NERSC Special Report no. 112

Useful Arctic Knowledge - Training, Collaboration, and Innovation in ocean observing

A contribution to the Ocean Decade

Report from research school and field campaigns in 2024

Group photo of the participants in the research school at Espegrend

Authors: Hanne Sagen, Espen Storheim, Astrid Stallemo, Stein Sandven, Lora Van Uffelen, Arne Kristoffersen, Daniel Koestner, Håkon Sandven, Børge Hamre, Yi-Chun Chen, Hongbo Liu, Rick Reynolds, Peter Worcester, Shea Cheatham, Sara Wergeland, Ingvild Nesbø ,Veronica Haugen, Torunn Sagen, Julian Pelaez, Jens Didrik Berg, Ole Høydal, Anjali Narayanan and Matthew Kehrli

Nansen Environmental and Remote Sensing Center (NERSC)
Jahnebakken 3
N-5007 Bergen, Norway
Phone: + 47 55 20 58 00
http://www.nersc.no

TITLE: Useful Arctic Knowledge - Training, Collaboration, and Innovation in ocean observing. Report from research school and field campaigns in 2024.	**REPORT IDENTIFICATION** NERSC Special Report No. 112
CLIENT: Research Council of Norway	**CONTRACT:** 337245
CLIENT PROGRAMME: INTPART	**AVAILABILITY**: Open
CONTRACT DURATION: 01.04.2023 – 31.03.2028	

PROJECT PARTNERS:

Norway:
Nansen Environmental and Remote Sensing Center (NERSC) (Coordinator),
University of Bergen (UiB), Department of Physics and Technology (IFT)
Xylem Aanderaa (AADI) (subcontractor)

USA:
Scripps Institution of Oceanography (SIO),
University of Rhode Island (URI),
INSPIRE Environmental (subcontractor)

Canada:
Takuvik Joint International Laboratory (TJIL), Université Laval, Quebec

INVESTIGATORS:
H. Sagen, E. Storheim, A. Stallemo, T. Hamre, S. Sandven (NERSC)
B. Hamre, A. S. Kristoffersen, D. Koestner, H. Sandven, C. Sætre (UIB IFT)
P. Worcester, D. Stramski, M. Dzieciuch (SIO)
L. van Uffelen (URI)
M. Babin (TJIL)
K. Vigness-Raposa (INSPIRE)
A. Tengberg (AADI)

Collaboration projects:

HiAOOS (High Arctic Ocean Observation System) funded by EU Horizon Europe programme, Grant Agreement No. 101094621 and

SFI Smart Ocean funded by Research Council of Norway, contract 309612

Signed: 21.10 2024

Hanne Sagen

Executive summary

The UAK project aims to strengthen the quality within education, research and innovation in ocean observing technology through partnership between Norway, USA, Canada. During 2024 the project has organized a workshop, an introduction course in underwater acoustics, a research school for master and PhD students at Espegrend biological station and participation in two Arctic field campaigns. Both NERSC and UiB have acquired new optical and acoustical instruments to make measurements in the research school and the field campaigns. Xylem AADI organised a 1-day workshop for the Norwegian partners with presentation of instruments and methods in ocean observations. The introduction course in acoustics was held over four days as preparation for the research school and participation in subsequent field campaigns. The course was given by Prof. Lora van Uffelen from University of Rhode Island while she had a 5 month guest visit at NERSC. The research school, which lasted for five days in June, had 25 participants in total, including four from Scripps Institution of Oceanography. The research school had focus on practical field work with different instruments and collection of data from the fjord outside Bergen. The students got first hand knowledge about the instruments, how they are used for data collection and experience in planning of the field work. One group of students worked with optical data and another with acoustical data, including training in processing and analysis of the data. On the last day of the research school the students presented preliminary results of their work. In August-September selected students and instructors participated in two research cruises in the ice-covered Arctic Ocean, the first with RV Kronprins Haakon and second with KV Svalbard. The students collected data which will be further used in their PhD and Master theses. After completed research school and the Arctic field campaigns, the students contributed to write this report about the UAK activities in 2024. The field work, data collection and training activities were conducted in collaboration with EU HiAOOS and SFI Smart Ocean projects.

List of contents

1. Introduction

The goal of UAK project is to strengthen the quality of education, research and innovation in ocean observing technology for use in arctic and fjord environments. The project will increase mobility and collaboration with industry and research institutions to advance innovation processes in ocean observing technologies with emphasis on underwater acoustics and marine optics. UAK is based on collaboration between research, educational institutions and industry in Norway, USA and Canada.

In the first UAK project (2018-2022) the focus was on organising three research schools in 2018, 2020 and 2021, addressing (1) natural and human-made hazards, (2) ocean acoustics, (3) cross-disciplinary data management and integration, (4) community-based monitoring, and (5) communication.

The second UAK project (2023-2027) has focus on two topics:

- Underwater acoustics including communication, localization and positioning of floats and gliders, tomography, passive acoustics, and influence of sound on marine life
- Marine optics including scattering and absorption of light in water, remote sensing, radiative transfer modelling, and importance for biomass production.

The project will organise a series of research schools in fjords and in the Arctic, as well as workshops and exchange visits between Norway and USA/Canada.

A field course was organized from 10-14 June 2024 at the Espegrend Marine Research Field Station in Bergen on marine optics and acoustics. The students were introduced to basic fieldwork, preparation of instruments, deploying and recovering instruments, and offloading and processing data. Most of the time as spent on field work in the fjord using the vessel "Emiliania" belonging to the station and work with data, lab analysis and models. 12 students and 12 instructors attended the course and all the students stayed together at the dormitory at the station. The field course was a contribution to training in ocean observing technologies as part of the EU HiAOOS and the SFI Smart Ocean projects.

Figure 1. The vessel "Emiliania" used in the research school

This report describes the activities and results from the research school at Espegrend and the two field experiments in the Arctic with participation of students from the UAK project.

2. Ocean optics

2.1 Research school - report from ocean optics group

The overall goal was to measure a complete set of ocean optical properties needed by radiative transfer models to calculate radiance and irradiance spectra both in the ocean and at the top of the atmosphere. Further, the plan was to compare the calculated spectra to both radiometric measurements and

This type of measurement and computational strategy fits into ongoing optics projects at UiB, which aim to build a database with such complete optical sets for highly varying types of fjord, coastal and open waters. In these projects, measured top-of-atmosphere spectra will be compared to modeled spectra that search the database for use of the best possible linear combination of different measured water types. Water constituents, such as chlorophyll, colored dissolved organic matter, and particle concentrations can then be read from accompanying data from filtered water samples, routinely measured together with each complete optical set.

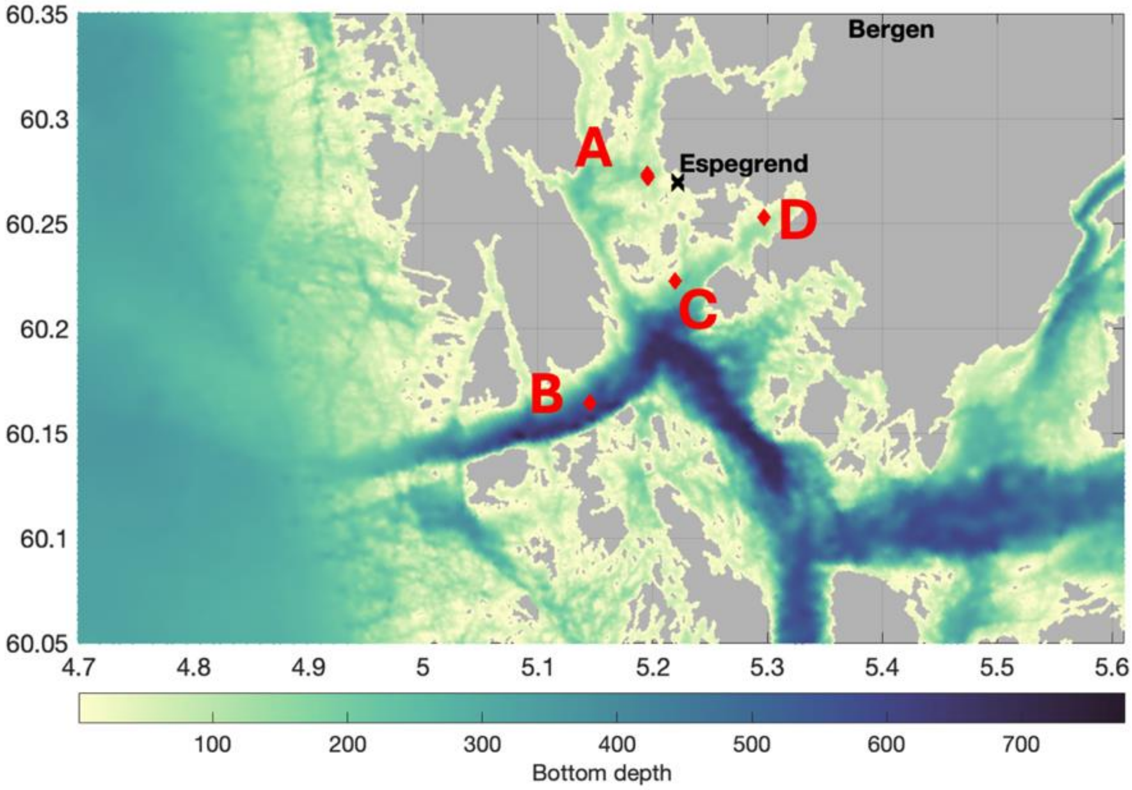


Figure 2.1. Map showing Espegrend research station and the four field stations A,B,C and D.

Summary of optics measurements

In situ measurements were conducted at four stations A, B, C and D (Fig. 2.1) and the following instruments were used:

- **Ramses** radiometer package consisting of two radiometers, both measuring below the surface. One facing downwards measuring radiance and the other facing upwards measuring irradiance.
- **LISST 200X** measuring scattered light in the forward direction and particle size and concentration.
- **RBR Tridente** measuring scattered light in the backwards direction and fluorescence.
- **AC-S** measuring absorption and attenuation.

- **CTD** measuring conductivity (salinity), temperature and depth.
- **Secchi disk** measuring water transparency.

In addition to these measurements, water samples were collected and brought back on land to the lab. The samples were filtered and the following instruments were used:

- **Spectrophotometer** measuring particulate absorption.
- **LWCC** measuring CDOM absorption.
- **Oven and scale** for drying and weighing filters to calculate mass concentrations of SPM and chlorophyll *a*.

List of participants

Instructors:

Name	Institution	Position
Børge Hamre	UiB	Professor
Arne Kristoffersen	UiB	Associate professor
Yi-Chun Chen	UiB	Senior engineer
Håkon Sandven	UiB	Postdoc
Daniel Koestner	UiB	Postdoc
Hongbo Liu	UiB	Postdoc
Rick Reynolds	Scripps	Professor

Students:

Name	Institution	Position
Shea Cheatham	UiB	PhD student
Sara Wergeland	UiB	HTEK student
Ingvild Nesbø	UiB	HTEK student
Jens Didrik Berg	UiB	HTEK student (master)
Ole Høydal	UiB	HTEK student (master)
Anjali Narayanan	Scripps	PhD student
Matthew Kerli	Scripps	PhD student

Summary of day-to-day activities

The Optics Group had focus on finding the concentrations of various organic and non-organic contents of Norwegian coastal waters and use of optical instruments and methods to quantify these, which included measurements with two Ramses radiometers, measuring incident light in the visible and near-visible ranges, both from above (coming from the Sun), and from below (reflected back from the contents of the water).

Day 1 – June 10

The first day of the researcher school started with all participants (acoustics and optics) gathering in the lecture room at Espegrend marine biological station. Arne held a welcome/introduction talk and Daniel held an optics overview talk. At the same time, Håkon did preliminary testing on board the vessel Emiliania to make sure everything was ready for going to sea with our instruments and equipment. After lunch, acoustics and optics separated and went on to prepare for the tasks ahead. It was decided in advance that optics group would go out with Emiliania before lunch on Tuesday, Wednesday and Thursday, while the acoustics group would go out after lunch. This was a practical decision since optics needed time after lunch to process the collected water samples.

Day 2 – June 11
Daniel, Håkon, Rick, Hongbo, Jens, Ingvild, Ole and Anjali went out with Emiliania in the morning and deployed instruments at 09.40 at Station A1. Arne, Sara, Shea and Matthew followed with the small boat and collected water samples and measured the Secchi depth. At 10.55 instruments were deployed at Station C1. The weather was partially cloudy, air temperature was around 11 degree C and it was very windy with average wind speed of around 9 m/s. It was quite large waves and several people got seasick. Water samples were filtrated and analyzed after lunch in the lab.

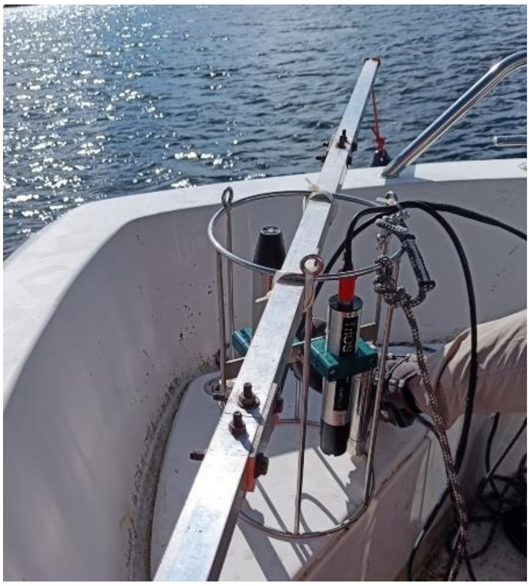


Figure 2.2. The RAMSES radiometers

Day 3 – June 12
Håkon, Hongbo, Rick, Thomas, Anjali, Matthew, Sara, Ingvild, Ole and Jens went with the Emiliania to Station A2 arriving at 09.17, and moved on to Station D1 arriving at 10.45. The weather was partially cloudy with air temperature ca 12 degrees Celsius. Still windy with wind speed around 7 m/s.After lunch, water samples were filtered and analyzed, and Børge started teaching the students to perform radiative transfer simulations using Flick and AccuRT.

Day 4 – June 13
Rick, Håkon, Hongbo, Jens, Sara, Ole, Matthew and Anjali went with Emiliania to Station A3 arriving at 09.20. Arne and Børge followed with a small boat. Emiliania moved on to Station B1 arriving at 10.55. There were issues with Ramses batteries and a replacement battery was picked up by the small boat. After lunch, water samples were filtered and analyzed as usual, and Børge continued teaching the students radiative transfer simulations. Matthew also started looking at Sentinel OLCI data.

Day 5 – June 14
After lunch both optics and acoustics gathered in the lecture room where the student groups presented their work. The optics group presented results from the water sample lab, data from the Ramses radiometers, data from satellites, and data from a radiative transfer model. There was also a competition where the optics and acoustics students showed two short films they made depicting the week's activities. Appropriately, the optics group won 'best cinematography', while the acoustics group won 'best sound editing'.

In the laboratory

Water samples were brought to the lab each day at lunchtime when Emiliania returned from the optics fieldwork. The lab hosted several activities. The starting point was to filtrate water samples and then dry the filters to determine the increase in mass and measure how much light was absorbed by the particles on the filter. The latter was done by inserting the filters into the spectrophotometer. Afterwards, the samples were bleached to destroy all organic components. This way, the important phytoplankton absorption could be determined by substraction.

Figure 2.3 Filtration of water samples.

Figure 2.4 Filters dried and weighed

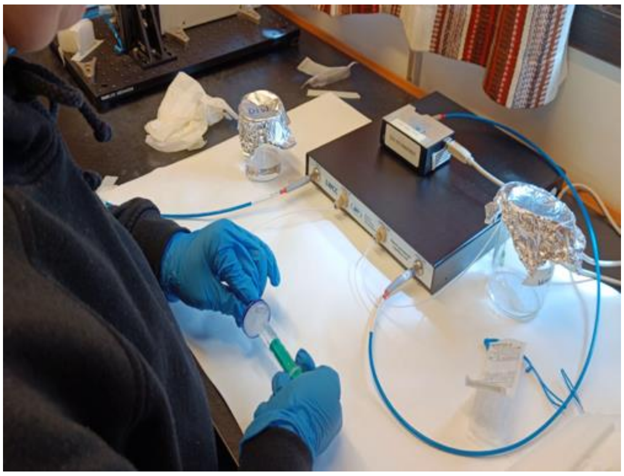


Figure 2.5 CDOM absorption was measured using a Liquid Waveguide Capillary Cell (LWCC

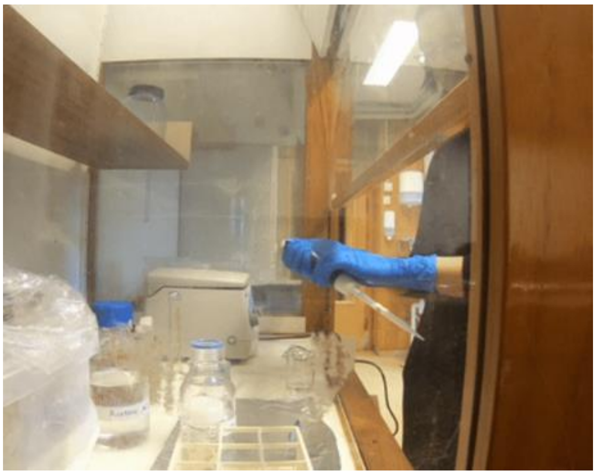


Figure 2.6 Extraction of chlorophyll in process

The chlorophyll content of the filtered samples was also determined by extracting the pigments using a 90% acetone solution and centrifuging the samples. All in all, the labwork worked out very well. Results were good, and the students stated that they learned a lot from actually getting hands-on experience in the lab. The microscope station was used to take a closer look at the water samples, and the students enjoyed the occasional (to us) unknown species showing up in the samples.

Fieldwork

The optics group went out to sea with Emiliania in the morning on the Tuesday, Wednesday and Thursday, in order for the collected water samples to be filtrated the same afternoon. Captain Tomas Sørlie of Emiliania was not only an essential part of this researcher school for making it possible to go to sea, but he also contributed with a positive attitude throughout the week, cheering everybody up.

Although the first two days were very windy, sampling and in situ measurements went well.

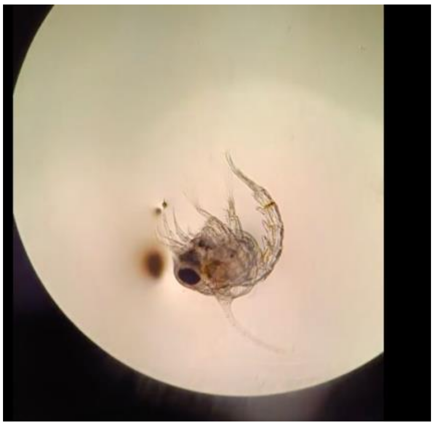


Figure 2.7 An image looking through the microscope at an unknown species found in a water sample

Figure 2.8 Emiliania ready to go to sea in the morning

Figure 2.9 Emiliania from a different angle

Figure 2.10 Shea, Matthew and Sara measuring the Secchi depth

Figure 2.11 Measurements in progress on board Emiliania

Teaching methods

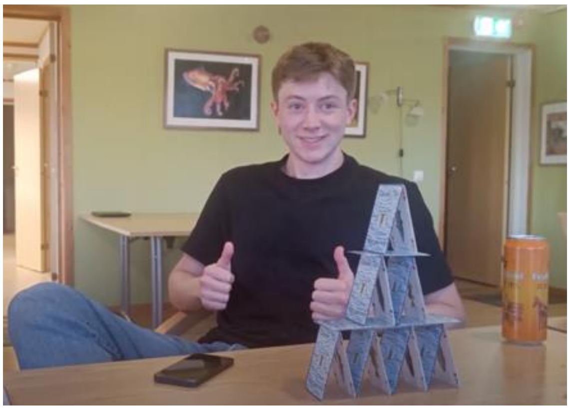
The researcher school was organized with a 'learning by doing' approach, where the instructors demonstrated and explained the activities and then let the students have a go at it. The students were allowed to try and fail, but always with close supervision from instructors until they showed that they could complete their tasks without help. The trained students would then attempt to instruct other students in doing various tasks. This was a successful teaching method, and feedback from the students was very good.

Figure 2.12 Sara (left) and Ole (right) instructed in filtration by Daniel (Center)

Food and recreation

Before the researcher school started, a query was sent out to all participants, asking whether anyone would like to be responsible for making dinner for the whole group any of the days. The response was great, and dinner was a really nice social event every day with both variation in the meals and people responsible for making them. The weather was nice, so two of the days we had barbecue outside. Espegrend is a large facility with plenty of space for recreation, and both instructors and students enjoyed some time off from work in the evenings, with games, discussions and hiking in the area. Unfortunately, it was just a little bit too cold for anyone to go swimming in the sea.

a



b

Figure 2.13 (a) Espegrend has a well equipped kitchen, (b) Ole enjoying some well-deserved time off in the evening

Summary and suggestions for the future

Although the general impression is that the researcher school was a success, there were also a few things that could have been better handled. It really boils down to the detail of beforehand planning. We did not have a good enough plan for which of the students would do what in the beginning. We should have made smaller groups and decided who will go out to sea when, who will stay in the lab etc. A detailed schedule for all activities would have ensured a much smoother process both in the field and in the lab. It would also have been beneficial if the instructors had decided on very clear roles for teaching the various activities in advance. Written tutorials would also have been advantageous for both instructors and students. It was also a slight problem during the week that sometimes part of the instructor team would agree on a change of schedule for something, and not being good enough to communicate the intended change to the whole group.

2.2 Arctic field work – report from the cruise with RV Kronprins Haakon

The UiB Optics group participated with one instructor (Daniel Koestner) and one master student (Ole Høydal) in the Fram Strait 2024 cruise (13–28 August) led by the Norwegian Polar Institute. This cruise was part of a long term (~30 year) monitoring program along the Fram Strait and typically includes the deployment and retrieval of moorings, and sea ice stations. This is a dynamic and hydrographically interesting region where the eastern portion includes warm Atlantic water feeding into the Arctic Ocean and the western portion contains south-flowing cold polar water.

The Optics group is involved in development and application of tools to study organic carbon production and export through analysis of particle concentration, composition, and size distribution. Besides the training and collection of data for master Student Ole Høydal, we had three main objectives:

1. Measure optical properties
    a. Spectral absorption (water samples)
    b. Backscattering (700 nm; in situ)
    c. Attenuation and forward scattering (660 nm; in situ)
    d. Photosynthetically Active Radiation (in situ)

2. Measure particulate properties
    a. Mass concentration of Particulate Organic Carbon (POC; water samples)
    b. Mass concentration of Suspended Particulate Matter (water samples)
    c. Mass concentration of Chlorophyll-a (water samples)
    d. Phytoplankton and non-phytoplankton absorption (water samples)

3. To build and validate inverse-optical algorithms aimed at estimating biogeochemically relevant parameters from optical measurements
    a. POC
    b. Particle Size Metrics
    c. Phytoplankton vs. non-phytoplankton content

The cruise was a great success, with 43 casts performed with the optical instrument package (Fig. 2.14 b) in the stations shown in Fig. 2.15 where over 150 filters were collected for particulate analysis. This dataset will serve as the basis for Ole's master's thesis project while also preparing Ole for any future work in the Arctic.

a

b

Figure 2.14. (a) R/V Kronprins Haakon docked in Longyearbyen. (b) Deployment of a mooring with specialized optical sensors. Targeted optical casts were performed to support validation of mooring data at two mooring locations at 5 and 8 ºW. Photos by Olaf Schneider, NPI

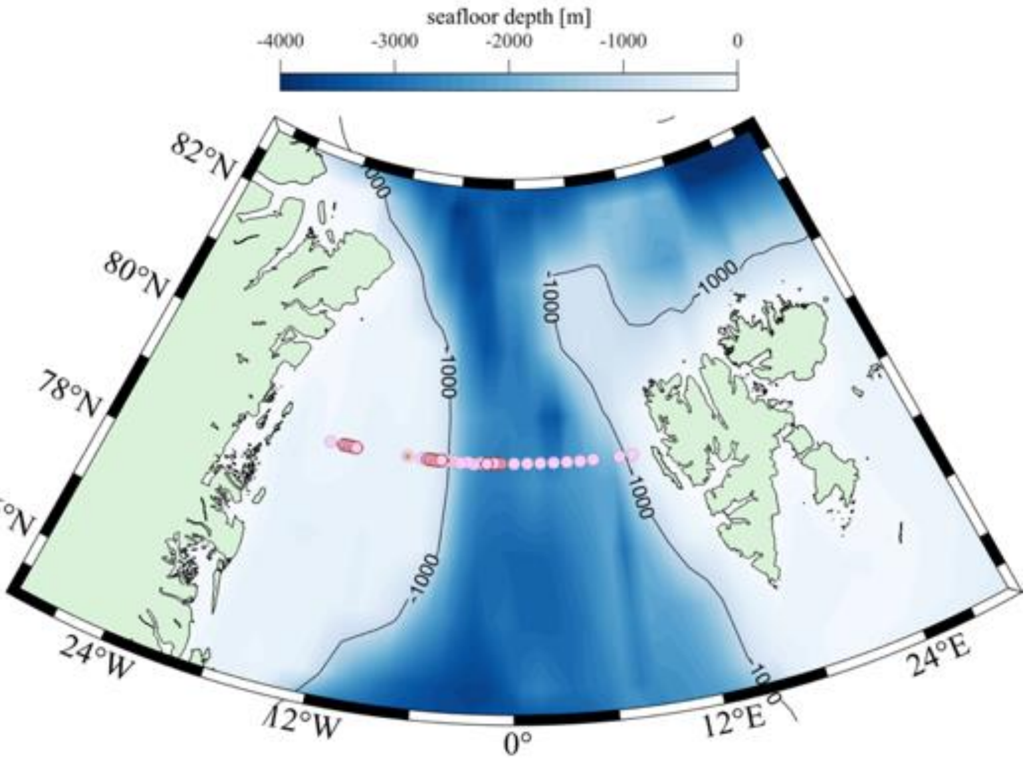
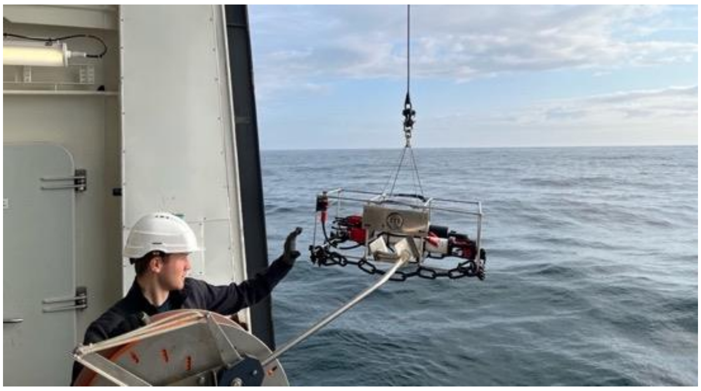


Figure 2.15. Map of stations where 43 optical casts were performed. Locations where mesoscale experiments of high-resolution sampling are marked with red outlines and orange squares denote moorings with optical sensors.

In preparation for this research cruise, Ole designed, troubleshooted, improved, and built an instrument cage to contain and safely deploy necessary optical instruments up to 500 m depth (Fig. 2.16). The optical package consisted of an RBR Concerto CTD.PAR.Tridente (temperature, salinity, depth, photosythentically available radiation, backscattering at 700 nm and ~120º, and chlorophyll-a and DOM fluoresence) and a LISST-200X (near-forward scattering with 36 detectors ~0.04–12º and narrow beam transmission at 660 nm). Sensors were placed appropriately in cage so that down and upcasts would be free from obstruction (i.e., Tridente was facing outwards and LISST-200X sample volume was open vertically).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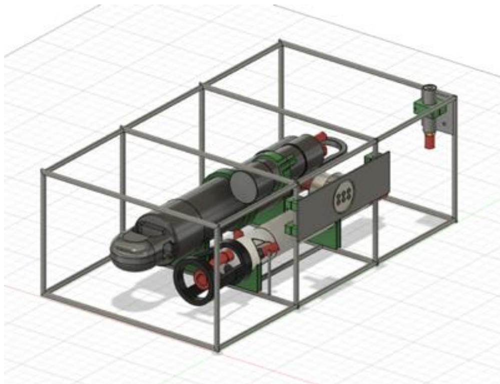
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Fig. 2.16 (a) Photo of Ole deploying the custom-build optical cage off the R/V Kronprins Haakon.(b) Rendering of optical instrument cage designed by Ole


a


b

Figure 2.17. Filtration set-up to collect material for particulate analyses. Photos by Olaf Schneider, NPI

Ole learned a lot about practicalities of collecting, processing, and visualizing oceanographic data. We planned and implemented an appropriate sampling program given time constraints. A standard profile was 0.3 m/s down and up to 200 m with 5-minute parking at 200, 100, and 25 m on the upcast at whole degrees which fit within the ship’s operating schedule. Examples of data are shown in Fig. 2.18.

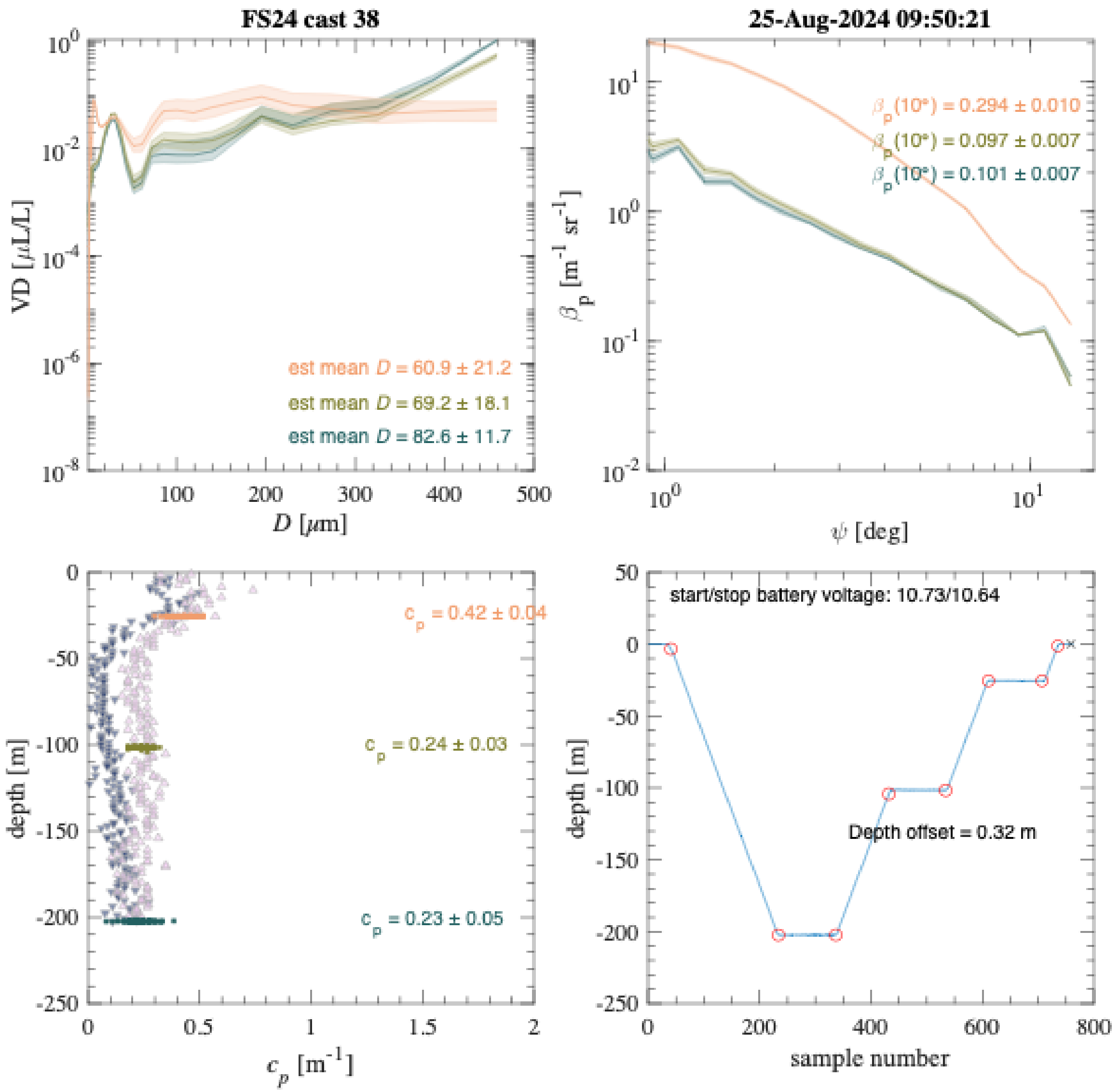

Figure 2.18. Example data from the LISST-200X from cast 38. The bottom right shows the typical sampling depths.

Due to faster transits than expected because of the very low sea ice concentrations, extra time became available to implement additional sampling. We designed three high-resolution experiments with optical sampling every 0.25° from 13–12 ºW, 6.5–5.5 ºW, and 2–1 ºW to explore interesting mesoscale features observed in CTD data of deep chlorophyll-a max. These profiles were typically 0.3 m/s down and up to 300 m with no parking. Two additional short casts with 5-minute park at approximate depth (55 m) of ECO-Triplet sensors on F13-25 (~5 ºW) and F17-20 (~8 ºW) moorings were also performed shortly after mooring deployments.

Approximately half of the casts included coincident water sampling at 25 m and 100 m for particle properties. Water samples were filtered onto 25 mm diameter glass fiber filters (Whatman Grade F; GF/F) for subsequent onshore analysis of mass concentrations of suspended particulate matter, particulate organic carbon, and chlorophyll-a (and additional pigments with HPLC). Water samples were also collected for absorption of particulate matter retained on GF/F filters and colored dissolved organic matter (i.e. 0.2 µm filtrate) using a liquid-waveguide capillary cell system with 1 m pathlength.

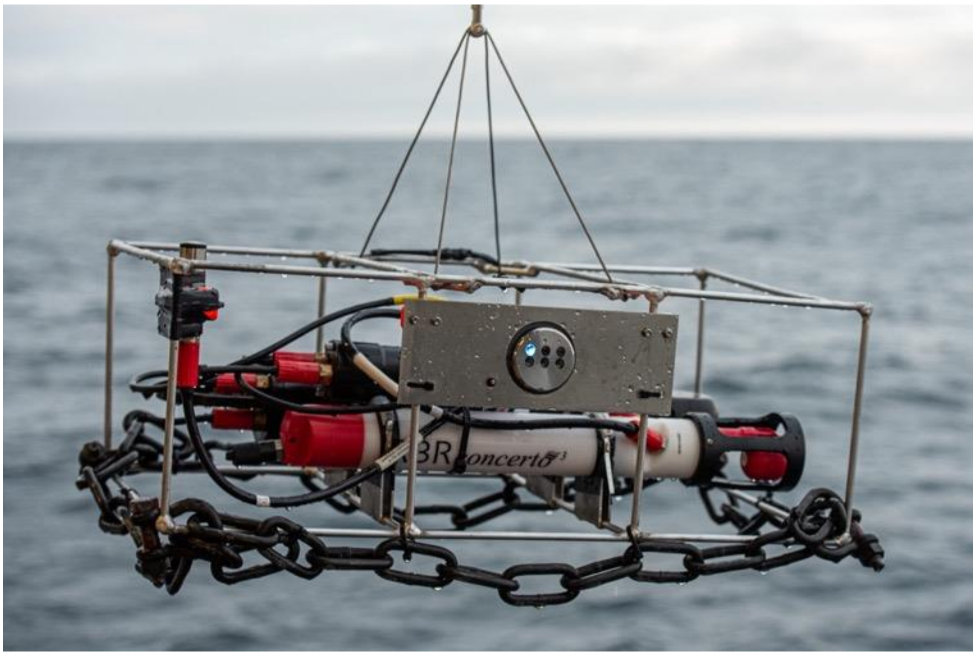

Figure 2.19 Photo of the completed instrument cage. We had to add additional chain to add weight to keep the instrument profiling vertically. We also decided to include additional tape in a few locations to keep instruments secure. Photo by Olaf Schneider, NPI.

We got a brief break from optical sampling when we finally found sea ice near the coast of Greenland. However, we spent those days taking turns on polar bear watch at the bridge. Here, we each spend 45-minute shifts watching for polar bears, so that we could keep the sea ice team safe. We had two very close visitors, and nobody was harmed (Fig. 2.20).

The cruise was a massive success and Ole has more than enough data to support his master's thesis project. We built connections with researchers at the Norwegian Polar Institute while supporting an extended sampling program for their cruise. We hope to send Ole up to NPI in Tromsø during early 2025 to gain invaluable experience with processing and interpreting the physical ocean variables collected with the boat's CTD. We also expect more future collaborations with researchers at NPI and DTU.

a

b

Figure 2.20 (a) Drone photo of the Kronprins Haakon during sea ice station1. (b) Polar bear observed from the vessel. Photos by Olaf Schneider, NPI

Figure 2.21 Ole happy the cruise is over, we can see land!

Figure 2.22. Science crew on the Fram Strait 2024 research cruise. Photo by Olaf Schneider, NPI

2.3 Arctic field work – report from Jens Didrik's trip with KV Svalbard

Jens Didrik Berg, master student with the Optics Group at the University of Bergen, participated in the Norwegian Coast Guard icebreaker KV Svalbard from the 19th of August to the 9th of September and has provided the following report. Reports from other activities on the KV Svalbard cruise are presented in Section 3.

Fig. 2.23 Jens Didrik on the ice

The purpose of the trip was to gather data for my master project, and to learn more about how environmental research and monitoring is performed in the ice-covered Arctic Ocean. After spending one day and night in the blue town of Sortland, the ship set sail, and we performed some safety drill, getting acquainted with the Officers Lounge, airlocks, and floating vests. At the beginning of the voyage, the navigators were worried that the ice would slow us down, and that time would be a restricting factor.

On the first proper day on the ship, I set up my instruments (three Ramses radiometers) on the starboard side of the helideck. Two instruments measuring irradiance (one in the ultraviolet and the other in the visible regions of the spectrum) were mounted pointing skywards, as close to normal to the ocean surface as possible. The third instrument measuring radiance was mounted pointing off the ship towards the water/ice surface at a 45-degree angle (Fig. 2.24a).

Figure 2.24 (a) Mounting the radiometers on the rail of the helideck. (b) working in ice with the small boat Sjøbjørn, (c) midnight sun, (d) polar bear observed from the ship

The three cables I had brought were connected on the one end to the three instruments on the helideck, and on the other end to my workstation situated snuggly on a box below some stairs in the hangar. When asked if I wouldn't rather have a desk and chair to place my controller PC on, I replied that the system was basically autonomous, and so I would not need to stay in the hangar that often. This was wrong. Many problems occured with the instruments. After this trip I have come to understand that all measurement systems are inherently faulty, and if it seems like nothing is going wrong you are simply not looking hard enough. Anyway, in the end I had the data I wanted to retrieve, and so I am happy with the experience.

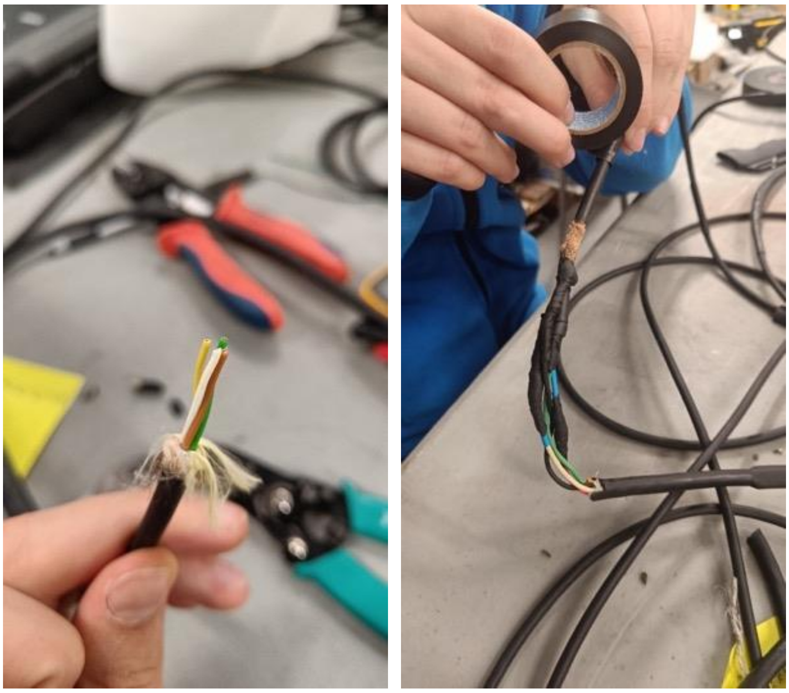

Figure 2.25. Playing with the wires of the instruments

One day, we went in one of the smaller boats to do some measurements in the water (Fig. 2.24d). Two instruments were put in the water and measured light coming up in the water column, and light coming down into the water column. After being trapped behind some ice floes we had to be rescued by the ship. However, preliminary data analysis shows that some things in the water might be glowing into the instruments, which is neat. The data will be used in my master thesis.

When not fighting my own instruments, I was part of the "pinging team". After deploying the big acoustic moorings and transponder network around it we had to position the anchor and the transponders around it. To do so a transducer was put over the side and to the water to do send acoustic signals (pinging) which the transponders and anchor replied to. We visited 13 pining stations. The data is there after used to position the transponders and anchor 4000 m below us. My job was lower the transponder and to make sure that the cable holding the device was not attacked by drifting ice, because taking care of your cables is important.

Mooring deployments was the main purpose of the scientific cruise. Each of the moorings was 4 kilometerhad 40 instruments. I was part of the team bringing the smaller instruments to the mooring technicians deploying the large acoustic moorings from the aft of the ship. When we were not deploying big moorings, we were in transit waiting for the next time we were going to deploy big moorings. During this time, I was working on my notes from the cruise, checking my instruments, and writing on my thesis. I also took part in preparing for deployment of the wooden small boats for the Float Your Boat Program.

Figure 2.26. I took part in delivering oceanographic instruments in the correct order to the mooring technicians. It is important that the instruments are at the right depths.

Figure 2.27. Myself to the left, Chris Miller from the Naval Post Graduate School, Veronica (UiB) and Astrid (NERSC).

It was an exciting cruise. I walked on the ice twice, and I saw three polar bears. On one of the mooring retrievals there was a handful of squid. I saw a grand Russian sailing vessel. Every day I ate a fantastic lunch, and a fantastic dinner. One day I was involved in making sushi for lunch and dinner. We played many rounds of Secret Hitler and Ligretto, and when we finally found a deck of cards we played some other intense games. I learned the flying bowline. I met a lot of really nice people. Great cruise.

3. Ocean acoustics

3.1 Acoustic primer

The acoustics primer was taught with the intention that students learn the basics of underwater acoustics in a classroom setting, thus enabling them to get the most out of their experience in the field. This allowed the students to take part in planning the fieldwork and maintained a focus on collecting high quality data. In the primer they were also introduced to the software needed for data processing and modelling so that they could bring this experience with them and incorporate real data in the field environment.

A flyer was distributed to recruit Master and PhD-level students to take part in the course (Fig. 3.1). Six students attended the acoustics primer, four of whom participated in the field week at Espegrend field station. These students came with backgrounds in Oceanography, Acoustics, and Engineering.

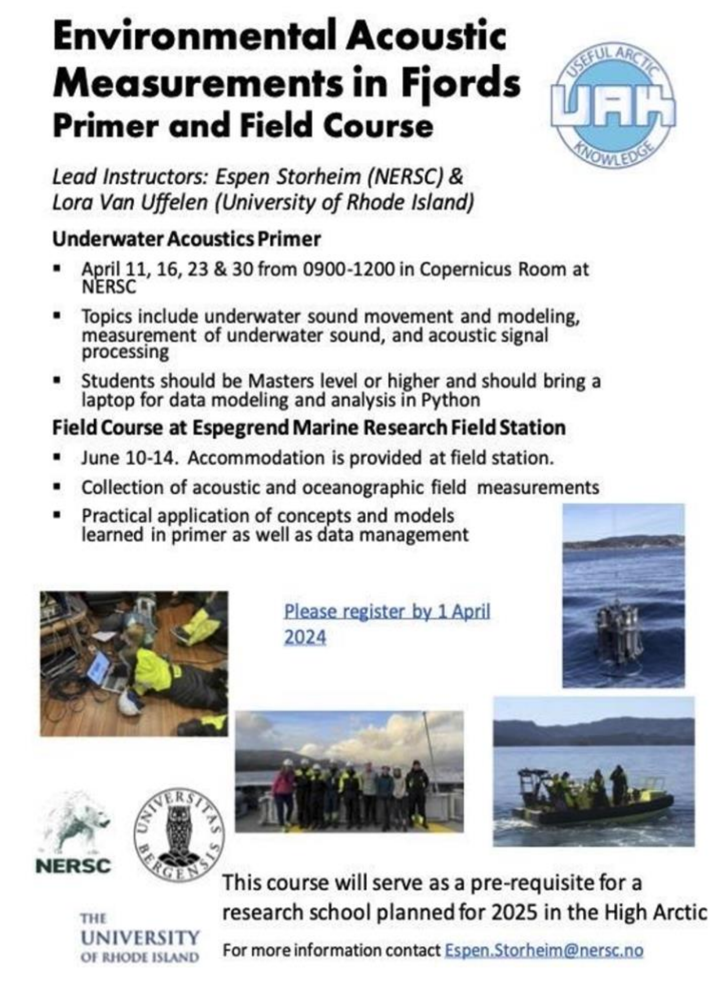

Figure 3.1. Invitation to the acoustic primer and field course at Espegrend

The Acoustics Primer consisted of four sessions, which were held on April 11, 16, 23, and 30. The sessions ran from 09:00 - 12:00 at NERSC. The first session was an introduction to Underwater Acoustics and an overview of the field portion of the course. Applications and importance of underwater acoustics was discussed, along with a differentiation between active and passive acoustic measurements. The sound speed equation was covered as well as its relationship to oceanographic measurements, with particular emphasis on the Arctic environment. Students downloaded the Docker Desktop interface and used Python code in a Jupyter notebook developed for the course to calculate sound speed profiles from measurements of temperature and salinity.

Sound movement in the underwater environment was covered in the second week, including the physics of reflection and refraction as it applies to underwater acoustics. In week three the focused was on how sound is measured. This included a discussion of the Decibel unit and its use in the SONAR equation as well as how hydrophones measure sound pressure.

Digitization of measured data was covered and sampling theory and aliasing were discussed. The hydrophones to be used in the field were brought into the classroom and students were able to use the hydrophones and a handheld recorder to make in-air recordings. This enabled students to gain experience with the operation of the instrumentation as well as modifying settings such as the bit rate and sampling frequency prior to being in a higher-pressure field environment.

The final week focused on processing data so that students would have the skills required to process the data that they collected in the field. The Fast Fourier Transform (FFT) and its parameters were covered, as was the formulation of spectrograms from FFTs. Students created spectrograms from the data files they recorded the previous week and modified spectrogram parameters such as FFT length and window length to observe their impact on the resulting spectrograms.

3.2 Research school – summary report from ocean acoustics group

The participants in the acoustics group included three instructors: Espen Storheim (NERSC), Lora van Uffelen (University of Rhore Island), and Peter Worcester (Scripps) and four students: Astrid Stallemo (NERSC), Veronica Haugen (UiB), Torunn Sagen (UiB) and Julian Palaez (UiB).

The intention of the research school was to provide the students with a fundamental basis for planning and conducting fieldwork, within a safe and supervised framework. Emphasis was put on hands-on experience. The area of operation has previously been surveyed (CTD samples) during three cruises funded by the SFI Smart Ocean project. This data, in combination with the material from the primer, was used in planning of the experiments and for comparison with the measurements acquired during this course. The ship tracks of the acoustic and oceanographic field work are shown in Fig. 3.2.

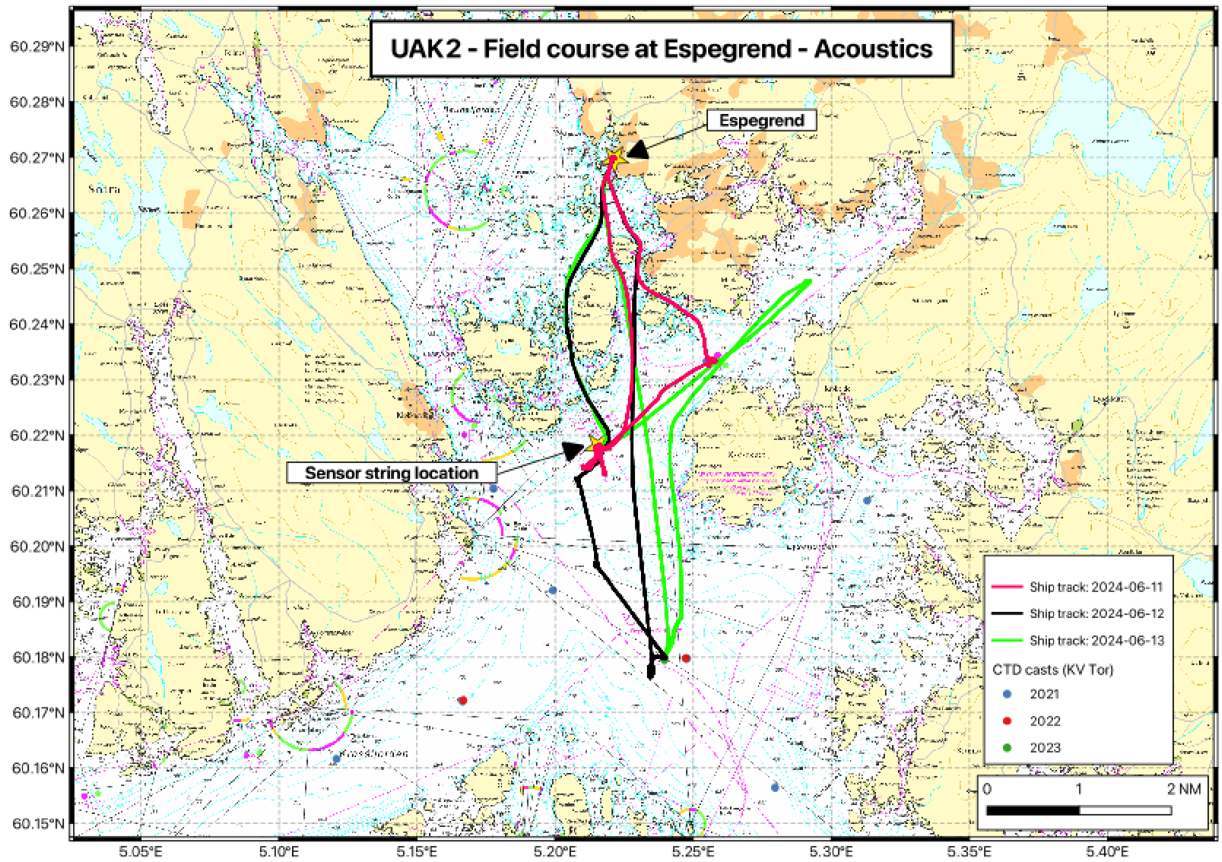

Figure 3.2 Map of the area with the ship tracks of the vessel Emiliania marked as colored lines. Locations of previous CTD casts from SFI Smart Ocean cruises are marked by circles.

The students assisted in the deployment of a tethered array which was established in connection to the floats belonging to a fish farm (Fig. 3.3). The array consisted of an oceanographic sensor string, data loggers and an autonomous underwater acoustic recorder. The sensor string continuously measured temperature, conductivity, oxygen, pressure, tides at 8 depths and current measurements (both point and profile) and a hydrophone at 23 m depth. The instruments collected data for almost 48 hours. In parallel, the students carried out CTD casts in the area, and performed active acoustic transmissions, where sound signals were transmitted at various locations relative to the receiver.

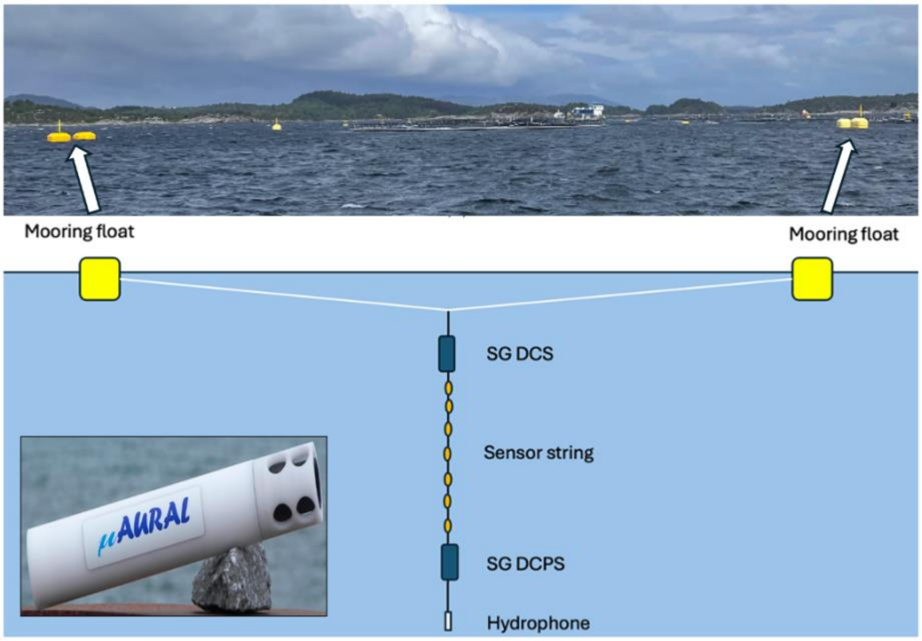

Figure 3.3. Photograph of the fish farm (upper part) and illustration of the tethered array (lower part) with picture of the μAURAL hydrophone.

Two different sound sources were used: a high frequency pinger (~10 kHz) and an underwater speaker (~1 kHz). These transmissions were in turn used for comparison with acoustic propagation modelling, to better understand how the different signals propagate under different conditions. The CTD profiles taken in the area showed a strong surface duct which can trap certain sounds. The students used the theory and the material from the primer to develop several different hypotheses which were tested in the field.

After the instruments were recovered and maintained, data was offloaded, and a preliminary analysis was carried out by the students. The data that has been collected will be used in future student work, e.g. Master theses and conference contributions. The sensor string also contained instruments for measuring turbidity, which is a measure of particles in the water, and an important parameter in marine optics. This is an example of the multi-disciplinary measurements and collaboration between different fields, which can be exploited in future work.

At the end of the week, the students reached a level where they were able to independently plan and carry out such field measurements. A presentation was given for all the participants at the end of the week with preliminary results, and the students also produced a video showing the different activities.

The data collected by the acoustic group are summarized in the following table:

Passive acoustic recordings with hydrophones	At pier (4 h & 20 min) Start Monday 10.06.2024 at 14:25 UTC At floating pier (4 h & 5 min) Start Tuesday 11.06.2024 at 16:15 UTC At fish farm (~ two days) Start Tuesday 11.06.2024 at 11:33 UTC End Thursday 13.06.2024 at 14:15 UTC
Active acoustics	Pings, sweeps and songs
Hydrographic data	CTD profiles (4 profiles)
Sensor string on tethered array	7-point measurements of Temperature, Conductivity, Oxygen, Turbidity, Pressure, Tides, Current (1 point measurement and a profile measurement)
Additional data	Ship (AIS) and flight trackings (ADS-B) Weather and tides

3.3 Research school – report from the students in the acoustics group

During the research school we had the freedom to design and direct our activities, choosing what to investigate and how to approach each task. Each day was split into two parts: mornings were spent planning the day's activities, including preparing ropes, cables, and instruments, and ensuring we had enough time to complete everything (i.e., backwards planning). We began by deploying the tethered array at the fish farm (Fig. 3.3 and 3.4). Then we moved on to Station 5 to conduct a CTD (Conductivity, Temperature, Depth) cast.

The data collected from the CTD provided valuable insights into the ocean structure of this fjord region, helping us plan the transmission scheme more effectively. We selected two distinct transects from the fish farm station for further investigation over the next two days. The first transect extended southward into Korsfjorden, where the bathymetry is deeper and likely more influenced by coastal water masses. The second transect led into Fanafjorden, characterized by shallower bathymetry and potentially more affected by river runoff and proximity to land (Fig. 3.4). By choosing these two transects, we aimed to compare how varying bathymetry and source depths might influence our transmitted signals. Additionally, we sought to compare the water masses along these transects to better understand any potential variations and their impact on our findings.

Figure 3.4. Map of CTD and active acoustic transmission stations along two different transects (orange and purple dots). The fish farm station (green triangle) was the location of our surface mooring measuring continuous during our stay at Espegrend (yellow star).

Some results from the data collection and the ray trace modelling

The first CTD cast at Station 5, presented in Fig. 3.5, reveals a shallow mixed layer, approximately 2 dbar (~2 m) deep, characterized by higher temperatures and relatively low salinity. Below this layer, the temperature gradually decreases, reaching values below 7°C at around 22 dbar. As the depth increases, salinity also increases steadily. The sound velocity, calculated from temperature, salinity, and pressure, closely follows the temperature profile at shallower depths. Notably, a sound channel, where the sound velocity reaches its minimum, is observed at approximately 18 dbar. This channel is significant because it allows sound to remain largely confined within it, providing an ideal pathway for transmitting our signals efficiently.

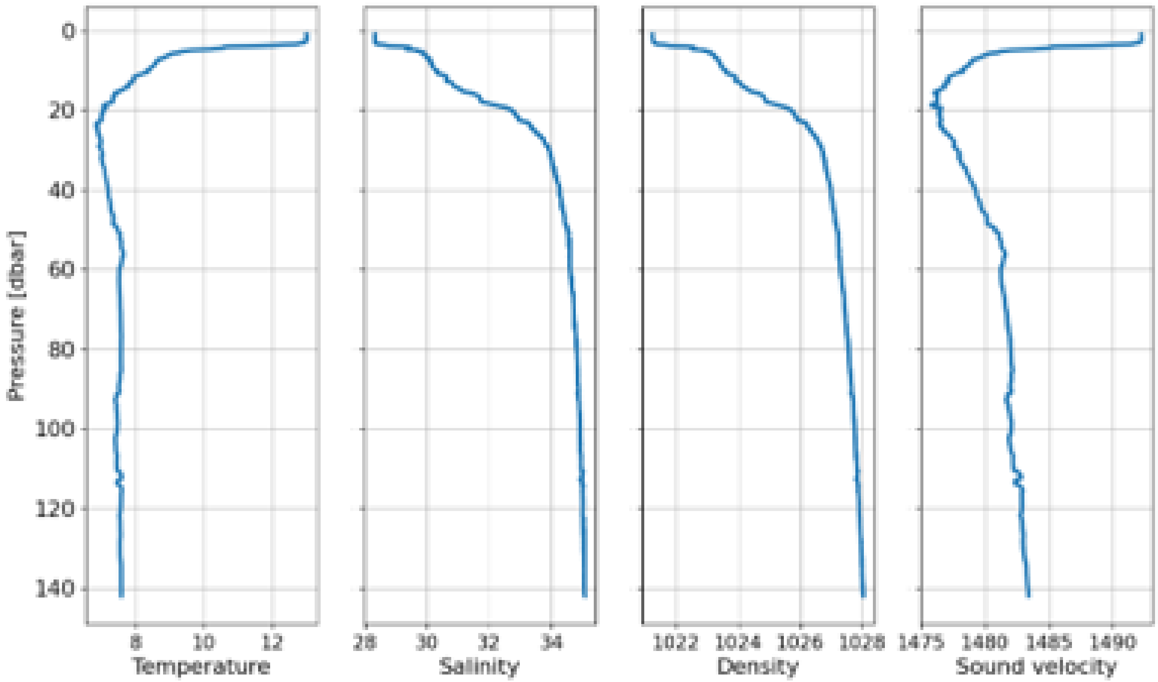

Figure 3.5. Profiles of temperature, salinity, density, and calculated sound velocity at station 5.

A detailed view of the sound velocity profile from station 5 highlights our chosen source depths at 5 meters and 15 meters (Fig. 3.6). The black dotted line indicates the 5-meter depth, where the sound source is positioned outside of the sound channel. In contrast, the grey dotted line marks the 15-meter depth, placing the sound source within the sound channel. This distinction is crucial because, at 15 meters, the sound waves are more likely to remain confined within the channel of minimum sound velocity, enhancing the efficiency of signal transmission.

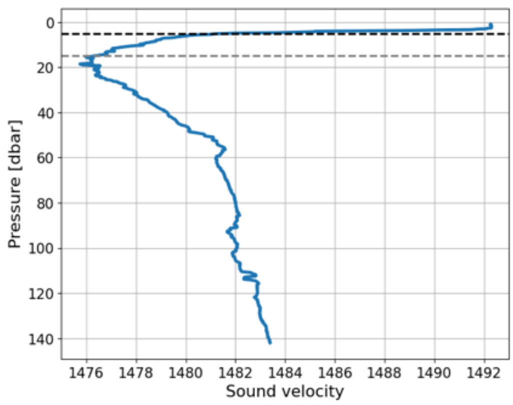

Figure 3.6. Enlarged plot of the sound velocity at station 5. We transmitted acoustic signals at 5 m (black dotted line) and at 15 m (grey dotted line). The sound channel (minimum sound velocity) is at about 18 m depth.

Active acoustics and spectrogram analysis

The students used two different sound sources to transmit various signals from the ship to the hydrophone on the tethered array. Firstly, a high-frequency source was used to transmit short pings (~10 kHz, 10 ms long). Such signals are more sensitive to the stratification in the ocean compared to lower frequencies, but has the added benefit of not needing advanced data processing for comparison with results from acoustic propagation modelling. Secondly, an underwater speaker was used to transmit frequency sweeps and custom audio recordings. These signals put more energy into the water, but must be processed for comparison with modelling results. Both these sources are easy to use, and great for student work. Examples of the different signals, as recorded on the hydrophone on the tethered array, are shown in Fig. 3.7. In (a), pings at 11 kHz can be seen approximately every 15 seconds. In addition, pings and sweeps were picked up from other sources. In (b), linear frequency sweeps are seen from 850 Hz to 950 Hz.

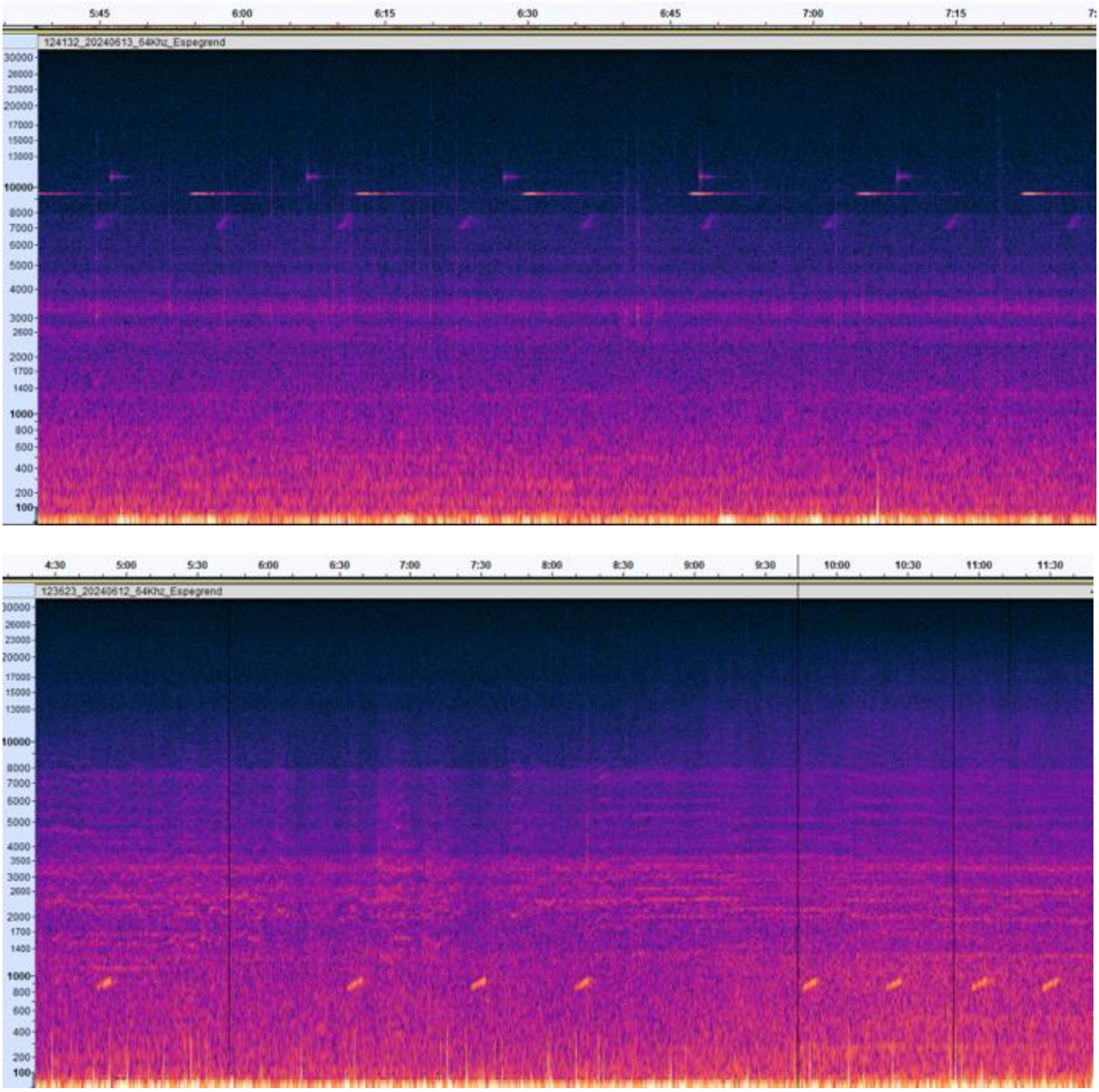

Figure 3.7: Spectrograms containing signals that were transmitted from the vessel using the different sources: The upper plot shows pings and the lower plot shows sweeps from 850 to 950 Hz.

Figure 3.7 presents the spectrogram of the pings transmitted from Station 5 at a depth of 15 meters, as recorded at the fish farm. In addition to the intended pings, the spectrogram reveals other acoustic signals, notably at 9,500 Hz and within the 7,000-8,000 Hz range, which appear to originate from the surrounding environment. This suggests the presence of other sources or noise within the water, possibly from nearby marine activity or equipment. This spectrogram highlights the clear transmission of our signals, as well as the ambient noise present in the aquatic environment.

Modelled ray traces

How sound propagates in the water can be predicted using acoustic propagation modelling. An example of this is the Bellhop ray-tracing model, which was actively used in the acoustics primer. This model uses sound speed profiles obtained from the CTD data (Figs. 3.5 and 3.6) together with the source depth. The sound speed channel has a minimum at 20 m, which was used to set up an experiment: What happens when you transmit sounds at two different depths?

The modelled ray paths, or eigenrays, between our source at 5 m depth Station 5 and the receiver located at the fish farm station (at a depth of 23 meters) are shown in Fig. 3.8. The intention was to model the paths of these eigenrays accurately. However, some modelling issues occurred during the process, resulting in few pure eigenrays. Despite these challenges, the plots clearly demonstrate how the ray paths vary depending on the source depth. When the source was positioned at 5 meters, outside the sound channel, no rays were trapped within the channel. Given that the hydrophone was situated at 23 meters, inside the sound channel, this positioning likely resulted in more received rays in the scenario where the source was at 15 m depth, within the sound channel (as shown in Fig. 3.9). Consequently, we would expect a stronger signal from transmissions made at 15 meters depth, where the source is inside the sound channel, than from those made at 5 meter.

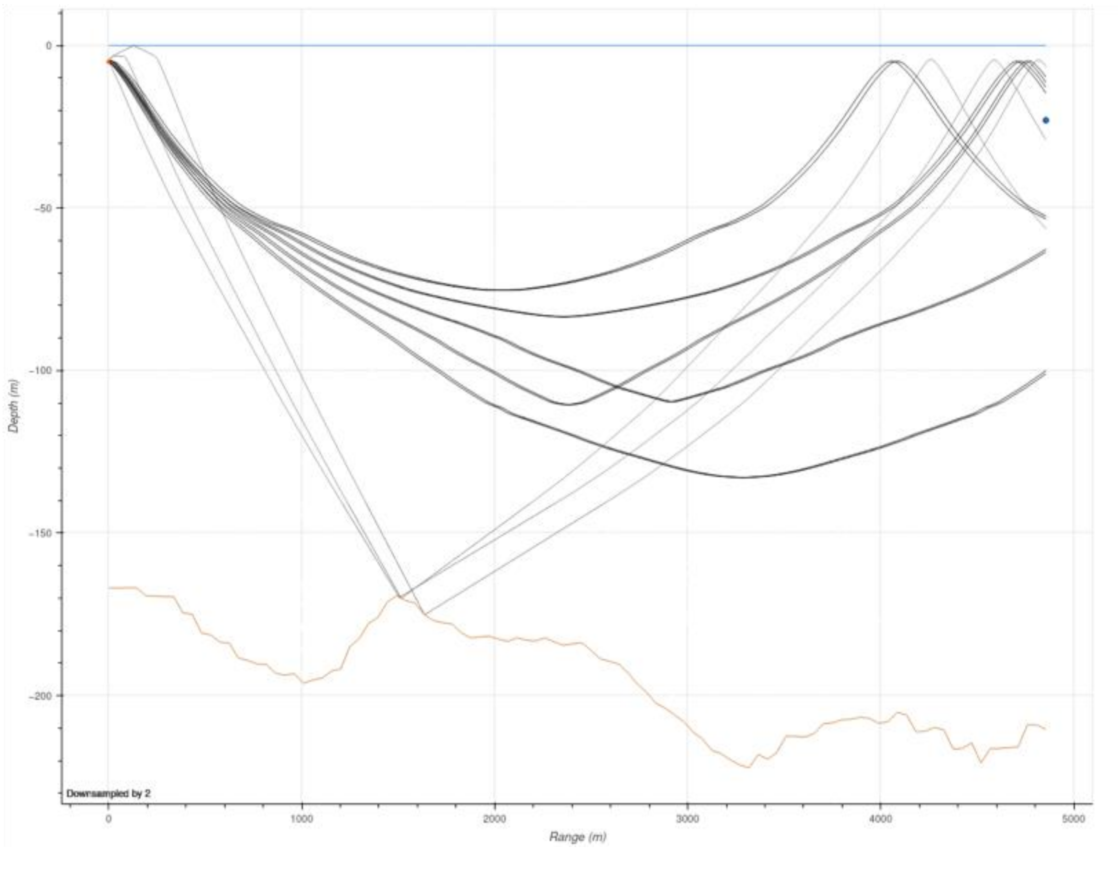

Figure 3.8. Modelled ray traces between station 5 (source at 5 m depth) and the hydrophone at 23 m at the fish farm. The CTDs profiles were used as input to create the ocean environment. Bathymetry is shown with the orange line.

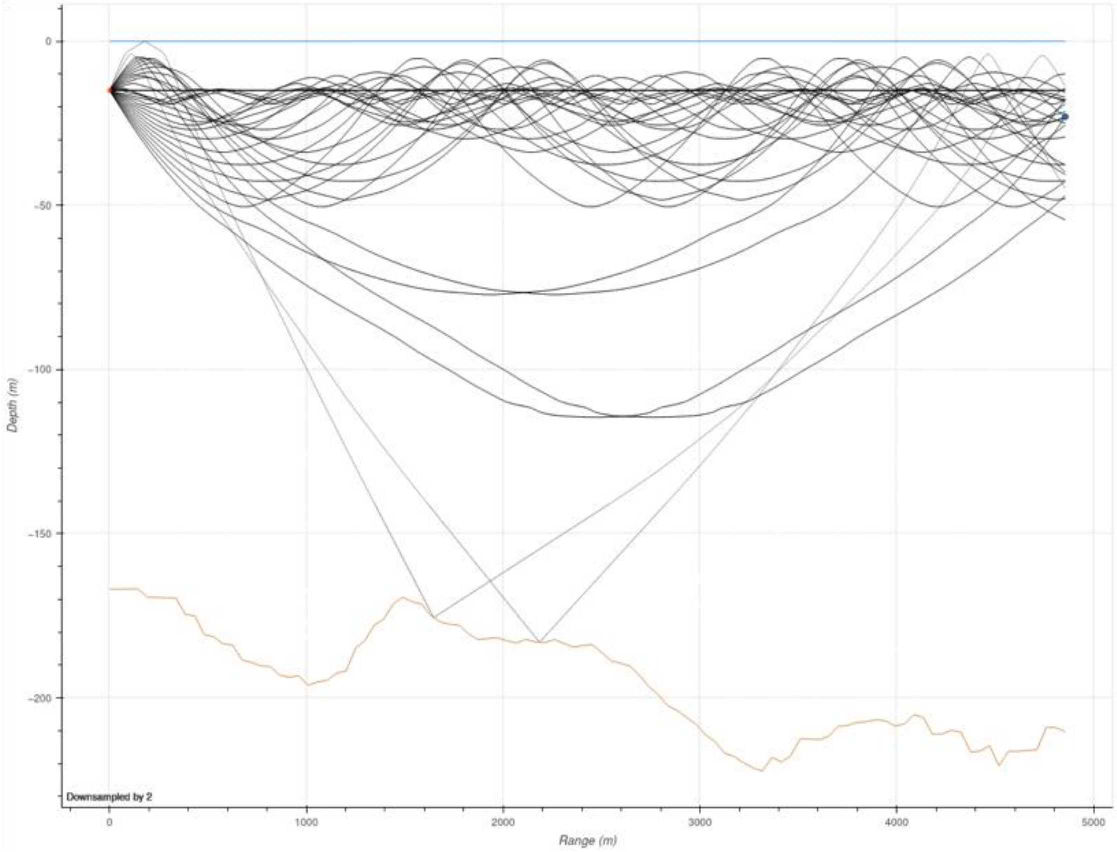

Figure 3.9. Modelled ray traces of eigenrays between station 5 (source at 15 m depth) and the hydrophone at 23 m at the fish farm. The CTDs along the transect was used as input to create the ocean environment. Bathymetry is shown with the orange line.

Broadband sound pressure as function of time

The 48 hour recording of broadband sound pressure at the tethered array (Fig. 3.3) was computed from 1 Hz to 10 kHz using the PAMGuide software, and averaged over 60 s. The pressure level is shown in Fig. 3.10, indicating a relatively high level. This is in part due to the strong winds which induced waves and noise due to water flow and movement.

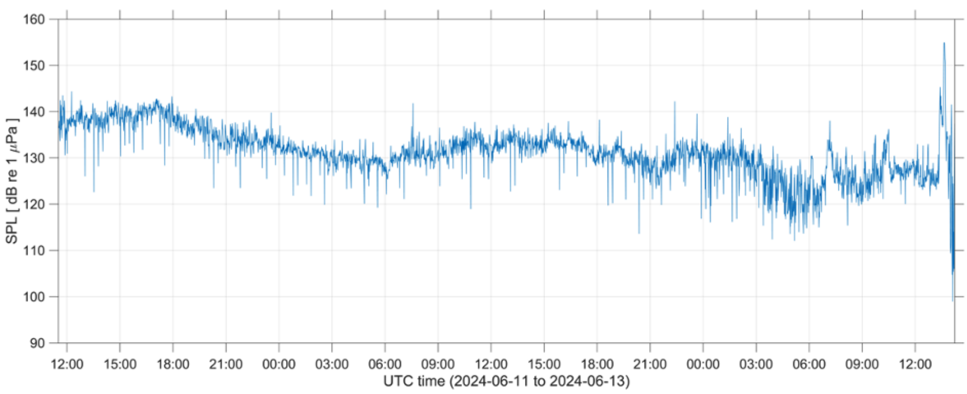

Figure 3.10: Broadband sound pressure level as a function of time from 1 Hz to 10 kHz, 60 s average.

Examples of sound generated by human activities

In fjords, the soundscape is primarily dominated by antropogenic (man-made) sounds, with the largest contributor being shipping. The autonomous recorder was positioned in close proximity of the main shipping lane south of Bergen. There are a number of different vessels passing by, both regularly. Using ship information from AIS (Automatic Identification System), data about the position, heading and speed of passing vessels can be obtained. This can thus be correlated with the passive acoustic data. Additionally, work was being carried out on the fish farm. The sound pressure is seen to decrease as the wind decreased, and during the night when ship traffic is reduced.

In addition to the tethered array, the students deployed a portable cabled hydrophone and recorder at different locations, such as the pier at Espegrend. This provided shorter recordings (e.g. over night), for the students to process. The station is located very close to Bergen Airport Flesland: only 1 km from the southern edge of the main runway, and right below the primary landing path of airplanes, and one of the landing paths for helicopters. During the week, airplanes were flying overhead regularly. Sounds of these aircrafts have been captured on passive acoustic recorders, and are clearly audible in the recordings. An example is shown in Fig. 3.11, a spectrogram of the recording when a two-engine jet plane flew over.

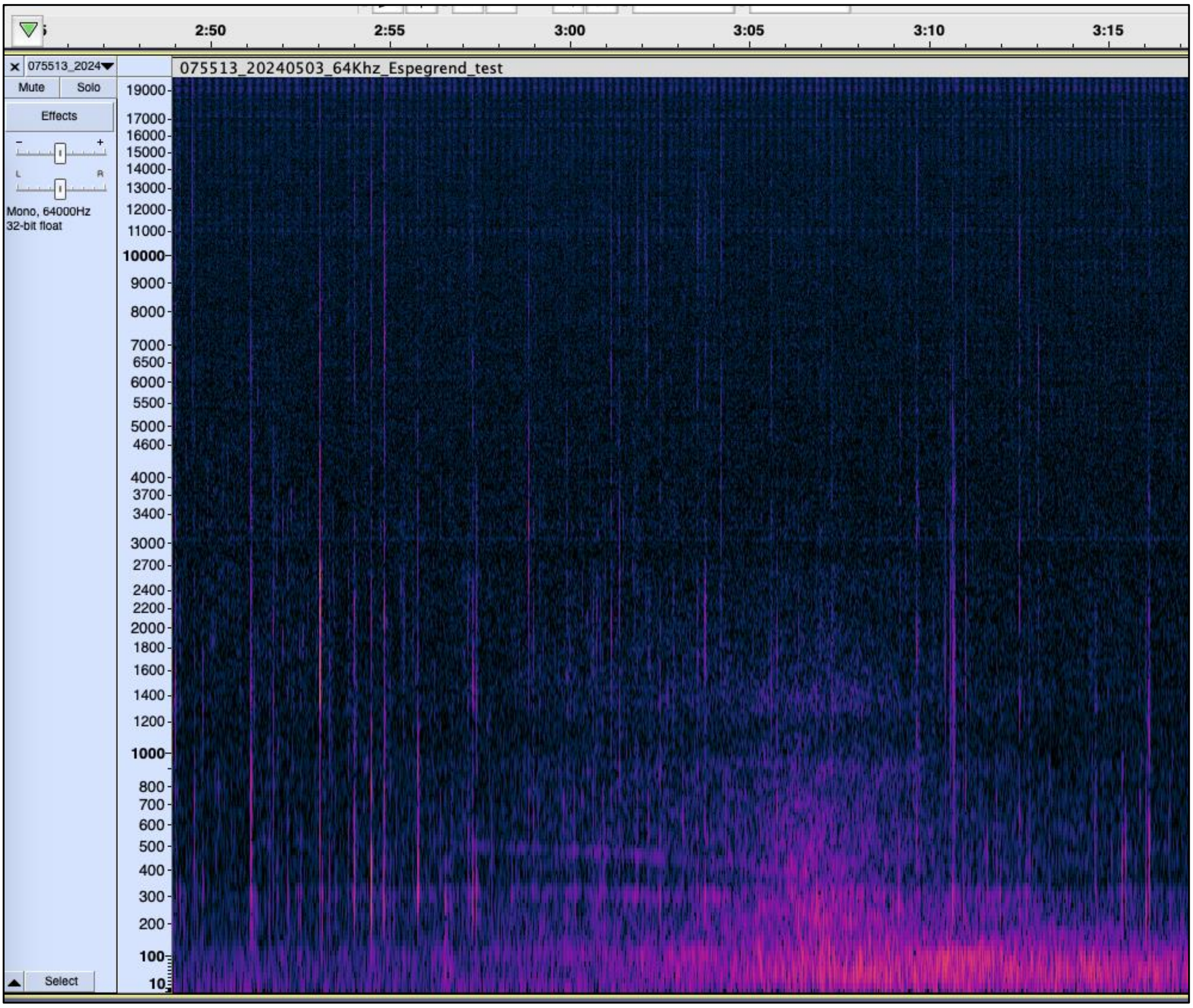

Figure 3.11 The spectrogram from an autonomous recorder off the pier as an aircraft flew over.

3.4 Arctic field work during cruise with KV Svalbard – report from ocean acoustics group

During the HiAOOS 2024 cruise on KV Svalbard to the Eurasian Basin in the Arctic Ocean, we contributed to a range of onboard activities. One of the three main activities included a small boat trip where we listened to signals from the transducer lowered from the ship and the deployed transponders at the ocean bottom. The second activity was to conduct an XBT and XCTD transect from the deck of KV Svalbard, investigating the temperature structure in the eastern Nansen Basin. The third main activity was the deployment of a surface buoy and small wooden boats on the sea ice for the project Float your Boat. Apart from these activities we helped on deck during deployments/recoveries and on general tasks onboard, learning useful practical and theoretical knowledge of the Arctic.

Measurements from the small boat Sjøbjørn

Beforehand of the trip with the small boat we prepared the gear and planed our measurement set up. The XBT cast at the RN mooring position showed a double ducted structure in the surface. Therefore, we planned to lower the micro–Autonomous Underwater Recorder for Acoustic Listening (µAURAL) to two different depths, 12 m and 50 m, one depth in each duct. Our aim for this was to be able to receive the signals from the transducer and the transponder, and to compare the signals depending on the depth of the hydrophone. Moreover, we brought a SAIV CTD instrument to measure the temperature and salinity in the upper 100 m for comparison with the XBT cast and to verify that the double ducted structure was present at our location. For this experiment, we prepared two sets of ropes with marked lengths of 1 m, 5 m and 10 m, so we could keep track of the instrument depths. We rehearsed knots for rope extension and for securing the instruments. Moreover, we tried keeping the ropes nice and tidy in separate buckets so that the deployment would go smooth and efficient. The instruments were checked and prepared for data collection.

Figure 3.11 Master students Veronica Haugen and Jens Didrik Berg conducting optical, oceanographic and acoustic measurements on the small boat Sjøbjørn.

Onboard the small boat we secured our gear to the boat and prepared for lowering the CTD. Despite our effort in keeping the ropes nice and tidy we spent some time untangling the rope for the CTD. After this, we figured we should have deployed the hydrophone first such that it could record longer while we worked on the other rope. We then prepared the hydrophone for deployment and learned from the first rope mistake and managed to lower the hydrophone smooth and efficient. We recorded for 10 minutes at each depth (12 m and 50 m). After this, we lowered the CTD to the target depth of 100 m. Due to surface drift and possibly subsurface currents, the lightweight instruments had a tendency of tilting relative to the vertical in the water column. We therefore decided to only have one rope out on each side of the boat at the same time. Thus, limiting the length of the hydrophone recordings. Additionally, the depth of the instruments based on marks on the rope became more inaccurate due to the tilt. We decided to lower the CTD to the full depth of our rope (~ 130 m), hoping it would cover the double ducted structure. Looking back, we should have brought additional weight, such as shackles, to ensure that the instruments sank more vertically in the water column.

Once back on KV Svalbard we plotted the profile from the CTD (Fig. 3.12) and the spectrogram of the hydrophone recordings (Fig. 3.13). Note the maximum depth of the CTD profile (Fig. 3.12) - we managed to reach our target depth! The SAIV CTD profile confirmed the double ducted structure we saw in the XBT profile. It also confirmed that our selected depths for the hydrophone was well inside each surface duct. Given the tilt of the rope, we were likely shallower than 12 m and 50 m. Assuming a linear tilt and using the information from the CTD cast we estimated the depths of the hydrophone to be at 9 m (not 12 m) and 39 m (not 50 m) depths. We can see that 9 m are still well placed in the middle of the upper duct, while the depth of 39 m is at the upper edge of the lower duct.

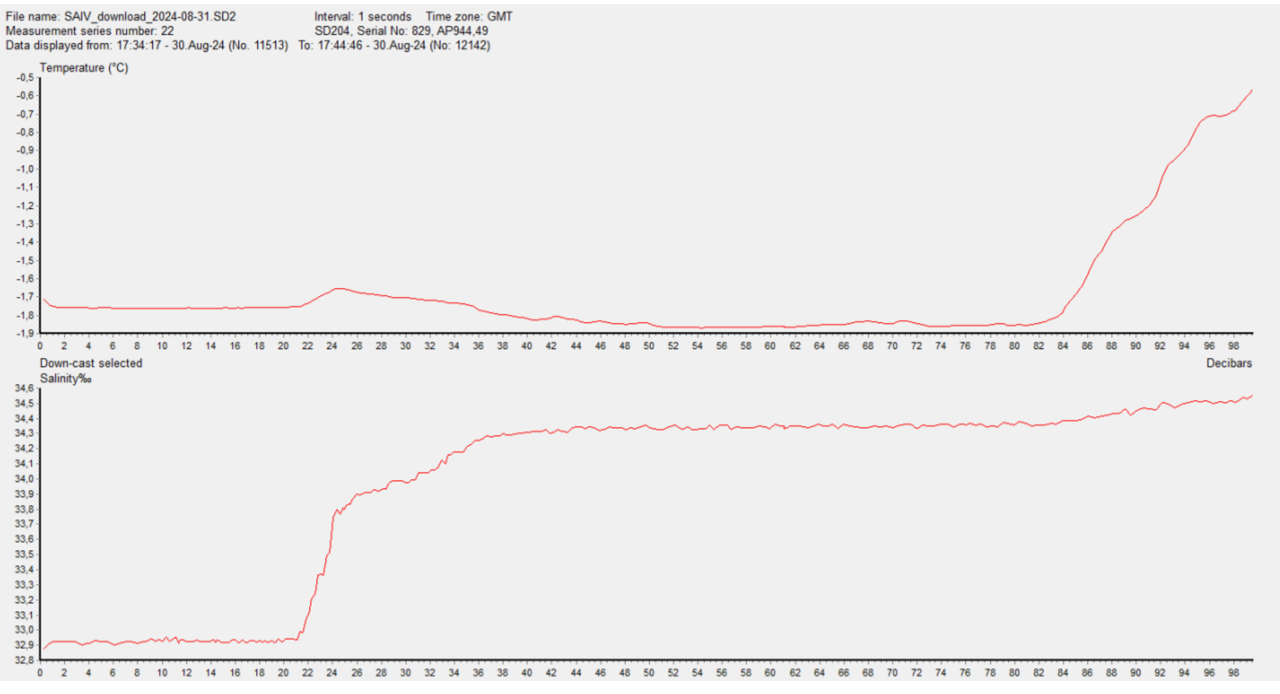

Figure 3.12. Temperature (top panel) and salinity (lower panel) profiles taken with the SAIV CTD from the small boat.

The spectrograms of the recordings show the survey of the transponder network at the second mooring site. The pings transmitted at 9000 Hz (orange arrow, Fig. 3.14) from KV Svalbard was received at 12 m (corrected to ~ 9 m). The signals were clear, but we could also see relatively strong broadband reflections between 6000 Hz and 32 000 Hz and harmonics at 18 000 Hz and 27 000 Hz coinciding with the transmitted signals (yellow oval, Fig. 3.14). A few seconds later in the recording, we could also see the answers from the transponders (red oval, Fig. 3.14).

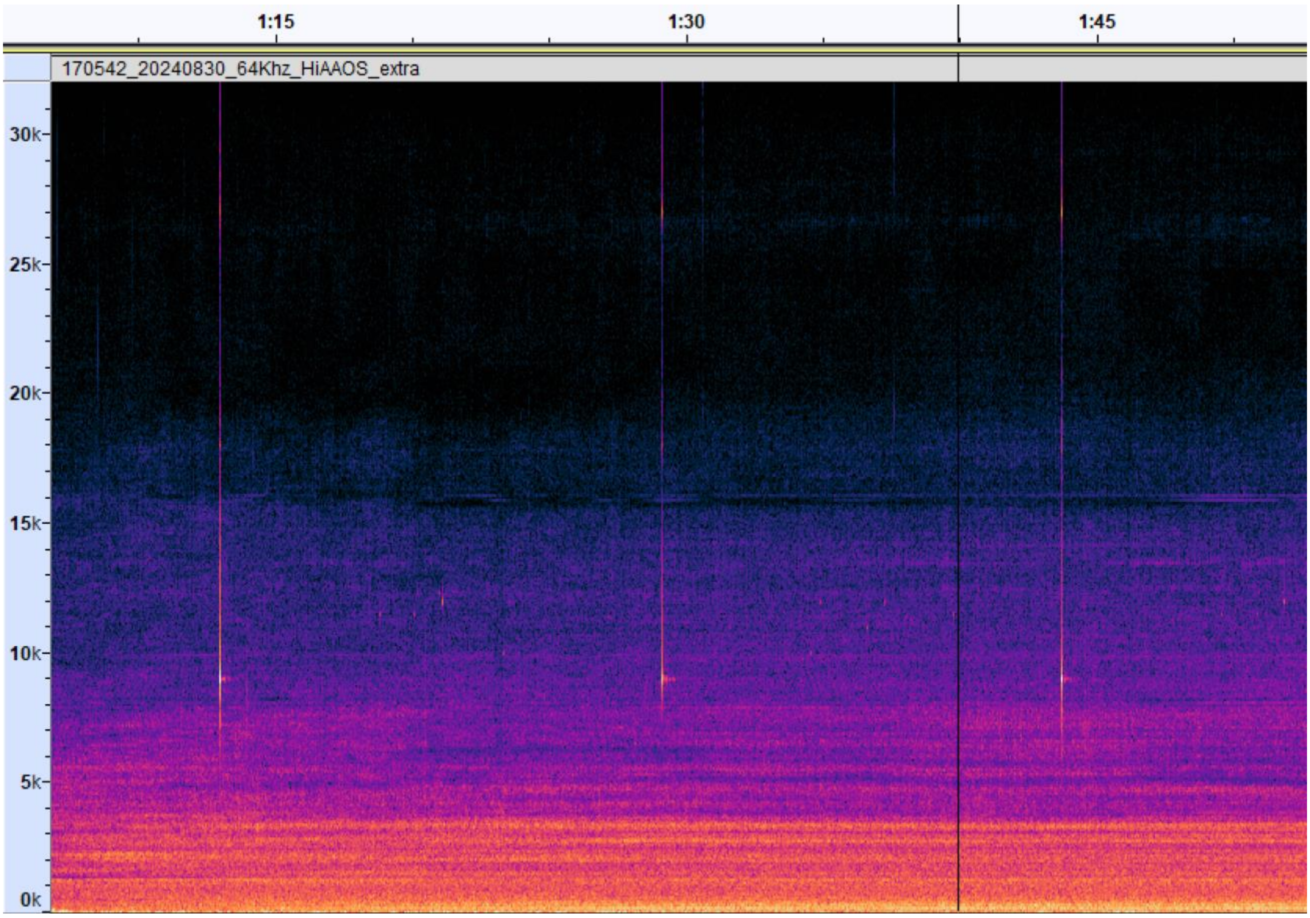

Figure 3.13. The three pings recorded on the hydrophone when out with the small boat (Sjøbjørn)

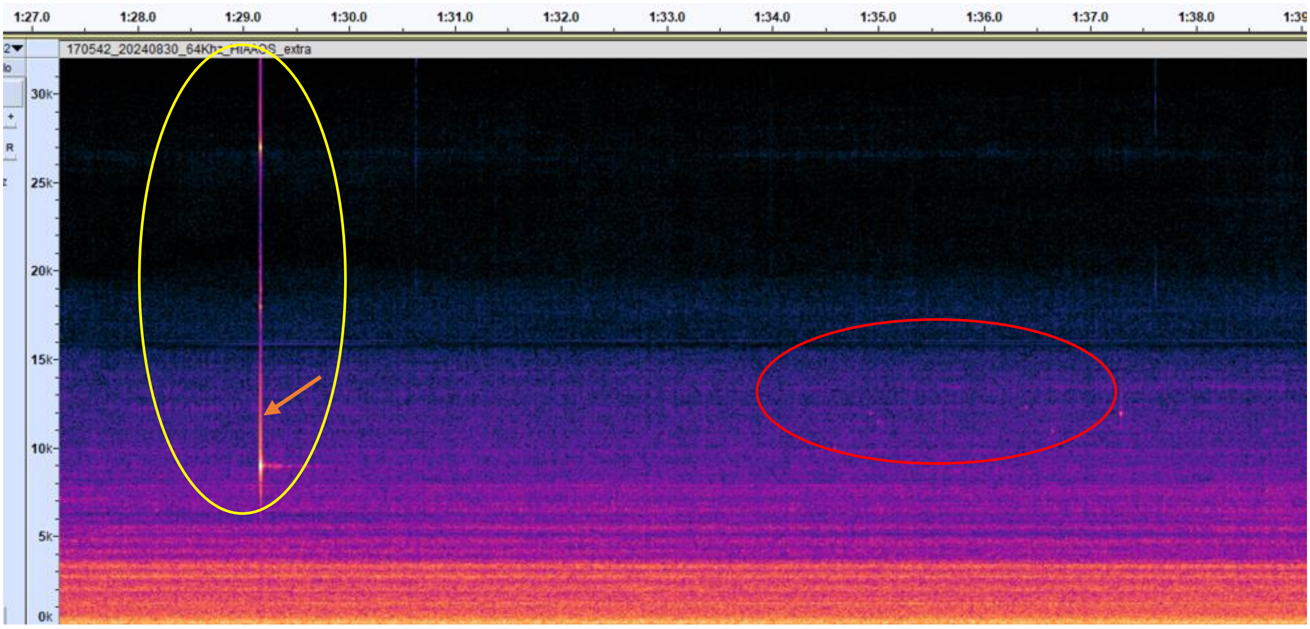

Figure 3.14. Outcrop of Figure 3.13 of one of the recorded pings, together with the answer from the transponders

The XBT/XCTD transect in the eastern Nansen Basin

After leaving the RN mooring position east in the Nansen Basin, an XBT/XCTD transect was conducted. The transect extended from the position of the RN mooring to the outside of the ice edge (Fig. 3.15). The profiles were taken at 9:00, 12:00, 15:00, 19:30 UTC the 30 August 2024, and 04:00 UTC 1 September 2024. At station 3, we took one XBT profile and one XCTD profile to compare the temperature measurements from the two different instrument types, as well as to get information about the salinity structure in the region (Fig. 3.17). The XCTDs are more expensive than the XBTs and were mainly dedicated to the deployment sites of the moorings during the cruise.

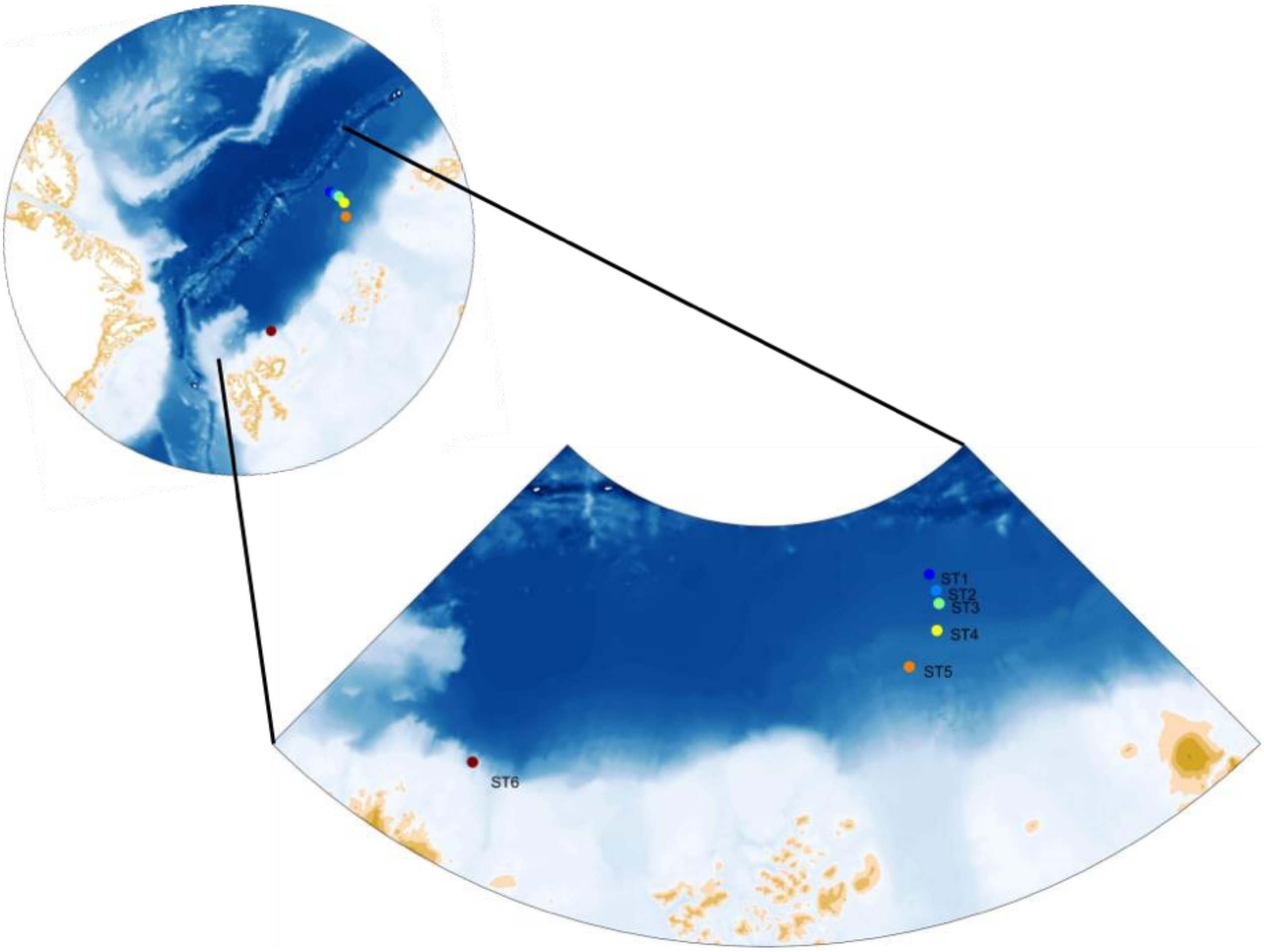

Figure 3.15. Overview map (upper left) of the Arctic Ocean, with a zoomed-in map (lower right) showing the positions of the stations along the XBT/XCTD transect east in the Nansen Basin, extending from the sea ice-covered region (ST1-ST4) to the ice edge (ST5).

The temperature profiles along the transect are displayed in Fig. 3.16. A small near-surface temperature maximum is present at a depth of approximately 20-30 m at all locations, showing only slight variations in magnitude (0.1 °C). The lowest salinity (30.4) is found at the surface and increases gradually until the shallow kink in the salinity profile at the depth of about 5 m. This pattern indicates the presence of a shallow layer of fresher and slightly colder meltwater from recently melted sea ice. Right below the meltwater layer, we find a thin mixed layer overlying the near-surface temperature maximum. The near-surface temperature maximum, likely resulting from atmospheric heating through openings or areas of thin ice during the summer, has been subsequently capped by this newly melted, fresher and colder layer.

Below the meltwater layer, the temperature decreased (to between -1.8 °C and -1.9 °C) at the depth of about 80 m. This well-mixed layer of low temperatures is likely to be remnant of the previous winter's mixed layer, indicating a wintertime mixed-layer depth of about 80-90 m at each station apart from station 5 (60 m). Below this, the pycnocline starts, indicated by the rapid increase in temperature and salinity with depth. The Modified Atlantic Water (also called Arctic Atlantic Water) is commonly defined by 0 °C < T < 2 °C. Around the Atlantic Water core (temperature maximum), between 150 m and 350 m, prominent interleaving structures are present at each station. These structures are created by Atlantic Water of different mixing history, thus different temperatures and slightly different salinities, creating these alternating layers.

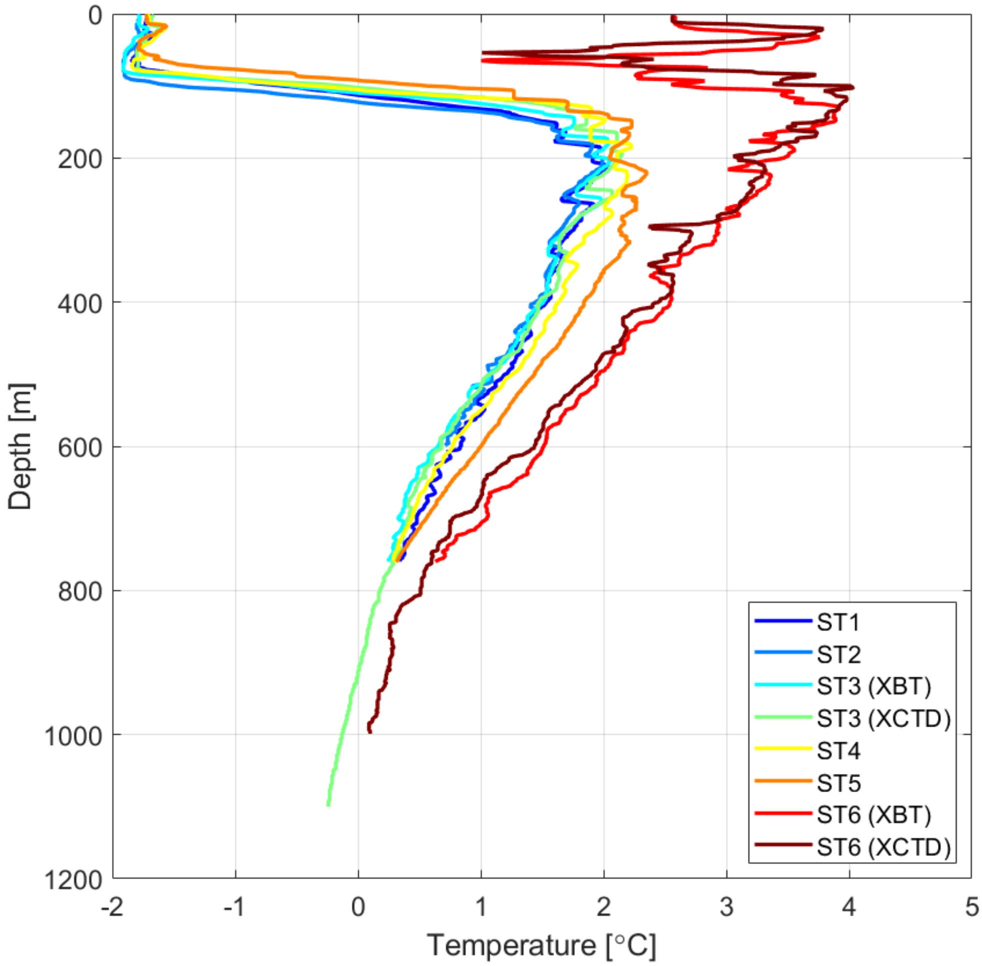

Figure 3.16. Temperature profiles from the XBT instrument (ST1, ST2, ST3 (XBT), ST4 and ST5) extending down to about 760 m depth. Whereas the XCTD instrument (ST3 (XCTD) extended down to about 1100 m depth. A small near-surface maximum and interleavings around the Atlantic Water core were present in all profiles. The colors correspond to the colors of the stations on the maps in Fig. 3.15.

During the transect we visually observed some variations in the sea ice cover between the stations. At station 1, we observed many large openings in the sea ice cover. Additionally, the sea ice looked slushier and softer compared to the other stations. At station 2, we observed a more compact and stronger sea ice which completely covered the surroundings around the station. At station 3 and station 4, the sea ice cover remained very similar, with relatively many but small openings. At station 5, which was about 400 m from the ice edge, small and scattered drifting ice was observed.

The temperature structure along the transect shows great smiliarities. A nea-surface temperature maximum and interleaving structures around the AW core is present along the whole transect. There are, however, slight differences in the temperature magnitude of these structures when moving towards the ice edge. The near-surface temperature maximum is slightly higher near the ice edge (station 4 and station 5) compared to the stations further into the ice cover (station 1 and station 2). Additionally, the upper boundary of the Atlantic Water layer shallows slightly and the Atlantic Water core temperature increases towards the ice edge.

The temperature profiles from the XBT and XCTD at station 5 can be compared in Fig. 3.17. Both instruments capture the same temperature structure in the water column at equal depths. However, there is an offset between the instruments in the upper 400 m of the water column. The offset is mainly around or below 0.1 °C, but in the sharp temperature gradient in the pycnocline, the offset is up to 0.5 °C. This resulted in a slight difference of 7.5 m in the depth of the upper boundary of the Atlantic Water layer (at T = 0 °C) between the XBT and XCTD profiles.

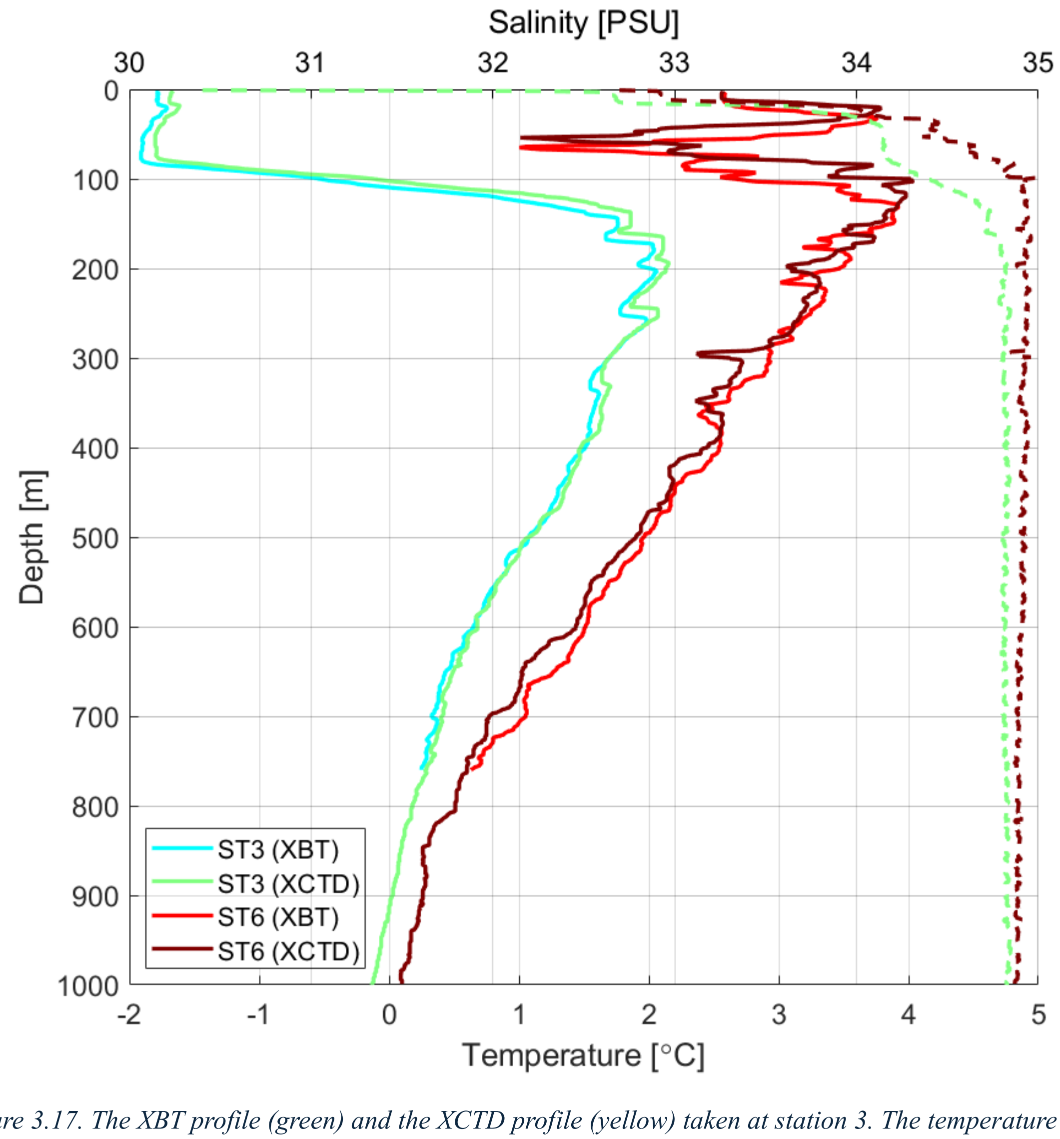

Figure 3.17. The XBT profile (green) and the XCTD profile (yellow) taken at station 3. The temperature profiles are in solid lines and the salinity profile is the dotted line.

The XBTs and XCTD were launched from the lower deck onboard KV Svalbard (left, Fig. 3.18). The hand-held XBT/XCTD Launcher (right, Fig. 3.18) is a lightweight and easy-to-use equipment. Data is transferred real-time through the cable and can be displayed on the computer as the probe sinks in the water column.

Figure 3.18 Veronica standing ready to launch an XBT at the aft deck (left) and the empty hand-held XBT/XCTD Launcher (right).

4. Other activities during the KV Svalbard cruise

4.1 Float Your Boat

Float Your Boat (FyB) is an outreach project of the International Arctic Buoy Programme. Their aim is to connect people to the Arctic. Engaging and sharing knowledge about the Arctic Ocean circulation and sea ice. The project supplies scientists with ice buoys and small wooden boats decorated by students. The ice buoy measure and transmit real-time sea level pressure, surface temperature and position data. The sea ice drift can be inferred from the GPS position over time. These are key parameters to understand more about the circulation and sea ice in the Arctic Ocean and how it is changing. More information about FyB is available on www.floatboat.org.

Ahead of the cruise, we were supplied with over 350 small wooden boats and three ice buoys with GPS positions from the FyB project. Over 300 of the small wooden boats had been decorated by young pupils from various primary and art schools in the US. The rest of the boats, including wooden boats made by the crew and recuits onboard KV Svalbard, were undecorated (Fig. 3.19). We arranged therefore two events and invited the recruits to decorate their own small boat (Fig. 3.20). The first deployment with an ice buoy was at the easternmost point during leg 1 at 84.9376° N, 128.1114° E (Dep1), the second deployment was near the North Pole (Dep2) and the third was during the return voyage back to Svalbard (Fig. 3.21).

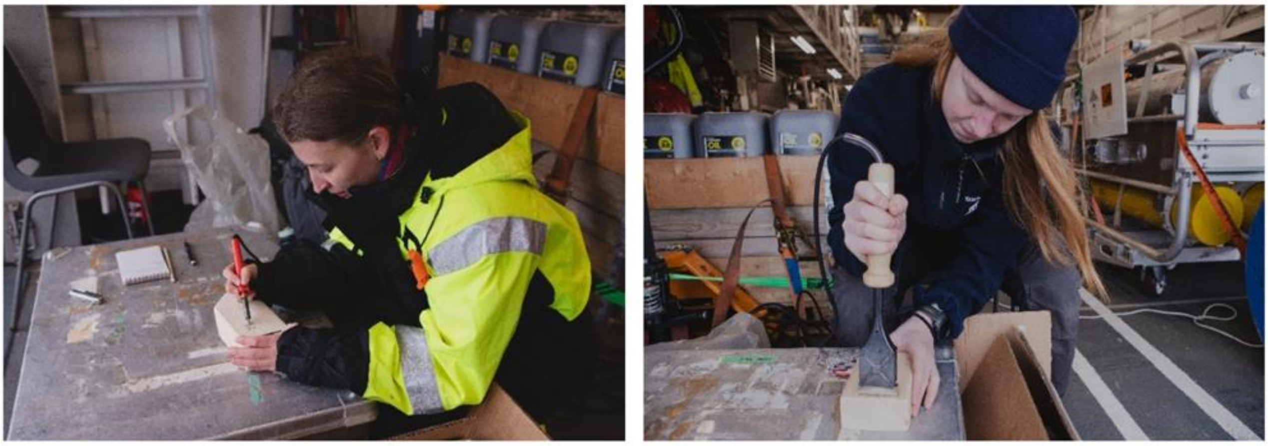

Figure 3.19. Prior to the decoration we labelled the small wooden boat made by the crew and recruits with the website (www.floatboat.org) and a unique number for tracing

Figure 3.20. The recruits and master student Jens decorating their own small boats (left) and the result (right).

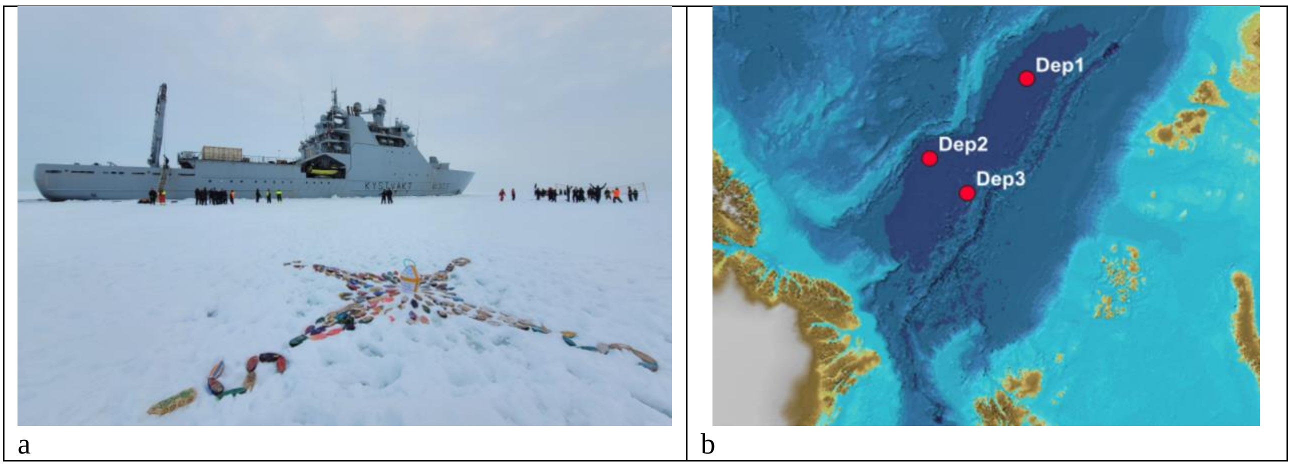

Figure 3.21. (a) The deployment of the small wooden boats and the GPS buoy near the North Pole- (b). Map of the deployment sites for the three clusters of wooden boats during the KV Svalbard cruise 2024.

4.2 Mooring deployments

Prior to deployments

During the cruise we were also part of the ping-team. The ping-team had a two-parted deck job prior and after the deployments of the moorings. The first part, prior to the deployments, was to lower the echosounder called Knudsen (left, Fig. 3.22) into the water from the deck. Knudsen gives information about the bathymetry. The data was compared to the ships echosounder and to the International Bathymetric Chart of the Arctic Ocean (IBCAO) bathymetry data to check for accuracy and possible offsets. The ships echosounder was found to be accurate enough and was used for the bathymetric survey after "8 ping stations". The IBCAO was found to have an offset of about 40 m compared to Knudsen. The bathymetric survey is an important part of the mooring deployment since the mooring length and planned depths of instruments need to match the ocean bottom depth. Additionally, a flat bathymetry area is ideal such that the anchor has a minimal tilt, and therefore laying stable at the ocean bottom.

At some locations, heavy drifting sea ice surrounded the ship. This has previously made these surveys more time consuming since the instruments had to be hived up when sea ice approached to limit harm on the wires. However, the bright idea of using a tractor tire as a moon pool came from the captain ahead of the cruise and was provided and set up (Fig. 3.22 right). The tire was very effective and fought off quite large floes drifting by.

Figure 3.22 The echosounder, Knudsen, used for the bathymetric survey prior to the mooring deployments (left). The tractor tire used to keep drifting ice away from the instrument wire.

Post deployments

The second part of the ping-teams job was after the mooring deployment. For this job we used a small acoustic pinger for ranging the mooring anchor and to get an accurate position of it. A transponder network consisting of four transponders were also deployed about 4 km from each mooring. The acoustic pinger was also used here to range and get their accurate positions. The transponder network is an important part of the mooring system. Due to ocean currents, the mooring does not necessarily stand completely vertical in the water column and may sway according to currents. The transponder network will range and locate the Coastal Acoustic Transponder (CAT) mounted at about 50 m depth on the mooring. This provides an accurate position of the mooring in the water column throughout the deployment period.

Figure 3.23. The ping team in action on deck (left) with a pulley system for lowering the Knudsen into the water (right).

During the deployments of the moorings, we helped in carrying and mounting instruments. During the deployments of the moorings, we helped in carrying and mounting instruments (Fig. 3.23). Four RBRs, sixteen hydrophones, and six Seabirds were placed at its assigned spot on the fluffy upper part of each mooring (Fig. 3.24). The fluffy part of the mooring wire was called the "hairy fairy". The function of the hairy fairy is to decrease the wire's vibration and thus noise in the hydrophone recordings.

Figure 3.24 Seabirds, hydrophones and RBRs arranged and ready to be attached to the "hairy fairy".

Figure 3.25 Master students Veronica Haugen and Jens Didrik Berg assisting the technicians on deck in mounting the instruments to the mooring wire

During transit days we helped with different things and learned new practical skills such as to solder. Jens Didrik Berg had three instruments for his optic measurements, but only two out of three cables were working. We then used a multimeter to seek out the location of the problem. After finding out that the problem was lying in the area where the cable had previously been fixed, we cut it and had to put it back together. With the practical skill we had learnt, soldering, we were able to solder each cable together with the correct match, using heat shrink to protect each cable and then using electrical tape on top to secure it (Fig. 3.26).

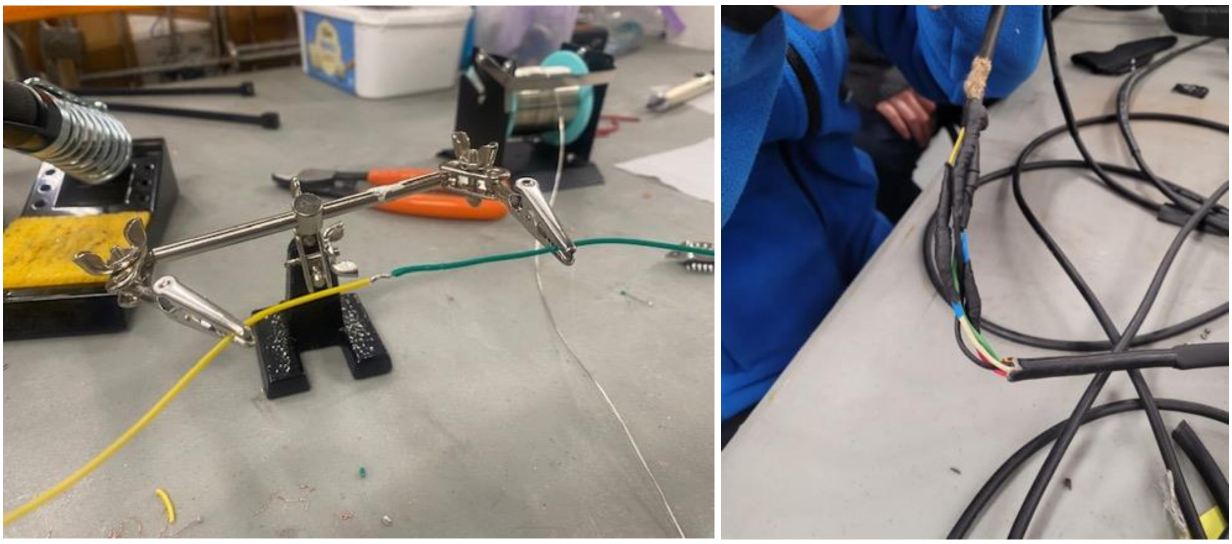

Figure 3.26 Learning to solder (left) and after soldering and fixing Jens Didrik Berg's cable (right).

During transit, we were also lucky to see three polar bears. One was very curious and came close to the boat (Fig. 3.27).

Figure 3.27 One out of the three polar bears we saw during transit.

4.3 Preparing and deploying Ocean Bottom Hydrophones (OBHs)

A total of four Ocean Bottom Hydrophones (OBHs) were deployed during the cruise, each positioned 500 meters above the seafloor on separate moorings. These OBHs will record sounds continuously over the two-year deployment period. The recordings will be used to detect and improve the positioning of earthquakes in the Arctic Ocean.

The instrument kit consisting of the OBHs including the data logger (6D7), the GPS-system (UHURA), and the communication unit (DIRC II) is manufactured by K.U.M. The original mounting clamps were swapped out with strong backs designed and made by Woods Hole Oceanographic Institution to ensure compatibility with the mooring design (i.e. mooring wire).

Figure 3.28 Preparing for deployment of 4 Ocean Bottom Hydrophones (OBHs)

During the preparations we connected the data logger and GPS to DIRC II. The photo on the left-hand side of Fig. 3.28 shows the DIRC II connected to the GPS and data logger 6D7. The DIRC II unit comes with the possibility of using Wi-Fi to communicate with the data logger and was quite handy during the preparations. When connected to its Wi-Fi, we could use our phone to check the status of the battery voltage and memory disk space, synchronize the internal clock to GPS time, and start the recording of the hydrophone. The Live

View feature allowed us to monitor real-time data, ensuring that all instrument functions were operating correctly. This procedure was carried out prior to each deployment and the metadata and serial numbers were carefully logged.

The deployments of the OBHs went smooth and efficient with the strong back mounts. The strong backs had connecting points on the top and bottom, resulting in a safe and easy in-line deployments.

Figure 3.29 Photos of the deployment of the OBHs.

4. Conclusion and further work

The research school at Espegrend Biological Station owned by University of Bergen was the first in a series of events planned in UAK over a period of five years. The research school was organized by UIB and NERSC with contribution from University of Rhode Island and Scripps Institution of Oceanography. The Espegrend station offered facilities for field-based research and education activities, including accommodation, laboratory facilities, lecture rooms and boats for field work in the fjord outside Bergen. The research school had 12 students and 12 instructors and most of them stayed together at the dormitory during the five days. The students learned about ocean fieldwork, preparation of instruments, deploying and recovering instruments, and offloading and processing data. The guest visit by Prof. Lora van Uffelen from University of Rhode Island was a very valuable contribution to UAK because she gave the introductory course in underwater acoustics and contributed to the acoustic activities at research school. Two other professors from USA, Rick Reynolds and Peter Worcester from Scripps, participated and gave valuable contributions to UAK. The research school was quite successful because Espegrend offered very good facilities, and it was a cost-effect location for organizing such events. It was therefore suggested to organize a follow-up workshop at Espegrend later in the project. The participation in the Arctic field campaigns with the two icebreakers was organized in collaboration with other projects, since UAK did not get a dedicated UAK cruise in 2024. The plans for 2025 will have focus on a research school organized by Laval University in the Canadian Arctic, and on a cruise with the Norwegian coast guard vessel KV Svalbard. Exchange visits, workshops and dissemination activities are also planned for 2025.