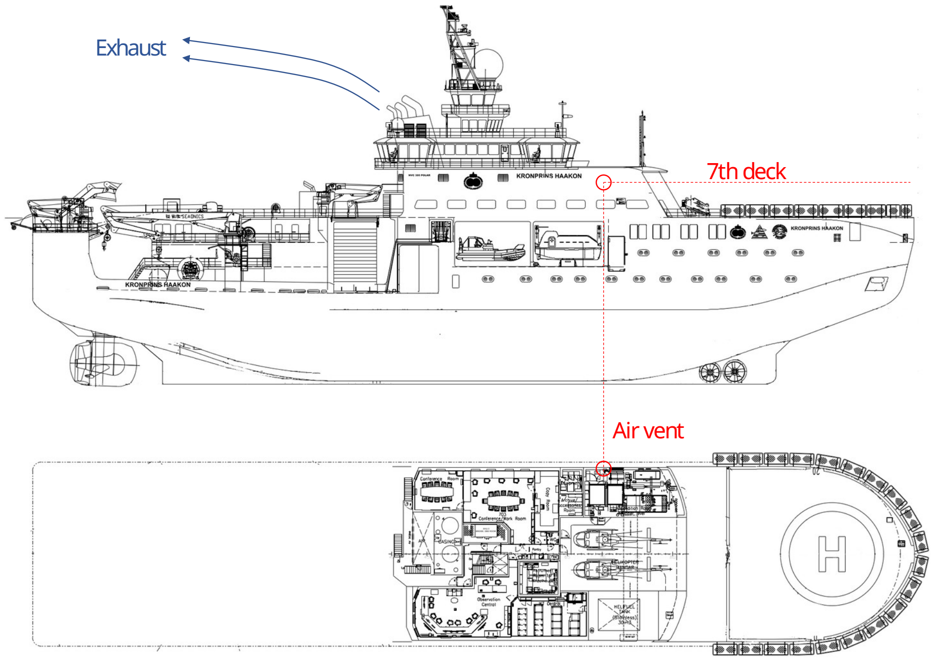

Figure 27. Location of the Picarro gas analyser on the 7th deck of the ship.

Methane measurements as function of time during the cruise are shown in Figure 28. Spikes have been given numbers from 1-9. Data where the ship is stationary is flagged as invalid, to avoid measurements from the ship's own emissions. The largest of the spikes is recorded while the ship were stationary.

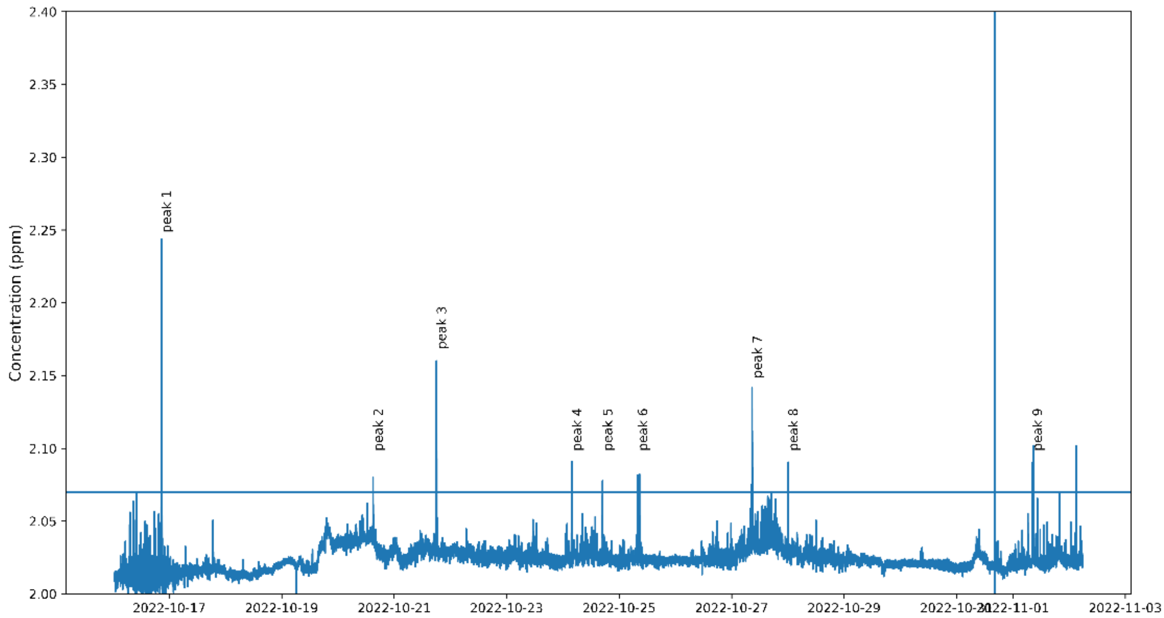

Figure 28. Methane measurements as function of time during the cruise.

Position of the spike occurrences are also plotted in the map below (Figure 29). The thin blue line shows the track from the entire cruise. Blue dots are methane spike positions from the gas analyser. The red dots are positions for known gas/petroleum seeps (kindly shared by Tom Arne Rydningen, UiT). The largest of the valid peaks (peak 1) is measured while passing a cluster of recorded seeps. Peak 6 is also in the close vicinity of a seep. Peak 2 is situated on an imaginary line going through the three northernmost seep positions. The rest of the peaks are gathered north of the 82nd latitude. It is easy to think, for example, that peaks 3-5 are part of the same instance of elevated values as the time scale is lost when plotting in a map. Peaks 3 and 5 which is recorded in the exact same position is acquired 28 hours apart, traveling in opposite directions. The dataset is incomplete and preliminary.

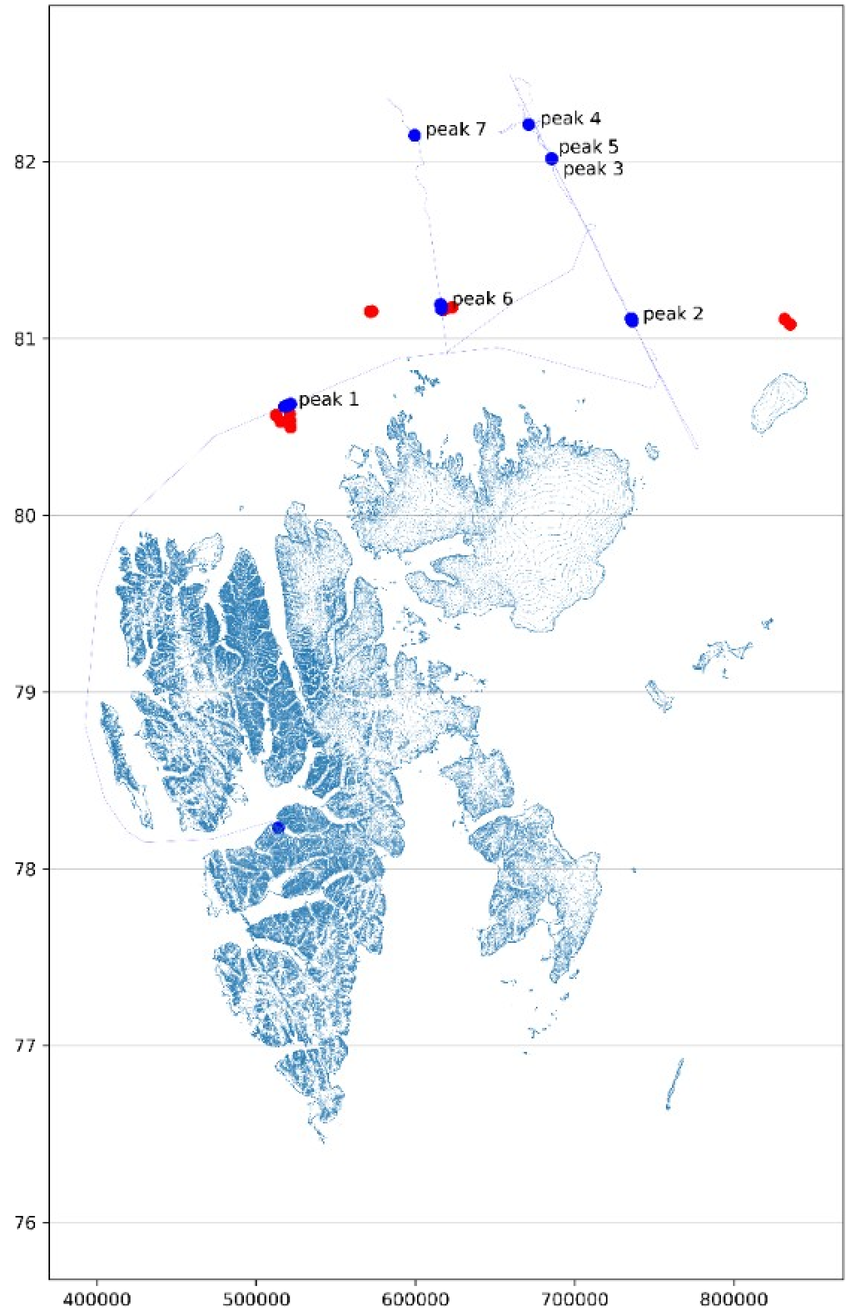

Figure 29. Position of the methane spike occurrences.

5.2.2. Sediment and ice sampling

by S. De Schepper and J. Thomassen Hestetun

Relevant research projects:

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (grant agreement No 818449).

AGENSI | A Genetic View Into Past Sea Ice Variability In The Arctic

5.2.2.1. Aim

For the AGENSI project (ERC Consolidator Grant #848339, PI S. De Schepper; 2019–2024), we collected sediments and sea ice samples for DNA analyses, palynology, and organic biomarkers. The collected sea floor sediment samples recovered by the multicorer will be added to the Arctic Surface Sediment DNA Database that is being built within AGENSI. This database will be used to establish new aDNA based sea ice proxies. The recovered 60+ cm long push core will be used to reconstruct the Arctic Ocean sea ice history of the Nansen Basin. Opportunistic sea ice samples and one sea ice core were melted and filtered for eDNA. This gives us information about potential useful sea ice organism that can be extracted from sediments for sea ice reconstructions.

5.2.2.2. Equipment for sediment coring

We mainly used the multicorer (MUC or MC) owned by the University of Bergen (Figure 30). This equipment built by KC Denmark A/S has a steel frame which carries four transparent plastic core liners (or tubes) of 60 cm length, an 11 cm outer and 10.6 cm inner diameter. The MUC was attached to a winch rope and lowered through the water column with a speed of ca. 1–1.2 m/s, and 0.5 m/s the last 50 m above the seafloor. When the MUC reaches the seafloor, a weight of ~650 kg pushes the cores into the sediments. When retracted from the sediments, arms with spatulas close the bottom of each core. The MUC and sediment cores are immediately heaved at ca. 0.8 m/s in order not to disturb the sediment and/or to lose material. Once on deck, the bottom and top of each core is secured with plastic end caps. Cores were cleaned, labelled, and subsampled for DNA, biomarker and microfossil assemblage analysis.

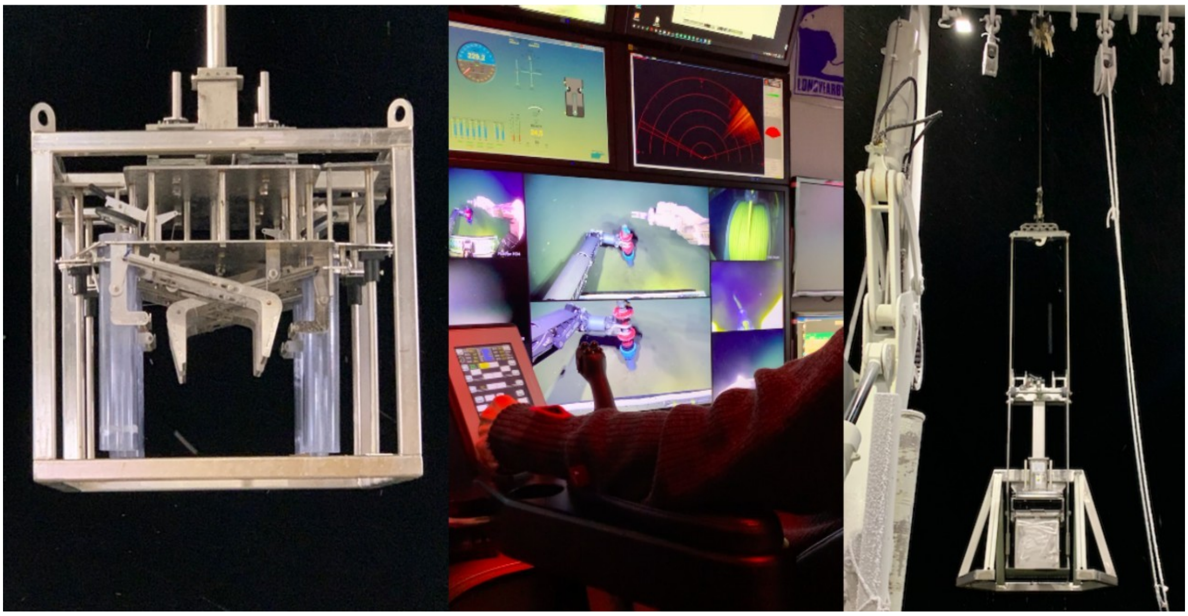

Figure 30. Multicorer deployed at midnight at Station 10 (Left). View inside ROV Ægir control room at the time when a push core was collected at Station 08 (center). Evening recovery of the box corer at Station 10 (right).

We collected 2 push cores (PC) using the ROV Ægir (University of Bergen). The ROV was deployed to recover seismic equipment from the sea floor under the sea ice during this expedition. On one occasion, two push cores were collected from the sea floor. The ROV took two tubes on its dive and pushed two plastic tubes of ca. 1.2 m length, and a 9 cm outer and 8 cm inner diameter into the sediment. The tubes were sealed from the top with a handle, which creates a vacuum and prevents the sediment from falling out. The push cores were stored onto the ROV's cable holder and brought back to the surface.

In addition, we took some samples of opportunity from three box corer (BC) deployments at Superstation 09 and 10. The BC samples uses a sampling box, closed off at the bottom as the gear is removed from the sediment, to extract a cube of sediment from the seafloor with a 0.2 m^2 surface area. Due to the lack of space in the hangar from stowed equipment, the BC was deployed from the aft deck.

5.2.2.3. Methods and protocols

5.2.2.3.1. Processing sea ice samples for eDNA

Method parameter: Metabarcoding (DNA) of eukaryotes

Method responsible: Stijn De Schepper, Jon Thomassen Hestetun

Description of parameter: Cells collected on Sterivex filters from sea ice melted at room temperature to be used for DNA analysis of sea ice biodiversity

Requirements: Clean area for filtration/sample handling, access to a -20 ˚C freezer. On this expedition, we used the Filtration Lab on Deck 3 (KH)

Equipment: Masterflex L/S 07528-10 pump, Sterivex filters = 0.22 µm

Samples: Samples of opportunity from the side of the vessel and sea ice cores

METHOD: The method is adapted from the protocol described in Nansen Legacy protocols document, Chapter 7.15 Metabarcoding (DNA and RNA) of protists and prokaryotes, and previous experience from expedition KH21-234 (REF).

IMPORTANT: Always use lab gloves (also when handling equipment, e.g. washing, storing). Immediately after use, rinse all containers, tubes and filtration equipment with distilled water and leave to dry in clean area.

Prior to sampling: Clean work surfaces, rinse carboys and tubes with Milli-Q/distilled water, prepare pump and tubing**,** label the Sterivex filters,

Sample collection: Samples of opportunity are collected from the side of the vessel using a net or by lowering a crew member in basket by crane to the sea ice. Smaller and larger chunks are collected, preferentially from sea ice with “brownish” colour. Sea ice samples were collected and stored in 10L buckets, covered by plastic and left to melt at room temperature.

Laboratory procedure at each station:

- Set the pump speed to 300 Rpm and put the pump in forward position
- Rinse tubes with 1L of **distilled water**
- Connect the <u>negative control</u> Sterivex 0.22 µm filter (labelled CON) to the Luer-Lok fitting
- Filter 1L of distilled water through Sterivex 0.22 µm filter unit
- At the same time, use a syringe to press air ca. 10 times through the <u>sampling control</u> Sterivex 0.22 µm filter (labelled AIR)
- Rinse the tubes with ~ 1L of **sea ice meltwater sample**
- Connect the Sterivex 0.22 µm filter unit (labelled ICE) to the Luer-Lok fitting to filter the sea ice meltwater sample
- Measure the volume of filtered water at the end of filtration

- Disconnect the Sterivex filter unit from the tube and remove remaining water using a syringe filled with air
- Mount the inlet and outlet caps on the Sterivex filters
- Transfer and store all filters frozen (-20 ˚C)

5.2.2.3.2. Multicore, box core and push core sampling

Method parameter: Ancient DNA (aDNA), organic geochemistry (biomarkers) and palynology

Method responsible: Jon Thomassen Hestetun, Stijn De Schepper

Description of parameter: Collect samples for aDNA, biomarker, dinocyst analyses.

Requirements: A cleaned and dedicated lab, which was the Ecotoxicology Lab on Deck 3 (KH)

Equipment: Multicorer with four sample tubes of the University of Bergen; push cores from the ROV.

Prior to sampling: ensure that all equipment and lab surfaces are cleaned for aDNA sampling, i.e.:

- use nitrile gloves when coming in contact with sediment
- soak end-caps and foam blocks in bleach and rinse with fresh water
- clean all working surfaces with bleach
- label sample tubes and bags
- clean spoons with bleach and rinse with MQ

Core on deck:

- retrieve core liners from MUC, close the top and bottom with endcaps or foam blocks
- clean exterior of core and label with cast and core number (e.g. MC1-A, MC2-B)
- record station number, cast number, time and date in multicore log sheet and document observations of core characteristics (lithology, core length) and photograph the core
- transport core to laboratory

Core in laboratory:

- siphon off top water from core
- place core on extruder and push it up until the surface can be easily reached
- collect fluffy layer/marine snow subsample (if applicable)
- take photo of core surface and make note of any additional observations
- subsample for DNA, biomarkers and palynology using bleach-disinfected equipment
- remove subsampled core from extruder and place in a plastic bin for cleaning
- store samples in freezer
- thoroughly clean Filter Lab working surfaces using 5% bleach solution and MQ to rinse

5.2.2.4. Results

5.2.2.4.1. Sea ice sampling

We collected opportunistic sea ice samples at Stations 03 and 04 from the side of the vessel. Colleagues from NTNU collected one ca. 1 m long ice core for DNA analyses from Station 06/Sea Ice Station 1 and two ca. 30 cm cores from Station 12/Sea Ice Station 2 (Figure 31, Table 7). Analysis of temperature and salinity indicates that the core from Station 06/Sea Ice Station 1 contained young second year ice, i.e., first year ice that formed in 2021 and survived the 2022 melt season. The ice at Station 12/Sea Ice Station 2 was first year ice.

Figure 31. Ice coring (left). Ice core recovered for eDNA analyses, just before it was left to melt in the dark prior to filtration (right).

Table 7. Ice sampling stations.

Station	Ice Sample	Longitude (deg. N)	Latitude (deg. E)	Water Depth (m)	Time (UTC)	Date	Sampling Comment	Notes
03	AGENSI ICE1	82.410318	26.255727	3877	10:00	19.10.2022	From side of ship with net (SDS)	Rather thin ice, ca. 25–40 cm thick.
04	AGENSI ICE2	82.344633	26.305091	3851	13:48	19.10.2022	From side of ship with crane and basket (crew)	Thick ice, with brown colour; multiyear ice
06	AGENSI ICE3	82.226000	26.690500	/	08:30	24.10.2022	Ice core (ca. 100 cm) from the Ice coring station 1	Second year ice
12	AGENSI ICE4	82.517500	17.500667	1675	09:30	30.10.2022	Two ice cores (ca. 30 cm) from Ice coring station 2	First year ice

All samples were filtered on a Sterivex 0.22 µm filter during the cruise following the protocol described above. Air and sample controls were taken for each ice sample.

Filters from **Station 03** did not show a lot of organic material on the filters after filtering a volume of 2.6 L. The ice from **Station 04** was visibly brown and likely presented multi-year ice, and the filters contained a lot of organic material after filtering 1.275 L and 1.400 L. The ice core from **Station 06/Sea Ice Station 1** was split in two parts, the top 20 cm which contained frozen snow and some sea ice, and the rest of the core. The top 20 cm were used to rinse the tubes (ca. 0.5 L), prior to filtering the rest of the sea ice core. The Sterivex appears to have retained some organic material. Two ice cores from **Station 12/Sea Ice Station 2** were melted together. Cores were only ~30 cm long. We rinsed the tubes with 0.3 L sample water, prior to filtering the sample water through a Sterivex filter (2.080 L). Rinsing was kept to a minimum in order to ensure enough actual sample on the filter. The Sterivex appears to have retained some organic material. Filters were stored frozen at -20˚C and will be analysed onshore for eDNA.

5.2.2.4.2. Sediment sampling

We did 11 multicore deployments at 9 stations, and collected 59 samples for DNA analyses, 9 for biomarker analyses and 9 for palynology (Table 8, Figure 32, Appendix 8). We sampled the top 0–2 cm of the multicores for sedimentary DNA analysis, biomarkers, and palynology. This happened in the Ecotoxicology Lab on Deck 3 of RV Kronprins Haakon, a lab that was frequently cleaned with household bleach to keep the lab space as sterile as possible.

Multicore deployment went generally smooth. At three stations there were problems with deployment, where the cable got stuck at the top of the multicore piston. This resulted once in no recovery (Station 02) and a second time, when tubes were hanging half below the frame, in mildly disturbed water-sediment interfaces and murky water above the sediment (Station 09). After that second event, a different connection to the cable was installed. At Station 11, the multicorer was dragged over the seafloor because of sea ice drift combined with a sub-bottom profiler that did not give a clear picture of the seafloor depth. This made it difficult to assess if/when the MC was on the sea floor. Two tubes were broken, and two remaining tubes recovered disturbed sediments.

The ROV collected 2 push cores during one dive (GoNorth Dive 594). These were differentiated into a station 07 and 08. The PC from Station 07 was sampled for the top 1 cm. The PC from Station 08 was sampled for the top 1 cm, and bottom cm. The remainder of the sediment was kept in the tube for later analyses and stored at 4˚C.

From each box core, two subsamples with 30 cm distance were sampled using clean gloves and put in Falcon tubes directly on the deck (i.e., not in the lab). The first of the three BCs did not close properly, leading to disturbed sediment; the next two deployments the sediment surface touched the top lid of the box, giving minor disturbances of the sediment surface, however, samples taken from these two deployments should still represent the sediment surface even though not completely undisturbed.

Table 8. Multicorer and ROV (Push corer) stations.

IMR/KH Log	Station	MC	Lat. (deg. N)	Lon. (deg. E)	Water depth (m)	sedDNA†	Bio-markers†	Paly.†	Notes
Multicorer 28	01	MC1	80.949019	23.757699	274	3	1	1	Good recovery
Multicorer 29	02	MC1	80.716510	28.931191	546	3	1	1	Good recovery
Multicorer 30	02	MC1	80.716299	28.932037	545	-	-	-	No recovery
Multicorer 31	02	MC3	80.716182	28.932459	545	6	-	-	Good recovery
Multicorer 32	05	MC1	81.606933	27.829552	2039	8	1	1	Good recovery
ROV Dive 594	07	PC1	82.227900	26.566200	3803	3	-	-	Push core
ROV Dive 594	08	PC1	82.266800	26.558700	3805	3	-	-	Push core; sampled top and bottom

IMR/KH Log	Station	MC	Lat. (deg. N)	Lon. (deg. E)	Water depth (m)	sedDNA†	Bio-markers†	Paly.†	Notes
Multicorer 33	09	MC1	81.693338	27.664398	2537	6	1	1	Possible disturbed recovery
Multicorer 37	10	MC1	81.390004	26.939664	810	5	1	1	Good recovery
Multicorer 38	11	MC1	82.311723	20.868039	3748	6*	1*	1*	*Disturbed sediment
Multicorer 43	13	MC1	81.392433	23.173245	396	8	1	1	Good recovery
Multicorer 44	14	MC1	81.311360	18.972598	543	4	1	1	Good recovery
Multicorer 45	15	MC1	80.464192	11.472363	642	4	1	1	Sandy sediment

†Shows number of samples collected

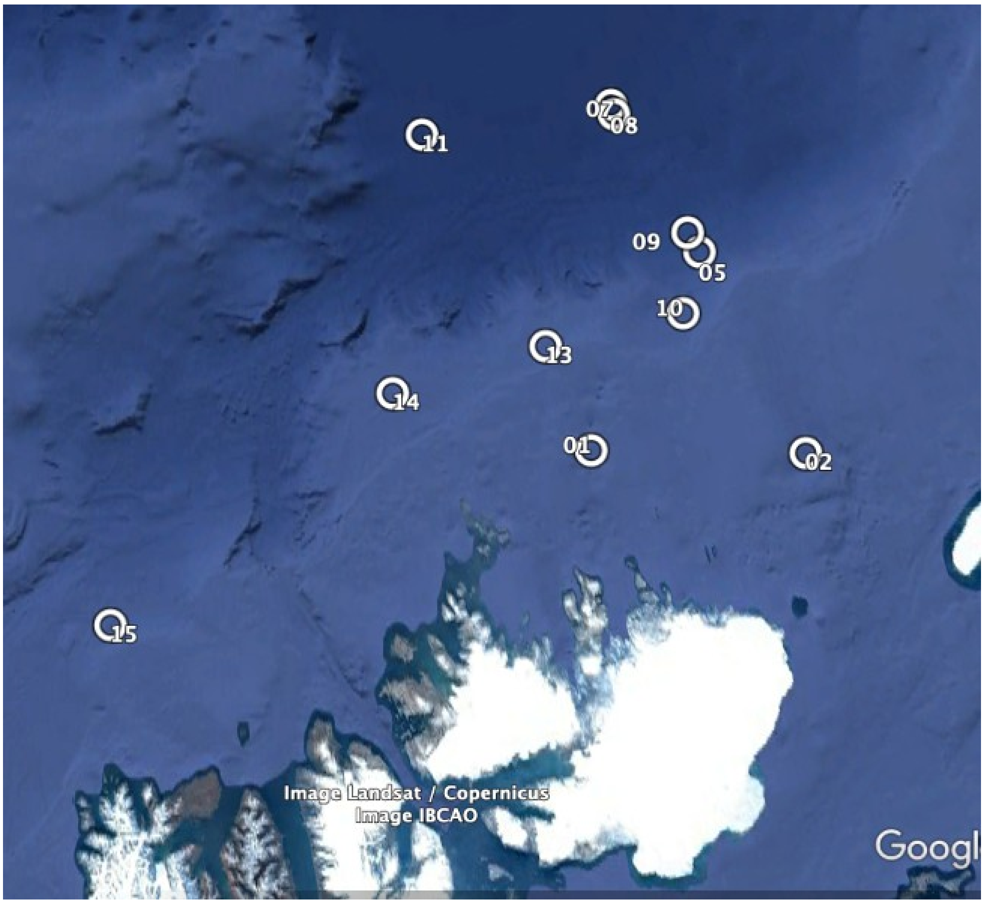

Figure 32. Map showing the location of the stations of Table 8. Maps data: Google IBCAO Landsat / Copernicus Data SIO, NOAA, U.S. Navy, NGA, GEBCO.

5.2.3. Spatial variability of sea ice physical parameters

by E. Salganik, V. Hornnes, P. J. Rübsamen-von Döhren, and N. Panchi

5.2.3.1. Thermophysical properties

This field report describes sea ice physics work performed during leg 1 of the GoNorth 2022 scientific expedition on 14 October–3 November 2022 (cruise number 2022713). This work was aimed to study physical parameters of the Arctic Ocean sea ice including its thickness, temperature, salinity, density, and texture. Additional ice cores were collected as a part of cooperation with expedition participants from NORCE and Akvaplan-Niva for DNA and diatom analysis. The density cores were co-located with the investigations of ice mechanical strength to study relationship between ice confined strength and microporosity. The ice cores were extracted with 7 cm internal diameter ice corer and sectioned with 5 cm vertical resolution, the ice temperature was measured *in situ* using thermometer, ice bulk salinity was measured from melted sections using a conductivity meter, ice density was measured using the hydrostatic weighing method in the freezer laboratory.

The coring activities were performed at two ice stations on October 24 and 30. The first station was located at the second-year ice (SYI) or multiyear ice with thickness of 109±10 cm, while the second was at first-year ice (FYI) with ice thickness of 31±1 cm. 10 and 17 ice cores were collected at each station including 19 ice physics and 8 DNA/diatom cores. The cores were located within a 3 by 3 grid with 5 m spatial resolution, co-located with NTNU borehole jack measurements. According to the marine radar imagery from RV Kronprins Haakon, the first ice station was located at the large 2.4 km by 2.4 km ice floe with 4 km^2 area and substantial roughness, typical for old and deformed ice (Figure 33a). At the studied location of the level SYI the snow depth was 8±4 cm. The second station was located at the small 0.2 km by 0.1 km ice floe with 0.013 km^2 area with a smooth surface. At the FYI site the snow depth was 3±1 cm. On October 24, the average air temperature was -19.6°C, water temperature was -1.7°C, and the wind speed was 8 m/s, while one October 30 the average air temperature was -8.0°C, water temperature was -1.6°C, and the wind speed was 12 m/s. The average geographical position was 82°13.56’ N and 26°41.43’ E for the first and 82°31.05’ N and 17°30.04’ E for the second site.

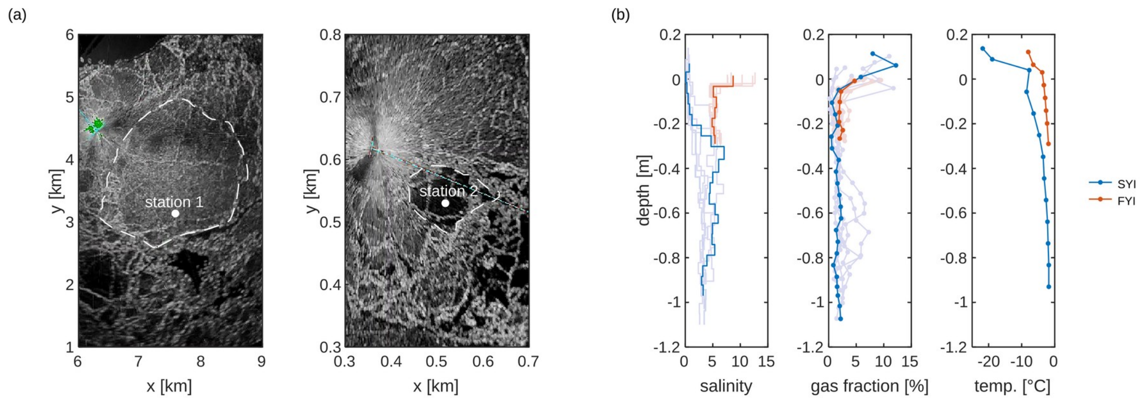

Figure 33. (a) Location of the investigated ice floes (white dashed line) and ice stations with the background from the RV Kronprins Haakon marine radar on October 24 and 30 and (b) salinity, gas fraction, and in situ temperature for selected cores of second-year ice (SYI) and first-year ice (FYI) relatively to the waterline sampled at ice station 1 and 2.

We measured bulk ice salinity of 3.1±0.5 for SYI cores with the thickness of 96–124 cm and salinity of 5.9±0.4 for FYI cores with the thickness of 29–32 cm (Figure 33b). Meanwhile, Kovacs (1996) gives higher average salinity of 7.6 for Arctic FYI of similar thickness. FYI cores had typical C-shape with salinity increase up to 7–13 at the surface. The upper 0–20 cm of SYI had higher values of gas volume fraction up to 12% and low salinity, characteristic for superimposed, formed by refreezing of melted snow. The upper 5 cm of FYI also had higher values of gas fraction up to 10% and higher salinity, typical for snow-ice, formed by snow flooding. At the depth above 20–40 cm, the investigated SYI has a linear decrease of salinity towards its surface, characteristic for summer desalination by flushing, which occurred presumably in the summer of 2022. The lower part of SYI has a salinity decreasing towards bottom, characteristic for summer desalination by brine rejection (Notz, 2005), also occurred presumably in the summer of 2022. Low effect of brine rejection may be related to the low ocean heat flux during summer (Griewank and Notz, 2013), indicating that the investigated ice was in the high Arctic during that period. Almost zero temperature gradient at the ice bottom also indicates the absence of new ice growth in 2022, despite low air temperatures.

Such high salinities of 3.1±0.5 for a relatively thick ice, recently transitioned from FYI to SYI, are rare. For example, in 2008–2018 Wang et al. (2020) measured bulk salinity of FYI as 1.9±0.6 at the end of melt season with the highest observed bulk salinity of 3.2. Meanwhile, such salinity measurements performed during high air temperatures and involving on-site sectioning may include substantial errors due to brine losses. This indicates the importance of the collected sea ice data at the period right after melt season, improving our knowledge about physical parameters of sea ice that survived summer melt. It is further supported by lower estimates of FYI and SYI gas fraction of 2.2±0.5% than 14.9±7.9% for FYI and 13.5±12.7% for SYI from Wang et al. (2020), which can be explained by gas substituting leaked brine during sampling in summer. In contrast, FYI salinities were substantially lower than average, which can be explained by a slow ice growth in 2022 season.

5.2.3.2. Mechanical properties

The mechanical strength of the ice was measured with the use of a borehole jack (BHJ) and co-located with measurements of other physical parameters. The BHJ measures the confined, in-situ indentation strength of the ice, by pushing an indentor horizontally into an augered borehole wall and measuring the encountered resistance. The measurements were carried out with 5 m horizontal resolution in a 3x4 and 3x3 grid for sea ice station 1 and 2 respectively, as illustrated in Figure 34.

Ice strength measurements at sea ice station 1 are shown in Figure 34. There is a sizeable spatial variability, with peak pressures of 30.3±8.9 MPa. Strength measurements of the first-year ice at the second ice station was more consistent, with peak pressures of 19.2±3.2 MPa. The estimated microporosity of ice at indentation depth including the sum of brine and gas volumes was 8±3% for SYI and 10±1% for FYI. Assuming a correlation between ice microporosity and strength, the smaller variability in strength for first-year ice could be explained by its lower variability in microporosity compared to second-year ice. Most of the spatial variability in the microporosity was caused by variability in brine fraction, where the variability was on the order of 3–9% for second-year ice, and 6.5–7.5% for first year ice.

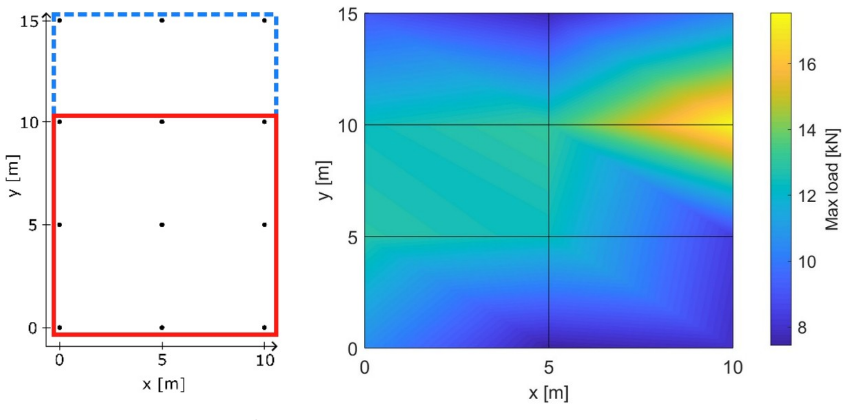

Figure 34. Illustration of the borehole grid layout used during ice station 1 (blue stapled line) and station 2 (red line) (left). Interpolated surface plot of the max load for each position in the grid during ice station 1 (right).

5.2.4. Marine icing on RV Kronprins Haakon in the Arctic Ocean during GoNorth expedition

by P. J. Rübsamen-von Döhren, E. Salganik, V. Hornnes

This field report describes marine icing during the first leg of the scientific GoNorth expedition from 14 October–3 November 2022 (cruise number 2022713).

Aluminium plates have been mounted at the aft of the vessel at the portside of deck 3 and within the nets around the helicopter deck (deck 6) at the bow of the vessel. These plates can not only be used to observe icing, but also allow for *in situ* adhesion test of spray ice on RV Kronprins Haakon. After adhesion tests, ice growing on the plates can be collected for salinity measurements and microstructure analysis. In addition, ice can be sampled with snow corers from any position of the ship.

During the cruise no icing from sea spray occurred due to the mostly calm sea. At Superstation 9 icing in -15°C and wind speeds of approximately 7 m/s occurred. Salinity measurements as well as the absence of spray showed that this icing was atmospheric. On the evening of October 30, sea spray occurred, but both the air and seawater temperature were too high for icing after the polar low brought air from southern regions.

5.2.5. Data collection for AI systems

by N. Panchi

This work was part of N. Panchi PhD project, internally funded by the Department of Marine Technology at NTNU.

Aim: Collection of geo-tagged sea ice information including optical images and ice-radar recordings**.**

Two 180-degree IP cameras were mounted in the observation room (deck 9) of RV Kronprins Haakon. A private network was setup comprising of the cameras, a controller (a Linux machine), and a Network Attach Storage (NAS). The cameras were calibrated using checkerboard patterns which were manually positioned in the field of view of the cameras. The cameras were set to record one picture roughly every five seconds which was then transferred to the NAS for storage. The pictures were time stamped using a clock synchronised with the ship, so that they can be geo-tagged using the AIS information from the ship. Sample images from the camera are presented in Figure 35.

Additionally, the CCTV camera facing the bow of the ship was also calibrated. Normally, the ship archives images (1 image/min) from only one camera (bow camera). But for this cruise, pictures from four different onboard cameras were exported through the ship's CCTV server (6 images/min).

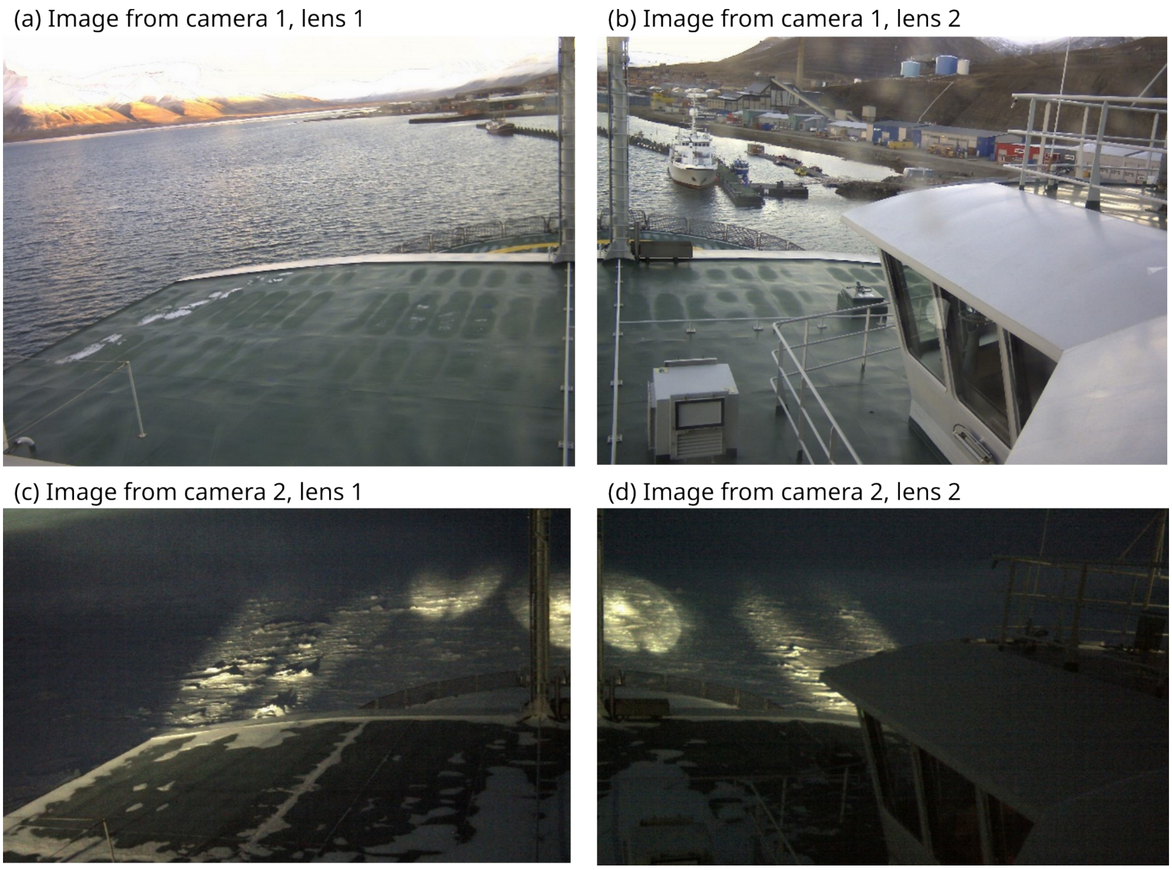

Figure 35. Sample images (a)–(d) from the camera. The top two images (a, b) were taken in Longyearbyen, and the bottom two (c, d) were taken when the ship was in ice.

Since the ship had some stations in ice, the ship's AIS records were analysed, and the cameras were made to record and export only for the operational duration in ice. Figure 36 presents the time intervals for data collection.

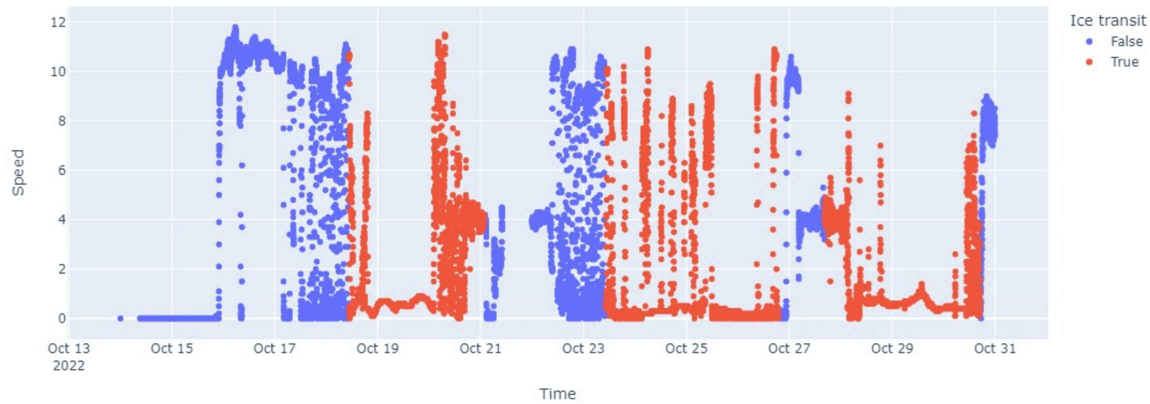

Figure 36. Ship speed (knots) vs time. The images were only recorded when the ship was transiting through ice (points colored in red).

Apart from automated data collection, manual sea ice observations were taken in the Egg code format. Post-cruise, these manual observations will be combined with corresponding optical images, and this will be made part of the public record through IceWatch.no.

5.2.6. Lander and Seaglider operation

by S. Pedersen

The purpose of the Lander "Rammeskeiv" and the glider in the expedition "GoNorth" was to collect data about the biology and lifeforms as well as bathymetric data in the area, using different type of sensorics.

As well as collecting general data for further use, we are interested to try and "match" these different recordings (from the UVP6 and EK80 specially) to the work Sabine Cochrane was doing on this expedition. Our post expedition work will be to match her physical collection of biology and lifeforms to the sensor recordings done. We hope this will help us to get a better understanding of the data we collect during autonomous missions.

Lander: The Lander, "Rammeskeiv", is a welded steel rig meant for standing stable at the seabed, recording from the start to the end of the expedition. The lander has the following integrated sensors:

- UVP6: Deep Ocean imaging sensor, designed to acquire digital images of zooplankton and quantify them in a known volume of water.
- Seaguard 1: The Seaguard 1 is a horizontal ADCP (Acustic Doppler Current Profiler), but will also log data from other sensors mounted such as turbidity, Optode (oxygen), conductivity (salinity) and pressure (depth)
- Seaguard 2: The Seaguard 2 is a vertical profiling ADCP, as well with a pressure sensor for depth measuring.

Seaglider: The Seaglider (Figure 37) is a AUV piloted by Ehsan Abdi from C.S.C.S. Limited. The glider will dive down to depths up to 1000 m and do transecting lines around the area of station 2 during the expedition, collecting data in the water columns. The seaglider has the following integrated sensors:

- UVP6: Same as the one described on the Lander.
- CT Sail: Conductivity and temperature sensor.
- Optode: Sensor for measuring oxygen levels.
- EK80: Echosounder, 333 kHz, giving us information of the biomass in the water column.

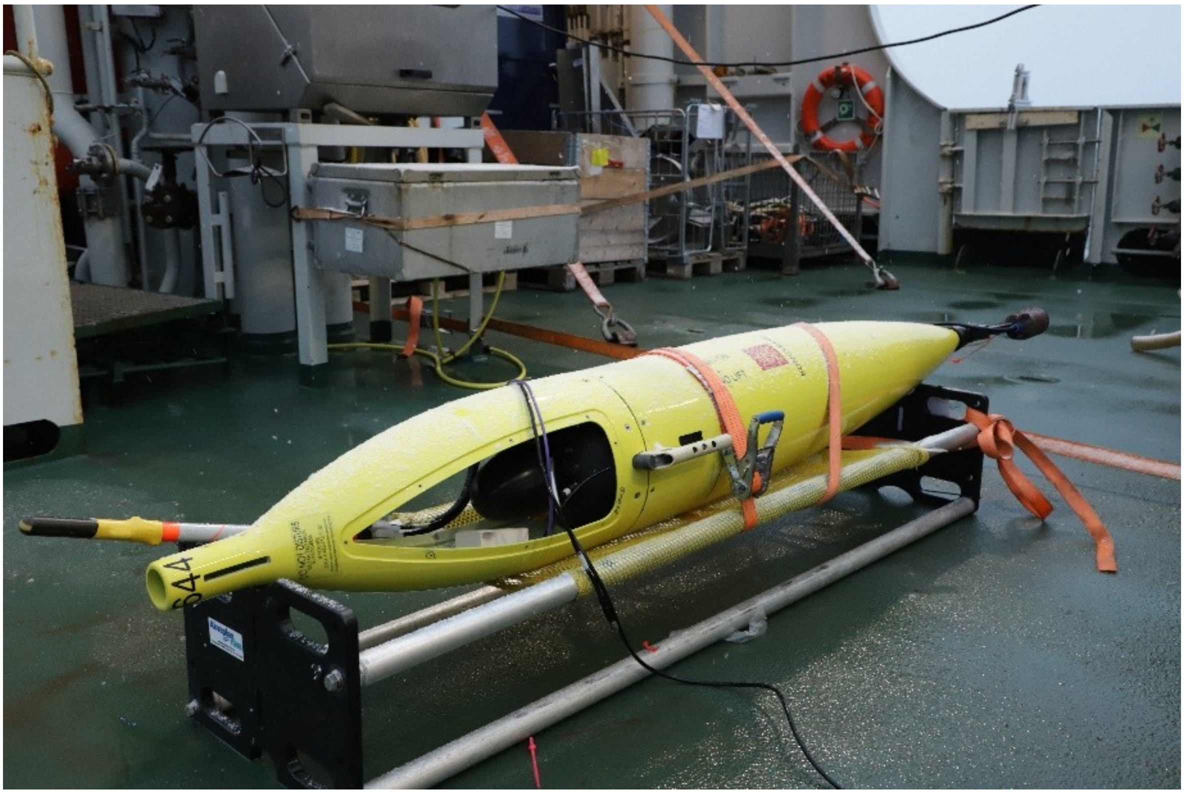

Figure 37. The Autonomous Underwater Vehicle (AUV) Seaglider. Photo by Daniel Albert, SINTEF/GoNorth.

5.2.7. GoNorth Ecology

by S. Cochrane

Disclaimer: This section is compiled by Sabine Cochrane, Akvaplan-niva, to the best of current available knowledge. Specific questions may be directed to skc@akvaplan.niva.no.

Field participants:

Sabine Cochrane. Senior Scientist, Akvaplan-niva. Marine ecologist, specialist competence on sea-floor biodiversity and contribution to ecosystem functioning.

Sondre Pedersen. Field technician, Akvaplan.niva. Specialist competence in sub-sea electronics and drone operations.

Land-based team:

Lionel Camus. Senior scientist, Akvaplan-niva. Manager for Digital Solutions. Specialising in application of remote/autonomous technology in marine ecosystems monitoring.

Maxime Geoffroy. Senior research scientist. Fisheries and Marine Institute of Memorial University of Newfoundland (MUN). Specialising in bioacoustics and range-expansions of north Atlantic and Arctic fish and pelagic ecosystems in general.

Morten Thorstensen. Senior sub-sea engineer, Akvaplan.niva. Head of section for field infrastructure and logistics.

Team of Engineers at Cyprus Subsea Consulting and Services C.S.C.S. Ltd. Remote piloting of the seaglider. In particular, **Ehsan Abdi** (via daily satellite-telephone contact): Head engineer with expertise in sub-sea electronics, construction and operation of autonomous underwater vehicles and sensors.

5.2.7.1 Background and aims

5.2.7.1.1. Overarching background and rationale

Text in this section is taken from the non-funded application to the Norwegian Research Council in early 2022, by Cochrane et al. ("White to Blue", application ref. ES 703754). The proposal was rated highly on most aspects, particularly scientific quality, but was not considered sufficiently central to the aims of the NFR programme.

The main purpose of the ecology component within GoNorth is to understand the ecosystem impacts of the rapidly changing marine ecosystems in the Polar oceans.

Our climate is changing, the polar icecap is melting, and the Arctic seas are becoming increasingly influenced by warm, salty Atlantic water (Muilwijk et al., 2018). We are expecting the Arctic Ocean to change from a year-round frozen sea to one with open waters in summer and annual ice in winter. These stressors cannot be managed as such, but we must address the consequences (Elliott, 2011) in this vulnerable habitat (Convention for Biodiversity; CBD 1992). The ongoing changes likely will have dramatic impacts on both the marine ecosystem and socio-economic activities, requiring astute management of the overall impacts. Moreover, the more change is expected, the more important it becomes that relevant decision makers have a good understanding of the most important features and processes in the system in order for them to put appropriate management responses into place (Crépin et al., 2017) and to properly address its consequences Elliott et al., (2020).

The continental shelf margin that extends north of the Svalbard archipelago (77–80°N) and the marginal ice zone are designated as particularly valuable and vulnerable habitats from a management perspective (Eriksen et al., 2021; Miljødirektorat M-13103/2019. Norwegian regulatory authorities need a solid knowledge base on how the northernmost area of its jurisdiction is changing, what is causing these changes and which ecosystem components and services are becoming either enhanced or threatened.

Atlantic water (AW) has for decades been expanding northwards into the Barents Sea (Polyakov et al., 2017), with the resulting warming and salinification of the water masses recorded since the mid-2000s (Lind et al., 2018). The decline in sea ice and increase in salination has reduced the extent of ocean stratification, enhanced vertical mixing and increased the upward fluxes of heat and salt that hinder sea ice formation (Serreze et al., 2019, Chen et al., 2015). As a result, the dynamic shelf-slope area north of Svalbard has increasingly become a semi-permanent ice-free lead/polynya area. At the same time, the overall thinning and retreat of the Arctic Ocean sea ice (Serreze et al., 2019) is making the entire area increasingly accessible and attractive for both non ice-dependent marine life as well as human activities.

The northern shelf margin now supports an active seasonal fishery for mainly shrimp, but occasionally also cod and haddock (Figure 38).

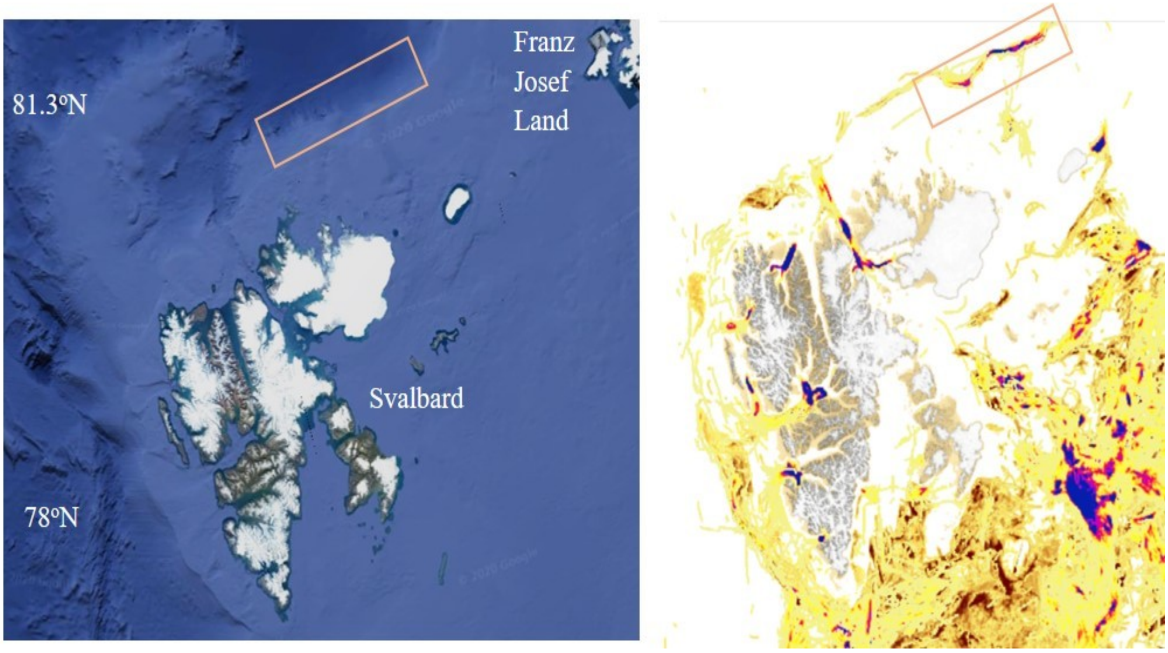

Figure 38. Svalbard, with the productive shelf margin boxed (left). Fisheries activities (darker=higher intensity, right). Sources: Google Earth/ Norwegian Fisheries Directorate.

Both naturally occurring and artificial gaps in ice-cover will allow off-shelf winds and atmospheric pressures to act on the exposed patches of open water, with cascade effects downwards and laterally within the water column, ultimately promoting mixing of nutrient rich water (Morales et al., 2004). With no ice-cover, this leads to a surge in primary productivity as soon as the polar sun re-emerges, followed by the various stages of secondary production, resulting in thriving oases of biological activity encased within a still ice-covered and (production-wise), semi-dormant system (Berge et al., 2015). The elevated biological productivity attracts secondary consumers and their predators. The vertical export of organic matter may in turn feed the benthos more directly (Wassmann, 2011). The combination of drift ice and open water provides favourable conditions for breathing, reproduction, resting and foraging of marine mammals and seabirds. Arctic shelf break areas and open water leads thus create 'biological hotspots' characterised by high primary and secondary zooplankton production, providing energy rich food throughout the food web (Morales et al., 2004, Falk-Petersen et al., 2015, Ostrom, 2009, Wassmann et al., 2011, Renaud et al., 2019, Falk-Petersen et al., 2000).

Although GoNorth has a primary focus on geo-physical sciences in the Arctic Oceans, there is a pressing need to link the emerging knowledge with observed and expected biological scenarios. Traditional biological sampling involving research vessels is costly, produces emissions and can only capture conditions at that moment in time. Further, the noise of the ship causes evasive behaviour, most notably in zooplankton, such that physical sampling using traditional nets may not reflect undisturbed conditions. There therefore is a pressing need to develop fully- or semi-autonomous vehicles, that can collect data over a longer period of time, without the need for daily physical intervention.

5.2.7.1.2. Specific aims for 2022 mission

The mission in 2022 took place during an interesting and little-studied period in the Arctic calendar, after the summer production has ceased and while the first-year sea ice is under formation. For this reason, our data collection mostly took the form of a fact-finding mission, as well as testing of the utility of autonomous vehicles for data-collection at high-latitude locations, also where there is a risk of encountering sea-ice.

Autonomous vehicles can be programmed to collect not only non-ambiguous oceanographic data, such as water temperature, salinity etc., but also some biological data on plankton, fish and mammals can be recorded, using primarily acoustic but also some visual methods. However, one of the challenges with the latter type of recordings is the uncertainty of exactly which species are being recorded. For this reason, we aimed to collect a set of physical biological samples from the water column (mostly plankton), with which to ground truth the autonomously collected data. Planktonic organisms generally have a short (usually 1–2 years) lifespan, drift within the water masses and can undergo vertical migrations (from surface to bottom water) on both a daily and seasonal basis. Note however, that this generally applies to shelf-associated plankton: that in the deep sea may conceivably have a more restricted pattern of motility.

Benthic fauna are the organisms which live on or in the seafloor. In the deep sea and areas around Svalbard (with the exception of rocky/stony bank areas), the sediments comprise fine silts and muds and generally are inhabited by organisms that burrow within the substrate (bristleworms/polychaetes and crustaceans such as small shrimps) and those which graze from the surface sediments, such as brittle-stars and starfish (Figure 39).

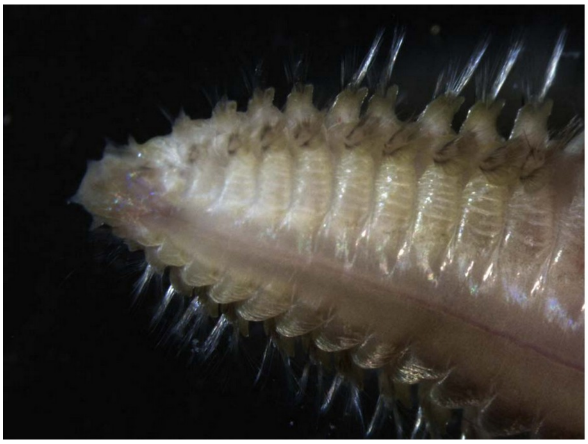


Figure 39. Anterior (front) end of the polychaete bristleworm *Aglaophamus malmgreni* (left) and the common mud-star *Ctenodiscus crispatus* (right). Note that the starfish is full of mud, visible through the "skin". This species simply engulfs sediment, and nutrients are absorbed by its gut system. Photos by Sabine Cochrane, Akvaplan-niva and Daniel Albert, SINTEF/GoNorth.

The community composition of benthic fauna is long-recognised as an indicator of general sediment and near-bottom water conditions. In soft-sediments with low bottom currents, most of the fauna tend to be burrowers, and eating from the sediment surface (like the above starfish), or within the sediments, either as carnivores (like the above polychaete) or by selecting food particles from between grains of sediment, or by simply engulfing/excreting sediment "en masse". Coarser sediments and/or where bottom currents are stronger, containing suspended food particles, the fauna tends to be dominated by filter-feeders, such as brittle-stars with flexible arms, fanworms, sponges and anemones, to name but a few. We therefore aimed to collect samples of benthic fauna using a box-core.

Being of small size (from 1mm and rarely more than 10 cm in length/height) benthic fauna are mostly influenced by the oceanographic processes that occur at the very boundary layer between the sediment and the bottom water. Most oceanographic sampling and recording (including from gliders) are taken from at best to an absolute maximum of 10 m above the seafloor, and often no closer than 50 m. For this reason, we deployed a benthic lander, which is a frame that sits on the sea floor, carrying instruments that will record from around 1 m from the bottom. The following general strategy was adopted:

1. Deploy glider at Erik Eriksenstretet, programmed to follow the approximate trajectory of the ship along the continental shelf, diving to a maximum of 1000 m and back to surface waters at approximately daily intervals. On-board sensors shall measure selected oceanographic and biological parameters.

2. Deploy benthic lander equipped with sensors at the same location (at around 200–250 m depth due to the limitations of the sensors), designed to record from the very bottom water (maximum 1 m over the seafloor).

3. Physical biological sampling of ice-algae, phytoplankton, zooplankton and benthic macrofauna (organisms >1mm), as ground-truthing for the remote data collection.

5.2.7.1.3. Collaboration networks and ambitions

The ecology part within GoNorth is anchored within a broad international and multidisciplinary collaboration within technical and research networks:

- Cyprus Subsea Consulting and Services C.S.C.S. Ltd (CSCS). Established in 2012, this company blends academic and technical expertise with seagoing and survey experience, particularly within marine robotics and autonomous systems, including telecommunications. Because of the limitations with internet coverage during the mission, CSCS piloted the glider using satellite connections and kept a daily overview of the functioning of the sensors.

- Cochrane is part of the steering group and co-founder of the EU Horizon research project Marine Biodiversity and Ecosystem Functioning (MARBEFES, 2022–2026). The project has approximately 20 partners across Europe, as well as two non-European partners, including Martinique. One of the study areas used to test monitoring tools and hypotheses is the Arctic and waters around Svalbard, so the GoNorth mission became linked with MARBEFES to mutual benefit.

- Manager of Akvaplan-niva's team for Digital Solutions Lionel Camus is part of the innovation and technology development financed by the EU MATERA funded BIOGLIDER project BIOGLIDER – Autonomous Exploration and Monitoring of Marine Ecosystems. The external glider piloting and some of the sensor operations for the GoNorth 2022 cruise were co-financed through this initiative.

5.2.7.2 Methods

5.2.7.1.4. Sampling locations

Most of the stations visited during the GoNorth cruise were dedicated to deployment and recovery of seismic transmission/receiving equipment, but three stations (stations 5, 7 and 9) were allocated to biological sampling. These corresponded to shelf (2–300 m), slope (around 2–3000 m) and deep locations (>4000 m), respectively (Figure 40).

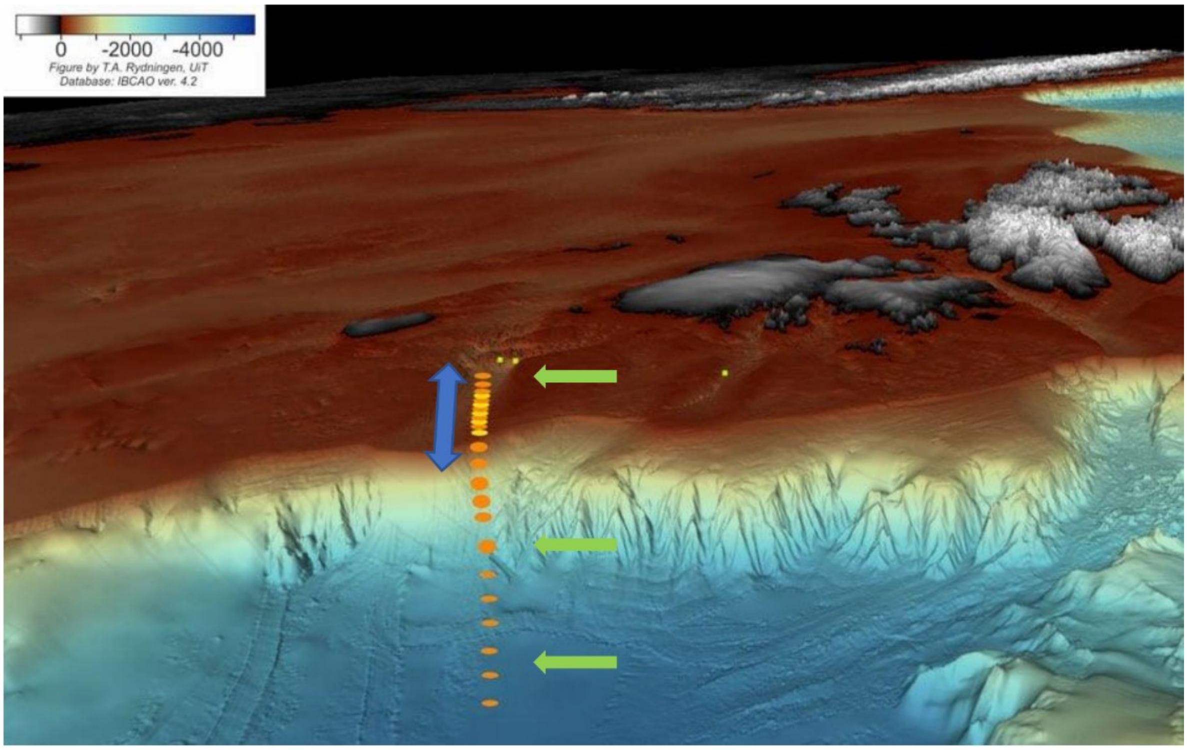

Figure 40: Approximate sampling stations for biological samples (green arrows). The lander was deployed near Station 2 and the glider moved along the trajectory indicated by the blue arrow, diving to a maximum of 1000 m and back to surface waters at approximately daily intervals. Image by T. A. Rydningen, UiT.

5.2.7.1.5. Autonomous oceanographic/plankton data collection

<u>Seaglider:</u> The Seaglider was deployed close to Station 2 shown in Figure 1, on October 17 and retrieved from the same location on the evening of October 31, both operations using a small-boat belonging to the main vessel (Figure 41). The vehicle was programmed to dive down to depths no deeper that 1000 m and travel in transecting lines following the path of the ship, to the extent of the continental shelf break, in a yo-yo like pattern (from near-bottom to near-surface on an approximately daily basis), continuously collecting data from its sensors, as described below.

The vehicle was piloted by engineers/technicians from Cyprus Subsea Consulting and Services C.S.C.S. Ltd (CSCS). The following sensors were mounted on the glider and were operational throughout the mission. The following sensors were mounted on the seaglider:

- **Underwater Vision Profiler (UVP 6)**: an imaging sensor designed to count and record size *in situ* large (>80 µm) particles in a known volume of water. The UVP6 also records images of larger aggregates and zooplankton (>700 µm) for later classification using the EcoTaxa/EcoPart web application. *(Generic text modified from Hydroptic.com)*

- **EK 80 echosounder**: a high-precision scientific echo sounder and ADCP system designed to quantify and monitor underwater ecosystems. The EK80 is a modular system capable of operating several different transceiver and transducer combinations, all through the same operator station. *(Text and instrumentation from Kongsberg.com).*

- **"CT-sail"**: device to record conductivity (measure of salinity), turbidity and other basic oceanographic parameters.

Figure 41. Field technician Sondre Pedersen from Akvaplan-niva assembling sensors onto the Kongsberg glider (upper left and right). Pedersen and crew members deploying the glider in Erik Eriksensstretet (bottom). Photos by Daniel Albert, SINTEF/GoNorth.

Benthic lander: The Akvaplan-niva benthic lander (affectionately known as "Rammeskeiv"), is a custom-designed, welded steel rig meant for standing stable at the seabed, recording from the start to the end of the expedition. The construction was made such that the lander can be deployed and retrieved without the need for ROV-assistance, with maximum stability and minimum risk for landing on its side.

The lander was deployed and retrieved on the same dates as the sea-glider, using the ship's aft-deck winch. During deployment, a line with a surface buoy was attached to the rig, to facilitate retrieval. The following sensors were mounted on the lander:

- **Underwater** Vision **Profiler (UVP 6)**: as above.
- **Seaguard 1:** a horizontal Acoustic Doppler Current Profiler (ADCP), which also was programmed to log data from other mounted sensors, including turbidity, Optode (oxygen), conductivity (salinity) and pressure (depth).
- **Seaguard 2**: a vertical profiling ADCP, also equipped with a pressure sensor for depth recording.
- **Optode**: a sensor for measuring oxygen levels.
- **EK80 Echosounder**: as above; programmed at 222 kHz.

5.2.7.1.6. Ground-truthing by physical biological sampling

Zooplankton: Zooplankton were collected using a combination of an WP3 net and the larger MIC net (both with 1000 µm cod-end mesh diameter), Figure 42. Hauls were made vertically, from 1000 m to the surface, to correspond with the diving depth of the glider. Samples were photographed and preserved, split between in an approximately 7% formalin/seawater mixture and 96% ethanol (the former best for taxonomic purposes and the latter necessary for any appropriate future DNA analyses).

Figure 42. MIC net for sampling zooplankton (left) and box core for sampling bottom sediments and fauna (right). Photos by Daniel Albert, SINTEF/GoNorth.

Benthic fauna: Benthic fauna was collected using a box core with 0.25 m^2 sampling area. Sub-samples corresponding to 0.1 m^2 were taken and sieved through a series of mesh sieves, from 1 mm, 0.5 mm, 0.25 mm and 0.15 mm. Due to clogging, the finest mesh sieves were used only for the "first wash" of the fine, upper sediments. This strategy was used to be able to process the samples according to different size fractions, which then can be compared with other existing samples, collected from different mesh sizes. Procedures for washing and conserving samples followed international guidelines (ISO 16665). One sample was fixed in formalin and the other in ethanol, for the same reasons as for zooplankton.

Phytoplankton: Phytoplankton was collected using the ship's net, with an estimated mesh diameter of 125 µm (to be confirmed). Because of net clogging, hauls were restricted to the upper 50 m of the water column. This was carried out despite the obviously low production in the upper water column, but as a matter of interest to check whether some residual phytoplankton may be remaining/occurring in the surface waters.

There was little, if any, material visible to the naked eye, but samples were fixed in a 2% seawater-formalin solution, for later assessment in the laboratory.

Ice algae: Ice algae were collected in two ways, from pieces of ice broken and upturned by the passage of the ship and on two occasions, from the ice-coring activities of the ice-group from NTNU. In total, 8 ice cores were obtained and kept frozen in black plastic bags for later analysis. Ice chunks were thawed, collected in basins and samples of the material was analysed and photographed under light microscopy.

The remaining material was preserved in an approximately 2% formalin/seawater solution for later species identification.

5.2.7.2. Provisional results and experiences

Results from the seaglider and the lander will not be available until later data processing. However, some biological/ecological observations were made.

Benthic macrofauna: The area on the shelf north-east of Svalbard (Erik Erikssenstretet) revealed a very typical fauna for around Svalbard. The benthic fauna comprised largely Atlantic-associated species, populated by the following taxa (in order of highest abundance): Amphipod crustacea, Thyasirid bivalve molluscs, Polychaete bristleworms (*Ophelina, Aricidea*, *Levensinia* and various terebellomorphs), Sea cucumbers (holothurians), ribbon worms (nemerteans) and other yet unidentified taxa. These taxa are typical of the shelf area to the north and east of Svalbard (e.g., Cochrane et al., 2009).

The deep area (around 4000 m) contained extremely low amounts of visible benthic fauna, and none at all were retained on the 1 mm sieve (in contrast to the above). We will examine in the laboratory whether macrofauna—or even smaller meiofauna—were retained on the finer sieves used and, if so, which species were present.

The area near the base of the slope also was poor in biota, with the exception of the occasional larger polychaete worm (Figure 43) and some individuals of worms known as Siboglinidae (Figure 44).

Figure 43. A bristleworm polychaete (Laonice: Spionidae) on soft sediment, caught in a core tube deployed by the ROV at around 2000 m depth, intended for genetic analyses by the NORCE team. Photo by Daniel Albert, SINTEF/GoNorth.

Siboglinids are evolutionarily advanced polychaetes that do not possess a gut, but instead use symbiotic bacteria to supply their energetic needs. Although siboglinids occur in low abundances in most marine sediments, they can occur in large numbers in anoxic sediments such as around hydrothermal vents (e.g., Karaseva et al., 2016) and around sites of contamination by raw oil (Cochrane, *pers. obs. and reports to Statoil, now Equinor)*.

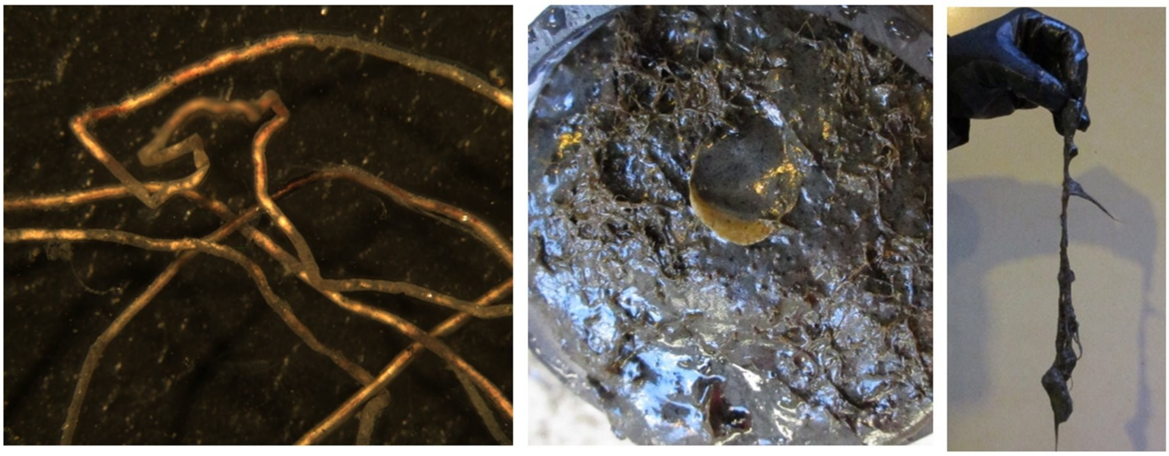

Figure 44. From left to right: Siboglinid worms in their tubes, isolated from the sediment, surface sediment with hair-like worms visible at the surface and a mat of worms, pulled from anoxic sediments. Illustration images from another area by Sabine Cochrane, Akvaplan-niva.

Zooplankton: The zooplankton communities sampled were rich, both in terms of species present, abundances and biomass. The organisms collected were largely comprised of pelagic crustaceans (see Figure 45 and Figure 46, text and images), but some gelatinous plankton and juvenile fish also appeared.

Figure 45. Zooplankton sample collected during the cruise. The large orange shrimps are euphausid krill, the rounded orange gammarid amphipods likely are Apherusa (or similar) and the transparent shrimp-like organisms with large black eyes are Themisto, all of which are typical in Barents Sea/Arctic waters. Barely visible at higher zoom are three species of Calanus copepods, typical in areas where Arctic and Atlantic water masses mix. Photo by Daniel Albert, SINTEF/ GoNorth.

Figure 46. Copepods - the lipid-rich Arctic *Calanus hyperboreus*, oceanic *Calanus glacialis* and the smallest Atlantic *Calanus finmarchicus*. Images by Malin Daase (left) and Fisheries and Oceans Canada / Jean-François St-Pierre, CC-BY-SA, source: Wikipedia (right).

<u>Ice algae:</u> Ice-algae were clearly, although patchily, observed on the underside of ice, overturned as the ship passed through it (Figure 47). There was little visible sign of ice algae on the underside of the cores drilled from the ice, likely due to small sample size and random location.

The single-celled alga (tentatively identified as *Phaocystis pouchetti*) was abundantly evident. This species is typical in Arctic waters and can be found both in sea ice as well as in open water at the beginning of the spring bloom. In addition, a variety of silicate diatoms were found in the sea ice.

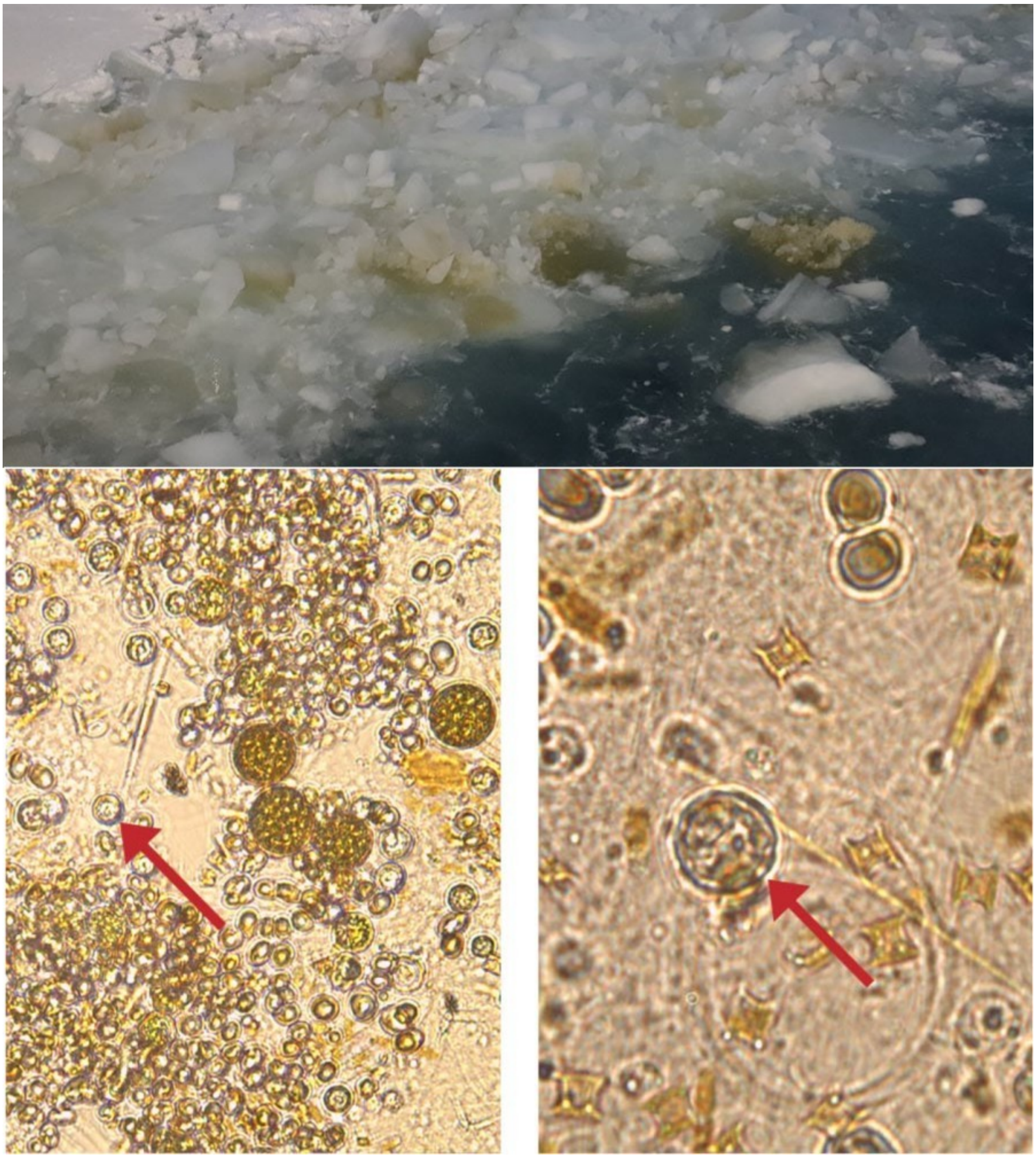

Figure 47: Broken ice, showing the presence of brownish ice-algae (upper). Light microscope image of ice algae collected from the underside of sea ice broken into pieces by the ship (bottom). The round cell (likely Phaeocystis pouchetii) indicated by the red arrow is less than 1/1000th of a millimetre (micron). The rod-like and cylinder-like organisms are diatoms. Photos by Sabine Cochrane, Akvaplan-niva.

5.2.7.3 Video observations

Video observations were made during the ROV-operations for deploying and retrieving seismic transmitters, and at one deep location (while waiting on weather) we also were able to deploy the ROV for a visual reconnaissance of the sea floor.

Generally, the entire area was characterised by very fine silt/muddy sediments, with occasional large organisms appearing on the surface (or in the water column). There were some holes and small tracks on the sediment surface, indicating the existence of macrofauna buried within the sediments.

Some illustrations are given below (Figures 48 to Figure 50; all images taken by the ROV team onboard the cruise):

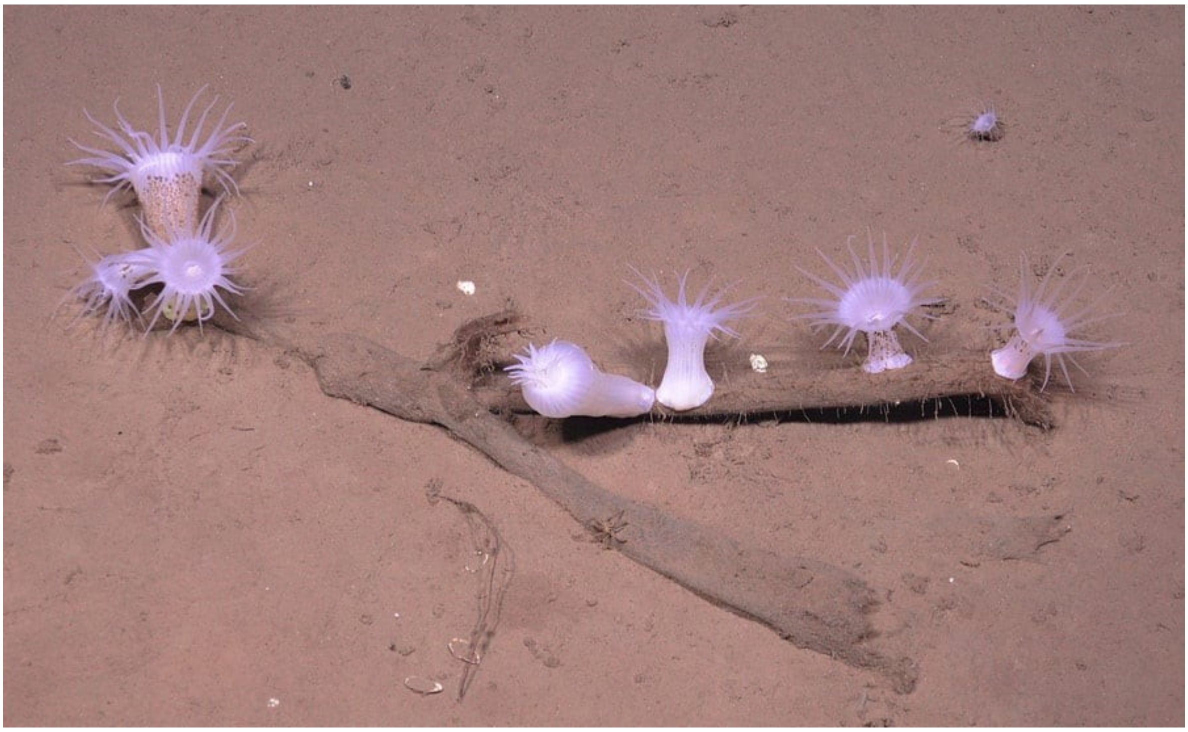

Figure 48. Soft bottom sediments, with some debris (pieces of vegetation?), providing a substrate for sea-anemones. Photo by Ægir 6000/NORMAR.

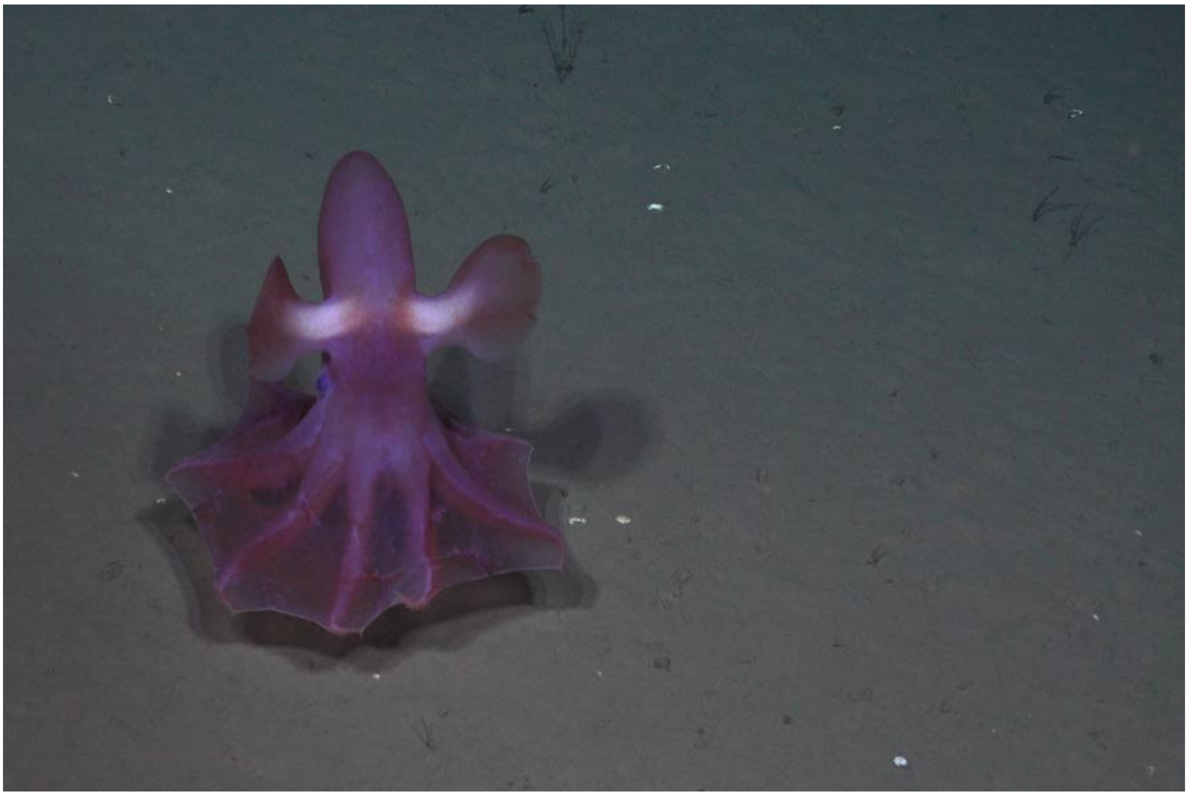

Figure 49. The charismatic Grimpoteuthis, a member of the family of pelagic umbrella octopuses, colloquially known as "Dumbo octopuses", so nick-named due to their resemblance to Disney's Dumbo elephant, on account of its large, ear-like fins. Photo by Ægir 6000/NORMAR.

Figure 50. An unidentified organism on a drop-stone, most resembling a stalked form of sponge. Photo by Ægir 6000/NORMAR.

5.2.7.3. Acknowledgements

We would like to thank in particular Gunnar Sand from SINTEF for being the primary motor behind GoNorth and "making it all possible". Also, thanks to Salve Dahle and Stig Falk Petersen for their role in having an ecology component incorporated within the program. We thank cruise leader Jan Sverre Laberg and co-leaders Tom Arne Rydningen and Alexander Minakov for excellent coordination. Thanks to many co-participants for collaboration and useful discussions. Last but by no means least, we are deeply appreciative of the facilities and operational support provided by the captain and crew of RV Kronprins Haakon.

6. Summary

During Leg 1 of the first GoNorth cruise the following data were acquired:

- Refraction seismic line T1, 242 km in length, using 24 OBS deployed on the sea floor in water depths from ~150–3700 m,
- Multichannel reflection seismic lines L3 and L9B, 156 km, and 141 km long, respectively,
- Sea water samples at 10 stations,
- Continuous measurements of the climate gas methane, identifying known and unknown areas of elevated values,
- Sediment sampling using Multi corer, Box corer, Push corer, Grab, and/or Gravity corer, including 59 samples for DNA analyses, 9 for biomarker analyses and 9 for palynology,
- 2 sea ice stations for in situ measurements and sampling of sea ice (first- and second-year ice), and sea ice fauna,
- Collection of data on marine icing, and geo-tagged sea ice information including optical images and ice-radar recordings,
- 4 stations for plankton sampling using various types of net (10 samples in total),
- Video/still photos of the sea floor, its flora and fauna at ~3800 m water depth in the Arctic Ocean, and
- A Lander (sea floor steel rig) and a Glider (AUV) were deployed and tested for about 14 days before recovered.

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GoNorth
GEOSCIENCES IN THE NORTHERN ARCTIC

LEG 2

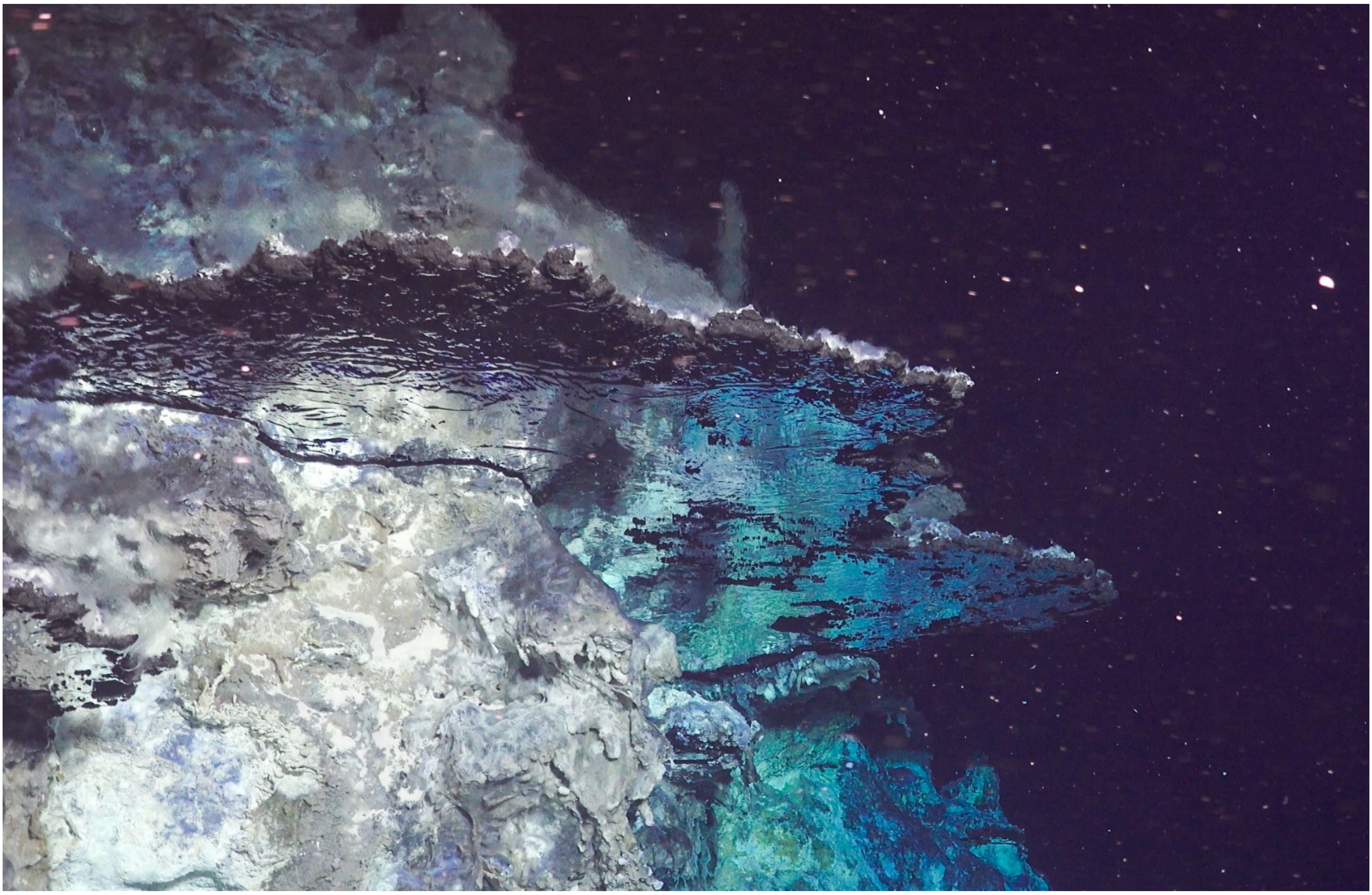
Part 2

Cruise report 2022

Knipovich Ridge 4–19 November

Norwegian Petroleum Directorate

Centre for Deep Sea Research



GoNorth
GEOSCIENCES IN THE NORTHERN ARCTIC

CENTRE FOR DEEP SEA RESEARCH

NORWEGIAN PETROLEUM DIRECTORATE

Front page image: Jøtul vent field. Picture: Centre for Deep Sea Research.

1. Introduction and background

The Norwegian Government has decided to initiate an opening process for mineral activities on the Norwegian continental shelf.

The Norwegian Petroleum Directorate has been tasked by the Ministry of Petroleum and Energy (MPE) to map the most commercially interesting mineral deposits on the Norwegian continental shelf.

The main objective of the cruise is to map the geology and morphology of the Knipovitch ridge and the area west of the spreading ridge. The data will be included in the NPD database for Seabed minerals and be included in the NPD resource evaluation of Seabed minerals

The cruise was funded by the Norwegian Petroleum Directorate and University of Bergen and made possible through a cooperation with the GoNorth project.

2. Operations

The cruise started in Longyearbyen on November 4, and demobilized in Tromsø on November 19.

The cruise on board the RV Kronprins Haakon aimed at further exploration of the northernmost part of the Knipovich Ridge and surrounding flanking areas. The cruise had two main objectives:

- Locate, map, and sample hydrothermal vent fields and mineral deposits
- Investigate, map and sample off-axis seamounts to study manganese crust

The cruise started at the newly discovered Jøtul vent field at 77.2° N. We started with ROV mapping of the entire area to get a better overview of the geology in the area. Several interesting features observed in the bathymetry and water column data were investigated. We located in total 4 areas of active venting, both focused and diffuse. In between, we found inactive hydrothermal mounds and piles of pillow lavas. Samples of rocks, sediments, biology, and fluids was collected from various locations. We also measured the temperature of two active smokers and left a temperature logger in the most active one, leaving it for next year.

The next part of the cruise was dedicated to investigating manganese crust on the Hovgaard Ridge and an off-axis seamount on the western flank of the rift valley. Ship based multibeam echo sounder was used to map the selected areas before slope-maps was used to find the steepest cliffs for diving. Several ROV dives was completed to locate manganese crust, estimate the thickness, and collect samples of both crusts and underlaying substrate.

Next, we headed back into the rift valley to a young lava field at 76.8N. Earlier cruises had reported potential signs of hydrothermal activity in the area. We investigated the area with our ROV and discovered beautiful fresh lavas and finally (after 25 years) discovered three small hydrothermal fields consisting of inactive chimneys and some active low-temperature areas. We collected rock samples of basalts and hydrothermal material, collected two sediment cores, and measured the temperature of the fluids.

The last part of the cruise was again dedicated to manganese crust a bit further south. Here, we mapped a potential off-axis lava field with the ship before diving with the ROV confirming thick manganese crust. We than moved even further south to the East Greenland Ridge for the first ever ROV sampling of this extinct transform fault.

Thank you very much to everyone who contributed to this report. Thanks to all the scientists and students, NPD, ROV pilots and to all the crew members on RV Kronprins Haakon.

3. RV Kronprins Haakon

The research vessel Kronprins Haakon has been built to operate in challenging ice conditions and can go further north and south than any other Norwegian research vessel. It is equipped with the very latest high-tech equipment, enabling us to perform more complex studies. The ship has a total length of 100 m and weighs above 10.000 tons.

RV Kronprins Haakon has a cruising speed of 15 knots and can break through ice up to one meter thick. Kronprins Haakon represents a state-of-the-art for research vessels. More details about the ship can be found here:

https://kronprinshaakon.hi.no/en/projects/kronprins-haakon/about-the-vessel/world-class-vessel

4. The Remotely Operated Vehicle (ROV) Ægir 6000

The ROV Ægir 6000 is a Kystdesign working class vehicle connected to a Kystdesign tether management system (TMS) capable of submerging down to 6000 m. It is equipped with one ATLAS manipulator and one Schilling T4 manipulator, telemetry sensors, 4 horizontal and 3 vertical thrusters, a high precision positioning system, one HD camera, and one 4K camera. Scientific equipment used during ROV operations include: a multi-beam echo sounder for high-resolution mapping, manipulators for rock sampling, grinder/diamond saw for cutting and sampling of rocks, push cores for sediment collection, one temperature probe for hot fluids and 2 titanium fluid samplers for collection of hydrothermal fluids.

In collaboration with TechnipFMC we tested a newly developed drilling rig for core sapling of manganese crust in steep areas. The rig is driven by the hydraulic engine on Ægir. A large thruster pushes the rig into the cliffs to holds its position independently of the ROVs manipulators. Diamond drill bits are used to drill cores up to 35 cm.

4.1 Positioning

Positioning of the ROV is obtained from a combination of: (1) a High Precision Acoustic Positioning system (HiPAP), (2) a Doppler Velocity Logger, and (3) an Inertial Navigation System. The HiPAP system uses the ship’s GPS position and a transducer that receives acoustic signals from transponders mounted on the ROV and TMS. The Doppler system gives additional information on the direction in which the ROV is moving and its speed. A gyroscope and an accelerometer in the Inertial Navigation System provide information on 9 rotation, velocity, altitude, and horizontal position. This combination of systems provides a position of the ROV within 5–20 m accuracy.

4.2 Cameras

Ægir 6000 is equipped with one pan-and-tilt HD camera for video recording, positioned at the centre and top of the ROV. The centre camera is a 4K camera. LED lights provide adequate background lighting.

4.3 Multibeam echo sounder

ROV Ægir 6000 is equipped with an EM2040-07 from Kongsberg Maritime, a single head multibeam echo sounder mounted in the back draw. The ROV is also equipped with a SeaNav 300 GPS and antenna. ROV Ægir 6000 operates at frequencies of 200–400 KHz. The multibeam surveys were performed at an altitude of about 40 m above the seafloor with a speed of 0.25–0.5 m/s. The raw bathymetry data were processed on board.

5. Seafloor mapping

5.1 Objectives

Mapping of large structure on the seafloor was done using the ship-based echo sounder to obtain higher resolution than on the already existing maps. Bathymetrical maps is key to understand the geology of various seafloor structured and to plan further investigation of selected sub-areas. During transit, the multibeam system was continuously recording bathymetry.

ROV surveys were conducted to gather detailed information about the seafloor. Knowing the topography of an area with a resolution of up to 0.5 m makes it possible to interpret small geological features at the seafloor. In addition, these maps are essential when planning ROV dives and to navigate during ROV surveys.

5.2 Equipment

5.2.1. Ship-based multibeam echo sounder

The RV Kronprins Haakon is equipped with an EM302 multibeam echo sounder capable of mapping a swath width up to 3.5 times the water depth with a resolution of up to 25 m.

ROV surveys were performed using a EM2040-07 from Kongsberg Maritime, a single head multibeam echo sounder mounted in the back drawer of Ægir6000.

5.3 Processing

The *NaviPack* software package were used to process the collected echo sounder data in a three-step process. Firstly, *NaviEdit* was utilized to preprocess the data files so they could be imported into NaviModel. The data files were always imported into NaviEdit and depending on if they were from the ROV or the hull mounted echo sounder they were processed accordingly. If from the ROV the pitch, roll and heading were changed to fit according to the placement of the multibeam on the ROV, whereas for the hull mounted echosounder this was not needed. Secondly, the data were cleaned in *NaviModel*, and the ROV track and coordinates of the sampling locations, were added to the map. Then it was grided and exported with the bathymetry and contour lines. Thirdly, to create the final map the contour lines and the DTM were added to *NaviPlot*, and then a scale bar, north arrow, title, and any other information needed were added. Also, maps with ROV tracks and rock samples was produced for each dive.

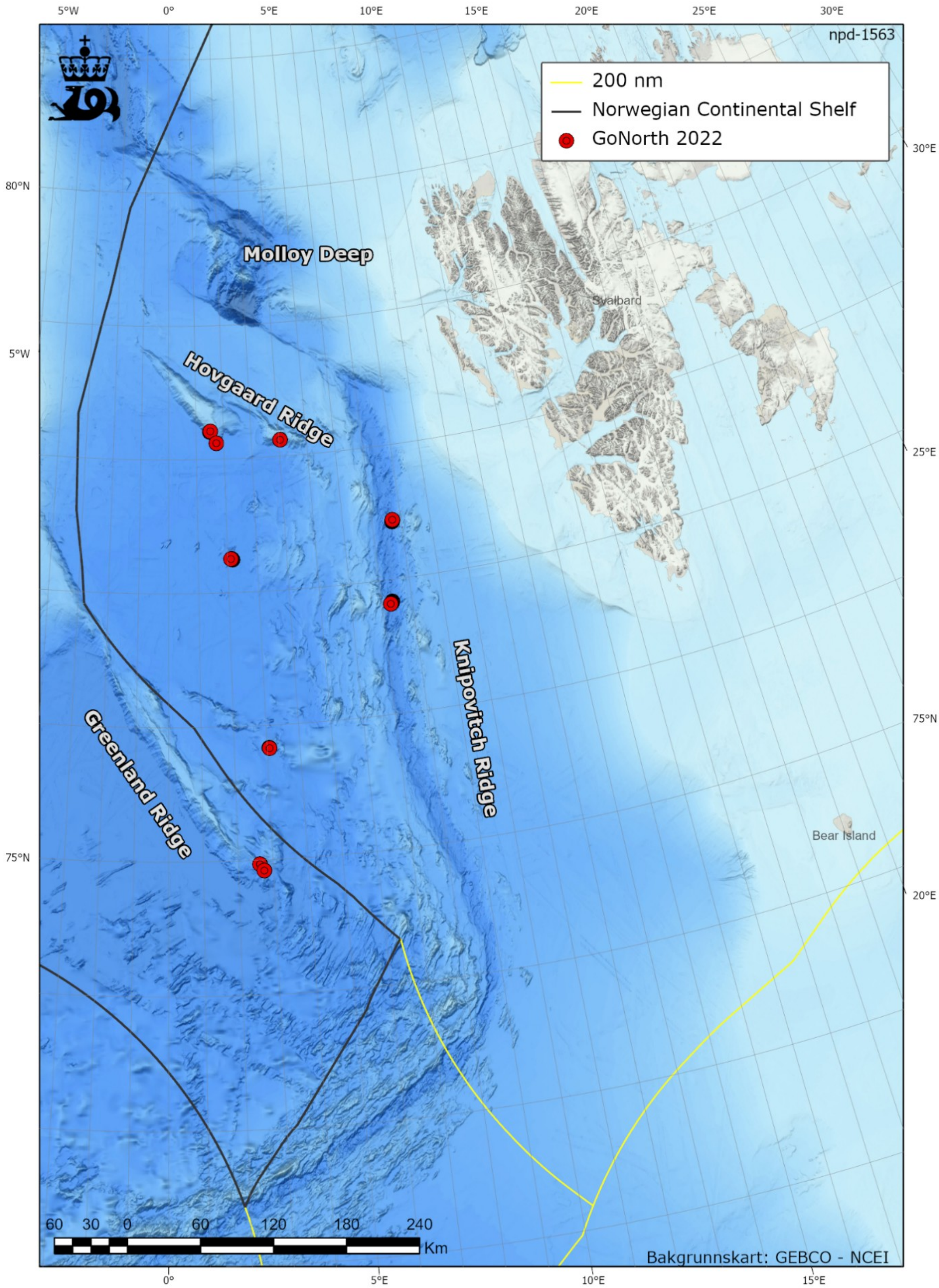


Figure 51. Overview map of surveyed areas.

6. List of participants

Name	Role
Jan Sverre Laberg	Professor, UiT, Cruise leader
Rolf Birger Pedersen	Professor, UiB
Ingunn Thorseth	Professor, UiB
Sissel H. Eriksen	Project coordinator, NPD
Sabina S. Palinkas	Associate professor, UiT/UiB
Pedro Ribeiro	Researcher in deep-sea biology, UiB
Mauro Passarella	Postdoc, UiB
Eszter Sendula	Postdoc, UiT
Håvard H. Stubseid	PhD candidate, UiB
Ingvild Aarrestad	PhD candidate, UiB
Maja Jæger	Master student, UiB
Thilde Voje	Master student, UiB
Eirik Siira	Master student, UiB
Eirik Valdar	Master student, UiB
Marco Micheel	Surveyor, Freelance
Anna Aase	Master student, UiB
Frode Evensen	ROV pilot, BSA
Eyvind Ernstsen	ROV pilot, HI
Jonas Broberg	ROV pilot, DWS
Kai Roger Loven	ROV pilot, DWS
Johan Skøld	ROV pilot, Saga subsea
Bjørn Løfquist	ROV pilot, Saga subsea
Simen Rønne	Engineer, TechnipFMC

Figure 52. Picture of scientific personnel when back onshore in Tromsø, Norway.

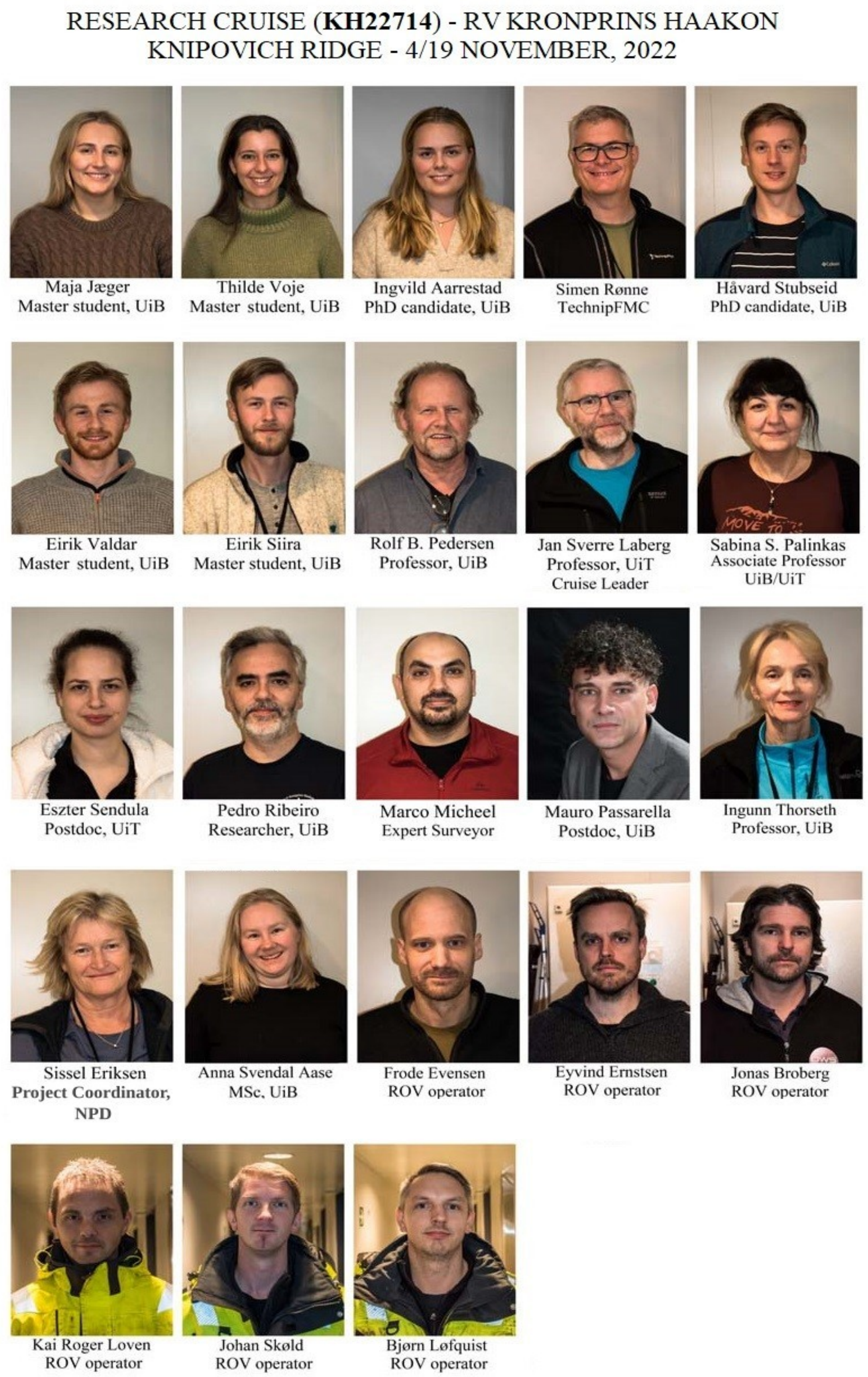


Figure 53: Cruise participant photos. Photos by Mauro Passarella.

Appendices (LEG 1)

Appendix 1. Overview of stations and activities during the GoNorth cruise leg 1. Not including seismic reflection and refraction profiles.

Super-Station	Gravi-ty Core	Box Core	Multi Core	Grab	Push Core (ROV)	Plank-ton Nets	Glider	Lander	ROV	CTD	Ice Sam-ple	Sea Ice Station
GoNorth-L1-1			x							x		
GoNorth-L1-2			x	x		x	x	x		x		
GoNorth-L1-3											x	
GoNorth-L1-4											x	
GoNorth-L1-5	x	x	x			x				x		
GoNorth-L1-6												x
GoNorth-L1-7					x							
GoNorth-L1-8					x							
GoNorth-L1-9	x	x	x			x				x		
GoNorth-L1-10			x			x				x		
GoNorth-L1-11			x						x	x		
GoNorth-L1-12												x
GoNorth-L1-13			x									
GoNorth-L1-14			x									
GoNorth-L1-15			x									

Appendix 2. Position and water depth for all Superstations. All position and water depths refer to the first activity on the station. See respective tables for detailed positions of other activities.

Superstation	Latitude (deg. N)	Longitude (deg. E)	Water depth (m)
GoNorth-L1-1	80.95	23.76	276
GoNorth-L1-2	80.733	28.573	196
GoNorth-L1-3	82.41	26.256	3877
GoNorth-L1-4	82.345	26.305	3850
GoNorth-L1-5	81.607	27.83	2036
GoNorth-L1-6	82.226	26.691	3825
GoNorth-L1-7	82.228	26.566	3802
GoNorth-L1-8	82.267	26.559	3804
GoNorth-L1-9	81.693	27.664	2543
GoNorth-L1-10	81.39	26.94	809
GoNorth-L1-11	82.312	20.868	3748
GoNorth-L1-12	82.51	17.503	541
GoNorth-L1-13	81.392	23.173	3950
GoNorth-L1-14	81.311	18.973	543
GoNorth-L1-15	80.464	11.472	642

Appendix 3. Full station table with station locations and gear used. All position and water depths refer to the start of the activity on the station. See tables for respective activities for more details.

Super-Station	Station Name	KH Station Name	Gear Type	Lat. (deg. N)	Lon. (deg. E)	Water depth (m)	Date	Start time	Notes
-	GoNorth1-KH22-SSW-01		Surface water sample	78,448	10.642	-	16.10.2022	06:58	
-	GoNorth1-KH22-Sewage-01		Ship sewage sample	-	-	-	16.10.2022	14:10	
-	GoNorth1-KH22-SSW-02		Surface water sample	80,937	22994	-	17.10.2022	03:20	
GoNorth-L1-1	GoNorth1-KH22-01-ASW1	CTD med vannhenter 298	CTD	80,950	23.760	276.18	17.10.2022	04:06:20	Three bottles on the CTD imploded (!). They will not be replaced for the upcoming CTDs. Water combined to sample GoNorth1-KH22-01-ASW1.
GoNorth-L1-1	GoNorth1-KH22-01-ASW1	CTD med vannhenter 299	CTD	80,949	23.758	274.17	17.10.2022	04:50:16	
GoNorth-L1-1	GoNorth1-KH22-01-ASW1	CTD med vannhenter 300	CTD	80,949	23.758	274.31	17.10.2022	05:19:20	
GoNorth-L1-1	GoNorth1-KH22-01-ASW1	CTD med vannhenter 301	CTD	80,949	23.758	274.20	17.10.2022	05:47:30	
GoNorth-L1-1	GoNorth1-KH22-01-ASW1	CTD med vannhenter 302	CTD	80,949	23.758	274.23	17.10.2022	06:13:13	
GoNorth-L1-1	GoNorth1-KH22-01-MC1	Multicorer 28	Multi corer	80,949	23.758	274.28	17.10.2022	06:24:38	Successful recovery of 4 tubes with ca. 46 cm sediment.
GoNorth-L1-2	GoNorth1-KH22-Lander deployment	Lander deployment 249	Lander	80,733	28.573	196.06	17.10.2022	12:18:53	Successful lander deployment
GoNorth-L1-2	GoNorth1-KH22-Glider deployment	Glider Deployment 250	Gliders	80,716	28.931	545.27	17.10.2022	13:29:11	Glider deployed, but initial check showed issue with plankton sensor. Glider in recovery mode, issue corrected from small boat and re-launched. Subsequent checks showed instrumentation functioning correctly.
GoNorth-L1-2	GoNorth1-KH22-02-MC1	Multicorer 29	Multi corer	80,717	28.931	545.47	17.10.2022	13:56:04	Successful recovery of 4 tubes with ca. 48 cm sediment.
GoNorth-L1-2	GoNorth1-KH22-02-MC2	Multicorer 30	Multi corer	80,716	28.932	545.15	17.10.2022	14:30:28	No recovery. All tubes broke off. No recovery. The winch cable got stuck on the top part of the piston
GoNorth-L1-2	GoNorth1-KH22-02-MC3	Multicorer 31	Multi corer	80,716	28.932	545.34	17.10.2022	15:16:05	Successful recovery of 4 tubes with ca. 45 cm sediment.
-	OBS deployment 251	OBS deployment 251	OBS (GEUS)	80,791	29.238	458.35	17.10.2022	17:39:42	
-	OBS deployment 252	OBS deployment 252	OBS (GEUS)	80,882	29.093	411.69	17.10.2022	18:33:17	
-	OBS deployment 253	OBS deployment 253	OBS (GEUS)	80,972	28.947	387.09	17.10.2022	19:14:45	
-	ROV 60	ROV 60	ROV + OBS (UiB)	81.016	28.876	366.28	17.10.2022	19:55:27	
-	OBS deployment 254	OBS deployment 254	OBS (GEUS)	81.063	28.798	327.41	17.10.2022	21:38:38	
-	ROV 61	ROV 61	ROV + OBS (UiB)	81.108	28.734	303.90	17.10.2022	22:10:55	
-	OBS deployment 255	OBS deployment 255	OBS (GEUS)	81.153	28.646	259.17	17.10.2022	23:32:53	
-	ROV 62	ROV 62	ROV + OBS (UiB)	81.198	28.569	210.92	18.10.2022	00:05:09	
-	OBS deployment 256	OBS deployment 256	OBS (GEUS)	81.243	28.491	184.15	18.10.2022	01:17:18	

Super-Station	Station Name	KH Station Name	Gear Type	Lat. (deg. N)	Lon. (deg. E)	Water depth (m)	Date	Start time	Notes
-	ROV 63	ROV 63	ROV + OBS (UiB)	81.287	28.413	-	18.10.2022	01:49:13	Wrong water depth from Seatrack (KH-system): 1724.58 m is recorded.
-	OBS deployment 257	OBS deployment 257	OBS (GEUS)	81.333	28.332	149.20	18.10.2022	03:02:57	
-	ROV 64	ROV 64	ROV + OBS (UiB)	81.379	28.250	147.86	18.10.2022	03:44:35	
-	OBS deployment 258	OBS deployment 258	OBS (GEUS)	81.423	28.170	367.44	18.10.2022	04:50:45	
-	OBS deployment 259	OBS deployment 259	OBS (GEUS)	81.469	28.089	862.04	18.10.2022	05:21:16	
-	OBS deployment 260	OBS deployment 260	OBS (GEUS)	81.514	28.005	1286.51	18.10.2022	05:58:08	
-	OBS deployment 261	OBS deployment 261	OBS (GEUS)	81.560	27.921	1668.89	18.10.2022	06:22:48	
-	OBS deployment 262	OBS deployment 262	OBS (GEUS)	81.603	27.837	2017.85	18.10.2022	06:46:19	
-	OBS deployment 263	OBS deployment 263	OBS (GEUS)	81.693	27.665	2540.55	18.10.2022	07:29:57	
-	GoNorth1-KH22-SSW-03	-	Surface water sample	81.694	27.668	-	18.10.2022	07:32	
-	OBS deployment 264	OBS deployment 264	OBS (GEUS)	81.783	27.488	2889.06	18.10.2022	08:13:11	
-	OBS deployment 265	OBS deployment 265	OBS (GEUS)	81.873	27.308	3135.63	18.10.2022	08:52:35	
-	OBS deployment 266	OBS deployment 266	OBS (GEUS)	81.963	27.125	3377.19	18.10.2022	09:31:19	
-	OBS deployment 267	OBS deployment 267	OBS (GEUS)	82.052	26.937	3555.11	18.10.2022	10:12:52	
-	OBS deployment 268	OBS deployment 268	OBS (GEUS)	82.142	26.745	3679.32	18.10.2022	10:57:27	
-	ROV 65	ROV 65	ROV + OBS (GEUS)	82.234	26.479	-	18.10.2022	12:41:53	No water depth in Seatrack (from KH-system).
-	GoNorth-2022-T1	Refraction Seismic 269	Refraction Seismic	82.466	26.030	3901.46	20.10.2022	08:10:53	No shooting from 10:33 to 11:15 due to repairs at airgun array (air leakage)
GoNorth-L1-3	GoNorth1_KH22 L1-3 ice piece 1	Ice sample from side of vessel 270	Ice sample from side of vessel	82.410	26.256	3877.06	20.10.2022	10:00:00	Ice piece selected where likely algae observed
-	GoNorth-2022-T1	Refraction Seismic 271	Refraction Seismic	82.428	26.108	3890.67	20.10.2022	11:26:50	No shooting from 12:35 to 14:54 due to repairs at airgun array (broken cables)
GoNorth-L1-4	GoNorth1 KH22 L1-4 ice piece 2	Ice sample from side of vessel 272	Ice sample from side of vessel	82.345	26.305	3850.78	20.10.2022	13:48:51	Ice piece selected where likely algae observed
-	GoNorth-2022-T1	Refraction Seismic 273	Refraction Seismic	82.356	26.274	3854.02	20.10.2022	14:51:16	
-	GoNorth1-KH22-SSW-04		Surface water sample	81.620	27.806	-	21.10.2022	09:58	
GoNorth-L1-5	-	CTD med vannhenter 303	CTD	81.607	27.830	2036.12	21.10.2022	03:03:38	Calibration of acoustic systems.
GoNorth-L1-5	GoNorth1_KH22_05_MC1	Multicorer 32	Multi corer	81.607	27.830	2038.83	21.10.2022	04:19:03	
-	GoNorth-2022-T1	Reflection Seismic 274	Refraction Seismic	81.626	27.793	2149.16	21.10.2022	09:51:59	Start-up refraction seismic; UiB system.
-	GoNorth-2022-T1	Reflection Seismic 275	Refraction Seismic	80.934	29.005	385.94	21.10.2022	23:54	Continuing refraction seismic; UiB system. One of the KH-compressors failed. We could only use 3 airguns (planned to use 4), due to i) issues with failed compressor, ii) cables to the instrument room, and iii) separation issues with the deployed acquisition system.

Super-Station	Station Name	KH Station Name	Gear Type	Lat. (deg. N)	Lon. (deg. E)	Water depth (m)	Date	Start time	Notes
-	GoNorth1-KH22-SSW-05		Surface water sample	80.672	29.421	-	22.10.2022	06:03	
-	OBS recovery 276	OBS Recovery 276	-	80.792	29.261	452.61	22.10.2022	11:59:53	OBS recovery from ship. Some issues with transmitting of signal to OBS. The problem was solved.
-	OBS recovery 277	OBS Recovery 277	-	80.972	28.941	380.36	22.10.2022	16:43:59	OBS recovery from ship.
-	ROV 66	ROV 66	ROV	81.016	28.875	359.88	22.10.2022	17:18:00	OBS recovery by ROV.
-	OBS recovery 278	OBS Recovery 278	-	81.062	28.786	319.73	22.10.2022	18:25:52	OBS recovery from ship.
-	ROV 67	ROV 67	ROV	81.108	28.735	295.42	22.10.2022	19:25:46	OBS recovery by ROV.
-	OBS recovery 279	OBS Recovery 279	-	81.152	28.638	-	22.10.2022	20:29:47	OBS recovery from ship. No water depth in Seatrack (from KH-system).
-	ROV 68	ROV 68	ROV	81.197	28.569	209.17	22.10.2022	21:28:48	OBS recovery by ROV.
-	GoNorth1-KH22-SSW-06	-	Surface water sample	81.109	28.742	-	22.10.2022	22:03	
-	OBS recovery 280	OBS Recovery 280	-	81.242	28.482	182.26	22.10.2022	22:25:57	OBS recovery from ship.
-	ROV 69	ROV 69	ROV	81.287	28.413	169.87	23.10.2022	00:26:42	OBS recovery by ROV.
-	OBS recovery 281	OBS Recovery 281	-	81.333	28.316	148.62	23.10.2022	01:27:27	OBS recovery from ship.
-	ROV 70	ROV 70	ROV	81.379	28.250	147.40	23.10.2022	02:23:43	OBS recovery by ROV.
-	OBS recovery 282	OBS Recovery 282	-	81.425	28.185	357.02	23.10.2022	04:06:06	OBS recovery from ship.
-	OBS recovery 283	OBS Recovery 283	-	81.473	28.122	874.45	23.10.2022	05:15:47	OBS recovery from ship.
-	OBS recovery 284	OBS Recovery 284	-	81.516	28.045	1291.46	23.10.2022	06:30:54	OBS recovery from ship.
-	OBS recovery 285	OBS Recovery 285	-	81.560	27.944	1702.36	23.10.2022	07:42:58	OBS recovery from ship.
-	OBS recovery 286	OBS Recovery 286	-	81.603	27.858	1996.89	23.10.2022	08:59:54	OBS recovery from ship.
-	OBS recovery 287	OBS Recovery 287	-	81.692	27.681	2535.11	23.10.2022	10:44:35	OBS recovery from ship.
-	OBS recovery 288	OBS Recovery 288	-	81.785	27.480	-	23.10.2022	11:29:31	OBS recovery from ship. No water depth in Seatrack (from KH-system).
-	ROV 71	ROV 71	-	81.873	27.322	-	23.10.2022	13:59:04	OBS recovery by ROV. No water depth in Seatrack (from KH-system).
-	ROV 72	ROV 72	ROV	81.963	27.125	3373.67	23.10.2022	19:39:57	
GoNorth-L1-6	GoNorth-2022-S1	-	Sea ice station	82.226	26.691	-	24.10.2022	07:48	Second-year ice, 10 cores, 24 borehole jack tests.
-	ROV 73	ROV 73	ROV	82.233	26.597	3792.80	24.10.2022	12:47:23	OBS recovery by ROV.
GoNorth-L1-7	GoNorth1_KH22_07_PC1	-	Push core (ROV)	82.228	26.566	3802,6	24.10.2022	14:21:26	ROV Dive 594 on 24.10
GoNorth-L1-8	GoNorth1_KH22_08_PC1	-	Push core (ROV)	82.267	26.559	3804,9	24.10.2022	14:37:56	ROV Dive 594 on 24.10
-	ROV 74	ROV 74	ROV	82.158	26.818	3712.82	24.10.2022	18:23:33	
-	ROV 75	ROV 75	ROV	82.151	26.797	3685.17	24.10.2022	23:19:38	Second dive (for OBS GEUS 18).
-	ROV 76	ROV 76	ROV	82.063	27.036	3571.36	25.10.2022	04:34:01	OBS recovery by ROV.
GoNorth-L1-9	GoNorth1-KH22-09-ASW2	CTD med vannhenter 304	CTD	81.693	27.664	2543.61	25.10.2022	12:00:29	CTD med vannhenter 304-309, water combined into sample GoNorth1-KH22-09-ASW02

Super-Station	Station Name	KH Station Name	Gear Type	Lat. (deg. N)	Lon. (deg. E)	Water depth (m)	Date	Start time	Notes
GoNorth-L1-9	GoNorth1-KH22-09-ASW2	CTD med vannhenter 305	CTD	81.693	27.665	2530.10	25.10.2022	14:08:24	
GoNorth-L1-9	GoNorth1-KH22-09-WP3-1	Håv 90	Plankton net	81.693	27.665	2534.95	25.10.2022	14:23:38	
GoNorth-L1-9	GoNorth1-KH22-09-ASW2	CTD med vannhenter 306	CTD	81.693	27.664	-	25.10.2022	15:39:54	No water depth in Seatrack (from KH-system).
GoNorth-L1-9	GoNorth1-KH22-09-WP3-2	Håv 91	Plankton net	81.693	27.664	-	25.10.2022	15:59:49	No water depth in Seatrack (from KH-system).
GoNorth-L1-9	GoNorth1-KH22-09-ASW2	CTD med vannhenter 307	CTD	81.693	27.665	2527.18	25.10.2022	17:08:25	
GoNorth-L1-9	GoNorth1-KH22-09-MIK-1	Mik 92	Plankton net	81.693	27.664	2525.87	25.10.2022	17:26:20	
GoNorth-L1-9	GoNorth1-KH22-09-ASW2	CTD med vannhenter 308	CTD	81.693	27.664	2544.52	25.10.2022	18:51:40	
GoNorth-L1-9	GoNorth1-KH22-09-ASW2	CTD med vannhenter 309	CTD	81.693	27.664	2538.41	25.10.2022	19:28:42	
GoNorth-L1-9	GoNorth1-KH22-09-PPNET-1	Håv 93	Plankton net	81.693	27.664	2537.54	25.10.2022	19:52:20	
GoNorth-L1-9	GoNorth1_KH22_09_MC1	Multicorer 33	Multi corer	81.693	27.664	2536.86	25.10.2022	20:25:11	
GoNorth-L1-9	IG-22-4-KH-GoNorth-13-GC-01	Gravity core 13	Gravity corer	81.693	27.665	2533.35	25.10.2022	23:00:52	Core length: 292 cm.
GoNorth-L1-9	IG-22-4-KH-GoNorth-33-BC-01	Box core 34	Box corer	81.693	27.665	2546.40	26.10.2022	02:41:54	Subsamples UiT (push cores): IG-22-4-KH-GoNorth-33-BC-01-#1 (62 cm), IG-22-4-KH-GoNorth-33-BC-01 (60 cm). Subsamples SINTEF (surface sediment): GoNorth1-KH22-09-BC-01-SINTEF1, GoNorth1-KH22-09-BC-01-SINTEF2, GoNorth1-KH22-09-BC-01-SINTEF3)
GoNorth-L1-9	IG-22-4-KH-GoNorth-33-BC-02	Box core 35	Box corer	81.693	27.665	2544.33	26.10.2022	06:29:02	Subsamples SINTEF (surface sediment): GoNorth1-KH22-09-BC-02-SINTEF1, GoNorth1-KH22-09-BC-02-SINTEF2, GoNorth1-KH22-09-BC-02-SINTEF3)
GoNorth-L1-5	IG-22-4-KH-GoNorth-14-GC-01	Gravity core 14	Gravity corer	81.607	27.830	2025.92	26.10.2022	10:00:09	Gravity core came up empty. No time for second attempt.
GoNorth-L1-5	GoNorth1-KH22-05-MIK-1	Mik 94	Plankton net	81.607	27.830	2071.14	26.10.2022	12:54:36	
GoNorth-L1-5	GoNorth1-KH22-05-PPNET-1	Håv 95	Plankton net	81.607	27.830	2031.88	26.10.2022	14:15:35	
GoNorth-L1-5	IG-22-4-KH-GoNorth-34-BC-01	Box core 36	Box corer	81.607	27.830	2036.05	26.10.2022	14:38:15	Subsamples UiT (push cores): IG-22-4-KH-GoNorth-34-BC-01#1 (60 cm), IG-22-4-KH-GoNorth-34-BC-01-#2 (60 cm). Subsamples SINTEF (surface sediment): GoNorth1-KH22-05-BC-01-SINTEF1, GoNorth1-KH22-05-BC-01-SINTEF2, GoNorth1-KH22-05-BC-01-SINTEF3)
-	GoNorth1-KH22-SSW-07	-	Surface water sample	81.607	27.830	-	26.10.2022	17:27	
GoNorth-L1-10	GoNorth1-KH22-10-ASW3	CTD med vannhenter 310	CTD	81.390	26.940	809.38	26.10.2022	18:11:42	Water from CTD 310-315 combined to sample GoNorth1-KH22-10-ASW3
GoNorth-L1-10	GoNorth1-KH22-10-MIK1	Mik 96	Plankton net	81.390	26.940	810.37	26.10.2022	18:53:57	
GoNorth-L1-10	GoNorth1-KH22-10-ASW3	CTD med vannhenter 311	CTD	81.390	26.940	811.21	26.10.2022	19:57:07	
GoNorth-L1-10	GoNorth1-KH22-10-ASW3	CTD med vannhenter 312	CTD	81.390	26.940	815.17	26.10.2022	20:22:14	
GoNorth-L1-10	GoNorth1-KH22-10-ASW3	CTD med vannhenter 313	CTD	81.390	26.940	814.33	26.10.2022	20:49:34	
GoNorth-L1-10	GoNorth1-KH22-10-ASW3	CTD med vannhenter 314	CTD	81.390	26.940	814.11	26.10.2022	21:17:30	

Super-Station	Station Name	KH Station Name	Gear Type	Lat. (deg. N)	Lon. (deg. E)	Water depth (m)	Date	Start time	Notes
GoNorth-L1-10	GoNorth1-KH22-10-ASW3	CTD med vannhenter 315	CTD	81.390	26.940	810.64	26.10.2022	21:43:51	
GoNorth-L1-10	GoNorth1_KH22_10_MC1	Multicorer 37	Multi corer	81.390	26.940	810.47	26.10.2022	21:58:52	
-	GoNorth-2022-L3	Reflection Seismic 289	Reflection seismic	80.970	21.843	145.20	27.10.2022	05:27:00	
-	GoNorth1-KH22-SSW-08		Surface water sample	80.975	22.328	-	27.10.2022	05:45	
GoNorth-L1-11	GoNorth1_KH22_11_MC1	Multicorer 38	Multi corer	82.312	20.868	3748.28	28.10.2022	04:15:24	Recovery of two distrubed tubes. Two tubes were broekn. Multicorer was dragged over seafloor - crew did not have the means to adequately assess the water depth (unclear echolot data). Combined with ice drift, this resulted in damaged tubes and recovery of distrubed sediments.
GoNorth-L1-11	GoNorth1-KH22-11-ASW4	CTD med vannhenter 316	CTD	82.327	20.809	3780.69	28.10.2022	06:40:04	Water from CTD 316-322 combined to sample GoNorth1-KH22-11-ASW4
GoNorth-L1-11	GoNorth1-KH22-11-ASW4	CTD med vannhenter 317	CTD	82.337	20.729	3752.93	28.10.2022	09:20:33	
GoNorth-L1-11	GoNorth1-KH22-11-ASW4	CTD med vannhenter 318	CTD	82.342	20.697	3785.94	28.10.2022	09:49:30	
GoNorth-L1-11	GoNorth1-KH22-11-ASW4	CTD med vannhenter 319	CTD	82.346	20.660	3778.86	28.10.2022	10:22:19	
GoNorth-L1-11	GoNorth1-KH22-11-ASW4	CTD med vannhenter 320	CTD	82.350	20.624	3721.83	28.10.2022	10:54:06	
GoNorth-L1-11	GoNorth1-KH22-11-ASW4	CTD med vannhenter 321	CTD	82.354	20.589	3756.28	28.10.2022	11:26:47	
GoNorth-L1-11	GoNorth1-KH22-11-ASW4	CTD med vannhenter 322	CTD	82.359	20.545	3760.54	28.10.2022	12:08:39	
-	ROV77	ROV 77	ROV	82.481	19.376	3860.01	29.10.2022	06:30:29	ROV dive for video and pictures.
GoNorth-L1-12	GoNorth-2022-S2	-	Sea ice station	82.51	17.503	-	30.10.2022	09:30:00	First-year ice, 17 cores, 18 borehole jack tests.
-	GoNorth1-KH22-SSW-09		Surface water sample			-	31.10.2022	00:35	
GoNorth-L1-2	GoNorth1_KH22 Lander recovery	Lander Recovery 290	Lander	80.736	28.565	158.80	31.10.2022	10:55:05	Successful recovery
GoNorth-L1-2	GoNorth1-KH22-02-ASW5	CTD med vannhenter 323	CTD	80.717	28.931	535.16	31.10.2022	12:01:24	Water from CTD 323-328 combined to sample GoNorth1-KH22-11-ASW4
GoNorth-L1-2	GoNorth1-KH22-02-ASW5	CTD med vannhenter 324	CTD	80.717	28.931	538.09	31.10.2022	12:43:40	
GoNorth-L1-2	GoNorth1-KH22-02-MIK1	Mik 97	Plankton net	80.717	28.931	538.41	31.10.2022	13:02:29	
GoNorth-L1-2	GoNorth1-KH22-02-ASW5	CTD med vannhenter 325	CTD	80.717	28.931	536.42	31.10.2022	13:46:05	
GoNorth-L1-2	GoNorth1-KH22-02-MIK2	Mik 98	Plankton net	80.717	28.931	538.74	31.10.2022	13:59:49	Cod bucket lost, sample lost
GoNorth-L1-2	GoNorth1-KH22-02-ASW5	CTD med vannhenter 326	CTD	80.715	28.931	540.45	31.10.2022	14:54:07	
GoNorth-L1-2	GoNorth1-KH22-02-PPNET1	Håv 99	Plankton net	80.715	28.931	537.65	31.10.2022	15:06:25	
GoNorth-L1-2	GoNorth1-KH22-02-ASW5	CTD med vannhenter 327	CTD	80.715	28.931	540.56	31.10.2022	15:20:32	
GoNorth-L1-2	GoNorth1_KH 22_02 Grab 1	Grabb 39	Grab	80.715	28.931	542.05	31.10.2022	15:34:53	overfilled, taken for sieving anyway
GoNorth-L1-2	GoNorth1-KH22-02-ASW5	CTD med vannhenter 328	CTD	80.715	28.931	543.15	31.10.2022	16:17:00	
GoNorth-L1-2	GoNorth1_KH 22_02 Grab 2	Grabb 40	Grab	80.715	28.931	542.04	31.10.2022	16:27:24	grab not released
GoNorth-L1-2	GoNorth1_KH 22_02 Grab 3	Grabb 41	Grab	80.715	28.931	542.37	31.10.2022	17:02:54	overfilled, taken for sieving anyway
GoNorth-L1-2	GoNorth1 KH_22_02 Grab 4	Grabb 42	Grab	80.715	28.931	542.09	31.10.2022	17:46:55	overfilled, taken for sieving anyway

Super-Station	Station Name	KH Station Name	Gear Type	Lat. (deg. N)	Lon. (deg. E)	Water depth (m)	Date	Start time	Notes
GoNorth-L1-2	GoNorth1_KH 22_12 Glider recovery	Glider Recovery 291	Glider	80.715	28.931	541.68	31.10.2022	18:20:17	Successful recovery
GoNorth-L1-13	GoNorth1_KH22_13_MC1	Multicorer 43	Multi corer	81.392	23.173	3950.87	01.11.2022	02:50:57	
GoNorth-L1-14	GoNorth1_KH22_14_MC1	Multicorer 44	Multi corer	81.311	18.973	543.18	01.11.2022	07:19:43	
-	GoNorth-2022-L9	Reflection seismic 292	Reflection seismic	81.295	18.773	543.31	02.11.2022	09:43:28	
GoNorth-L1-15	GoNorth1_KH22_15_MC1	Multicorer 45	Multi corer	80.464	11.472	642.20	02.11.2022	05:23:13	

Appendix 4. Stations and Superstations where water sampling was done.

Date	Start Time (UTC)	Stop Time (UTC)	Super-Station	Station Name	Lat. (deg. N)	Lon. (deg. E)	Depth (m)	Volume (L)	Notes (in Norwegian)
16.10.2022	06:58	07:30	-	GoNorth1-SSW-1	78.4482	10.6417	4	620	Prøve tatt av overflatevann (4 m) under seiling, vest for Ny Ålesund. Første test
16.10.2022	14:10	-	-	GoNorth1-Sewage-01	79.5838	10.0356	-	0.75	Prøve tatt av renset kloakk. 3x250 ml
17.10.2022	03:20	03:49	1	GoNorth1-SSW-02	80.9012	20.8425	4	600	Prøve tatt av overflatevann (4m) under innseiling til superstasjon 1
17.10.2022	04:13	-	1	GoNorth1-1-ASW-01	80.94976	23.7597	110	470	Prøve tatt med CTD-rosett ved Superstasjon 1. 5 CTD-kast (CTD 298-302)
18.10.2022	07:32	08:00	9	GoNorth1-SSW-03	81.69412	27.6682	4	600	Overflatevann tatt mellom GEUS13 og GEUS14 under transekt T1
18.10.2022	07:52	-	-	GoNorth1-Lense-01	81.5126	28.0102	-	0.25	Lensevann pumpet ut over skuteside babord. Kan inneholde surfaktanter
21.10.2022	09:58	10:28	-	GoNorth1-SSW-04	81.61987	27.80575	4	60	Overflatevann tatt etter bytte til Bergen seismikk. Nær Multicorer 32
22.10.2022	06:03	06:32	2	GoNorth1-SSW-05	80.6715	29.4212	4	600	Overflatevann tatt under seismikk, mulig litt forbi (sør for) Superstasjon 2
22.10.2022	22:03	23:59	-	GoNorth1-SSW-06	81.1089	28.7422	4	610	Overflatevann tatt under seismikk.Omtrent midt på T1 linjen
25.10.2022	14:00	-	-	GoNorth1-Sewage-02	81.6933	27.6644	-	0.75	Prøve tatt av renset kloakk. 3x250 ml
25.10.2022	14:10	-	9	KH2022-GoNorth1-09-Bottom	81.69331	27.66441	2551	5	Akvaplan NIVA
25.10.2022	14:10	-	9	KH2022-GoNorth1-09-Mid	81.69331	27.66441	180	5	Akvaplan NIVA
25.10.2022	14:10	-	9	KH2022-GoNorth1-09-Upper	81.69331	27.66441	34	5	Akvaplan NIVA
25.10.2022	14:10	-	9	GoNorth1-09-ASW-02	81.69331	27.66441	180	515	Prøve tatt med CTD-rosett ved Superstasjon 9. 6 CTD-kast (CTD 304-309)
26.10.2022	17:27	17:55	10	GoNorth1-SSW-07	81.6069	27.8298	4	600	Overflatevann tatt under innseiling til Superstasjon 10
26.10.2022	18:12	-	10	KH2022-GoNorth1-10-Bottom	81.38996	26.93972	817	5	Akvaplan NIVA
26.10.2022	18:12	-	10	KH2022-GoNorth1-10-Mid	81.38996	26.93972	120	5	Akvaplan NIVA
26.10.2022	18:12	-	10	KH2022-GoNorth1-10-Upper	81.38996	26.93972	20	5	Akvaplan NIVA
26.10.2022	18:12	-	10	GoNorth1-10-ASW-03	81.38996	26.93972	120	515	Prøve tatt med CTD-rosett ved Superstasjon 9. 6 CTD-kast (CTD 310-315)
27.10.2022	05:45	06:17	-	GoNorth1-SSW-08	80.97540	22.3283	4	600	Overflatevann tatt ved starten av seismikklinje L3
28.10.2022	06:40	-	11	KH2022-GoNorth1-11-Bottom	82.31172	20.86804	3823	5	Akvaplan NIVA
28.10.2022	06:40	-	11	KH2022-GoNorth1-11-Mid	82.31172	20.86804	280	5	Akvaplan NIVA
28.10.2022	06:40	-	11	KH2022-GoNorth1-11-Upper	82.31172	20.86804	42	5	Akvaplan NIVA
28.10.2022	06:40	-	11	GoNorth1-11-ASW-04	82.31172	20.86804	280	605	Prøve tatt med CTD-rosett ved Superstasjon 12. 7 CTD-kast (CTD 316-322)
31.10.2022	00:35	01:04	-	GoNorth1-KH22-SSW-09	81.7257	21.2723	4	600	Prøve tatt under seiling mot Superstasjon 2
31.10.2022	12:01	-	2	KH2022-GoNorth1-02-Bottom	80.717	28.931	540	5	Akvaplan NIVA
31.10.2022	12:01	-	2	KH2022-GoNorth1-02-Mid	80.717	28.931	120	5	Akvaplan NIVA
31.10.2022	12:01	-	2	KH2022-GoNorth1-02-Upper	80.717	28.931	20	5	Akvaplan NIVA
31.10.2022	12:01	-	2	GoNorth1-KH22-02-ASW-05	80.717	28.931	120	515	Prøve tatt med CTD-rosett ved Superstasjon 2. 6 CTD-kast (CTD 323-328)

Appendix 5. Superstations where plankton net was done.

Date	Time (UTC)	Super-Station	Station Name	Latitude (deg. N)	Longitude (deg. E)	Depth (m)	**Notes** (in Norwegian)
25.10.2022	14:23	9	GoNorth1-KH22-09-WP3-1	81.69330948	27.6644117	1000	WP3 Håvtrekk. (Håv 90). Akvaplan NIVA
25.10.2022	15:59	9	GoNorth1-KH22-09-WP3-2	81.69330948	27.6644117	1000	WP3 Håvtrekk. (Håv 91)
25.10.2022	17:26	9	GoNorth1-KH22-09-MIK1	81.69330948	27.6644117	1000	MIK Håvtrekk. (Mik 92). Akvaplan NIVA
25.10.2022	19:52	9	GoNorth1-09-PPNET1	81.69330948	27.6644117	50	Phytoplankton håvtrekk. (Håv 93). Akvaplan NIVA
26.10.2022	12:54	5	GoNorth1-KH22-05-MIK1	81.69330948	27.6644117	1000	MIK Håvtrekk. (Mik 94). Akvaplan NIVA
26.10.2022	14:15	5	GoNorth1-KH22-05-PPNET1	81.69330948	27.6644117	50	Phytoplankton håvtrekk. (Håv 95). Akvaplan NIVA
26.10.2022	18:54	10	GoNorth1-KH22-10-MIK1	81.38996	26.93972433	800	Håvtrekk (MIK 96)
31.10.2022	13:02	2	GoNorth1-KH22-02-MIK1	80.71653772	28.93100315	540	Håvtrekk (MIK 97) Akvaplan NIVA
31.10.2022	13:59	2	GoNorth1-KH22-02-MIK2	80.71653772	28.93100315	540	Håvtrekk (MIK 98) Cod bucket lost
31.10.2022	15:06	2	GoNorth1-KH22-02-PPNET1	80.71653772	28.93100315	50	Phytoplankton håvtrekk. (Håv 99). Akvaplan NIVA

Appendix 6. Overview of all gravity cores acquired.

Super-station	Station Name	KH Station Name	Gear Type	Latitude (deg. N)	Longitude (deg. E)	Water Depth (m)	Date	Start time	Notes
GoNorth-L1-9	IG-22-4-KH-GoNorth-13-GC-01	Gravity core 13	Gravity corer	81.693	27.665	2533.35	25.10.2022	23:00:52	Core length: 292 cm.
GoNorth-L1-5	IG-22-4-KH-GoNorth-14-GC-01	Gravity core 14	Gravity corer	81.607	27.830	2025.92	26.10.2022	10:00:09	Gravity core came up empty. No time for second attempt.

Appendix 7. Overview of all box cores acquired.

Super-Station	Station Name	KH Station Name	Gear Type	Latitude (deg. N)	Longitude (deg. E)	Water Depth (m)	Date	Start time	Notes
GoNorth-L1-9	IG-22-4-KH-GoNorth-33-BC-01	Box core 34	Box corer	81.693	27.665	2546.40	26.10.2022	02:41:54	Subsamples (UiT; push cores): IG-22-4-KH-GoNorth-33-BC-01-#1 (62 cm), IG-22-4-KH-GoNorth-33-BC-01 (60 cm).
GoNorth-L1-5	IG-22-4-KH-GoNorth-34-BC-01	Box core 36	Box corer	81.607	27.830	2036.05	26.10.2022	14:38:15	Subsamples (UiT; push cores): IG-22-4-KH-GoNorth-34-BC-01#1 (60 cm), IG-22-4-KH-GoNorth-34-BC-01-#2 (60 cm)

Appendix 8. Multicore description

KH22 MC Log 28

CRUISE	**GoNorth1 KH22**		
STATION	**01**		
MULTICORE	**MC1**		
TIME and DATE	**06:24 (UTC) 17.10.2022**		
LONGITUDE (N)	**80˚56.941169 N**		
LATITUDE (E)	**23˚45.461922 E**		
WATER DEPTH (m)	**274**		
Cores	**Visual sediment description**	**Core length (cm)**	**Notes**
A	0-3 cm: dark brown mud; 3-6 cm light brown mud; 6-45.5 cm grey mud; 6-12 cm brown patches and or smear	45.5	AGENSI: Sampled for DNA and biomarkers 17.10.22
B	0-4 cm dark brown mud; 4-8 cm light brown mud; 8-47.5 cm grey mud, with from 8-23 cm light brown patches/smear	47.5	AGENSI: sampled 0-1 cm entirely for palynology and DNA 17.10.22 (in clean lab)
C	0-3.5 cm dark brown mud, one black (charcoal?) patch visible; 3.5-7 cm light brown mud; 7-46 cm grey mud, 7-22 cm light brown patches/smear	46	Stored for SINTEF
D	0-3.5 cm dark brown mud, one black (charcoal?) patch visible between 0-1 cm with diamter of ca. 1 cm; 3.5-6 cm light brown mud; 6-44.5 cm grey mud, 6-18 cm light brown patches/smear	44.5	Stored for SINTEF

CRUISE	**GoNorth1 KH22**
STATION	**02**
MULTICORE	**MC1**
TIME and DATE	**13:56 (UTC) 17.11.2022**
LONGITUDE (N)	**80˚42.990578 N**
LATITUDE (E)	**28˚55.871447 E**
WATER DEPTH (m)	**545.5**

Cores	**Visual sediment description**	**Core length (cm)**	**Notes**
A	0-4.5 cm: dark brown mud; 4.5-48 cm grey mud, 4.5-19 cm: dark brown patches/smear, 30-48 cm: black lines/smear becomes more intense towards the bottom	48	AGENSI: Sampled for DNA and biomarkers 17.10.22
B	0-4.5 cm: dark brown mud; 4.5-51 cm grey mud, 4.5-22 cm: dark brown patches/smear, 32-51 cm: black lines/smear	51	AGENSI: sampled 0-1 cm for palynology and DNA 17.10.22 (in clean lab)
C	inclined surface, the measurements may be a bit off because of that; 0-3/5 cm: dark brown mud; 3/5-48 cm grey mud, 3/5-21/24 cm: dark brown patches/smear, 34/35-48 cm: black lines/smear	48	Sampled for DNA x2 17.10.22
D	0-5 cm: dark brown mud; 5-48.5 cm grey mud, bioturbated transition	48.5	Core liner fell over - sediment disturbed. Not used for sampling

CRUISE	**GoNorth1 KH22**
STATION	**02**
MULTICORE	**MC2**
TIME and DATE	**14:30 (UTC) 17.11.2022**
LONGITUDE (N)	**80˚42.977974 N**
LATITUDE (E)	**28˚55.922224 E**
WATER DEPTH (m)	**545**

Cores	**Visual sediment description**	**Core length (cm)**	**Notes**
A	No recovery	/	All tubes broke off during deployment. The cable from the winch was wrapped and locked around the top of the MC piston. Shovels were hangin out half under the MC. The was likely tilted upon recovery, breaking off the tubes at the sea floor.
B	No recovery	/	as above
C	No recovery	/	as above
D	No recovery	/	as above

CRUISE	**GoNorth1 KH22**
STATION	**02**
MULTICORE	**MC3**
TIME and DATE	**15:16 (UTC) 17.11.2022**
LONGITUDE (N)	**80˚42.970944 N**
LATITUDE (E)	**028˚55.947575 E**
WATER DEPTH (m)	**545**

Cores	Visual sediment description	Core length (cm)	Notes
A	0-4 cm: dark brown mud; 4.5-45 cm grey mud, 4-19 cm: brown patches/smear, 33-45 cm: black lines/smear; transition at 4 cm is chaotic/gradual - bioturbation	45	Sampled for DNA x2 18.10.22
B	0-3 cm: dark brown mud; 3-41.5 cm grey mud, 3-7 cm: brown patches/smear, 26-41.5 cm: black lines/smear; transition at 3 cm is chaotic/gradual - bioturbation	41.5	Sampled for DNA x2 18.10.22
C	0-4 cm: dark brown mud; 4-17/22/24 cm light brown mud, 17/22/24 -42.5 cm: grey mud, 31-42.5 cm: black lines/smear; transition at 17/22/24 cm - undulating	42.5	Sampled for DNA x2 18.10.22
D	0-3.5 cm: dark brown mud; 3.5-44.5 cm grey mud, 3.5-18 cm: brown patches/smear; messy transition at 3 cm - bioturbation	44.5	Sampled for DNA x2 18.10.22

KH22 MC Log 32

CRUISE	**GoNorth1 KH22**
STATION	**05**
MULTICORE	**MC1**
TIME and DATE	**04:19:03 (UTC) 21.10.2022**
LONGITUDE (N)	**81˚36.415950 N**
LATITUDE (E)	**027˚49.773143 E**
WATER DEPTH (m)	**2038.83**

Cores	**Visual sediment description**	**Core length (cm)**	**Notes**
A	0-7 cm: light brown mud; 7-47.5 cm grey mud, 44-47.5 cm: black spots; boundary at 7 cm is not straight, likely bioturbated. Small (<0.5 cm) crustacean at surface.	47.5	AGENSI: Sampled for DNA and biomarkers 21.10.22.
B	0-6.5 cm: light brown mud; 5.5-6.5 cm dark brown mud; 6.5-46.5 cm grey mud; transition at 6.5 cm is not straight, likely bioturbated.	46.5	AGENSI: Sampled for biomarkers 21.10.22; Sampled for DNA.
C	0-7 cm: light brown mud; 7-47.5 cm grey mud, 44-47.5 cm: black spots; boundary at 7 cm is not straight, likely bioturbated. Small (<0.5 cm) crustacean at surface.	48.5	Sampled for DNA x2
D	0-5.5 cm: light brown mud; 5.5-48 cm dark brown mud; 6.5-46.5 cm grey mud; transition at 5.5 cm is not straight, likely bioturbated. Polychaete at surface.	48	Sampled for DNA x2

KH22 MC Log 33

CRUISE	GoNorth1 KH22		
STATION	09		
MULTICORE	MC1		
TIME and DATE	20:25:11 (UTC) 25.10.2022		
LONGITUDE (N)	81˚41.600253 N		
LATITUDE (E)	027˚39.863904 E		
WATER DEPTH (m)	2536.86		
Cores	**Visual sediment description**	**Core length (cm)**	**Notes**
A	0-6 cm: light brown mud; 6-41.5 cm grey mud, boundary at 6 cm is undulating and likely bioturbated. Smear of l brown mud down the core.	41.5	Murky water * Sampled for DNA x2
B	0-6.5 cm: light brown mud; 5.5-6.5 cm dark brown mud; 6.5-46.5 cm grey mud; transition at 6.5 cm is not straight, likely bioturbated.	39.5	Murky water, and seafloor at an angle, likely due to the problem with recovery. * Sampled by SINTEF
C	0-7 cm: light brown mud; 7-47.5 cm grey mud, 44-47.5 cm: black spots; boundary at 7 cm is not straight, likely bioturbated. Small (<0.5 cm) crustacean at surface.	42	Murky water *. Probably most intact / least disturbed core. AGENSI: Sampled for DNA and biomarkers 26.10.2022
D	0-5.5 cm: light brown mud; 5.5-48 cm dark brown mud; 6.5-46.5 cm grey mud; transition at 5.5 cm is not straight, likely bioturbated. Polychaete at surface.	34	Very murky water * [pic 1:17] AGENSI: Sampled for palynology; sampled for DNA 26.10.2022

The cable from the winch was wrapped and locked around the top of the MC piston. Shovel had deployed and kept in most sediment but were hanging out half under the MC. Likely disturbed recovery of sediments.

CRUISE	**GoNorth1 KH22**
STATION	**10**
MULTICORE	**MC1**
TIME and DATE	**21:58:52 (UTC) 26.10.2022**
LONGITUDE (N)	**81˚23.400218 N**
LATITUDE (E)	**026˚56.379855 E**
WATER DEPTH (m)	**810.47**

Cores	Visual sediment description	Core length (cm)	Notes
A	0-12/21 cm: light brown mud; 12/21-41.5 cm grey mud, boundary between different coloured lithologies is dificult to identify. It is likely bioturbated and smear of brown mud makes it difficult to pinpoint exactly. The surface has several wormtubes and delicate, small flower-like organisms.	43.5	AGENSI: Sampled for DNA and biomarkers 27.10.22. Wormtubes were removed with tweasers before sampling.
B	0-5/9 cm: light brown mud; 5/95-43.5 cm grey mud; boundary at 5/9 cm is very unclear, there are brown patches down to 20 cm and smear even further down. Removed two living Cumaceans from the water. Worm tube is sticking out of the sediment. The surface has several wormtubes and several tiny Ophiourids (small sea star).	43.5	AGENSI: Sampled for biomarkers 27.10.22; Sampled for DNA. Wormtubes and Ophiourids were removed with tweasers before sampling.
C	0-19 cm: light brown mud; 19-42.5 cm grey mud. At 11.5 cm there is a dark band. This may be the cleaerest and best representation of the lithology. The surface has several wormtubes and several tiny Ophiourids (small sea star).	42.5	Sampled for DNA x2 27.10.22. Wormtubes and Ophiourids were removed with tweasers before sampling.
D	0-17 cm: light brown mud; 17–42.5 cm dark brown mud; Surface has polychaete tubes, with debris on.	42.5	SINTEF

CRUISE	**GoNorth1 KH22**		
STATION	**11**		
MULTICORE	**MC1**		
TIME and DATE	**04:15:24 (UTC) 28.10.2022**		
LONGITUDE (N)	**82˚18.703365 N**		
LATITUDE (E)	**020˚52.082335 E**		
WATER DEPTH (m)	**3748.28**		
Cores	**Visual sediment description**	**Core length (cm)**	**Notes**
A	0-3 cm: darker brown mud; 3-16.5 cm light brown mud. The core was originally longer and had 14 cm of brown mud smear on the side of the liner above the seafloor surface. Surface was disturbed.	16.5	** Distrubed sample ** AGENSI: Sampled for DNA and biomarkers 28.10.22. Flakes of smeared sediment were lying on top of seafloor and were removed before sampling.
B	0-3 cm: darker brown mud; 3-15 cm light brown mud. The core was originally longer and had 14 cm of brown mud smear on the side of the liner above the seafloor surface. Surface was distrubed.	15	** Distrubed sample ** AGENSI: Sampled for DNA and palynology 28.10.22. Flakes of smeared sediment were lying on top of seafloor and were removed before sampling.
C	Only smeared sediment sticking to the core liner were recovered		
D	Core liner broke off		

CRUISE	GoNorth1 KH22		
STATION	13		
MULTICORE	MC1		
TIME and DATE	02:50:57 (UTC) 01.11.2022		
LONGITUDE (N)	81˚23.545985 N		
LATITUDE (E)	023˚10.394674 E		
WATER DEPTH (m)	395.87		
Cores	**Visual sediment description**	**Core length (cm)**	**Notes**
A	0-3 cm: light brown mud; 3-42 cm: grey mud, brown smear down to 19 cm. Possible sponge spicule mat at ca. 30 cm. The surface 0-1 cm has several wormtubes with overgrowth. One Ophiourid.	42	Clear water when recovered. AGENSI: Sampled for DNA and biomarkers 01.11.22. Some wormtubes and Ophiourid were removed with tweasers before sampling.
B	0-5 cm: light brown mud; 5-48.5 cm grey mud; brown smear for 5-10 cm. Surface 0-1 cm had a lot wormtubes with overgrowth and one large stone, red in colour.	48.5	Clear water when recovered. AGENSI: Sampled for palynology 27.10.22; Sampled for DNA. Some wormtubes were removed with tweasers before sampling.
C	Surface strongly inclined; 1.5 cm difference between opposite sides of surface in the tube. 0-4.5 cm: light brown mud; 4.5-38/39.5 cm: grey mud. Small crustacean in the water. Surface has wormtubes.	38-39.5	Murky water when recovered. Sampled for DNA x2 27.10.22. Some wormtubes were removed with tweasers before sampling.
D	Surface inclined. 0-5 cm: light brown mud; 5-39 cm: grey mud. Surface has wormtubes, small rocks, one tiny "kanskjell" and a sponge spicules mat	39	Murky water when recovered. Sampled for DNA x2 27.10.22. Wormtubes were removed with tweasers before sampling.

The core was taken on a slope, with nearby the station a steep cliff of a few meters high.
The heterogenous surfaces and different core lengths recovered indicate this was not a flat seafloor.

CRUISE	**GoNorth1 KH22**
STATION	**14**
MULTICORE	**MC1**
TIME and DATE	**07:19:43 (UTC) 02.11.2022**
LONGITUDE (N)	**81˚18.681613 N**
LATITUDE (E)	**018˚58.355882 E**
WATER DEPTH (m)	**543.18**

Cores	Visual sediment description	Core length (cm)	Notes
A	0-4 cm: light brown mud; 3-42 cm: grey mud, brown smear down to 23 cm. The surface 0-1 cm has several wormtubes, soft coral, agglutinated forams, sponge spicule mat, crustacean. 1 cm diamter hole in the sediment at ca. 10 cm depth.	51	Clear water. AGENSI: Sampled for DNA and biomarkers 01.11.22. Some wormtubes and sponge spicule mat were removed with tweasers before sampling.
B	0-4 cm: light brown mud; 4-48 cm grey mud; brown smear down to 23 cm. Surface has wormtubes with overgrowth. Rather large (~4 cm diamter) airpocket visible at 9.5-11 cm depth.	48	Clear water when recovered. AGENSI: Sampled for palynology 27.10.22; Sampled for DNA. Some wormtubes were removed with tweasers before sampling.
C	0-3/4 cm: light brown mud; 3/4-40.5 cm: grey mud, brown smear down to 22 cm. The surface is not straight and there is a sea urchin on the sea floor. Several small white shells (forams) are present in the top cms. Some sediment likely slid out from the bottom on the way up in the water column. Ca. 10 cm, based on the water level in the tube and the lengths of the other sediment recovered in this cast.	40.5	Sampled by SINTEF
D	0-4 cm: light brown mud with worm tube, sponge spicules and forams; 4-49.5 cm grey mud; brown smear down to 20 cm. Air bubbles escaped from the sediment (ca. 20 cm deep) along the core liner when taking the core off the Multicorer. Minor distrubance in the area indicated on the tube is likely.	49.5	ARCHIVE MC for JS Laberg / UiT

CRUISE	**GoNorth1 KH22**
STATION	**15**
MULTICORE	**MC1**
TIME and DATE	**05:23:13 (UTC) 02.11.2022**
LONGITUDE (N)	**80˚27.851515 N**
LATITUDE (E)	**011˚28.341766 E**
WATER DEPTH (m)	**642.2**

Cores	**Visual sediment description**	**Core length (cm)**	**Notes**
A	Uneven surface, with lots of stones in 0-2 cm. 0-4 cm: brownish grey sandy mud, black grains; 4-32 cm: dark grey mud that is sandy at the bottom, transition between lithologies appears very gradual	32	Clear water, excellent recovery. AGENSI: Sampled for DNA and biomarkers 02.11.22. A lot of stones were removed with tweasers before sampling.
B	Uneven surface, with lots of smaller stones (diamter 0.5 cm), one large stone was 3-4 cm in diameter, one small sea star. 0-5 cm: brownish grey sandy mud, black grains, forams; 5-32 cm: dark grey mud that is sandy at the bottom, transition between lithologies appears very gradual	32	Clear water, excellent recovery. AGENSI: Sampled for DNA and palynology 2.11.22. A lot of stones were removed with tweasers before sampling.
C	Uneven surface, with lots of stones (mostly 0.5 cm diameter, max. diameter up to 2.5 cm) and life. 0-5 cm: brownish grey sandy mud; 5-33.5 cm: dark grey mud that is sandy at the bottom, transition between lithologies appears gradual. Some brown sediment smear to bottom	33.5	Clear water, excellent recovery. Sampled by SINTEF (0-1 cm)
D	Uneven surface, with lots of stones and life (sea star). 0-5 cm: brownish grey sandy mud; 5-32 cm: dark grey mud that is sandy at the bottom, transition between lithologies appears gradual. Some brown sediment smear to bottom.	32	Clear water, excellent recovery. Sampled by Aquaplan Nivå.