The calibration described below is not applied to the data submitted to NMDC - the submitted data are calibrated using the watersamples collected and analysed by HI per text here For

Note that calibrations described in the report are not applied to the data submitted to NMDC.

Salinity was calibrated using water samples collected and analyzed by HI.

University of Bergen

The described calibrations have not been applied:
- O2, see separate document,
- conductivity/salinity, the constant offset determined by the analysis at HI was applied

Geophysical Institute

Oceanographic instruments

Study of Osterøy-region and Masfjorden

Author: GEOF232 students

Spring 2023

Table of Contents

Abstract

This joint cruise report presents the findings and outcomes of two collaborative research efforts that took place on the research cruises in February and March. The first cruise, which took place from 14th to 16th February, explored Masfjorden, a narrow and deep fjord located north of Bergen. The second cruise, which occurred from 6th to 9th March, focused on the fjords around Osterøy.

The cruises were carried out by a team of students in the subjects GEOF232 and GEOF337 and researchers from multiple institutions, the boating crews, and professors. It was carried out with the goal of collecting data on various aspects of the atmospheric and oceanographic environment in these areas. The joint cruise report summarizes the research methodologies employed during both cruises, including data collection, analysis, and discussion.

1 Oceanographic survey – G.O Sars

1.1 Introduction

This cruise report summarizes the results of an expedition from the 6th to the 9th of March around the Osterøy region. This report focuses on the oceanographic aspects of the four-day cruise. During the cruise, we conducted a series of experiments and routine measurements both at sea and in the fjords around Osterøy. This report provides a detailed account of the experimental design, instrumentation, and data collected during the cruise, as well as different analysis of the collected results.

1.2 Oceanographic survey

1.2.1 Participants

The partakers of the cruise consisted of 14 students from GEOF232, as seen in the picture in figure 1. In addition to the students, Dr. Kjersti Birkeland Daae, Helge Bryhni, Dr. Stephan Thomas Kral, Dr. Pirmin Philipp Ebner, Torunn Sandven Sagen were also present. The attendees from Havforskningsinstituttet as well as the crew members of G.O Sars were also in attendance and contributed to our sense of welcome and security throughout the duration of our stay.

***Figure 1**: Picture of the 14 students from GEOF232 and Torunn S. Sagen on the right, on the front deck on G.O Sars. Photo: Kjersti Birkeland Daae, 2023*

1.2.2 Cruise overview

This report presents the findings of a four-day expedition to the Osterøy area (Osterfjorden, Romarheimsfjorden, Eidsfjorden, Veafjorden, and Sørfjorden), conducted from March 6th to March 9th, with a focus on the oceanographic aspects of the cruise. Throughout the expedition, we carried out a variety of experiments and routine measurements. In the GEOF232 course, the students are to plan a project either individually or in small groups prior to the cruise. The projects dictated to a large degree what experiments and tests were conducted during the cruise.

It was performed multiple series of CTD measurements, where the collected test samples were subjected to measuring of oxygen concentration, salt concentrations, carbon dioxide concentration and contents of nutrients.

In addition, multiple drifter buoys were deployed both prior and during our cruise at different locations. All the drifters were collecting continuous data regarding position and some of the drifters were additionally collecting data regarding wave height. Furthermore, it was provided continuous data from a LIDAR for the duration of the cruise.

1.2.3 Environmental conditions

Unlike the everyday circumstances in Bergen, with cloudy and windy weather, the four-day cruise had its surprises. During the first day, all the way from the shore of Bergen to beyond the coast of Sotra, Bergen, the sky was clear, and the temperatures were around 2-4 degrees. This resulted in little to no waves. The following day we had cool weather with temperatures dropping below zero, and partly cloudy and sunny skies. The cool temperatures resulted in snow on Wednesday while we were heading in to Sørfjorden. In the narrower, deeper parts of the Osterfjord and the Sørfjord, the ocean was covered in ice. There was also little to no waves all around Osterøy on Tuesday and Wednesday. On the final day of the cruise, the sunny skies were back, and the cool spring weather continued.

1.2.4 Oceanographic instruments

1.2.4.1 LIDAR-Light Detection and Ranging

The Light Detection and Ranging is an instrument that relies on Doppler velocity measurement, by sending out laser beams and then analyzing the returning beams that have interacted with particles in the atmosphere (Leosphere, 2019). It can then calculate the Doppler shift from the returning light, and then determine the wind speed and wind direction. The particles that interact with the beams are aerosols like dust and water droplets, which are moving at wind speed. The range differs between 40 to 290 meters, depending on the conditions of the atmosphere. The instrument sends out five beams, one beam emitted vertical and the other four are emitted in four cardinal directions along a 28° scanning cone angel. By sending out beams in a conical formation, the light that is reflected back is received by very sensitive systems that are able to reconstruct a three-dimensional wind vector. See table 1 for specifications about the Windcube v2.0.

The Windcube v2.0 LIDAR Remote sensor was mounted starboard side of the ship on the 5th deck. The 5th deck was approximately 11 meters above the sea level.

Table 1*: Information about important measurement of the Windcube v2.0 LIDAR remote sensor.*

Measurement	Windcube v2.0 LIDAR Remote sensor
Range	40 meters - 290 meters
Data sampling rate	1 second
Number of measurement heights	12
Speed accuracy min-max bias versus reference	0.1 m/s
Speed range	0 m/s to 60 m/s
Direction accuracy	2°

1.2.4.2 Drifters

1.2.4.2.1 Description of the different types of drifters

In figure 3 and 4, you will see the two different types of drifters that were used during the cruise. Both drifters are "home-made" drifters, built and designed by senior engineer, Helge Thomas Bryhni, who works at the Geophysical Institute at the University of Bergen.

The drifter in figure 3 is primarily used to measure the movement of the drifter caused by the circulation in the top layer of the ocean induced by wind (Bryhni, 2023). The purpose of the other drifter in figure 4 is to registrate the movement of the drifter when influenced by the ocean layer further down in the sea column.

Both drifters are kept afloat by moorings buoys. They also have a rod, as seen in figure 3, or a thin wire and a rod, as seen in figure 4, which purpose is to make the drifters easy to spot and pick up from the ocean. Above the mooring buoys you will find an orange box which contains a lithium battery. The purpose of the orange box is to protect the battery from harm and water damages. The battery functions as a GPS tracker, and by sending a text message to a given number you can track the drifter simultaneously. The location of the drifter is updated frequently. The battery needs to be charged, and the duration is unknown. However, it lasted long enough for the cruise. Both the drifters have heavy chains connected to either the mooring buoys, as seen in figure 3, or to the bucket, as seen in figure 4. In figure 4 there is a thin, turquoise, 10 meter long, rope that is connected between the rod through the mooring buoy and the bucket. The thin rope's purpose is to elongate the drifter, so that you can collect data from further down in the sea column. The rope is specifically chosen to be thin so that it will have minimal impact on the movement of the drifter when the water drags the bucket, and therefore the drifter, along.

Figure 2: *The image shows one of the drifters used during the cruise. From above: An orange box containing a lithium battery connected to a pole. The battery serves as a GPS tracker of the drifter's movements. Further down you will see two mooring buoys, which keeps the drifter afloat. Down below there is a heavy chain connected to the rod. Photo: Nora Bringaker, 2023.*

Figure 3: *The image shows one of the drifters used during the cruise. From above: An orange box containing a lithium battery connected to a pole. The battery serves as a GPS tracker of the drifter's movements. Further down you will see a mooring buoy, which keeps the drifter afloat. Down below there is a thin, turquoise, 10-meter rope that is connected to two buckets. Inside the connected buckets there is a heavy chain. Photo: Nora Bringaker, 2023.*

1.2.4.2.2 Time and position of deployment and recovery of the drifters

During the four-day cruise, several different drifters were deployed and recovered various amounts of times. Down below you will find tables presenting date, time, and coordinates for when the different drifters were deployed and recovered.

Before the cruise around the Osterøy-fjords, there was a cruise to Masfjorden in February, from Tuesday the 14th to Friday the 17th. During the cruise, a few drifters were deployed and recovered, but two drifters were also anchored, see table 2. On Friday the 17th, the WB26 was anchored near the island Sotra, Agnøy (depth: 74,27 meters), while the UiB01 was anchored at Frekkhaug (depth 107,75 meters). The drifters were picked up during the Osterøy-cruise, respectively on the 6th of march and on the 9th of march.

On the first day, Monday, only one drifter was deployed beyond the coast of Sotra, Bergen, to collect wave data, see table 3. This was the only drifter that was deployed and recovered by G.O Sars. The rest of the drifters deployed on Tuesday and Wednesday were handled from a small boat that was on the ship, see table 4 and 5, respectively. On the last day, no drifters were deployed.

In table 5, you will observe that recovery data for drifter #4 is absent. The drifter was not found when a small group of students were supposed to pick it up because it was apprehended by a local fish farm. A week later, the drifter was picked up at the fish farm.

Table 2: *Overview of the drifter that was deployed and recovered on Monday, 6th of march. Down below you will find information regarding the date, time (UTC), latitude (N), and longitude (E) of the deployment and recovery of the drifter.*

	Deployment				**Recovery**			
Drifter	Date	Time (UTC)	Latitude (N)	Longitude (E)	Date	Time (UTC)	Latitude (N)	Longitude (E)
UiB01	16.02.23	10:20	60°53.420	5°29.268	16.02.23	15:43	60°53.301	5°29.201
WB26	16.02.23	10:35	60°53.190	5°29.090	16.02.23	15:15	60°53.031	5°27.624
WB26	17.02.23	10:38	60°36.118	4°55.106	06.03.23	12:00	60°36.118	4°55.106
UiB01	17.02.23	13:00	60°30.625	5°14.668	09.03.23	05:15	60°30.625	5°14.668

Table 3: Overview of the drifter that was deployed and recovered on Monday, 6th of march. Down below you will find information regarding the date, time (UTC), latitude (N), and longitude (E) of the deployment and recovery of the drifter.

	Deployment				**Recovery**			
Drifter	Date	Time (UTC)	Latitude (N)	Longitude (E)	Date	Time (UTC)	Latitude (N)	Longitude (E)
WB 1	06.03.23	16:10	60°51.35	4°34.85	06.03.23	19:37	60°51.35	4°34.85

Table 4: Overview of the drifters that were deployed and recovered on Tuesday, 7th of march. Down below you will find information regarding the date, time (UTC), latitude (N), and longitude (E) of the deployment and recovery of the drifters.

	Deployment				**Recovery**			
Drifter	Date	Time (UTC)	Latitude (N)	Longitude (E)	Date	Time (UTC)	Latitude (N)	Longitude (E)
WB 2	07.03.23	05:00	60°35.215	5°26.866	07.03.23	14:11	60°33.308	5°14.064
#1	07.03.23	13:57	60°33.239	5°21.554	07.03.23	18:10	60°31.805	5°15.076
#2	07.03.23	13:57	60°33.239	5°21.554	07.03.23	18:10	60°31.805	5°15.076
#4	07.03.23	17:52	60°32.790	5°13.853	07.03.23	18:50	60°33.21	5°13.730
#1	07.03.23	18:10	60°31.805	5°15.076	07.03.23	18:38	60°31.767	5°15.172
#2	07.03.23	18:10	60°31.805	5°15.076	07.03.23	18:36	60°31.771	5°15.178

Table 5: Overview of the drifters that were deployed and recovered on Wednesday, 8th of march. Down below you will find information regarding the date, time (UTC), latitude (N), and longitude (E) of the deployment and recovery of the drifters.

	Deployment				**Recovery**			
Drifter	Date	Time (UTC)	Latitude (N)	Longitude (E)	Date	Time (UTC)	Latitude (N)	Longitude (E)
UiB02	08.03.23	10:00	60°25.8	5°37.5	08.03.23	16:36	60°44.40	5°61.86
#4	08.03.23	10:03	60°26.1	5°36	08.03.23	-	-	-
UiB04	08.03.23	10:07	60°25.86	5°34.32	08.03.23	17:55	60°29.16	5°25.02
#1	08.03.23	10:08	60°25.86	5°34.32	08.03.23	17:41	60°25.86	5°30.18
#2	08.03.23	10:23	60°27.84	5°40.38	08.03.23	17:50	60°27.48	5°28.68

1.2.4.3 CTD profiling

The CTD-instrument measures conductivity, temperature and pressure. The CTD can also calculate other water characteristics such as salinity and density. Salinity is calculated from conductivity and pressure and density is calculated from conductivity, temperature and pressure. On our CTD-instrument there were also fixed and oxygen meter that measured dissolved oxygen content. In addition to this, water samples were taken at different depth levels at all stations and analyzed for salinity and dissolved oxygen content using Winkler titration. The results are used for calibrating the CTD. At some stations we analyzed the water samples of carbon and nutrients.

The CTD system at the boat is a Sea-bird 9plus CTD with the 11plus V2 Deck unit, this system is often called 911plus together. The system has 12 bottles that are called Niskin-bottles which are sorted in a Rosette, these bottles are used to collect water samples, see figure 4 We lower the CTD to 10 meters above the seafloor where we fire the first bottle. It is important to wait 30 seconds before firing a bottle. We do this so that the water gets time to stabilize from the moving CTD-instrument. We can also fire a bottle on the way up, when it stops, we also have to wait 30 seconds before closing the bottle. All the communication on how deep we want the CTD to go is done whit the crew members through a radio from the operation room. Through the CTD we can display profiles of salinity, temperature, density, oxygen and fluorescence, this data will also be saved. (Sea-Bird scientific, 2015)

Figure 4: *Picture of the CTD (Sea-bird 9 plus) used at G.O Sars. Photo: Astrid Berg Rosland, 2023*

When the CTD is pulled up we first start with taking the oxygen sample. After all the oxygen sample is taken, we start with taking salinity, carbon and nutrients. After taking all samples we rinse the CTD on the inside and outside.

During our cruise we made a full transect and a half transect on the coast outside Sotra (VK036-VK042, except VK038, in figure 6 131-136). We also made a transect circling around Osterøy in the Osterfjorden (O1-O23 in figure 8, see zoom in figure 5, there named 137-174). At station O21 we took a 12-hour timeseries lowering the CTD every 1 hour. We also did a timeseries at station O16 between 09pm and 02am every hour. In total we took 43 CTD (including the timeseries). At station O1 we also deployed mini CTD and at 60° 27.84' N, 5° 40.38' E.

__Table 6:__ Overview of CTD sections

Section	Date occupied	Number of stations
Coastline	06.03.23 14:33 UTC- 06.03.23 22:06 UTC	6 stations (VK039-036, except VK038)
Osterfjorden North	07.03.23 07:05 UTC – 07.03.23 19:26 UTC	9 station (O9-O1, except O7, but added O4b)
Osterfjorden South	07.03.23 20:22 UTC- 09.03. 23 02:209 UTC	12 stations (O21- O10, timeseries at O21 and O16)
Outside Osterøy	09.03.23 05:49 UTC	1 station (O22)

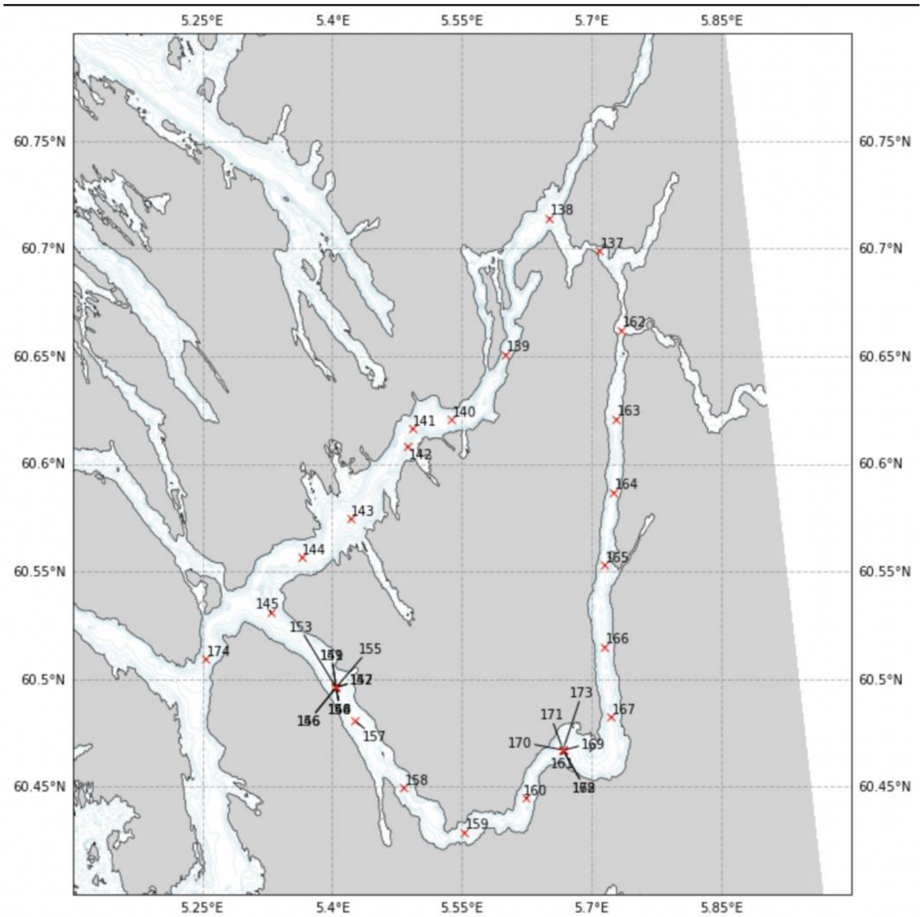

__Figure 5:__ Zoom: Osterfjorden

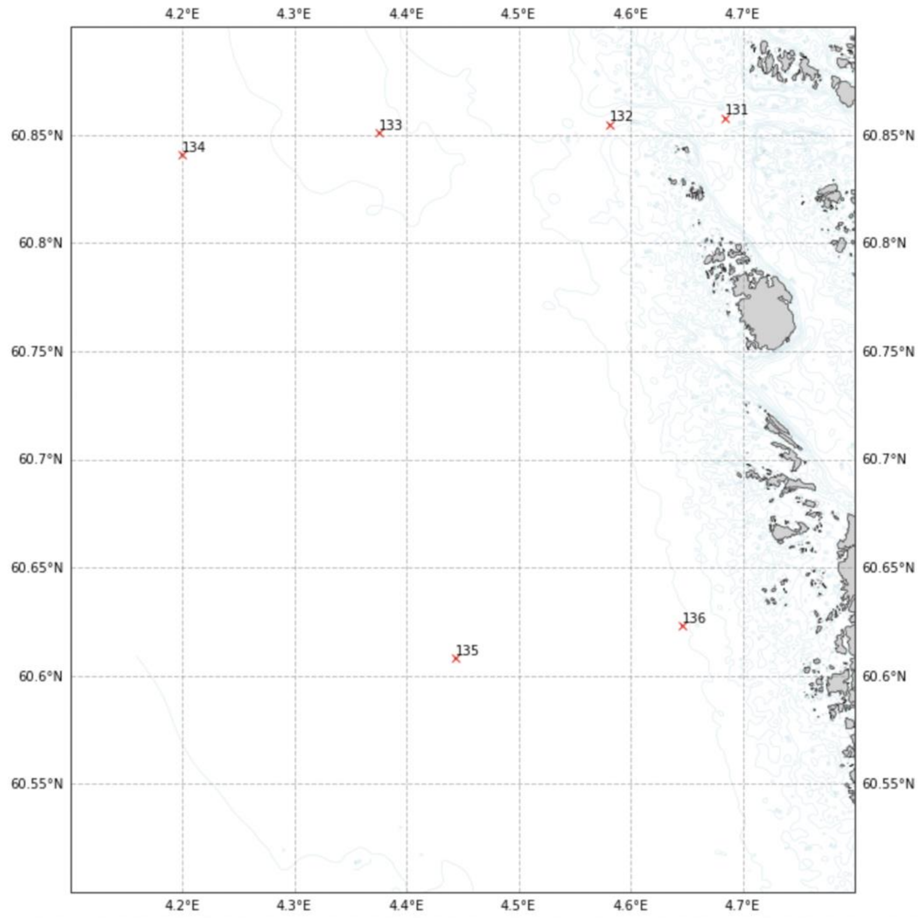

Figure 6: *Zoom: Coastal stations west of Sotra.*

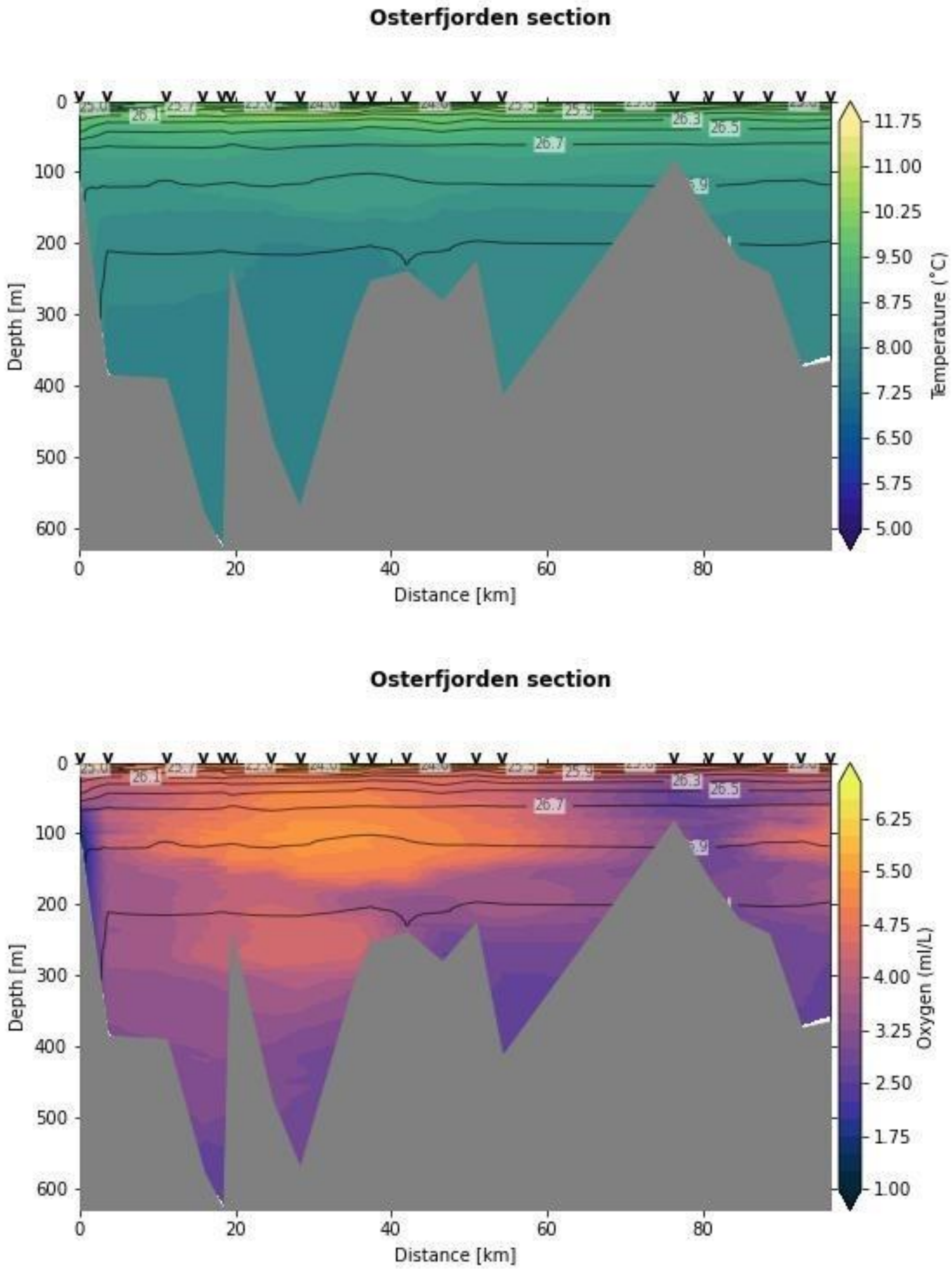

Figure 7: *Temperature and oxygen section of Osterfjorden, north to south.*

1.2.4.4 Water sampling

Oxygen, carbon, salinity and nutrients were measured in water samples collected from different depths at 28 different CTD stations around Osterøy and by the coast (see *figure 8* and *table 7*). The samples were collected using Niskin bottles attached to the CTD-instrument. To ensure accurate results, the samples were then immediately distributed into suitable bottles and prepared for further analysis.

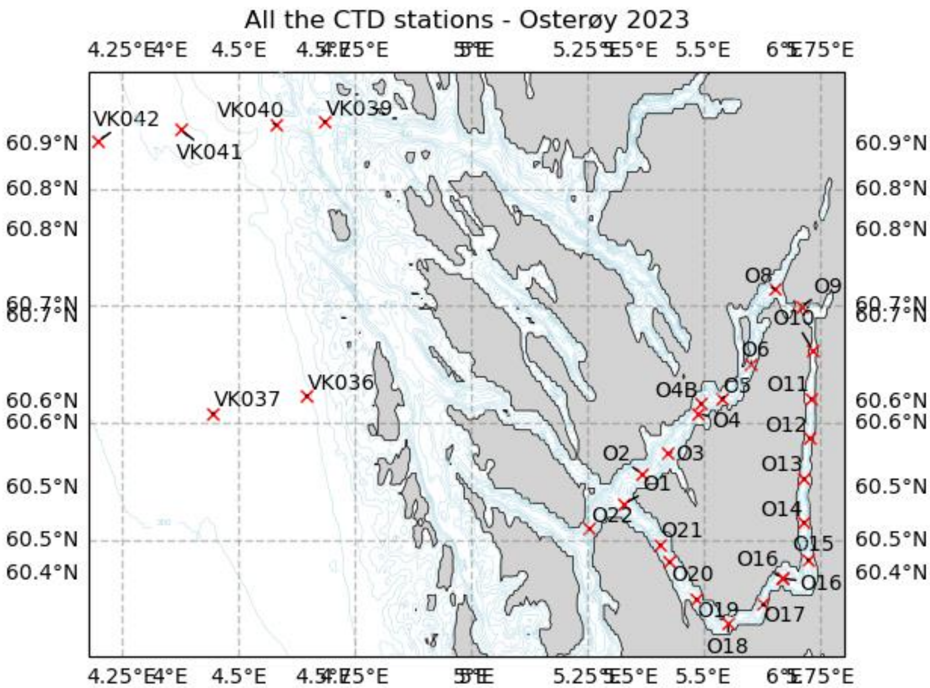

Figure 8: *CTD-stations. Overview of all the 28 CTD-stations around Osterøy and by the coast.*

Table 7: Overview of the different samples collected at each of the 28 CTD stations. The number of water samples represents how many depths the samples are collected from. The numbers are retrieved from sheet "Water samples_flasks" and sheet "CTD" in GOS2023001003_CTD.xlsx. For a full overview of the different depths, see Appendix A.

	Name of Station	**Corresponding CTD files**	**Number of salinity samples**	**Number of oxygen samples**	**Number of carbon/nutrient samples**
	VK039	131	3	3	-
	VK040	132	2	2	-
	VK041	133	1	1	-
	VK042	134	1	1	-
	VK037	135	2	2	-
	VK036	136	1	8	-
	O9	137	2	3	-
	O8	138	2	3	-
	O6	139	2	3	-
	O5	140	3 (2*****)	4	-
	O4b	141	2 (0*****)	3	-
	O4	142	1	1	-
	O3	143	2	4	-
	O2	144	2	3	-
	O1	145	2	4	-
	O21	146 + 156	4	7	-
	O20	157	2	2	-
	O19	158	1	2	-
	O18	159	1	3	-
	O17	160	1	3	-
	O16	161 + 168	15 (14*****)	15	12
	O10	162	1	1	-
	O11	163	1	2	-
	O12	164	1	2	-
	O13	165	1	2	-
	O14	166	2	3	-
	O15	167	1	3	-
	O22	174	1 (0*****)	3	-
Total	**28**	**30**	**60 (55*)**	**93**	**12**

number of salinity samples according to sheet "Water samples_flasks" (unknown error has caused some inconsistency between the number of salinity samples stated in sheet "CTD" and sheet "Water samples_flasks").

1.2.4.4.1 Oxygen sampling and titration

On the cruise we collected 92 samples from 28 locations, shown in figure 6 for costal and figure 9 for in the fjord, to analyze oxygen, both inside and outside the fjord. We took samples from various depths to ensure a spread of values from different layers in the fjord. There were also samples taken at multiple locations to see if this parameter changes at both sides of the fjord and if so, how they change.

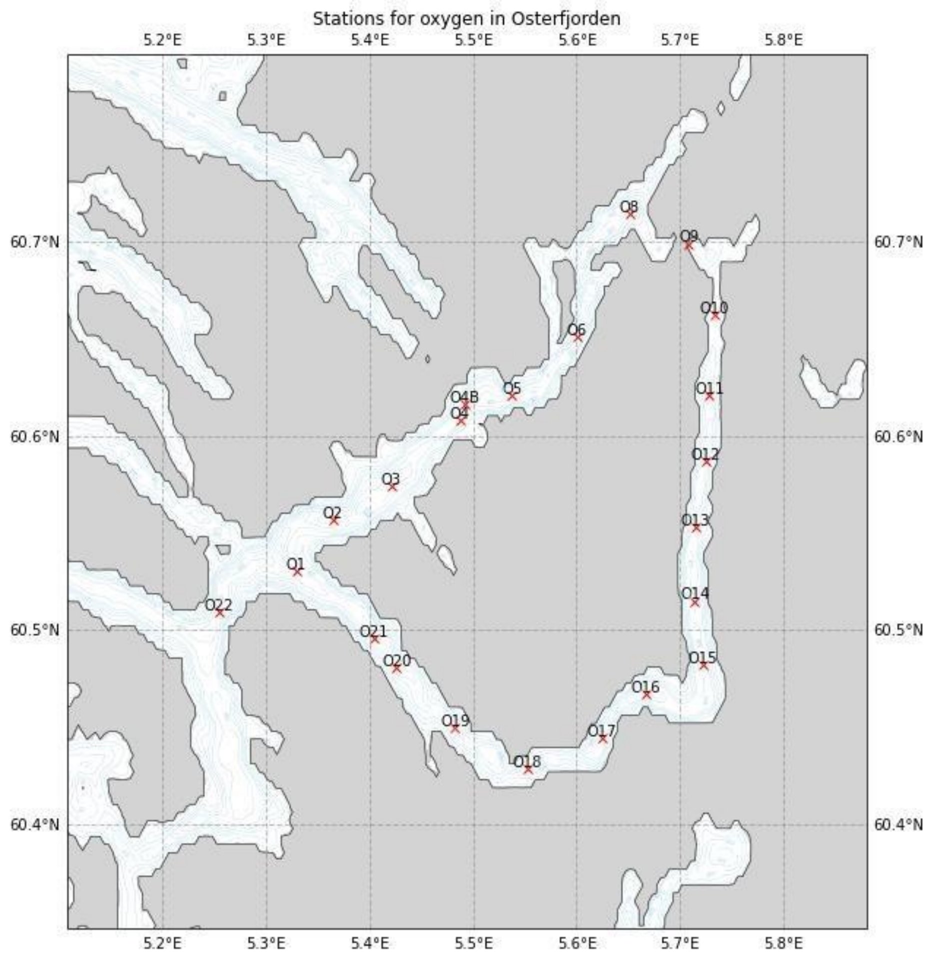

Figure 9: Overview of oxygen sampling stations in Osterfjorden.

After sending down the CTD and getting the samples in the niskin bottles it is important to fill the water for oxygen samples as soon as possible. This is because there can be organic material that uses oxygen, so we must add chemicals right away to avoid this. Also, when taking the samples care had to be taken so we avoid contamination.

When collecting the oxygen sample, we first connected a plastic sampling tube to the bottom of the niskin bottle. We then let water run through the tube while pressing it lightly to make sure there were no air bubbles in the tube. The tube, cap and collection bottle can then be rinsed three times by putting water in the bottle and using it to pour water on the outside of the tube and the cap. After this was done the tube and a thermometer were placed inside the bottle with the tube to the bottom and the thermometer not touching any of the sides of the bottle. For this we let the bottle overflow two or three times while the thermometer stabilized. The tube and thermometer were then carefully removed from the bottle while the water was still flowing. Now the bottle was as full as possible, and we could add the chemicals. We added 1 mL $MnCl_2$ and then 1 mL NaOH/NaI. This gave the water a fall out with a color between brownish for oxygen rich water and whiteish for oxygen poor water. The cap was then put in the bottle and the sample was shaken till it was the same color in the whole sample, this was for about 20-30 seconds. The samples were then put in a box that was closed so they did not get too much light on them. After about thirty minutes to an hour precipitate was formed and the bottles were shaken for a second time, so the color again was equally distributed. They were this time sealed with distilled water. After this we waited with the titration until there were precipitate again. The samples were titrated within 24-48 hours of sample taking, so the samples were continuously analyzed onboard via Winkler titration.

The Winkler titration was done according to the lab manual and instructed, with a semi-automatic titration device and computer. Before starting the titration of the samples taken, at the beginning of the day, we analyzed four standards and blanks. Standards is a reference point to the concentration of thiosulfate that is used. When determining the standards, we prepared four bottles with 50 mL distilled water and 10 mL KIO_3. To the first bottle we then added 1 mL H_2SO_4, 1 mL NaOH/NaI, 1mL $MnCl_2$ and filled up with distilled water so it was filled to the brim. This solution was titrated with sodium thiosulfate and the steps were done again with the next three bottles. The blanks follow right after and are calculated by first preparing the four bottles like we first did to the standards, with distilled water. Instead of adding 10 mL of KIO_3 this time we just added 1 mL and the three chemicals and some distilled water. We then titrated one time and then were asked to add 1 mL more of KIO_3 and could titrate a second time.

The samples taken from the CTD were then analyzed continuously after the standards and blanks. First the correct information was put into the computer so the results could be paired to the correct station and depth. The station ID, flask ID, niskin bottle number and draw temperature were put in. Then we could take the bottle with the correct flask ID out of the box and prepare it for titration. First, we gently put in a stirring magnet and then added a dose of 1mL H_2SO_4. The sample was then put into the titration device and was titrated with sodium thiosulfate, as in figure 10 and the device was started on the computer. When the sample was done the device stopped automatically and the result of oxygen content could be read on the computer screen.

The calibration below is not applied to the data submitted to NMDC

one described below is not applied to the data submitted to NMDC - the submitted data are calibrated using the watersamples collected and analysed by HI.pe text here

Figure 10: Semi-automatic titration device located in the laboratory on the G.O Sars.

1.2.4.4.2 Oxygen calibration

The calibration described here is not applied to the data submitted to NMDC

From the oxygen samples we collected om the cruise we had a wide spread of values at various depths to calibrate the values from the CTD.

The calibration was done by using linear regression by plotting the oxygen measurements from the Winkler with oxygen levels from the CTD as in figure 11. We than use the method of finding the mean offset between the CTD data and the water samples. Since we use the mean offset we saw that there were some offsets or mistakes done with the water samples that had to be addressed before we could calculate this. For the water samples the titration device had some malfunctions during the cruise that gave negative values for the oxygen levels. If these were not removed before hand the mean offset gets really high and it is hard to calculate an accurate mean offset. After the knowingly wrong values are excluded, we also exclude the first 50 meters because of the large gradient. After getting a plot of the offset1 and a value of 0.451. We want to get the most correct mean offset so we remove the outliers from the water samples. We do this by removing all the points that are outside a range of ±2*the standard deviation and repeat this to there are close to no outliers left in offset2. We did this four times because then we got almost all the outliers away, but still had enough data points to calibrate with. As seen in figure 12 we can see the first plot of offsets(circles) and when the outliers are removed(squares). From this we get a new number for the mean offset on 0.401 and this is then added to the CTD data, figure 13, and we want this to get as close to the Winkler titration as possible.

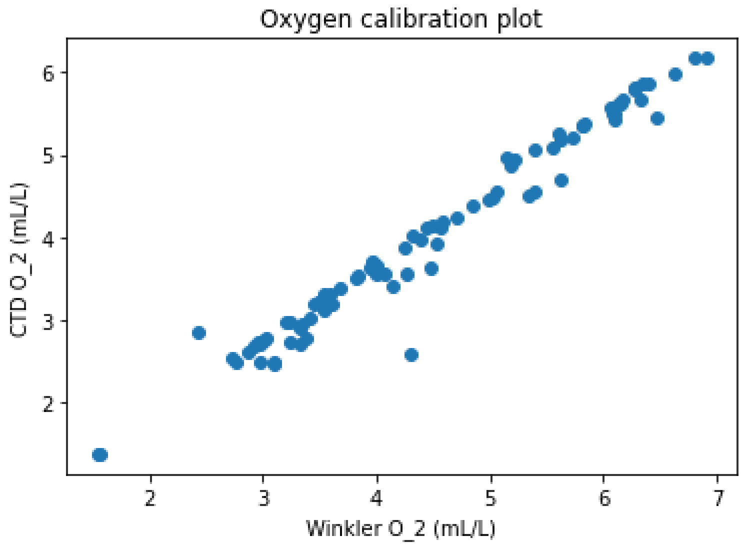

Figure 11: *Oxygen values from Winkler titration plotted against CTD values after values from under 50 meters and the negative values from malfunction has been removed, but not outliers.*

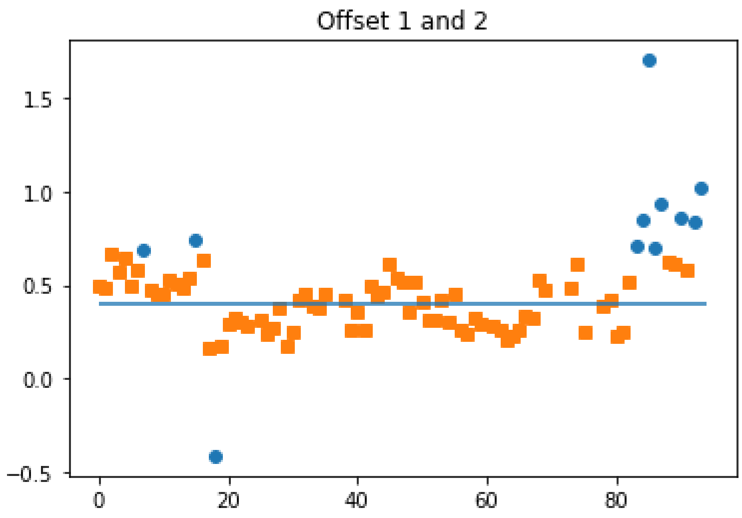

Figure 12: *Offset plot showing the difference between when outliers are removed and not. Blue dots: before outliers removed. Orange squares: after outliers removed.*

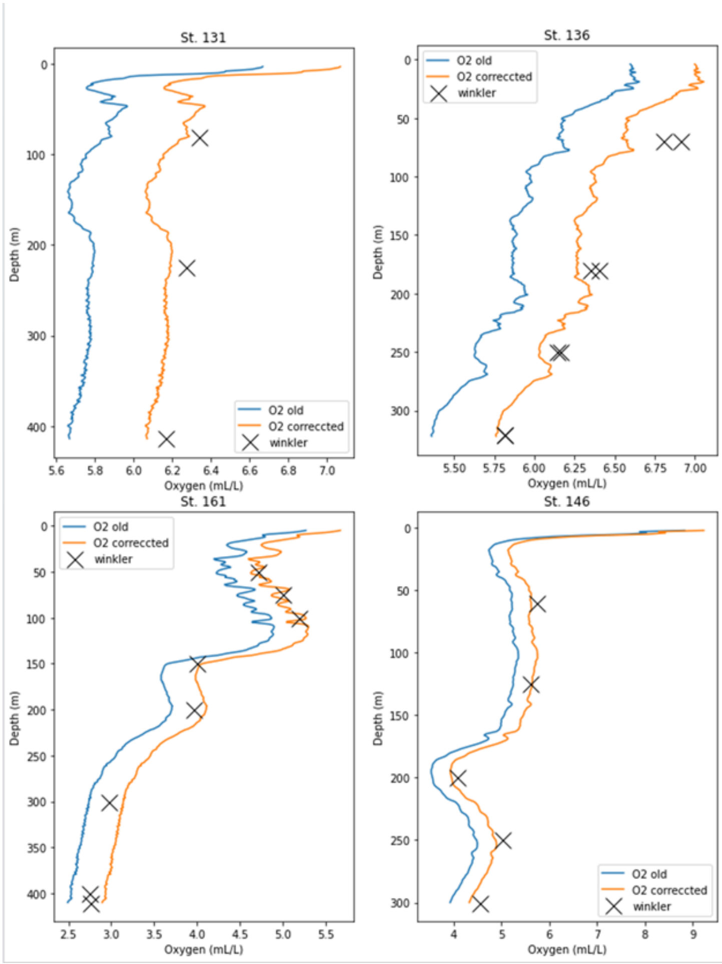

Figure 13: *Effect of calibration. Oxygen profiles from CTD measurements (blue), corrected CTD data (orange) and Winkler titration (black cross) for 4 different stations.*

1.2.4.4.3 Nutrient and carbon samples

A total of 12 water samples were collected at station O16 (see *figure 14*) to measure the ocean concentration of carbon as well as the following nutrients: nitrate, nitrite, phosphate, and silicate. The samples were taken from the following 12 different ocean depths: 410 m, 400 m, 300 m, 200 m, 150 m, 100 m, 75 m, 50 m, 30 m, 20 m, 10 m and 5 m.

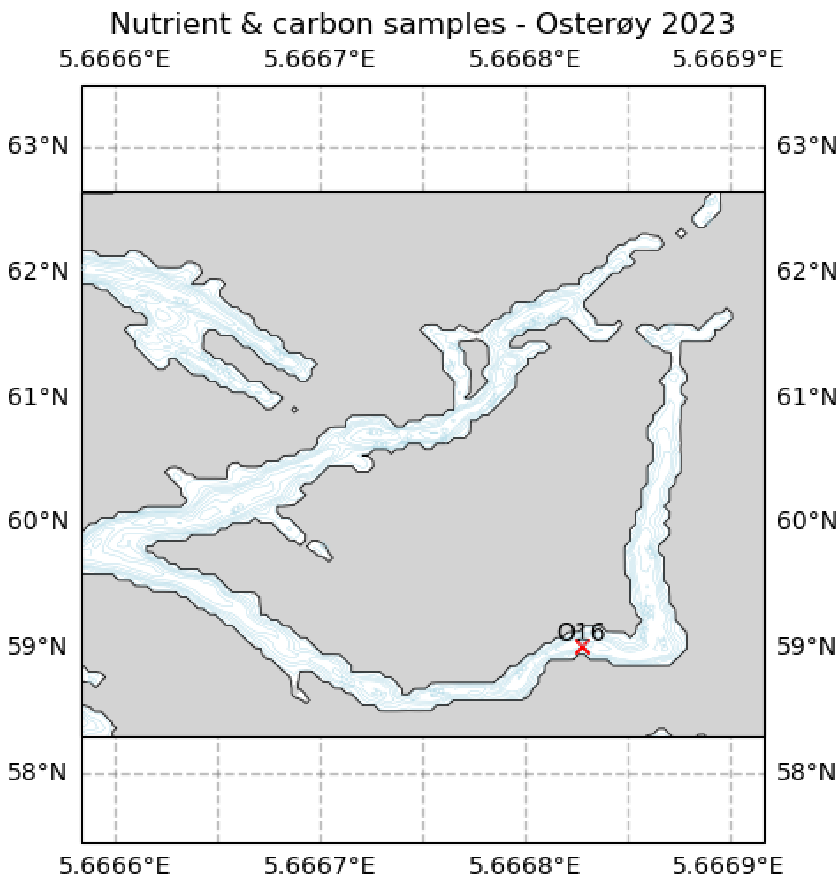

Figure 14: *Overview of station O16. 12 nutrient and carbon samples were collected here.*

1.2.4.4.3.1 Nutrient samples

To collect the nutrient samples, a 20 mL polyethylene scintilla bottle was rinsed three times before filled to the brim – both with seawater from the Niskin to avoid water from somewhere else contaminating the sample. To persevere the real concentration of nutrients in the samples until analysis, 0.2 mL chloroform was added to inhibit biological activity from causing a nutrient decrease. The samples were stored in the fridge during the cruise. They were then sent to the Institute of Marine Research (IMR) for spectrophotometric analysis (HAVFORSKNINGSINSTITUTTET et al., 2022).

1.2.4.4.3.2 Carbon samples

Dissolved inorganic carbon (DIC), total alkalinity (ALK), pH and partial pressure of CO2 (pCO2) are the four main parameters to consider when studying ocean carbon absorption and acidification. The parameters are related (see equations in *figure 15*). Thus, if two of the four parameters are measured the rest can be calculated using the program CO2SYS. It is common to measure DIC and ALK along with salinity and ocean temperature and calculate the remaining inorganic carbon parameters as well as the saturation of calcite and aragonite in CO2SYS (Olsen & Universitetet i Bergen, 2023, p. 21) (Lewis & Wallace, 1998, p. 5).

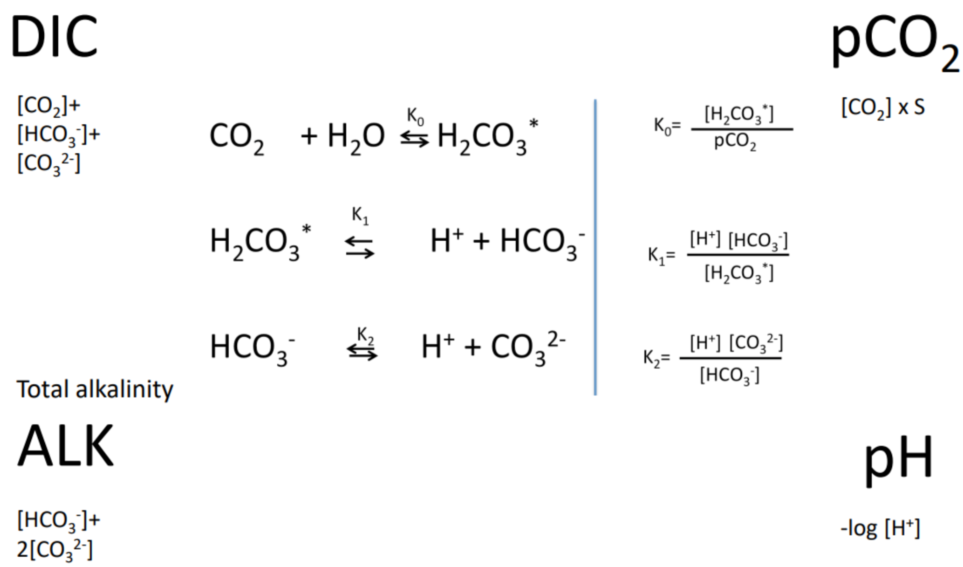

Figure 15: *DIC, ALK, pH and pCO2. The relation between DIC, ALK, pH and pCO2 (Olsen & Universitetet i Bergen, 2023, p. 21).*

More specifically, DIC is the total concentration of aqueous carbon dioxide (dissolved carbon dioxide and hydrated H_2CO_3), bicarbonate ions and carbonate ions (Cole & Prairie, 2009, p. 30) (World Meteorological Organization, 2023). ALK refers to the concertation of acid-neutralizing ions such as bicarbonate ions, carbonate ions and hydroxide ions – all of which can act as buffers by binding to e.g. acidic hydrogen ions and thus creating neutral stable structures (Woods Hole Oceanographic Institution, 2023) (Bozorg-Haddad et al., 2021, p. 217-257).

The carbon samples were collected from the Niskin and put into 250 mL flasks through an attached plastic tube. The flasks were first rinsed three times with sample water from the Niskin and air bubbles were squeezed out of the tube. Thereafter, the tube was inserted all the way into the flask making it touch the bottom. When the flasks were filled to its brim without any air bubbles, the tube was carefully removed and 0.02 mL $HgCl_2$ was added before capping. The samples were then adequately mixed and stored in a dark and cool environment until analysis post cruise. The analysis method is titration for both DIC and ALK. The type of titration is however different. The analysis was not carried out by students.

DIC in the sample is determined using coulometric titration. DIC is first mixed with phosphoric acid and thus converted into carbon dioxide. A reaction between the carbon dioxide and monoethanolamine will thereafter create an uncoloured acid which can be titrated with a base until its original blue colour has been restored. The base is generated by a current, and the amount of generated current is thus equivalent to the concentration of carbon dioxide in the sample (Hartman et al., 2011, p. 7). The precision of these kinds of laboratory DIC analyses is approximately ± 0.05 % (PMEL Carbon Group, 2023).

ALK in the sample is determined using potentiometric titration with HCl. Software is used to calculate the ALK based on the amount of reagent needed to reach the endpoint and the current of the electrode (Hartman et al., 2011, p. 7) (Vandeginste et al., 1998, p. 507). The precision of these kinds of laboratory ALK analyses is approximately ± 0.1 % (PMEL Carbon Group, 2023).

Prior to both the DIC- and ALK titrations, the samples are put in a 25°C ± 0.3°C water bath. To reduce sample handling time and increase accuracy, the titration instrument is equipped with two automatic pipettes making it possible for the DIC and ALK to be titrated simultaneously (Hartman et al., 2011, p. 7).

To ensure precise analysis results, it is important to pay attention and limit errors in the pre-analytic phase as this phase is often particularly vulnerable to human errors. In this phase, it is also important to check the accuracy of the analysis instrument by carrying out a quality control including e.g. running standard and blank samples.

The calibration described below is not applie to the data submitted to the NMDC. Salinity is calibrated using the watersamples collected and analyzed by HI. For oxygen, see separate document.

1.2.4.4.4 Salinity samples and calibration

A total of 60 (55*) salinity samples were collected from various depths at all 28 stations around Osterøy and by the coast (see *figure 8* and *table 7).* For a full overview of the sample depths, see appendix A.

To collect the samples from the Niskin, flat 500 mL glass bottles with double lids to ensure reliable seal were used. Both the bottle and cap were rinsed three times with sample water from the Niskin before filling. The bottles were only filled to the "shoulder" to avoid the formation of salt crystals (Shkvorets, 2023). To keep the samples from freezing, they were stored in room temperature (22°C) until analysis on Portasal 8410A Salinometer. The samples were continuously analysed while onboard. The analysis was carried out as stated in the analysis procedure found in the ship laboratory.

During analysis, the room temperature is set to 22°C and the salinometer is set to 24°C ± 0.6°C. As a form of quality control, both a zero- and standard calibration must be carried out prior to sample analysis every time the instrument is turned on. Thereafter, the instrument is ready to run samples. The samples must reach room temperature before analysis.

The Portasal 8410A Salinometer is a semi-automatic instrument, meaning a human is needed to operate the instrument during analysis. With each sample, the operator must wipe down the sample tube and rinse the conductivity cell four times with sample water. When all the chambers are filled properly with sample water and no air bubbles are in sight, salinity measurement readings can be carried out by the instrument. The salinometer will do ten parallel measurements with each reading before calculating the standard deviation between the parallels. A standard deviation below 0.00020 is considered good quality. If the standard deviations are within the approved range, the operator will carry out three measurement readings pr. sample and flush the cell between each reading.

As with all semi-automatic instruments, human errors are a big potential source of error. Insufficient flushing/refilling of the cell can contribute to inaccurate readings and thus an increased uncertainty. Other potential sources of errors are pre-analytic errors such as too cold samples, samples that are filled up too much, leaking caps, insufficient cleaning, wrong storage conditions, inadequate mixing before analysis (not homogenous sample) etc.

Measurement of salinity concentration in water samples using a salinometer is considered the standard method as it is more accurate than salinity measurements obtained by CTD. After the cruise, 52 of the collected salinity samples were thus used to calibrate the conductivity sensor the CTD uses to measure salinity. The calibration was carried out using linear regression.

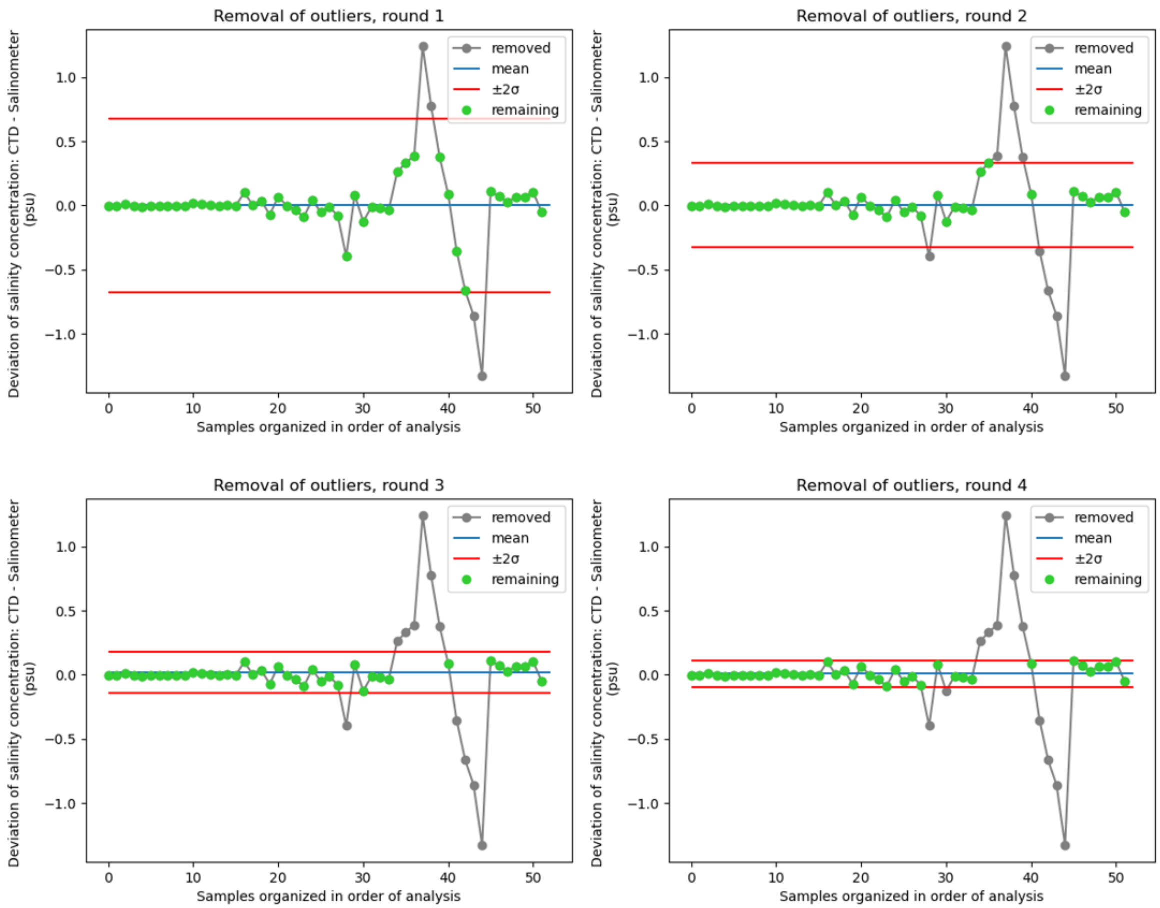

Figure 16: *Removal of outliers. A total of 12 outliers outside the limit of* $\pm 2\sigma$ *were removed in four rounds.*

First, the deviation or difference between the salinity concentrations obtained from the two methods were calculated by subtracting the salinity concentration measured by the salinometer from the salinity concentrations measured by the CTD conductivity sensor. The mean deviation and standard deviation σ were then calculated, and limit values were set to $\pm 2\sigma$. All outliers, meaning values outside of $\pm 2\sigma$, were then removed. A total of 12 outliers were removed in four separate rounds. This is shown in *figure 16* and *figure 17*.

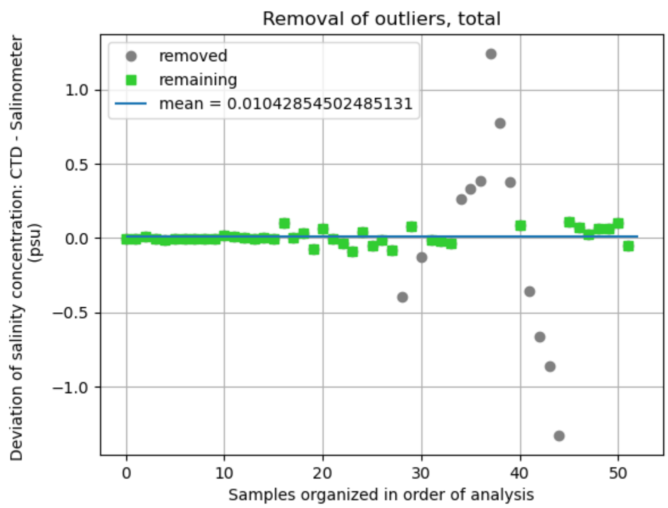

Figure 17: *Mean deviation after removal of outliers. New mean deviation was 0,01042854502485131 psu*

As shown in *figure 17*, the new mean deviation after removing the outliers was $\pm$ 0,01042854502485131 psu. This mean was added to the salinity concentrations measured by the CTD conductivity sensor to correct them.

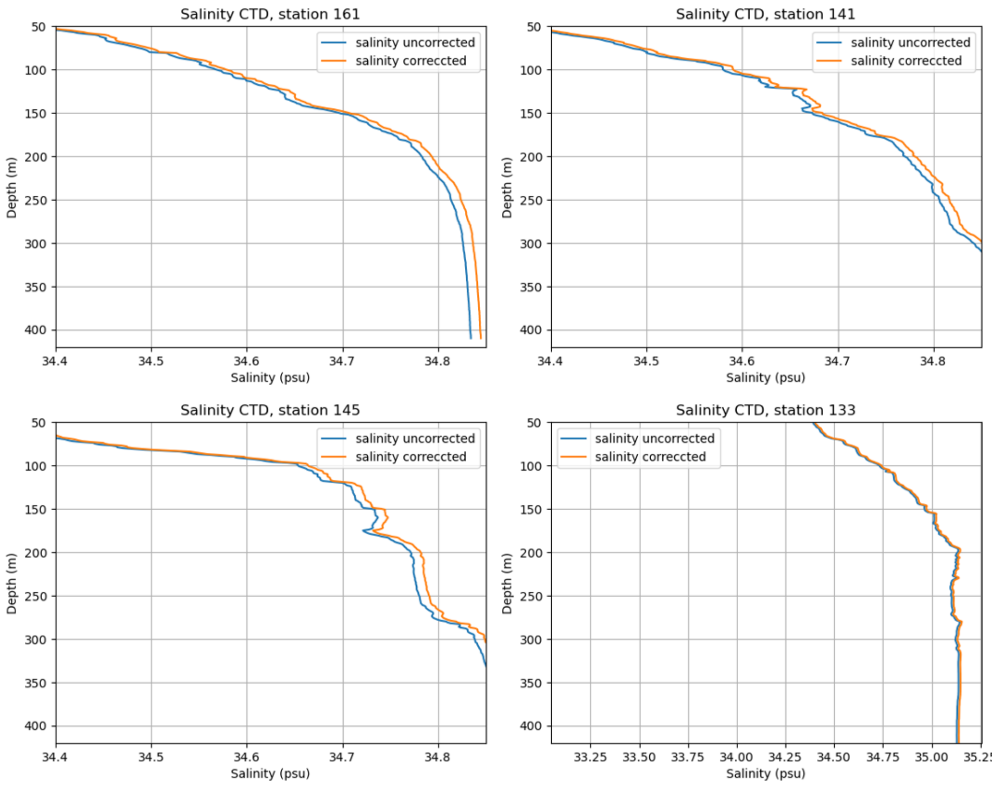

Figure 18: *Result of calibration. The effect of salinity calibration for stations 161, 141, 145 and 133.*

A comparison between the corrected and uncorrected data set for stations 161, 141, 145 and 133 is shown in *figure 18*.

1.2.4.5 Wave measurement buoys

To effectively map waves, a type of wave sensor has been used which was developed with the help of Helge Brynhi. The setup consists of a 3D-printed battery holder which is placed inside a bottle for protection and to make the setup waterproof. The holder is designed to accommodate as many batteries as possible. The cables and batteries have been soldered to provide power to the board (as presented in figure 14). The batteries are connected to a capacitor which in turn is connected to the board. This is done to provide the batteries with a more even load so that they last longer. The board itself is a Redboard Artemis Nano, which provides features such as SD memory card, GPS, and USB-C connector, allowing for position updates and storage of measured data. GPS position and measured data are transmitted at 20-minute intervals using a transmitter antenna connected to the rig. Collected data and position are received by a server at MET, where we can track the buoys position and download data. The buoy to which the wave sensor is connected consists of a basket that allows water to pass through, with the purpose of making the buoy more stable. This is done by filling the basket on the underside with chains. This reduces rotations around the x and y axes and reduces forward motion due to wind. It is important not to have too much weight, as this can cause the buoy to have insufficient buoyancy to follow the waves properly. In other words, we want enough weight to stabilize the buoy while still being light enough to follow the waves.

Waves are measured using an accelerometer. This measures the acceleration of the buoy so that position can be determined by integrating acceleration twice later. This position can then be used to determine significant wave height, wave number, wave period, etc. The accelerometer measures acceleration in the x, y, and z directions. Since the accelerometer does not know which way it is pointing, a magnetometer and gyroscope are also used to determine the direction and rotation of the buoy. This allows for accurate determination of the directions in which the buoy has accelerated.

The calibration described bewlo is not applied to the data submitted to NMDC.
Salinity was calibrated using the watersamples collected and analyzed by HI.

__Figure 19:__ Overview of the wave measurement rig, to the left presenting the battery series connection and the microcontroller unit and to the right presenting the drifter in the water.

Wave sensors had different designs for different applications. The sensors used during this expedition consisted of bottom-mounted sensors and drifters. If waves need to be measured in shallower water where a specific point is of interest, bottom-mounted wave sensors may be more useful. Another advantage of bottom-mounted wave sensors is that they allow for measurements over a long period of time without the sensor drifting ashore. On the other hand, if waves are to be measured in an open fjord, it may be advantageous to use a drifter. This way, data can be collected on how surface currents affect the waves, and results can be collected for multiple experiments during the same deployment. Another advantage of drifters over bottom-mounted sensors is that drifter measurements are likely to be more accurate. This is because the anchor will limit the buoys movement, and you may end up losing waves that you would otherwise have measured.

2 Oceanographic Survey – Kristine Bonnevie

2.1 Participants

From the 14th to the 17th of February, the cruise consisted of GEOF232 and GEOF337 students. The crew members of the research boat, Kristine Bonnevie, also took part in collecting data. The list below shows all the participants from the UiB.

Last name	First name	Role
Darelius	Elin	Cruise Leader
Daae	Kjersti Birkeland	Teacher
Bruvik	Emil	GEOF232 Student
Sirnes	Anette Sigstad	GEOF232 Student
Hausken	Audun Høyland	GEOF232 Student
Auestad	Solrun Marie	GEOF232 Student
Kvamme	Eirik	GEOF232 Student
Saltalamacchia	Francesco	GEOF337 Student
Latuta	Linda	GEOF337 Student
Vikanes	Stian	GEOF337 Student
Nordang	Halvor	Chemist
Sagen	Torun Sandven	Teaching Assistant
Johannesen	Reidar	Instrument Manager
Bryhni	Helge	Engineer

2.2 Cruise Overview

The cruise on board Research Vessel Kristine Bonnevie was undertaken as part of the GEOF232 and GEOF337 courses at the Geophysical Institute (GFI), University of Bergen.

During the cruise on 14th to 17th of February, it was collected data from Masfjorden and Fensfjorden. The data collected was aimed to study the chemical composition of the fjord, the geostrophic flow across Fensfjorden, the fjord circulation in Fensfjorden, the isotopic distribution across Masfjorden and calculate significant wave height in some chosen locations.

The students participated in the planning phase for the cruise. During the cruise, the students participated in the data collecting onboard and became familiar with different oceanographic instruments and their measurement systems. The students used ship-based measurements from CTD, thermosalinograph and vessel mounted current profiling system. They used the mini-CTD from the working boat and took measurements of oxygen, salt concentration, CO2, nutrients, and isotopes, from water samples. After the cruise, each student wrote a report for an individual project using the data collected. The individual reports are presented in this final report.

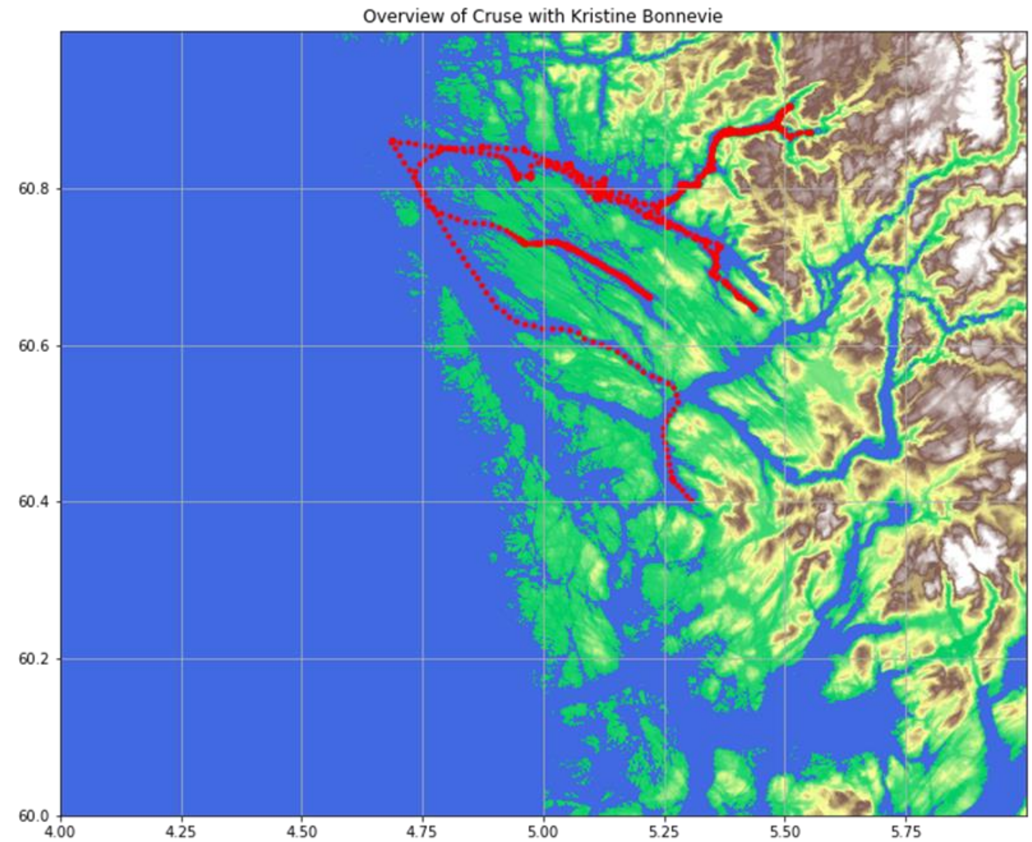

Figure 20: *Position of Kristine Bonnevie from 2023-02-14-08:00 to 2023-02-17-15:30 using the coordinates from the ADCP measurements from the boat throughout the Cruise.*

2.3 Environmental Conditions

Weather observations from Fensfjorden and Masfjorden from the 14th to the 17th of February.

14.02: The sky was mostly overcast, windy out by the coast.

15.02: Overcast and windy during the day, a little rain in the evening.

16.02: Overcast and windy during the day, a little rain in the evening.

17.02: The wind picked up, storm moving in.

2.3.1 Meteorological data from the weather station onboard

On research Vessel Kristine Bonnevie there are several meteorological instruments. These instruments measured temperature, humidity, wind speed and wind direction. They were continuously measuring throughout the cruise.

To measure relative humidity and temperature, the HMP45A and HMP45D probes delivered by Vaisala were used. The humidity measurement is based on a capacitive thin film polymer sensor called HUMICAP 180 (Vaisala, 2006). The probe measures within a range of 0.8 to 100%RH and has an accuracy of ±3%RH. When it comes to the temperature measurements, it is based on resistive platinum sensors. The temperature probe measures within a range of -40 to 60 °C, with an accuracy of ±0.2 °C. Both the sensor for humidity and temperature are located at the tip of the probe. The pressure was measured by the PTB220 digital barometers, which is installed inside a weather resistant enclosure. It uses the BAROCAP silicon capacitive absolute pressure sensor for barometric pressure measurement applications (Vaisala, 2001). The pressure range is 500 to 1100 hPa, with an accuracy of ±0.45 hPa. The accuracy does not include any wind or air conditioning system measurement errors. Wind speed and direction was measured by Gill WindObserver II wind sensor, a robust and lightweight unit with no moving parts (Gill Instruments, 2009). The sensor for wind speed covers a range from 0 to 65 m/s, with an accuracy of ±2% and offset of ±0.01m/s. While the sensor for wind direction covers a range of 0 – 259 °, with an accuracy of ±2°.

Figure 21 shows the air temperature, humidity, and wind direction and speed from the meteorological instruments onboard during the cruise. The observations done during the cruise corresponds with the instruments onboard. The humidity was measured to be approximately 45-90 percent, which corresponds to overcast and a little rain. From the measurements, you can also see that there was quite a bit of wind, which is consistent with the observations.

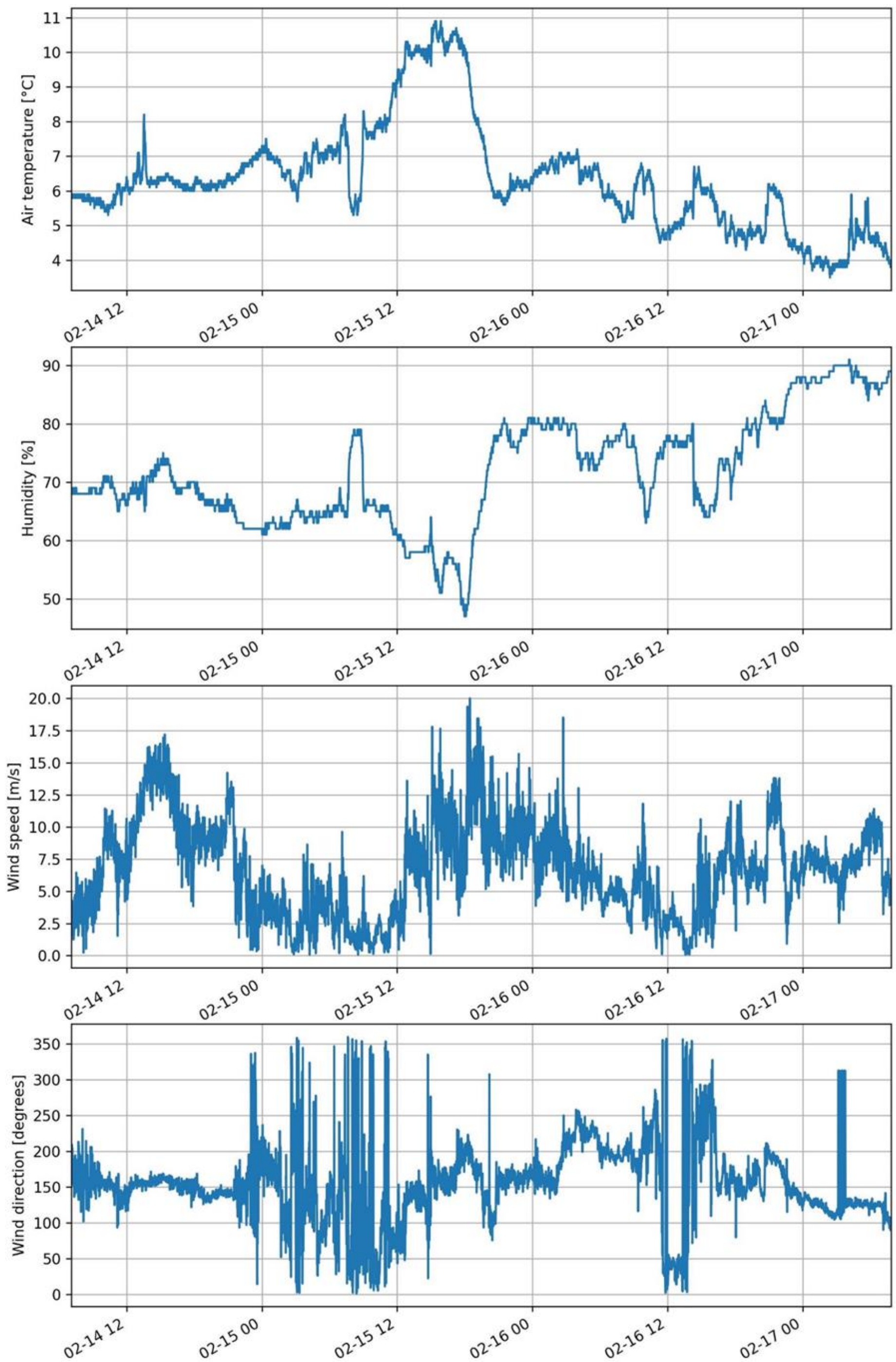

Figure 21: *Air temperature, humidity, wind speed and wind direction taken from the ship log during the cruise. The measurements started the 14.02.2023 at 07:05 and ended the 17.02.2023 at 07:50.*

2.4 Oceanographic instrumentation

2.4.1 CTD Profiling

The CTD instrument is a large and heavy instrument, used to measure conductivity, temperature, and depth. The instrument also has mounted niskin flasks that can be closed individually at a point of interest to collect a water sample of the specific depth it is located at. The instrument is lowered to approximately 15 meters above the sea bottom, and for each depth it is located at, it needs to be stationary for approximately 30 seconds before a niskin bottle is fired. We do this so that the water gets time to stabilize from the moving CTD-instrument. When we move the CTD instrument up, we still have to wait 30 seconds to fire a niskin bottle for the water to stabilize, if we want measurements at different depths. We communicated how deep the CTD could go to the crew by using a radio from the operation room.

On Kristine Bonnevie, the CTD instrument with pump was combined with 12 niskin bottles and oxygen measurement. During the cruise we took 59 CTD profiles with water samples.

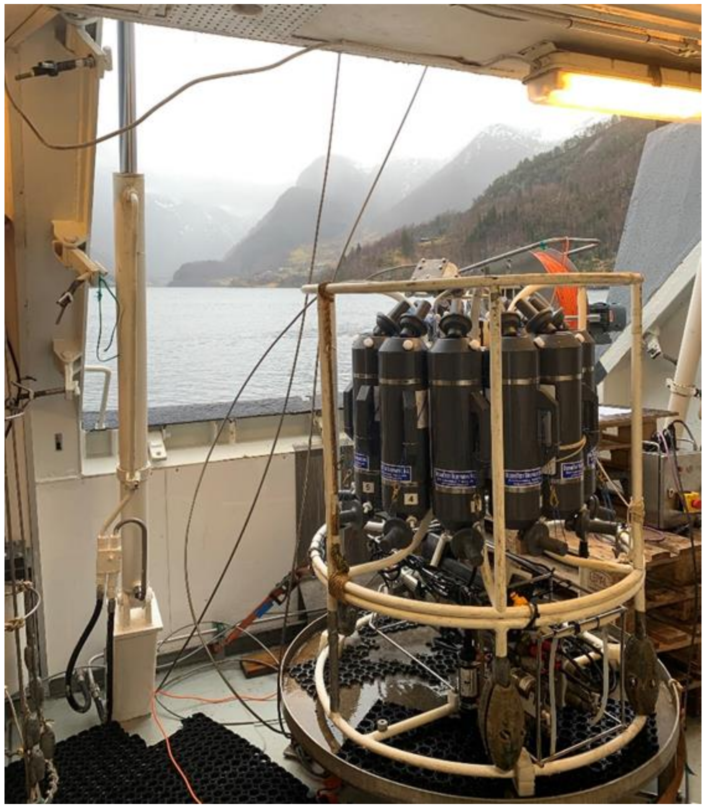

Figure 22: *Photo of the CTD instrument on Kristine Bonnevie, taken by Eirik Kvamme.*

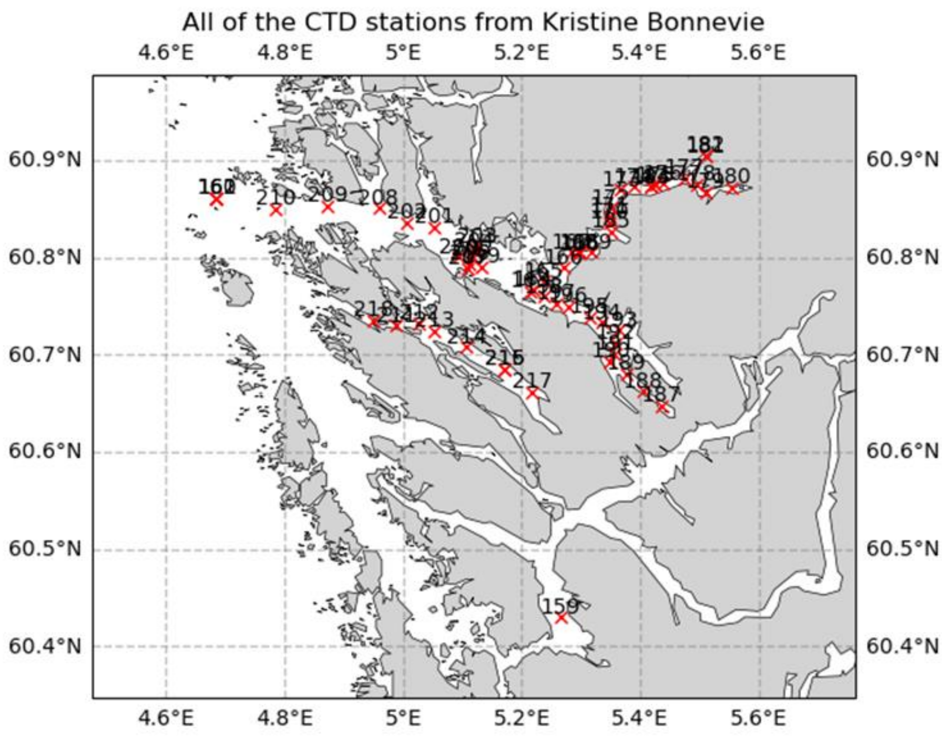

Figure 23: *Plot of all of the CTD stations taken during the cruise with Kristine Bonnevie, numbered in the order they were taken from station 159 to 218.*

The calibration described bewlo is not applied to the data submitted to NMDC.
Salinity was calibrated using the watersamples collected and analyzed by HI.

2.4.2 Water Sampling

Throughout Fensfjorden, Lurefjorden, Byfjorden and Masfjorden water samples were taken together with the CTD, some water samples were also taken from the working boat and from land. The next sections will go into detail about what type of water samples were taken.

2.4.2.1 Dissolved Oxygen

We collected 64 oxygen samples during the cruise, that were analysed, from different depths and stations. Some were planned beforehand; others were added from areas where the oxygen profiles from the CTD looked interesting. When taking the oxygen samples a tube were added to the Niskin bottles, which was then used to fill the oxygen bottles. This was done as to remove air bubbles by gently pressing on the tube while water was running. The after rinsing the bottles thrice, the bottle was filled up and the temperature of the bottles were taken. The bottles were then carefully removed so that they were filled to the brim. Then 1 mL of $MnCl_2$ were added to the bottles followed by 1 mL of NaOH & NaI. The cap was then added to the bottles and the bottles were shaken well in a downwards motion.

Before analysing the oxygen samples, we calibrated the instrument by running a blank. Then the oxygen samples were analysed using Winkler Titration on board the boat. The data were meticulously written down in a book during the titration to keep track of the data. First 1mL of H_2SO_4 and a magnet stirrer were manually added to the samples. The rest of the process was automatic. 0,1 mL of NaS_2O_3 were added as doses until the solution was colourless, then 3-4 drops of starch were added as an indicator, so that the solution become purple. Again, we added doses of NaS_2O_3, but this time the doses were 0,01 mL, this was repeated till the solution again became colourless. A couple of the samples did not contain oxygen and did therefore not undergo this same colour change.

The calibration described bewlo is not applied to the data submitted to NMDC

2.4.2.2 Water Isotopes

The research on water isotopes is focused on understanding the water circulation of the fjord, and for this purpose, we are specifically interested in studying the stable isotopes of oxygen and hydrogen, namely 18O and dD. These isotopes provide us with valuable insights into the origin and mixing of water masses within the fjord.

On February 14th and 15th, we collected water samples at different positions using a CTD. During this period, we extracted isotope samples from 9 different positions in Masfjorden at various depths. The bottom depth was sampled at every position, as well as depths of 4, 6, 8, 10 and 15m. At certain stations we also used a bucket to collect surface samples.

On February 15th and 16th, a separate isotope project was carried out using a small boat to extract surface samples from locations deeper into the fjord. To collect the surface samples, we used a syringe to extract water from locations where we expected to find freshwater input from land runoff. We rinsed the syringe three times before taking each sample to avoid contamination from previous samples. We noted the coordinates and time for each position using a GPS in a small notebook. Additionally, we gathered five river samples since rivers are the primary source of freshwater input to the fjord, and we were interested in analysing the river water composition.

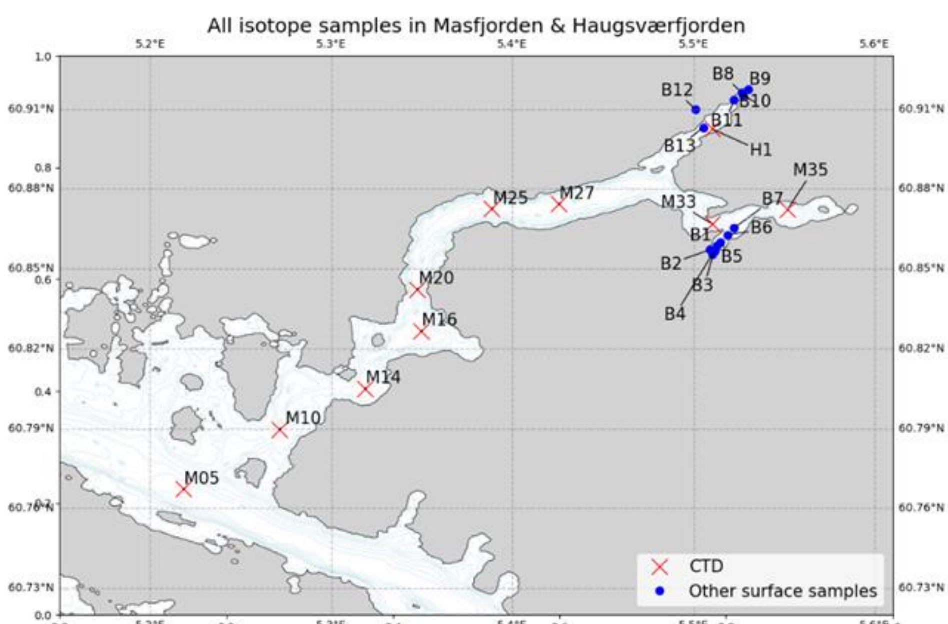

Figure 24: Location of all isotope samples. Stations named "M.." (red crosses) are collected with a CTD. Stations named "B.." (blue dots) are collected with syringes.

The calibration described bewlo is not applied to the data submitted to NMDC.
Salinity was calibrated using the watersamples collected and analyzed by HI.
For oxygen, see separate document

2.4.2.3 Biogeochemical Sampling

Through the CTD, salinity, nutrients and dissolved inorganic carbon/ alkalinity samples were taken. Salinity was also measured together with the water isotopes taken from the working boat. These samples can then be used to look at changes in the composition in the fjord both at different depths and locations. Most of the salinity measurements were done on board the boat, while the rest of the samples were sent to the laboratory for analysis. When taking the samples, the bottles were rinsed three times with the seawater before being filled up. This was done to minimize the risk of contaminating the samples before analysis.

57 salinity samples were taken with the CTD and 8 were taken from the working boat. For every salinity sample we took from the sea bottom, an extra sample was taken for HVL. After the salinity bottles had reached room temperature, we used a salinometer to measure the salt content of the samples. First the system was flushed four times in between the different samples and then each sampled was run three times, flushed once between the runs, to get an average salinity value from the samples. There was, however, a problem with the equipment that sometimes one of the pipes within the machine did not fill up, so the system had to be flushed additional times until all the pipes were filled up before accepting the data.

The nutrient and DIC/alkalinity bottles were sampled at 7 different stations throughout the fjords. To prevent a change in nutrients from sampling to analysis, 5 droplets of chloroform were added to the nutrient samples. To the DIC/alkalinity bottles a droplet of $HgCl_2$ was added to kill the biological activity in the sample. These bottles were then refrigerated until they could be analysed at the lab.

The calibration described below is not applied to the data submitted to NMDC - the submitted data are calibrated using the watersamples collected and analysed by IHI.

The described below is not applied to the data submitted to NMDC - the submitted data are calibrated using the watersamples collected and analysed by IHI pe text here For

Salinity was calibrated using the watersamples collected and analyzed by HI.

2.4.2.4 CTD Calibrations

Data from water samples were used to calibrate the data collected from the CTD measurements. First, the salt data that corresponded with depth and station were compared by taking the water sample minus the CTD to find the difference. Then we determined the average S and standard deviation σ. The outliers were found by using the following: ($S \pm 2 * \sigma$) and removed, this process was repeated 3 times. In total 11 outliers were found and removed from the data set, as can be seen in Figure 25.

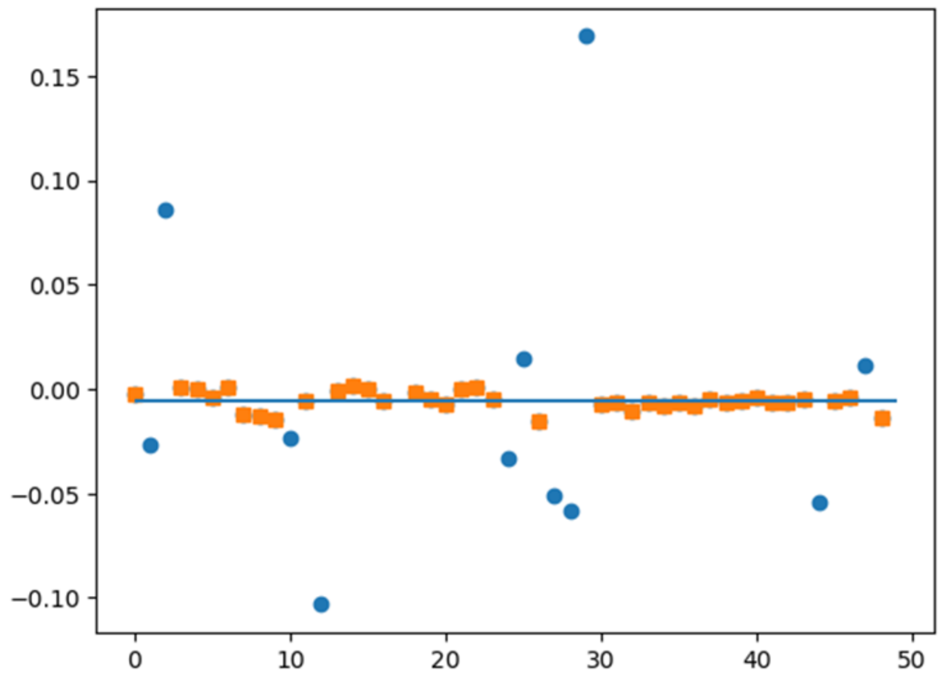

Figure 25: *Shows the correlation between the salt data from water samples and CTD, where the blue points are the outliers, with a mean value of -0.00550.*

Then the oxygen samples were calibrated using the same method as above, only with the oxygen data from the water samples and CTD data. As can be seen in Figure 26 below, the data points above 0.4 were removed due to large variations in values from the last points. In addition, 10 outliers were found and removed from the data set, as can be seen in Figure 26.

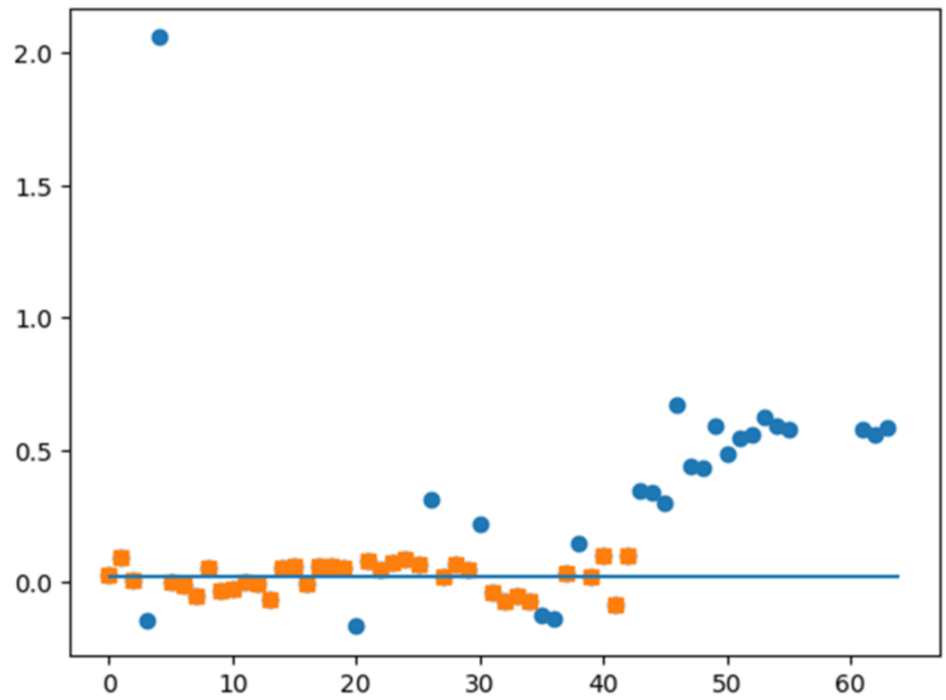

Figure 26: *Shows the correlation between the oxygen data from water samples and CTD, where the blue points are the outliers, with a mean value of 0.023.*

2.4.2.5 Radio-active tracer sampling

Water samples for radioactive tracer analysis were carried out during the cruise. The samples were collected for Jixin Qiao (jiqi@dtu.dk) at the technical University of Denmark. Water was collected in 10L plastic cans. The cans were not rinsed. Details about the samples are given in Table 8.

Table 8: *Details on water samples collected for radioactive tracer analysis. The position of the stations can be found in the CTD-table.*

Station name	Date	Time (UTC)	staxxxx	Depth (m)	Niskin	Bottle #
Shelf/F01	14.02.2023	1447	160	200	1-2	KB2023006004 - 1
Shelf/F01	14.02.2023	1447	160	200	3-4	KB2023006004 - 2
Shelf/F01	14.02.2023	1447	160	120	6-7	KB2023006004 - 3
Shelf/F01	14.02.2023	1447	160	50	8-9	KB2023006004 - 4
Shelf/F01	14.02.2023	1447	160	10	10-11	KB2023006004 - 5
H1	15.02.2023	08:00	181	100	1-2	KB2023006004 - 6
H1	15.02.2023	08:00	181	100	3-4	KB2023006004 - 7
H1	15.02.2023	08:00	181	100	5-6	KB2023006004 - 8
H1	15.02.2023	08:00	181	100	7-8	KB2023006004 - 9
M26	15.02.2023	11:30	183	450	1-2	KB2023006004 - 10
M26	15.02.2023	11:30	183	450	3-4	KB2023006004 - 11
M26	15.02.2023	11:30	183	175	5-6	KB2023006004 - 13
M26	15.02.2023	11:30	183	175	7-8	KB2023006004 - 14
M26	15.02.2023	11:30	183	50	9-10	KB2023006004 - 15
M26	15.02.2023	11:30	183	10	11-12	KB2023006004 - 16
L6	17.02.2023	00:48	215	400	1-2	KB2023006004 - 17
L6	17.02.2023	00:48	215	175	3-4	KB2023006004 - 18
L6	17.02.2023	00:48	215	45	5-6	KB2023006004 - 19
L6	17.02.2023	00:48	215	10	7-8	KB2023006004 - 20

2.4.3 Mini CTD

A mini-CTD is a small, portable instrument used to measure salinity, temperature, and pressure in water. Mini-CTDs are often used when it is not feasible or practical to use larger, more expensive CTDs. They can be deployed from small boats, research vessels, or even from shore. On February 15th and 16th, the mini-CTD was deployed at a total of 9 different locations in Haugsværfjorden and Matresfjorden from a small boat, with the greatest depth recorded at approximately 100m. Figure # illustrates the exact positions where these measurements were taken. Unfortunately, the mini-CTD's pump experienced a defect during the sampling period, which led to no salinity data from the 9 locations where it was deployed. Due to the absence of reliable salinity data, we decided to exclude the mini-CTD measurements from the analysis in this report.

__Figure 27:__ Photo of the mini CTD used in Haugsværfjorden.

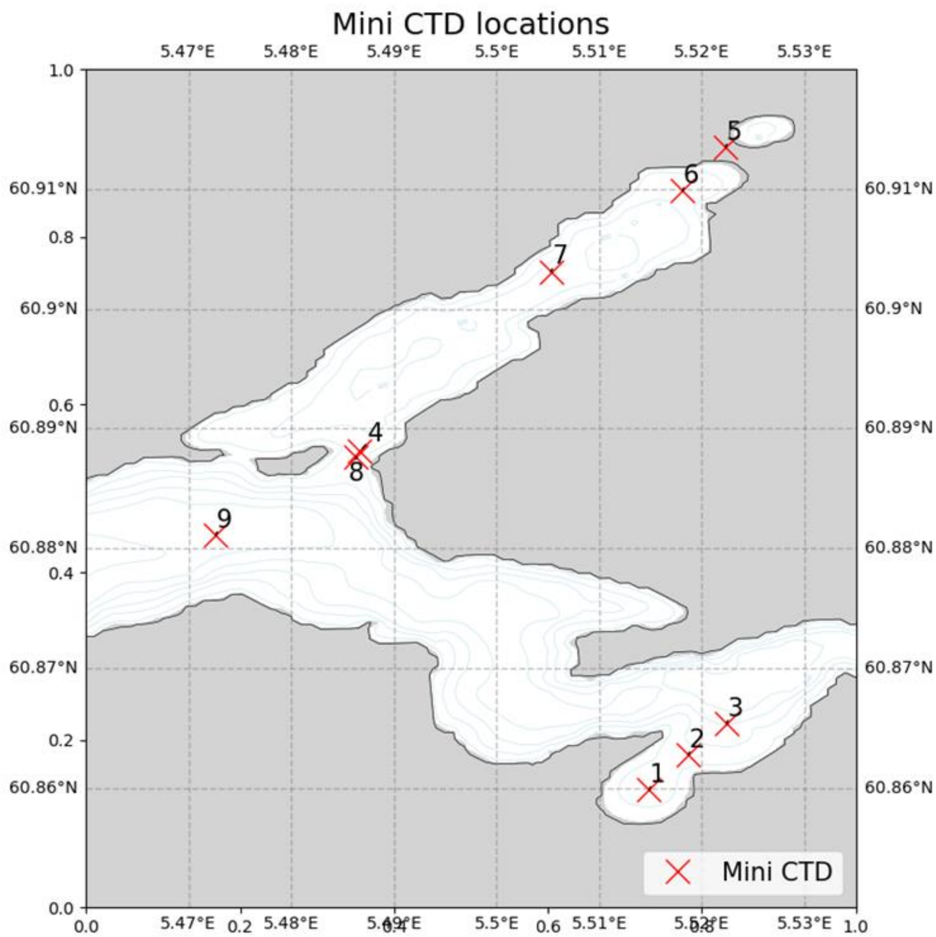

__Figure 28:__ Plot of the mini CTD locations and their respective station number

2.4.4 Acoustic Doppler current profiler (ADCP)

From Thomson & Emery (2014, p. 93), an acoustic Doppler current profiler are nonmechanical current meters that measure flow speed and direction by transmitting high-frequency sound waves and determining the Doppler frequency shift of the returned signal. The signal is returned by hitting micro-objects in the water column, thus the instrument will not work for perfectly "clean" water since the signal would not be reflected. This technology makes it possible to profile flow velocity as a function of distance from the instrument. The ADCP provides time series of the flow averaged over a suit of ensonified depth bins. ADCP's works the same as having a stack of current meters with the assumption that the flow is homogenous over the individual volumes of water.

On the cruse with Kristine Bonnevie, there was two separate locations with ADCP measurements. One of them was stationary for over 24 hours at the sill to Haugsværfjorden using a mooring installation, while the other was taken by the mounted instrument on Kristine Bonnevie while going across Fensfjorden. The ADCP on Kristine Bonnevie was taken approximately around 2023-02-16-06:12 to 2023-02-16-08:48, while the stationary ADCP called ECO, was active approximately around 2023-02-15-08:18 to 2023-02-16-15:30. In figure 29, the different locations are illustrated using a scatterplot of their coordinates.

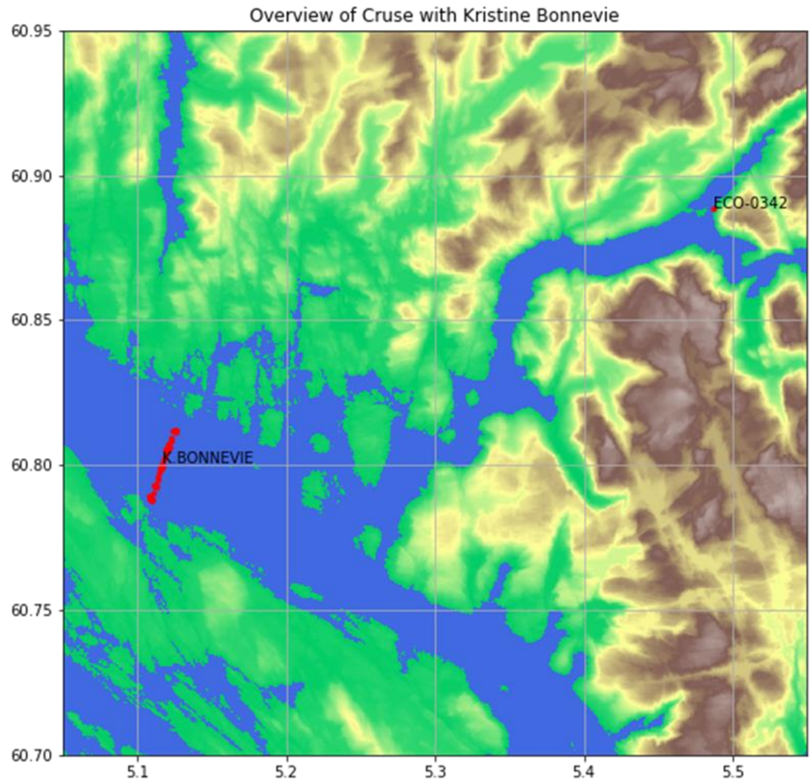

Figure 29: *Plotted the location of the different ADCP areas from the Cruse with Kristine Bonnevie. Each location is marked with the instrument used to measure the current profile, where the axis of the plot represents the longitude on the bottom axis, and latitude on the axis to the left.*

The ADCP used on the sill at Haugsværfjorden was ECO-0342, shown in figure 30. The ADCP was placed facing upwards inside a round oval buoy to help it stay stationary an upwards at the bottom of the sill. Connected was a rope to retrieve it, which was weighted downward away from the ADCP location with a buoy at the top. This is illustrated I figure 31. From NORTEK (2023), the ECO-0342 has a maximum profiling range of 20 meters, where its cell size is self-configured with a range of 0.3 meters to 20 meters. Its minimum blanking is at 0.1 meter and a maximum number of 3 cells. ECO-0342 has an accuracy of the measured value.

Figure 30: *Photo of the ECO-0342.*

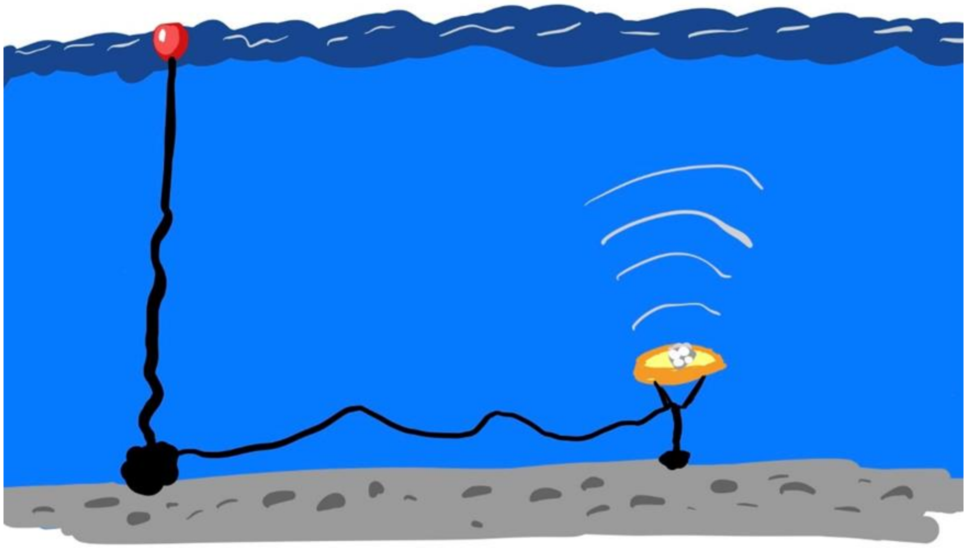

Figure 31: *Illustrating the ADCP mooring setup at Haugsværfjorden. The red buoy is used for recovering the ECO-0342 ADCP.*

The ADCP used on Kristine Bonnevie was UHDAS, which used the narrowband parameter. The ADCP is mounted onto the boat, and measures downwards from the boat. Its bin size was set to 8 meters, with a total of up to 50 bins. This gives it an uncertainty of $\pm 0.5\ cm/s$ on each measurement since the ship is using $150\ kHz$. From Daae (2023, p.11), the ADCP has an uncertainty of $\pm 0.03\ cm/s$ with $600\ kHz$ but lower range (50 meters). While a ADCP which has a higher range (600 meters) with an uncertainty of $\pm 0.5\ cm/s$. Thus, we assume a higher uncertainty since the instructions of the instrument does not say anything about its uncertainty. Figure 32 illustrates the ship mounted ADCP.

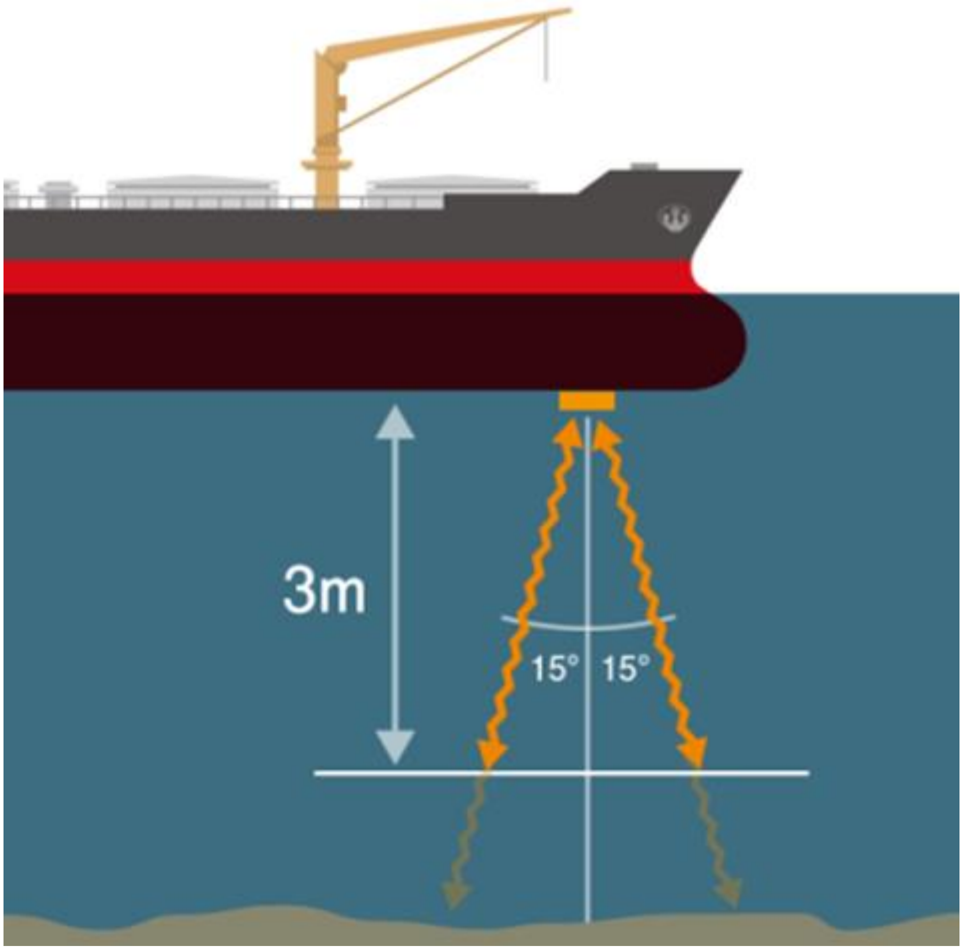

Figure 32: *Illustration of ship mounted ADCP. Figure is used from Daae (2023, p.11).*

2.4.5 Microstructure sonde

The MSS winch was set up in the CTD-shack as usual. We managed to close the "roof" during night by pulling the winch backwards. We lifted the winch into the position using the big crane.

There were initial communication problems, and we had to change winch to get it to work. After that, everything run smoothly. Two casts (6-7) had to be aborted.

We did in total 11 casts, see Table 9 for details.

Table 9: *Details about the MSS-stations occupied during KB2023006004*

File	Station	Date/UTC			Time/UTC		E. Depth	Latitude/N		Longitude/E		End	
name	name	year	mon	dd	hh	min	m	deg	min	deg	min	m	Comments
0001	HF_test	2023	2	16	13	27	109	60	53,871	5	29,766	90	
0002	H1	2023	2	16	13	53	124	60	54,26	5	30,578	120	
0003	M31	2023	2	16	14	25	265	60	52,879	5	28,403	255	
0004	M26	2023	2	16	15	15	465	60	52,409	5	24,96		
0005	M18	2023	2	16	16	50	198	60	50,152	5	20,873		aborted
0006	M18	2023	2	16	16	55	198	60	50,152	5	20,873		aborted
0007	M18	2023	2	16	16	55	124	60	50,152	5	20,873	95	
0008	M16	2023	2	16	17	13	299	60	49,317	5	21,038		high acceleration at times
0009	M14	2023	2	16	17	43	151	60	48,307	5	19,534	135	
0010	M12	2023	2	16	18	12	155	60	48,255	5	18,425	130	
0011	L04	2023	2	17	8	17	200	60	43,154	5	3,729	235	

2.4.6 Moorings

Five oceanographic moorings (MF_sill, MF_outer, MF_inner, LF_sill and HF_sill) were deployed during the cruise see Table 10, one of which was recovered (HF_sill). The moorings are part of the RCN-funded project FJO2RD and the internal Bjerknes project CLIFORD and are deployed to monitor exchange processes and deep water renewals in Masfjorden and Lurefjorden. HF_sill was deployed as part of student projects to observe tidal flow across the sill of Haugsværfjorden.

Drawings of the moorings are shown in Figure 33 - Figure 36.

The compass of current meters were not calibrated prior to deployment. The pressure sensor of the V50 gave an error message. One SBE56 was deployed with a "normal" AA-battery and sampling interval was reduced from 10s to 10 min. The wiper on RBR DO 209989 was started. All RBR CTDs (except for 209989) was deployed with only one clamp.

Table 10: *Details about mooring deployment and recovery during cruise KB2023006004.*

			Deployment		Recovery	
Name	**Latitude**	**Longtitude**	**date**	**time**	**date**	**time**
HF_sill	60 53.301 N	5 29.201 E	15.feb	08:18	16.feb	15:30
MF_inner	60 52.163N	5 22.011E	15.feb	10:20		
MF_outer	60 49.447N	5 20.588E	15.feb	15:40		
MF_sill	60 47.680N	5 18.346E	15.feb	18:20		
LF_sill	60 43.899N	4 58.593E	17.feb	08:00		

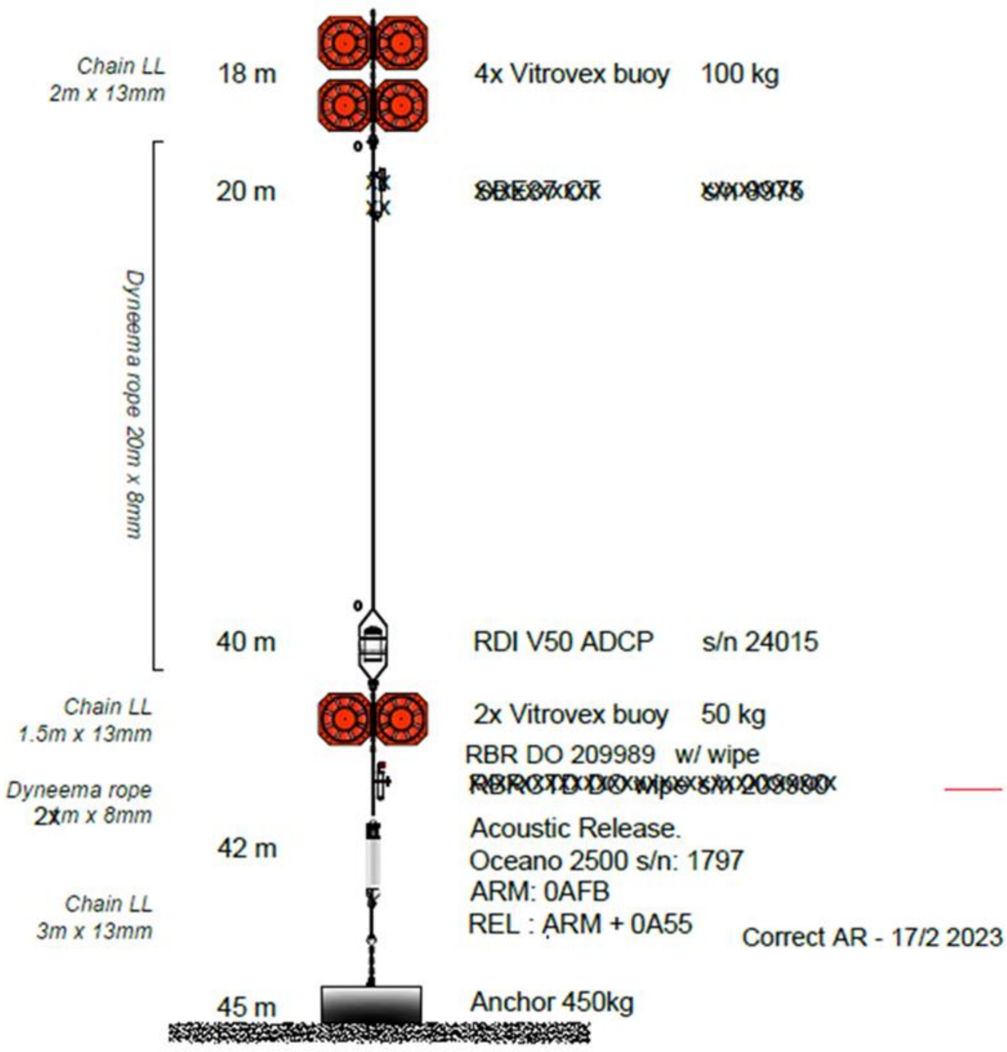

Figure 33: *Drawing of the mooring LF_sill.*

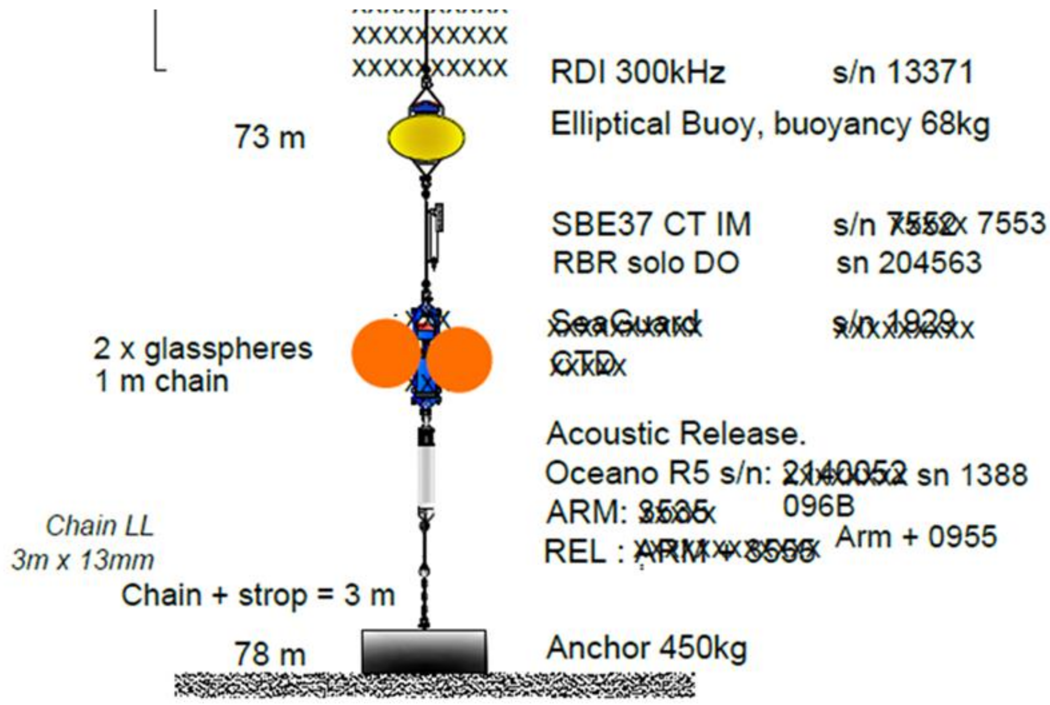

Figure 34: *Drawing of the mooring MF_sill*

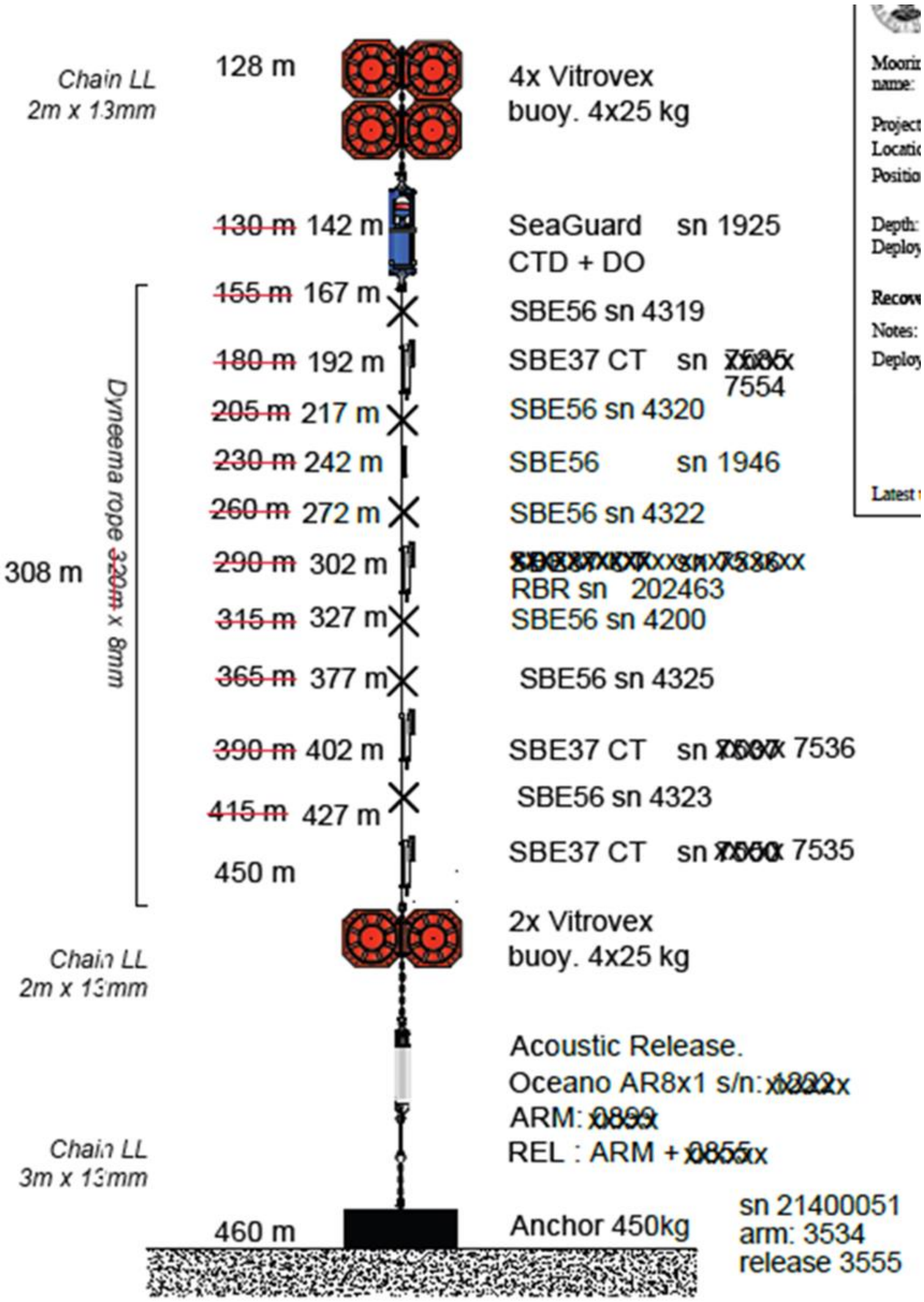

Figure 35: Mooring MF_inner

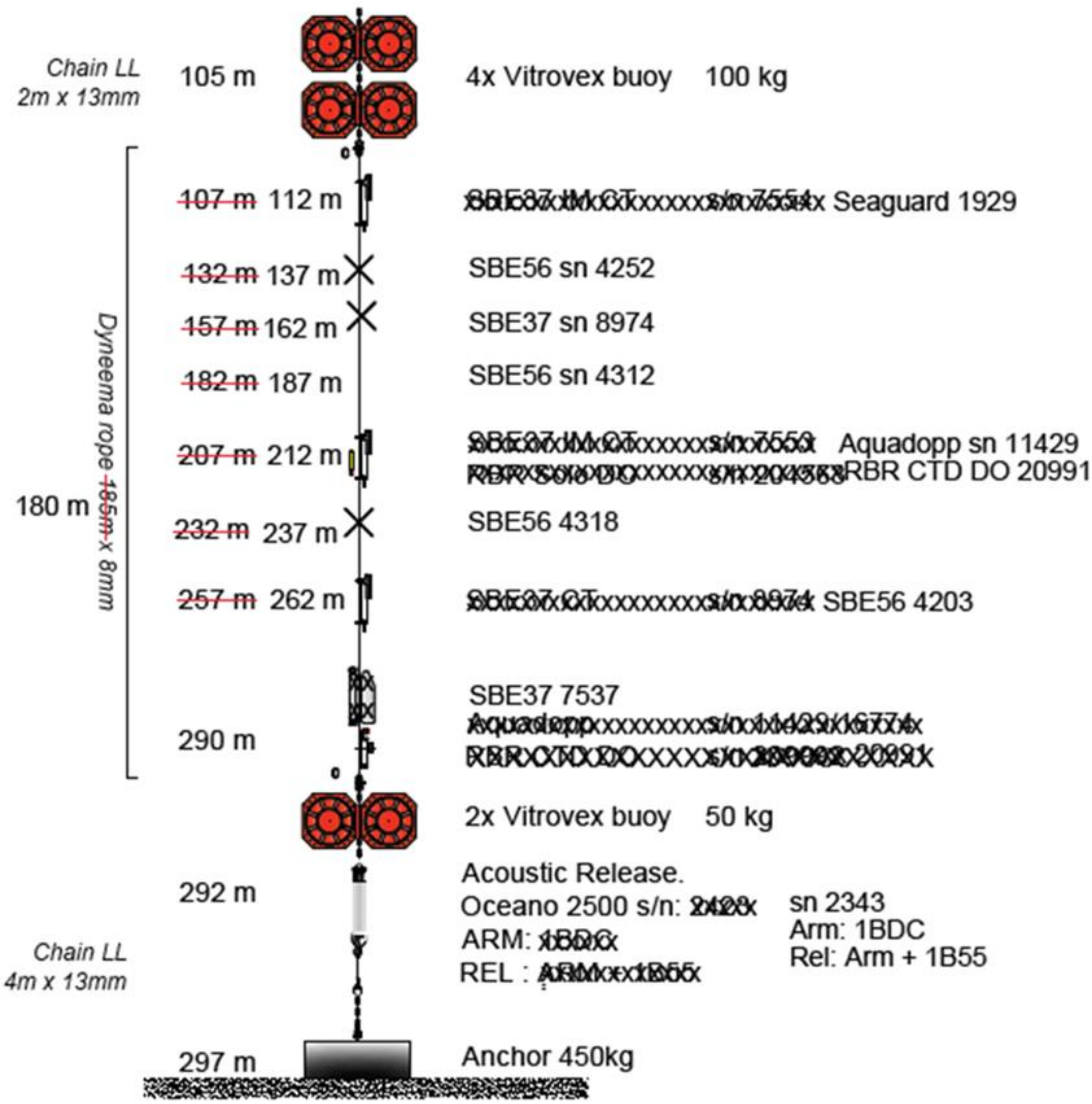

Figure 36: *Mooring MF_outer*

2.4.7 Wave buoy and Drifters

Prior to the cruise one of the wave buoys that we utilized, called Wavebug26, had been deployed January 25th and retrieved again February 14th. A problem occurred with Wavebug26 on February 13th as the wave buoy had stopped gathering data. We did not notice that the wave buoy had stopped gathering data until after Wavebug26 had been deployed again as a drifter on Thursday on February 16th.

In order to be able to map waves effectively and fairly accurately, we used a type of wave sensor which has been made with the help of engineer Helge Brynhi. The setup consists of a 3d printed battery holster that is then put inside a bottle for protection and to make the setup waterproof. The holster is designed to fit as many batteries as possible and we have used 6 1,5-volt batteries as seen in figure 37. The cables and batteries have been soldered so that there is a power supply for the board. 3 and 3 of the batteries were connected in series and the two series were then parallel connected. The batteries are connected to a capacitor which is in turn connected to the board. This is done to give the batteries a more even load so that they last longer.

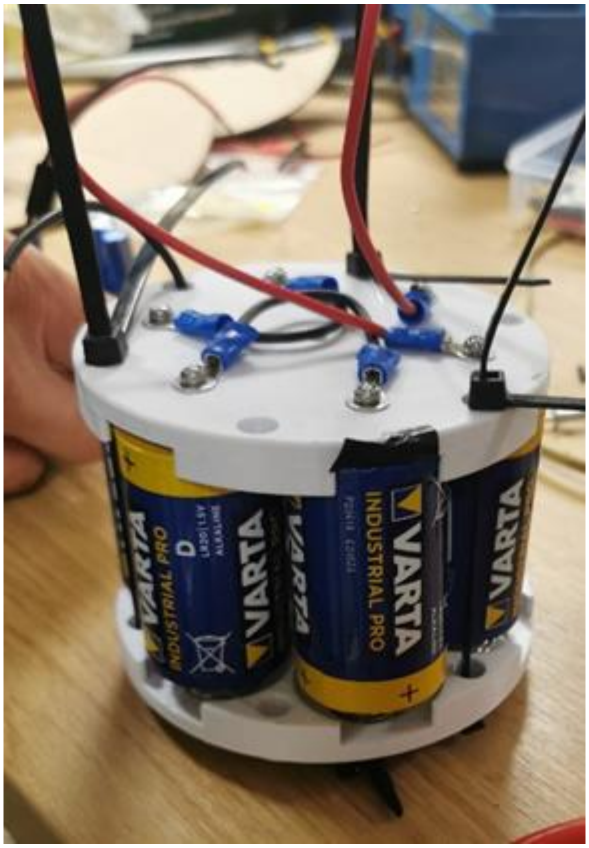

Figure 37: *Battery pack designed for Uib02*

The board itself is a Redboard Artemis Nano, which allows for, among other things, an SD memory card, GPS, USB-C connector, which allows for updating the position, as well as storing data that is measured. GPS position and measured data are sent out at 20 minute intervals using a transmitter antenna connected to the board. The collected data and position are received by a server at MET, where we have the opportunity to get an overview of the buoy's position and download data.

We built the battery holster on February 15th and the new wave sensor was called Uib02 in the MET server. Unfortunately, the transmitter antenna which broadcasts the position was bent when we put the battery holster in the bottle. The transmitter antenna is designed to be straight, and the bend resulted in problems in delivering its position.

The waves are measured using an accelerometer. This measures the acceleration of the wave buoy. We can then get the position by integrating the acceleration twice. This position can then be used to find significant wave height, wave number, wave period etc. The accelerometer measures acceleration in the x, y and z direction. Since the accelerometer does not know which way it is pointing, a magnetometer and gyroscope are also used to find the direction and rotation of the buoy. This means that it is possible to determine with good accuracy in which directions the buoy has accelerated.

On February 16th we made a new battery pack and put the battery pack, board and transmitter antenna in a larger container to prevent the transmitter antenna from bending. Uib01 is the name of the new wave buoy with the new battery pack and is shown in figure 38. We deployed Uib01 at 10:20 UTC and Wavebug26 at 10:35 UTC. Wavebug26 was retrieved at 15:15 UTC and Uib01 was retrieved at 15:43 UTC. Uib01 and Wavebug26 were placed on both sides of the sill at Haugsværfjorden as shown in figure 40.

Figure 38: Battery pack designed for Uib01 as a drifter.

Figure 39: Uib01 ready to be deployed as a drifter.

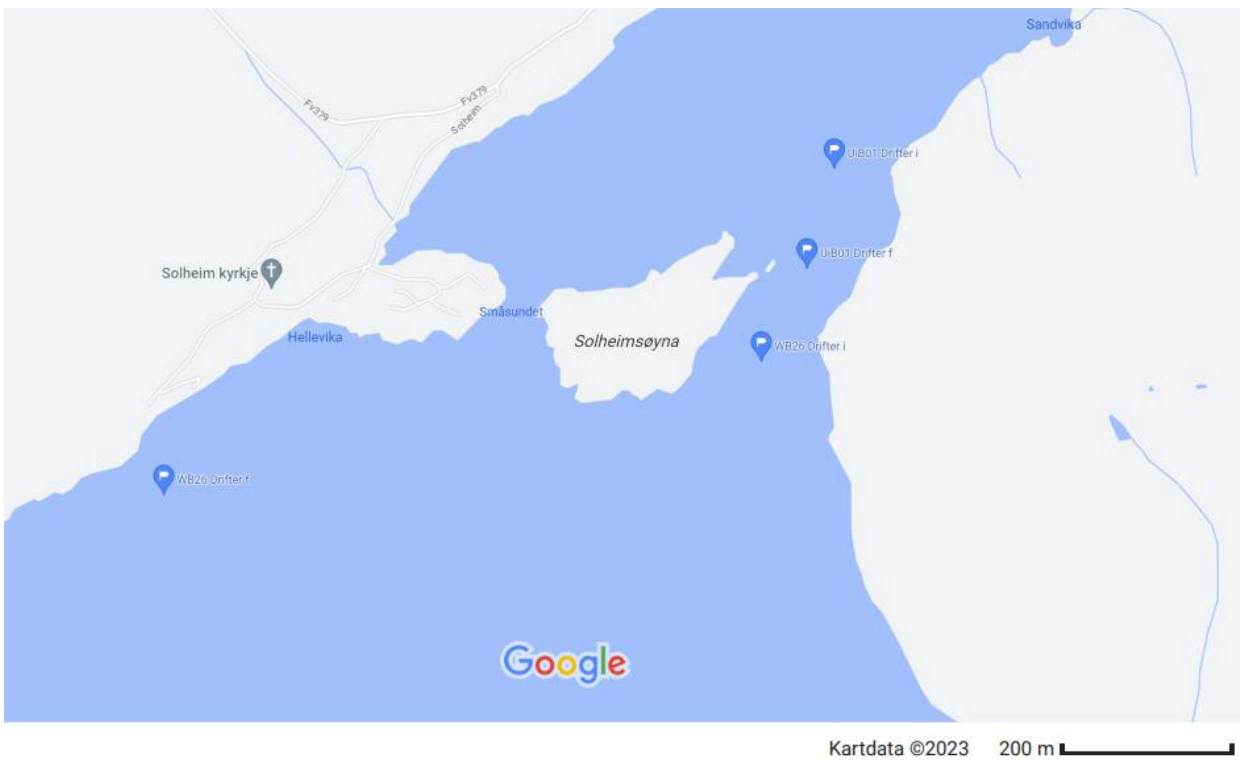

Figure 40: *Deployment and retrieval of drifters at Haugsværfjorden*

While Wavebug26 was deployed as a drifter, we discovered that it had stopped gathering data around February 13th. We thought that the reason it had stopped recording data was because of the SD memory card. We replaced the SD memory card and put the board and the tube it was in back in the wave buoy and closed the wave buoy with sip ties. After that we had to pump air back into the wave buoy so that it could float. We got an air flush from the crew, but it had water inside it, so we accidentally sprayed a bit of water inside the wave buoy. After we noticed the water coming out, we cleared the air flush of water and finished filling the wave buoy up with air.

The wave buoy Uib01 consists of a basket that allows water to penetrate, the purpose of which is to make the buoy more stable as seen in figure 39. This is done by filling the basket on the underside with chain. This reduces rotations around the x and y axis and also means that propulsion due to wind is reduced. It is important not to have too much weight, as this can cause the buoyancy to be too small for the buoy to be able to follow the waves in a good way. We have to have enough weight for the buoy to be stable at the same time that it is light enough to follow the waves.

On the last day of the cruise, we were going to anchor two wave buoys so that the next cruise to Osterøy could gather them and we could get more data. When we deployed the wave buoys, we must make sure how deep it is and that the chain could reach the bottom without dragging the wave buoy under water. We deployed Wavebug26 first near the coast where there are more waves since that wave buoy is more resilient. We deployed it near an island called Stora Agnøy at 10:38 UTC as seen in figure 41. We anchored this wave buoy where there was a depth of around 74.27 meters. The battery pack that we constructed on February 16th would most likely not be able to power the wave sensor until the next cruise to Osterøy. We ended up combining the board and the unbent transmitter antenna from Uib01 and connecting it to the battery holster we designed for Uib02 on February 15th. We deployed Uib01 at Frekkhaug at 13:00 UTC as seen in figure 42. We anchored this wave buoy where there was a depth of around 107.75 meters. Before we deployed Uib01 we coated the aluminium rod in the wave buoy with tar to prevent the aluminium from corroding. The details regarding the deployment and recovery of the wave buoys are shown in table 11.

Figure 41: *Deployment of Wavebug26 near Stora Agnøy*

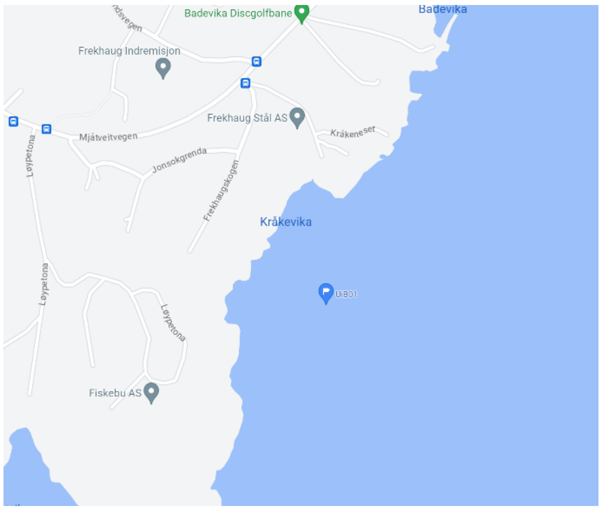

Figure 42: *Deployment of Uib01 near Frekkhaug*

Figure 43: *Wave buoy: Wavebug26*

Figure 44: *Wave buoy: Uib01*

Table 11: *Details about deployment and recovery of the wave buoys Uib01 and Wavebug26*

Wave buoy	APPROXIMATE POSITION						
	LATITUDE			LONGITUDE			
	deg	min	N/S	deg	min	E/W	The wave buoys measure acceleration, which we integrate into position and can then use to calculate, among other things, significant wave height.
UIB01	60	53.420	N	5	29.268	E	Deployed. This wave buoy acted as a drifter and was not anchored. Deployed 16.02.23: 10:20 UTC.
UIB01	60	53.301	N	5	29.201	E	Retrieved. This wave buoy acted as a drifter and was not anchored. Retrieved 16.02.23: 15:43 UTC.
WAVEBUG26	60	53.190	N	5	29.090	E	Deployed. This wave buoy acted as a drifter and was not anchored. Deployed 16.02.23: 10:35 UTC.
WAVEBUG26	60	53.031	N	5	27.624	E	Retrieved. This wave buoy acted as a drifter and was not anchored. Retrieved 16.02.23: 15:15 UTC.
WAVEBUG26	60	36.118	N	4	55.106	E	Deployed. This wave buoy was anchored near the island Stora Agnøy. Depth: 74.27 meters. Deployed 10:38 UTC

UIB01	60	30.625	N	5	14.668	E	Deployed. This wave buoy was anchored at Frekkhaug. Depth: 107.75 meters. Deployed 2023-02-17 13:00 UTC

The wave buoys had different designs for different areas of use. The buoys used during this cruise consisted of anchored wave buoys and drifters. If you are going to measure waves in shallower water where there is a specific point that is interesting, anchored wave buoys can be more interesting. Another advantage of anchored wave buoys is that it enables measurements over a long period of time without the buoy ending up on land. On the other hand, if you are going to measure the waves in an open fjord, it can be worthwhile to have it together with a drifter. In this way, you can get data on how the currents in the sea surface affect the waves, and you can collect results for several different experiments along the way. Another advantage of drifters over anchored buoys is that the measurements of drifters are likely to be more accurate. This is because the anchor will limit the movement of the buoy, and you may therefore end up losing waves that you would otherwise have measured.

3.0 Meteorological survey

3.1 Participants

The list below shows all the participants who were collecting data from land-based observations and measurements from Osterøy in the period 24th of February to 17th of March.

Last name	First name	Role
Eilertsen	Merethe	GEOF232 Student
Hansen	Bettina	GEOF232 Student
Strøm	Adrian	GEOF232 Student
Sæle	Vegard	GEOF232 Student
Vindedal	Marte	GEOF232 Student

3.2 Overview meteorology

The data collected from the period have been used in several studies, including microclimate in forests and the effect of topography and terrain on metrological parameters. All students actively participated in planning and assembling the equipment, this gave practical and technical insight in operating metrological instruments.

3.3 Meteorological instruments

3.3.1 Hobo rain gauge RG2M

The Hobo rain gauges consist of a precipitation data collector, and a HOBO pendant event data logger. The precipitation collector is made up of an aluminum ring, screen and funnel that guides the precipitation to a tipping-bucket mechanism, which is covered by an aluminum housing. The tipping-bucket mechanism consists of two tipping-buckets, where when one of the buckets is full and tipping, the other one will be filled. One tip of a bucket will occur for each 0.2 mm of rainfall and is detected when a magnet attached to the tipping-bucket activates a magnetic switch as the bucket tips. The magnetic switch is connected to the HOBO event logger, which registers each tip. The data logger has a storage capacity of 16,000 or more measurements or “tips”. Maximum precipitation rate is 127 mm/h with an accuracy of ±1% (Onset Computer Corporation, n.d.).

Figure 3.3.1: *Picture of a Hobo rain gauge RG2M. Source: Onset Computer Corporation.*

3.3.2 TinyTag

The TinyTags used in our collections of data are TGP-4505’s. These are temperature and relative humidity (RH) data collectors, made for industrial and outdoor use (Gemini2, n.d.). The sensors are protected by robust and waterproof casings, and the complete TinyTag weighs 165g, which makes it easy to place wherever one wants, even in remote areas. As we were recommended to place the TinyTags between 1-2m above ground, the only real limitation was where we could drive a pole into the ground. The device's reading range is -25°C to 85°C for temperature and 0%-100% RH. The resolutions are 0.01°C for temperature and ±3.0% for RH, and the accuracies are 0.35°C for temperature and 0.3% for RH. The logging interval can be between 1s and 10 days, and can in total have 32,000 readings. RH is measured by a capacitive sensor, which measures the change in electrical resistance in a thin layer of lithium chloride, which depends on the humidity (Britannica, n.d.). For temperature the TinyTag uses a 10k NTC thermistor.

Figure 3.3.2: *Picture of a TGP-4505 TinyTag, for measuring temperature and humidity.*

3.3.3 Automated Weather System AWS

The automated weather system is a combination of meteorological equipment used to collect, measure and transmit data from the atmosphere. These stations can operate individually or as a part of a weather network, both on land and at sea. They have a low power requirement, and the ability to communicate over long distances allow the station to operate remotely for long periods without human intervention. For this reason, AWS is at the core of many critical functions, especially in metrology and climate research. The following paragraphs will explain the components used for the purpose of GEOF 232.

3.3.3.1 Campbell Scientific CR1000 datalogger

The CR1000 is a data logger used for various scientific and industrial applications to collect and store data from a range of sensors and devices. It can operate efficiently in remote locations and is therefore mounted on the AWS. There it will store, analyze and communicate meteorological parameters such as temperature, humidity, precipitation, solar radiation, wind speed, and direction (Campbell Scientific Companies, 2016).

Figure 3.3.3: *Picture of a Campbell Scientific CR1000 datalogger*

3.3.3.2 RM Young 61302V Pressure Sensor

The pressure sensor on the AWS measures the atmospheric pressure, with measurements and calculations every hour. The sensor has a pressure range of 500hPa to 1100hPa with a resolution of 0,01 (ITAS, n.d, p.5). The sensor makes measurements every hour, and stores data every hour.

3.3.3.3 Vaisala HMP155 temperature- and humidity sensor

The Vaisala HMP155 sensor measures air temperature within a range of -80°C to +60°C and with a resolution of 0,001, and air humidity from 0 to 100% with a resolution of 0,1 (ITAS, n.d, p. 5). The sensor measures every 5. and 60. second and storage of data happens every hour.

Figure 3.3.4: *Picture of a Vaisala HMP155 temperature- and humidity sensor*

3.3.3.4 Pessl IM523 precipitation sensor

The sensor measures precipitation with a tilting vessel with 0,2mm per tilt, in other words, a measuring range of 0-0,2 mm precipitation and a resolution of 0,2. The max load is 12mm/min and the measurements are done every second (ITAS, n.d, p.6). The precipitation sensor makes measurements every second, every minute and every 10. minute. Storage of data happens every minute, every 10. minute and every hour.

Figure 3.3.5: *Picture of a Pessl IM523 precipitation sensor*

3.3.3.5 Apogee SP110 – Radiation

The apogee SP110 sensor measures shortwave radiation from above with a range of 0 to 1000 W/m^2 with a resolution of 0,1. Spectral range for the shortwave radiation is from 360 to 1120 nm (ITAS, n.d, p.6). The sensor measures every second, every minute and every hour. Storage of data happens every hour.

3.3.3.6 R.M. Young 5106-45 Alpine Sensor

The R.M. Young 5106-45 Alpine wind speed- and wind direction sensor is the precision instrument that measures wind direction and wind speed in the horizontal direction (campbell sci, n.d). The instrument takes measurements every second, calculations are done every second and every minute. Storage of the data happens every ten minutes and every hour. The data is stored every ten minutes and every hour. The wind speed is measured with a helicoid-shaped, four-blade propeller, and the rotation of the propeller produces a sinusoidal AC signal with frequency proportional to wind speed (ITAS, n.d, p. 5). The wind sensor has to be directed to the north and made sure to be leveled. The specifications for the instrument are shown in table 1.1.

Figure 3.3.6: *Picture of a R.M. Young 5106-45 Alpine wind speed- and wind direction sensor.*

Table 3.1: *Specifications for R.M. Young 5106-45 Alpine wind speed- and wind direction sensor. Source: ITAS, p.5.*

Measurement	Measuring range	Resolution	Accuracy	Unit
Windspeed	0-100	0.001	± 0.3 m/s or 1% of measurements	[m/s]
Wind direction	360 mechanic, 355 electric , 5 open	0.001	± 3%	[°]

3.3.4 Radiosonde

To get a view of the local conditions at different altitudes at Osterøy, we launched two Windsond weather balloons. A Windsond weather balloon takes measures of temperature, wind, relative humidity, location and altitude, and atmospheric pressure.

According to the catalog, the weather balloon can reach an altitude of 8000-9000 meters above sea level. We sent up one radiosonde at the CTD station O14. The second balloon we sent up between Stura og Toska, and it got up to 14500 meters. The balloon did lose radiocontact around 8500 meters, but still sent pressure data so we could extrapolate height above sea level. You can see technical data in the images below (Windsond, 2019).

S1H2 Humidity

Operating range
-40 ~ +80 °C
0 ~ 100 %RH

Temperature
Type: Band gap
Accuracy: 0.3 °C
Resolution: 0.01 °C
Response time: 6 s

Humidity
Type: Capacitive
Accuracy: 2.0 %RH
Resolution: 0.05 %RH
Response time: 6 s

Feature	Range	Resolution	Accuracy	Unit
Air pressure	300 ~ 1100	0.02	1.0	hPa
Wind speed	0 ~ 150	0.1	ca 5 %	m/s
Wind direction	0 ~ 360	0.1	Depends on GPS conditions	degrees

Figure 3.3.7: *Technical data and specifications for the radiosonde*

3.4 Locations of instruments

3.4.1 HOBOs and TinyTags

Our first location was south-west on Osterøy, in Mjelddalen. The topography in the valley was steep. The first set of instruments were placed at 60 meters above sea level on an open plateau in the hill side. The next set of instruments were placed 70 meters above sea level, in the forest to the south. We placed the instruments in a small opening between trees on a steep mount. Both of the stations were in a field facing north.

Our second location was north-west of Osterøy, near Ranen. The first set of instruments were placed at 150 meters above sea level on a flat, open field, with only a few trees nearby. The second set of instruments we placed in the forest to the east, 160 meters above sea level midway through the forest in a small opening. The topography in the forest was very steep. Both of the stations were facing west, we therefore expect there to be some differences in sun exposure for the two locations.

Figure 3.4.1: *Installed instruments in Mjelddalen*

Figure 3.4.2: *Installed instruments on Ranen*

3.4.2 AWS-stations

All of the equipment was out in the period 24th of February to 17th of March, roughly three weeks of data.

1434: We placed one AWS-station in the valley “Askelandsdalen” on the south-west side of Osterøy out on a swamp near a little barn with a forest nearby. The area close to the AWS-station was an open field, but the high forest may have provided some shelter for the wind, so this is a clear limitation to the measurements made from this station. The purpose of this location was to see the effect the valley has on the wind speed and direction.

Figure 3.4.3: *Picture of the AWS-station (1434) in the valley*

1433: Another AWS-station was placed approximately on sea-level in Votlo, on the south-west side of Osterøy in a garden next to the fjord with the valley behind. There were some small trees nearby and a house. The purpose of this location was to measure possible differences in the wind speed in the valley (with more sheltering from the wind) versus outside of the valley.

Figure 3.4.4: *Picture of the AWS-station (1433) on sea-level in Votlo*

1432: The third AWS-station was placed on a hill 250 meters above sea-level with nearly no obstacles in the immediate vicinity. We measured a forest approximately 30 m from the station towards the west. There was a water tank approximately 25 m from the station towards the east. There was a thin layer of snow covering the ground.

The purpose of this AWS-station was to see how the wind is affected by the height.

Figure 3.4.5: *Picture of the AWS-station (1432) on a hill*

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Appendix A: Full overview of CTD and water samples

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