Cruise name/number:	Alliance F2022-090 FINAL REPORT

Authorizations:

Coastal State	Authorization Document Number	National Participant(s)
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Brief description of scientific objective:

The Northern Ocean Rapid Surface Evolution (NORSE) Departmental Research Initiative (DRI) focuses on characterizing the key physical parameters and processes that govern the predictability of upper-ocean rapid evolution events occurring in the ice-free high latitudes. The goal is to identify which observable parameters are most influential in improving model predictability through inclusion by assimilation, and to field an autonomous observing network that optimizes sampling of high-priority fields. The objective is to demonstrate improvements in the predictability of the upper ocean physical fields associated with acoustic propagation over the course of the study.

Update on anticipated dates for delivery of final results:

Metadata:	See attached cruise report
Raw Data:	Raw data has already been shared with Norwegian partners
Processed Data:	Will be provided with publications to be produced within 2 years
Data Analysis:	Will be provided with publications to be produced within 2 years
WODC Data Registration (if applicable):	Accession number

Append image or URL illustrating the route of the platform, locations where measurements were taken, and actual cruise track:

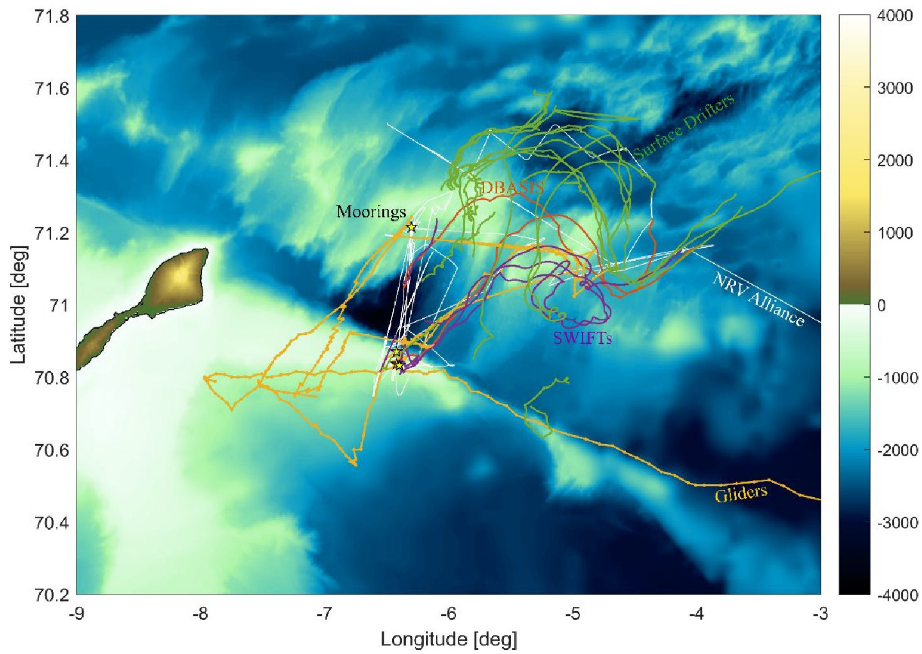


Figure 1. Map of the area around Jan Mayen showing the location of the NRV Alliance and autonomous assets between 21 October and 2 November.

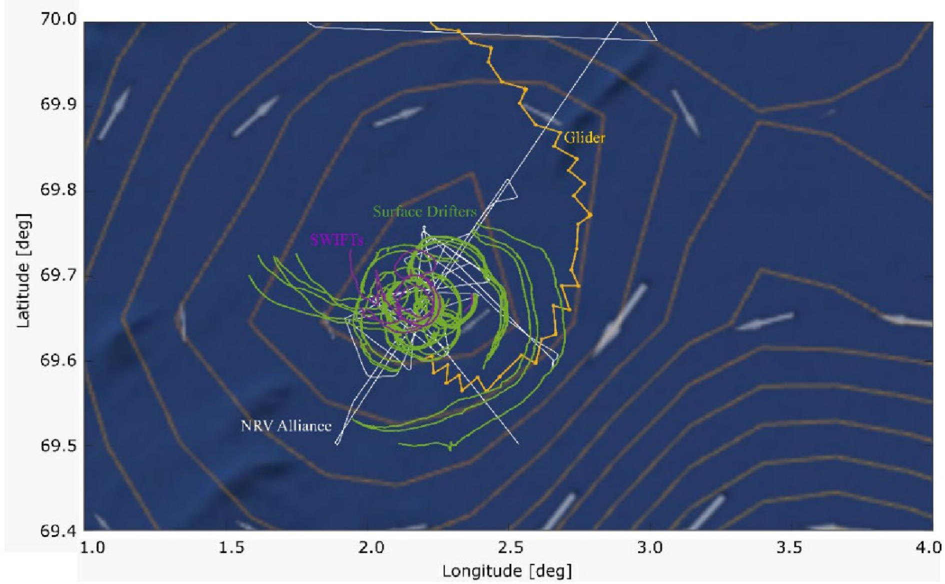
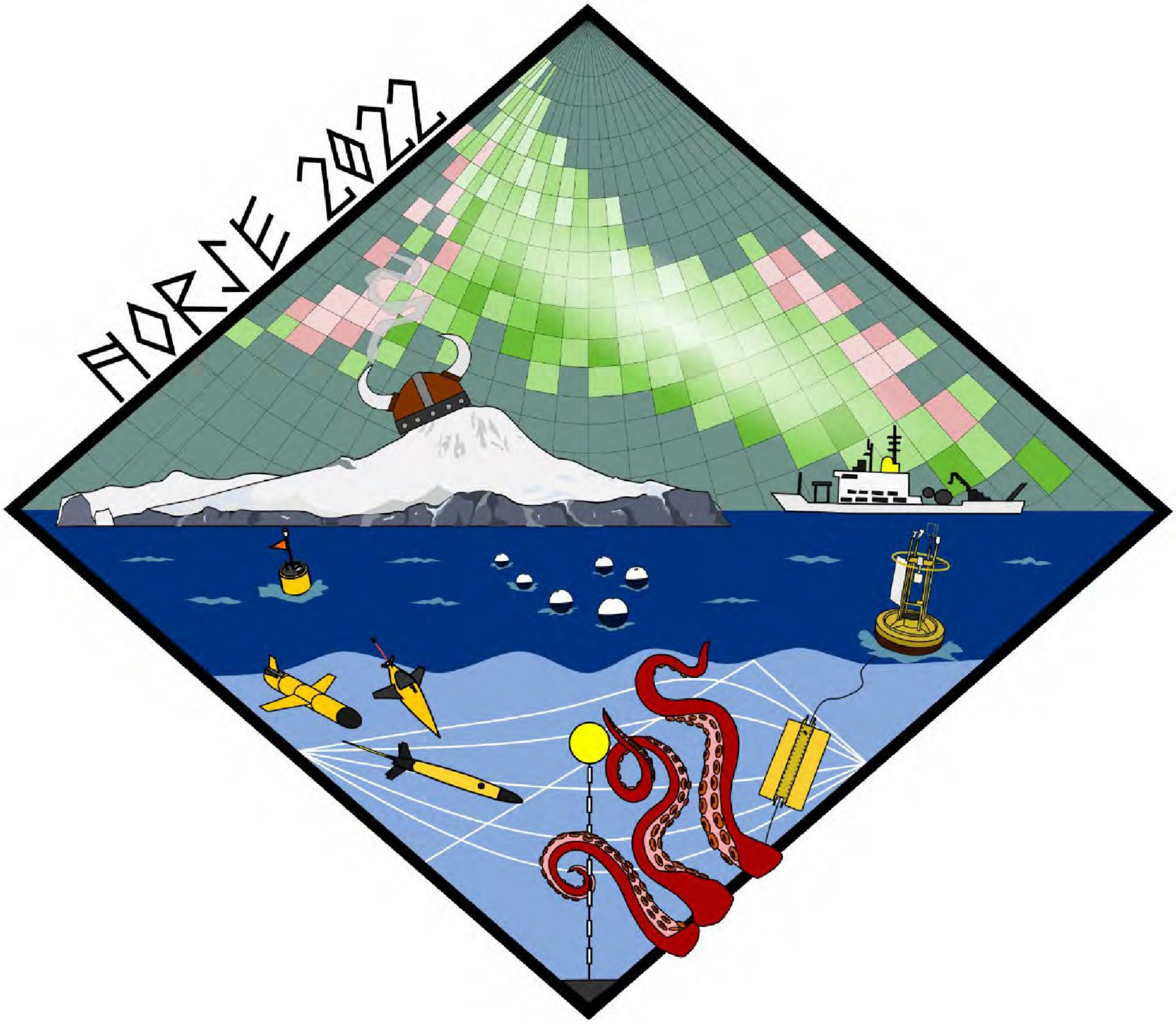


Figure 2. Sea surface height contours showing the location of the Lofoten Basin Eddy, the NRV Alliance and autonomous assets between 3 and 7 November.



NORSE 2022 Cruise Report

Megan Ballard, Jennifer Mackinnon, Riley Baird, Kerstin Bergentz, Ailin Brakstad, John Eischer, Laur Ferris, Sara Goheen, Micheal Goldin, Donglai Gong, Emerson Hasbrouck, Jonathan Ladner, Richard Lenhart, Andrew Lucas, San Nguyen, Devon Northcott, Pierre-Marie Poulain, Jason Sagers, Alejandra Sanchez-Rios, Joseph Talbert

Context

The Northern Ocean Rapid Surface Evolution (NORSE) Departmental Research Initiative (DRI) focuses on characterizing the key physical parameters and processes that govern the predictability of upper-ocean rapid evolution events occurring in the ice-free high latitudes. The goal is to identify which observable parameters are most influential in improving model predictability through inclusion by assimilation, and to field an autonomous observing network that optimizes sampling of high-priority fields. The objective is to demonstrate improvements in the predictability of the upper ocean physical fields associated with acoustic propagation over the course of the study.

Scientific objectives

The main objective of NORSE is to understand and develop knowledge on how to predict the changes in acoustic propagation across ranges of less than 100 km, over time scales of a few days, particularly around times when the ocean changes rapidly (e.g., storms). The governing questions include both those that are primarily physical oceanography questions and those that are primarily acoustics questions: the crux of this experiment is the unique ability to look at how these physical oceanography and acoustics questions are intertwined and interdependent. The NORSE campaign will be guided by the following broad questions and the numerous implicit questions behind them. From a physical oceanography perspective, the following questions will be investigated:

1. During times of rapidly varying surface forcing, how well do one-dimensional models of mixed-layer evolution agree with observations? To what extent are any discrepancies related to non-equilibrium surface wave states, near-inertial shear instability, or fundamental failure of stratified turbulence parameterizations in surface boundary layers (SBL)?
2. To what extent does lateral variability in near surface water properties on mesoscale, submesoscale, or sharp frontal scales influence how the ocean SBL responds to strong and variable forcing? Are there ways in which those scales of lateral variability feedback or imprint onto either the atmosphere or the stratified transition layer below?
3. How are temperature and salinity (and sound speed) characteristics in the stratified upper ocean influenced by the interplay between mesoscale eddies, stratified fronts, internal wave interaction with or trapping by either, subduction and mesoscale stirring of spice?

Each of the questions have implications for acoustic propagation. For every physical oceanography question, the following questions relate to its effects on acoustic propagation, including mixed layer acoustic duct (MLAD) characteristics, diffraction, scattering, and surface loss:

4. What spatial and temporal information about the upper ocean structure is needed to predict the available acoustic propagation across an existing front or eddy? How accurate are state-of-the-art ocean sampling and assimilative modelling techniques at predicting acoustic path availability?
5. What are the spatial and temporal scales of phase and transmission loss for various sound paths propagating through a dynamically evolving ocean, e.g., across a front, eddy, or spatially inhomogeneous rain or wind event?
6. Are stochastic small-scale processes like internal waves and spice important for determining acoustic path availability, and how do we measure upper ocean internal wave and spice models to predict this stochastic variability?

Measurements collected during NORSE will provide a better understanding of the coupled processes that drive rapid changes in the upper ocean at high latitudes, leveraging the adaptability and persistence of autonomous platforms.

Cruise Overview

Schedule

16.10.2022	Begin Mobilization in Tromsø
18.10.2022	Depart Tromsø
9.11.2022	Return Tromsø
10.11.2022	Unloading in Tromsø

Summary of Meteorological Conditions

Overall atmospheric conditions during the cruise were favorable but not calm (see Fig. 1). Upon leaving Tromsø, the vessel headed directly to Jan Mayen to shelter in the shadow of the volcanic island in anticipation of an incoming low-pressure system. This forced us to abandon our original plan to deploy autonomous assets in the Lofoten Basin Eddy on the way to Jan Mayen. Upon arrival at Jan Mayen, we deployed all four gliders before proceeding to shelter near the island. We remained in the shadow of the island overnight, and in the morning, we were able to venture out to begin science activities. We did not need to shelter again at any point during the cruise.

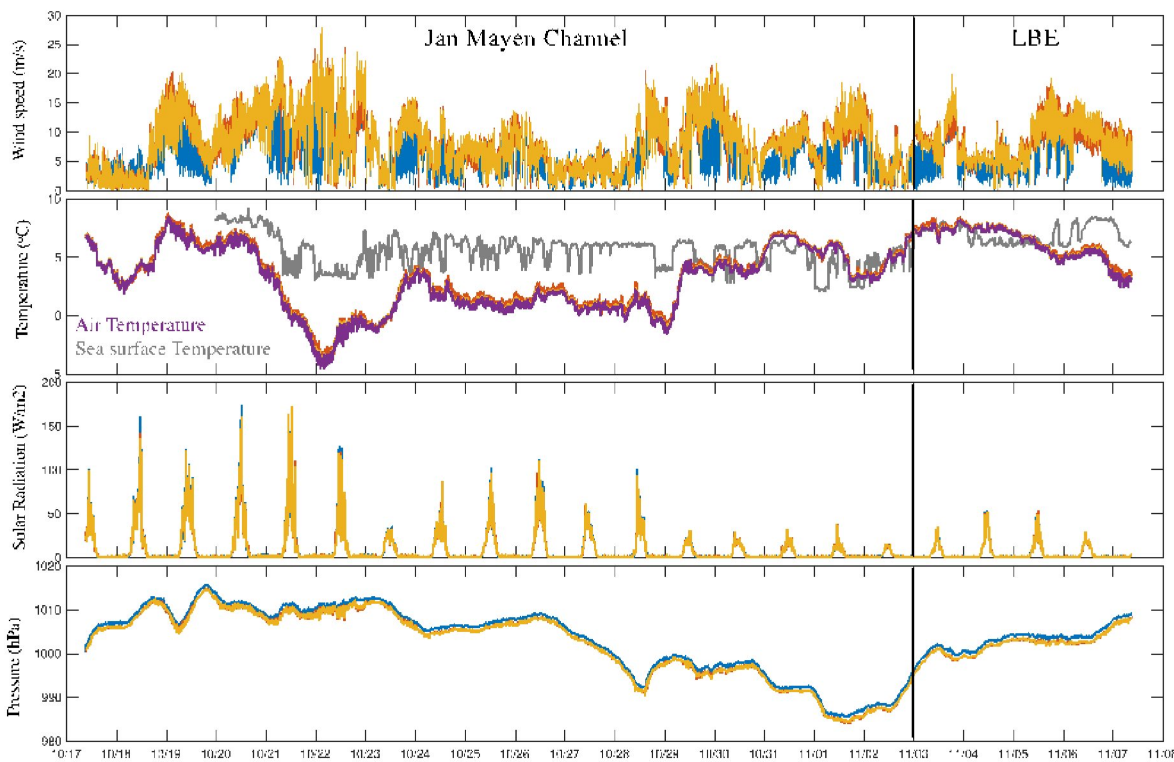


Figure 1. Meteorological data from ship base sensors, two located at the fore-mast and one located at the aft-mast. First panel shows wind speed, second panel air temperature with the background value of the temperature of the sea surface from the shop flow through data (gray line). Third panel is sola radiance and last panel is the surface pressure.

Cruise Overview by Site

The primary experimental site was the area to the east and northeast of Jan Mayen Island (see Fig. 2). The Alliance occupied this site from 21 October through 2 November. This location was the site for the yearlong moorings, the deployment of four gliders, two DBASIS buoys, four SWIFTS, and 18 surface drifters (SVP/Minimet/DWS). Shipboard sampling with the FCTD, Epsifish, and TPAD were carried between the moorings and at various other strategic locations to sample large temperature and salinity gradients and turbulent features.

The Lofoten Basin Eddy was studied from 3 to 7 November (see Fig. 3). At this site, the VIMS SeaExplorer was redeployed, as well as 35 surface drifters (SVP/Minimet/DWS), four ALTO floats, and four SWIFT drifters. Shipboard sampling with the FCTD, Epsifish, and TPAD as well as the bow chain were carried out within the Lofoten Basin Eddy and neighboring eddies. Before leaving the area, we recovered the UIB glider.

A day-by-day summary of cruise activities is contained in Appendix A.

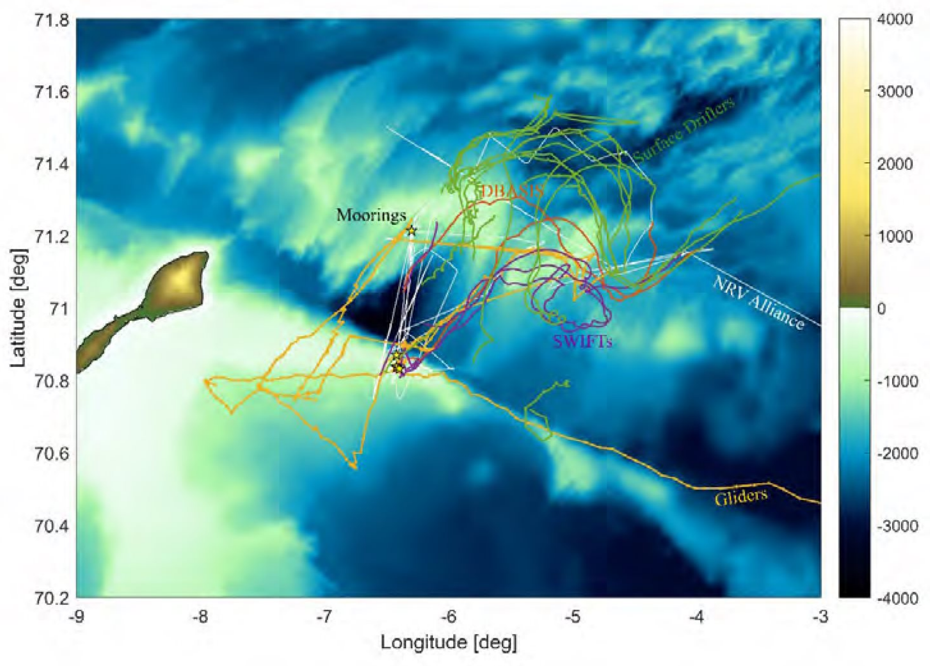


Figure 2. Map of the area around Jan Mayen showing the location of the NRV Alliance and autonomous assets between 21 October and 2 November.

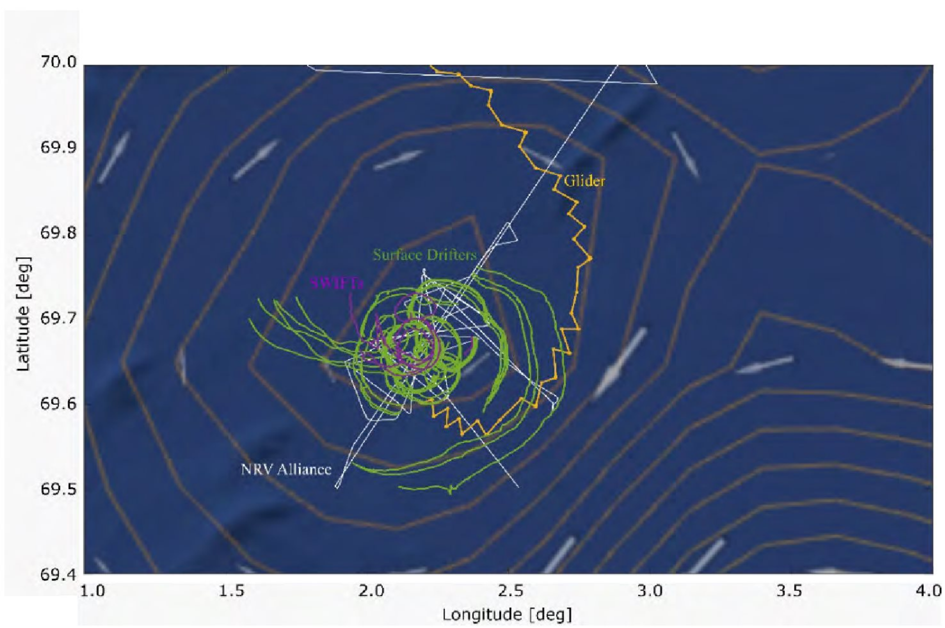


Figure 3. Sea surface height contours showing the location of the Lofoten Basin Eddy, the NRV Alliance and autonomous assets between 3 and 7 November.

Cruise Summary by Instruments

Mooring Deployments

The four NORSE moorings that will sample the Jan Mayen channel for a period of one year were deployed over a three-day period beginning on October 24. A summary of the mooring locations, water depth, and positional uncertainties are contained in Table 1. As-deployed mooring diagrams are included in Appendix B.

Mooring	Type	Lat [deg N]	Lon [deg W]	Depth [m]	Uncert [m]
PECOS	Triangulation	70.836847	-6.411678	413	3
PECOS Recovery Mooring	Anchor drop	70.841858	-6.401289	485	n/a
Acoustic Source	Triangulation	71.211565	-6.298711	1165	10
SW Environmental	Anchor drop	70.831946	-6.399105	413	n/a
UIB Environmental	Anchor drop	70.869161	-6.415010	1505	n/a

Table 1. Summary of mooring deployments and localizations.

Deployment Descriptions

Because of the weather conditions and other operation considerations, the PECOS mooring was deployed first. The deployment procedure typically involves deploying the array, lowering the PECOS recorder to the seafloor, and then deploying the recovery mooring while holding station. This procedure was not possible from the Alliance because the vessel does not have DP, and its ability to hold station was further compromised by its nonfunctional bow thruster. For these reasons, the vessel had to maintain a speed of 2 knots to maintain heading. Furthermore, the maximum winch speed is only 0.5 m/s (~1 knot), meaning that it was not possible to set down anything on the seafloor without dragging it.

An alternative deployment procedure was created to work within the capabilities of the vessel. Per this procedure, the recovery float was deployed first from a 1000 m length of miniline. The hydrophone array was deployed parallel to the miniline on the recovery float. Then the PECOS recorder was lowered to the seafloor with an acoustic release attached to a separate piece of miniline. When the PECOS system landed on the seafloor the acoustic release was triggered and recovered. Then the vessel circled around to the recovery float, brought it onboard, quickly attached the anchor and release and chain, and deployed the recover mooring to the seabed. Because of the additional risks of entanglement associated with this procedure, additional effort was made to survey the mooring and ensure the array was straight.

The remaining three moorings were deployed as conventional anchor last deployments. The source mooring was deployed on 25 October, and the two environmental moorings were deployed on 26 October.

Mooring Localization

The PECOS mooring and the Source mooring locations were surveyed using the acoustic releases to estimate the two-way travel time (twtt) from three repeated inquiries at three locations around the location of the anchor drops. The triangulation used an XBT to measure the sound speed profile and a ray trace code to model the ray refraction. This procedure resulted in a positional uncertainty of 3 m for the PECOS location and 10 m for the Source mooring location.

The location and condition of the PECOS array was further assessed using the vessel's multibeam system. The stabilized multibeam water column images are shown in Fig. 3 with a comparison to the as-built array element spacing. The agreement was exceptional, and the imagery shows no evidence of entanglement with the miniline from the recovery mooring. The location of the PECOS system was also assessed from the intersection of two multibeam tracks by accounting for the vessel's position and heading, the EM302 across beam distance of the item of interest (which is low resolution), and the time of the ping. The resolution of the multibeam estimate was 4 m and is in agreement with the estimate from the triangulation.

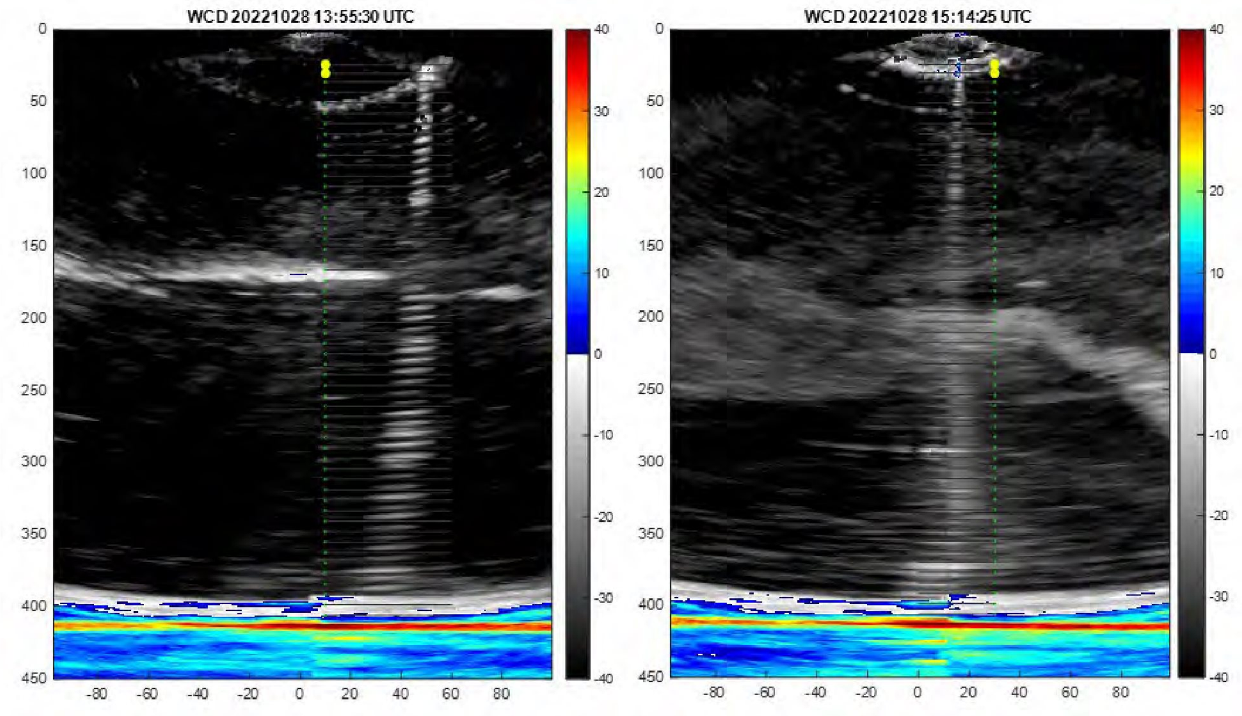


Figure 3. Multi-beam images of the hydrophone array in the water column. There is excellent agreement with the as-built array element spacing (green dots) and float depths (yellow circles). The left image is from a north-south track, and the right image is from an east-west track.

PECOS Continuous Record

The PECOS system was put into a three-hour continuous record mode on 25 October at 2249UTC to record signals from the source on the DBASIS NORSE1, which was deployed near the PECOS system earlier in the evening. This recording period was chosen to align with a time when the drifting source on the DBASIS NORSE1 buoy would be nearby as well as the deployment of a number of surface drifters, three of which included arrays of hydrophones, and the APL-UW glider with the towed array. During this three-hour period, the FCTD measured the water column properties between the drifting source and PECOS. After the three-hour period of continuous recording, the PECOS system automatically reverts to its scheduled recording of 24-minute records every four hours beginning at 0000UTC.

Measurement of Moored Source Signals

The signals from the moored source were recorded by the CMRE acoustic array deployed from the Alliance at a depth of 19 m. Recordings were acquired 29 October at 0800UTC when the vessel was located at 71.030952, -5.747002, which was 15.33 NM (28.391 km) from the source mooring position, and at 1600UTC when the vessel was 71.225696, -6.238480 at a range of 1.448 NM (2.682 km). There is some uncertainty about the absolute level that was measured. The hydrophone sensitivity (-201 dB), the hydrophone preamplifier gain (33 dB), and the SR560 gain (20 dB) are known, but the gain/attenuation of the signal conditioning card has not been quantified. The best estimated attenuation of 4 dB would make the final sensitivity equal to -151.2 dB. A later comparison to the ARL:UT electronics found the CMRE setup to be 8 dB less sensitive than reported. The approximately calibrated received level is shown in Fig. 4 for the signal recorded near the source mooring.

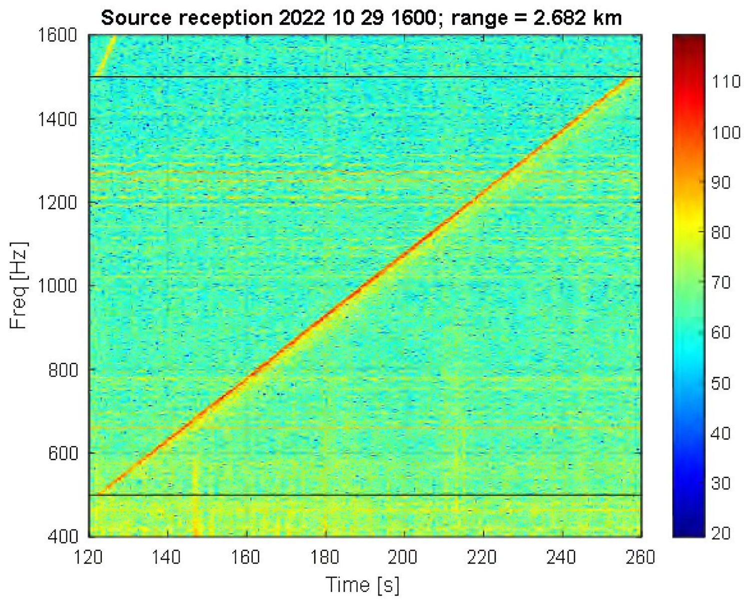


Figure 4. Signal from the moored source recorded by the CMRE array deployed from the Alliance at a depth of 19 m. The reception was recorded on 29 October at 1600UTC when the vessel was 1.448 NM (2.682 km) away from the source.

The source signals were also recorded by the CMRE drifters equipped with three-channels hydrophone arrays. The drifters were deployed on 25 October 2022 at 2200 UTC near the PECOS location. Over the next eight days, the drifters moved north, eventually circulating east and then southward. The drifters started at approximately 40 km from the source location, closed to approximately 13 km, and then opened to 70 km. During this time, the acoustic source was transmitting a 135-second-long LFM upsweep in the 500-1500 Hz band at 00:02:00, 04:02:00, 08:02:00, 12:02:00, 16:02:00, and 20:02:00 of every day.

Figure 5 shows the spectrograms of all three drifters for 26 October 2022 20:00 UTC. Several observations are made:

- The direct path arrival times between source and receiver aligned well with a simple time of flight computation (marked by the colored squares on the spectrograms). The average sound speed used in this computation was 1465 m/s.
- A second arrival was seen in Drifters 2 and 3 which corresponded to a ray launched by the source, reflected from the Jan Mayen ridge, and received by the drifters. The time of flight computation for this path is marked on the spectrograms by the yellow circles.
- A third arrival was seen in Drifters 2 and 3 which corresponded to a ray launched by the source, reflected near the Jan Mayen volcano, and received by the drifters (a path length of over 130 km). The time of flight computation for this path is marked on the spectrograms by the purple stars.

The second and third arrivals were seen on all three drifters (when the noise level was low enough) as they drifted northward from their deployment location across the Jan Mayen channel. By the time the drifters were positioned north of the channel, the wave height had increased and it was no longer possible to see these arrivals above the background noise level.

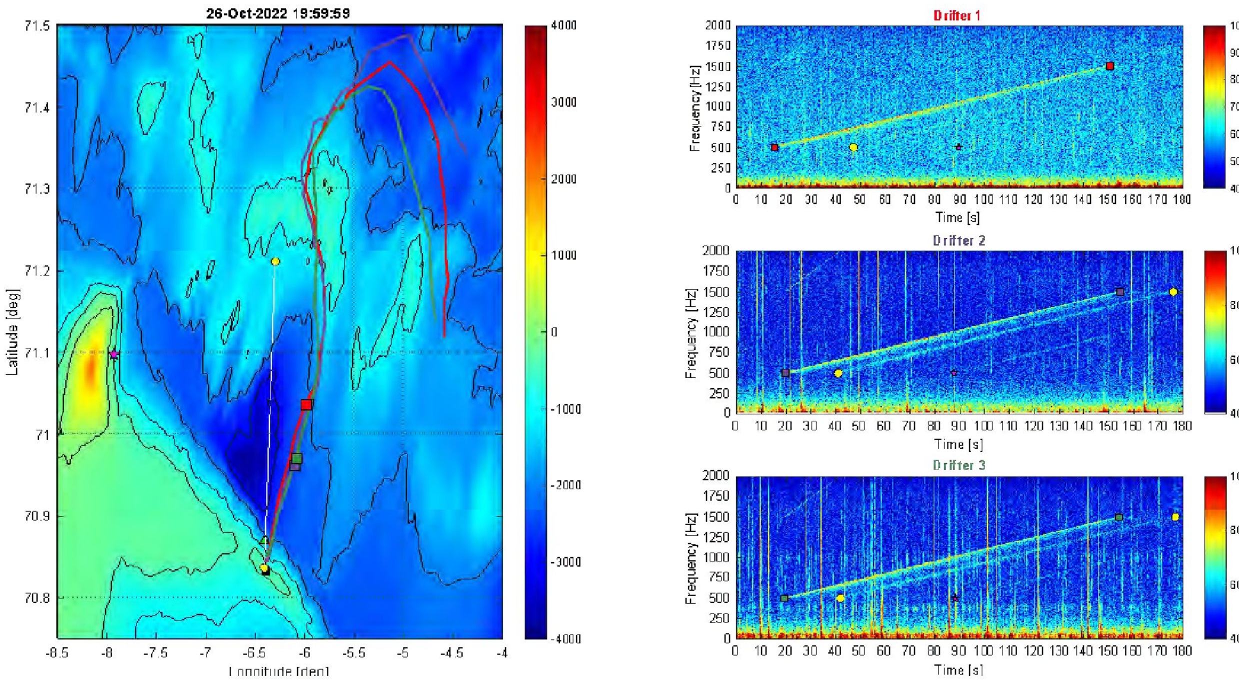


Figure 5. (left) Map showing the locations of the acoustic source mooring (yellow circle) and drifter tracks (red, purple, and green lines). (right) The receptions from the 26 October 2022 20:00 UTC broadcast on each of the three drifters. The location of the drifters at the time of the reception is indicated by the squares in the map.

Gliders

Four of the five NORSE gliders were deployed on 21 October 2022 shortly after the Alliance arrived on site at Jan Mayen. The APL-UW SeaGlider 234 was first deployed, followed by UIB's Slocum glider, then the SeaExplorer X2 SEA064, then APL-UW Slocum glider Freya. The APL-UW Slocum glider Apollo with towed array was deployed four days later on 25 October.

Seaglider SGX 234 - Rainville, Lee, Johnson (APL-UW)

SGX 234, equipped with a temperature and conductivity sail, was deployed by Ferris in Jan Mayen on 21 October at 1010 UTC from the aft A-frame and winch. The glider was piloted by Geoff Schilling and Jason Gobat (APL-UW). On 22 October, the glider was noted to experience data quality issues with the conductivity-temperature sensing. On 24 October, the science processing board became nonfunctional, and its internal humidity began rising on 28 October. The glider was recovered on 30 October via small boat operation. As the glider was scheduled to remain deployed for one year in support of the acoustic moorings, a replacement glider is being planned.

SeaExplorer X2 Glider SEA064 "French Lady" - Gong (VIMS), Ferris (APL-UW)

The VIMS SeaExplorer X2 (SEA064, aka "French Lady") is a 1000-meter glider built by ALSEAMAR and equipped with RBR CTD, Wetlabs EcoPuck, Nortek AD2CP, and Rockland Scientific MR1000G. The glider has a rechargeable battery pack with a nominal endurance of 30 days. The glider was operated by Gong and Ferris and is a part of the NORSE 2022 field campaign focusing on mesoscale and submesoscale physical oceanography. The glider has real-time data processing modules for both turbulent kinetic energy (TKE) dissipation rate and absolute velocity.

SEA064 was air shipped from VIMS and arrived at Tromsø Norway on 10 October 2022. Gong, Ferris, Shapiro conducted functional checkout and compass calibration of the glider pier side on 16 October

2022. Calibrations of the glider's compass and the onboard AD2CP compass were challenging on the dock rounded by steel structures. A sub-optimal but still improved solution was accepted as the final calibration. A simulated mission performed pier side showed the system operating nominally. SEA064 glider was loaded onto NRV Alliance on October 17, 2022. The glider was charged onboard the Alliance on October 19, 2022 and prepared for deployment. The glider was piloted by Gong and Ferris from the Alliance. The MR1000G sensor on SEA064 is equipped with the following shear and temperature probes: Sh1: M2485, S = 0.0872, Sh2: M2486, S = 0.0880, T1: T2162, T2: T2163.

SEA064 conducted two transits across the Jan Mayen channel from SW to NE then back (Fig. 6). There was a bank to the SE corner of Jan Mayen that SEA064 went over for the third time. It then transited along the western flank of the Jan Mayen channel toward the deep-water environmental mooring for recovery by the Alliance on 29 October 2022 at 1124 UTC. The glider conducted 110 yos total at depths ranging between 285m and 1000m. All the sensors were sampling at full cycle except for the EcoPUCK which was turned off after the first couple of days of deployment. The glider was recovered using a small vessel by Gong with assistance from a CMRE technician. At recovery, the glider's battery voltage was 27.5V. Raw data from the glider is downloaded post recovery and the glider was recharged to 29.4V. The MR1000G probes were in good shape upon visual inspection and the glider overall appeared healthy. Preliminary real-time data for the Jan Mayen deployment is shown in Fig. 7.

SEA064 was charged and redeployed in the NW quadrant of the Lofoten Basin Eddy (LBE) on 3 November 2022 at 13:38 UTC approximately 50 km from its center (Fig. 6). The glider will survey the LBE through mid-November and then transit toward the Norwegian Gimsøy line for recovery by *RV Johan Hjort* on its 22 November – 6 December 2022 hydrography cruise. Preliminary real-time data for the Jan Mayen deployment is shown in Fig. 8.

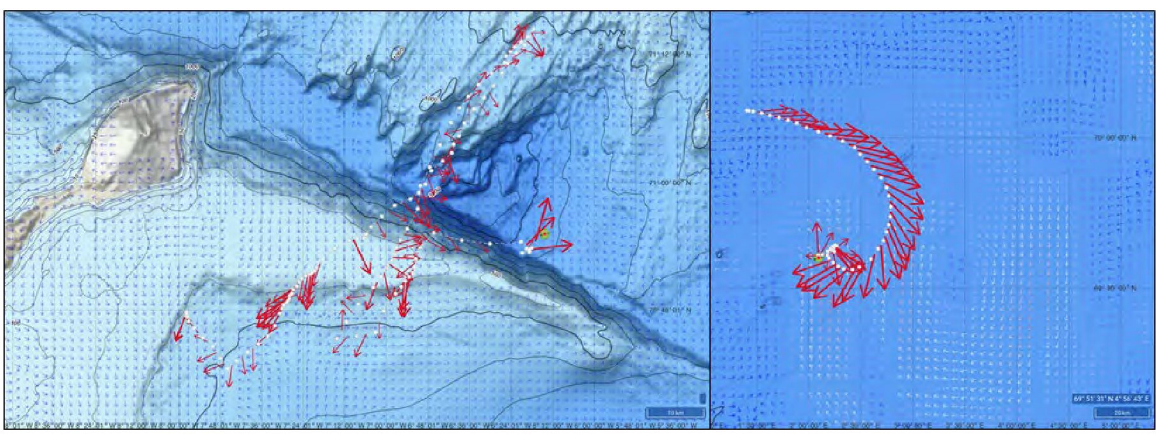


Figure 6: (left) Full Jan Mayen deployment and (right) LBE deployment as of 7 Nov 0630 UTC of SEA064 French Lady. Showing depth-averaged currents (red arrows) compared to surface currents predicted by Operational Mercator during one timestep on 26 October and 07 November, respectively.

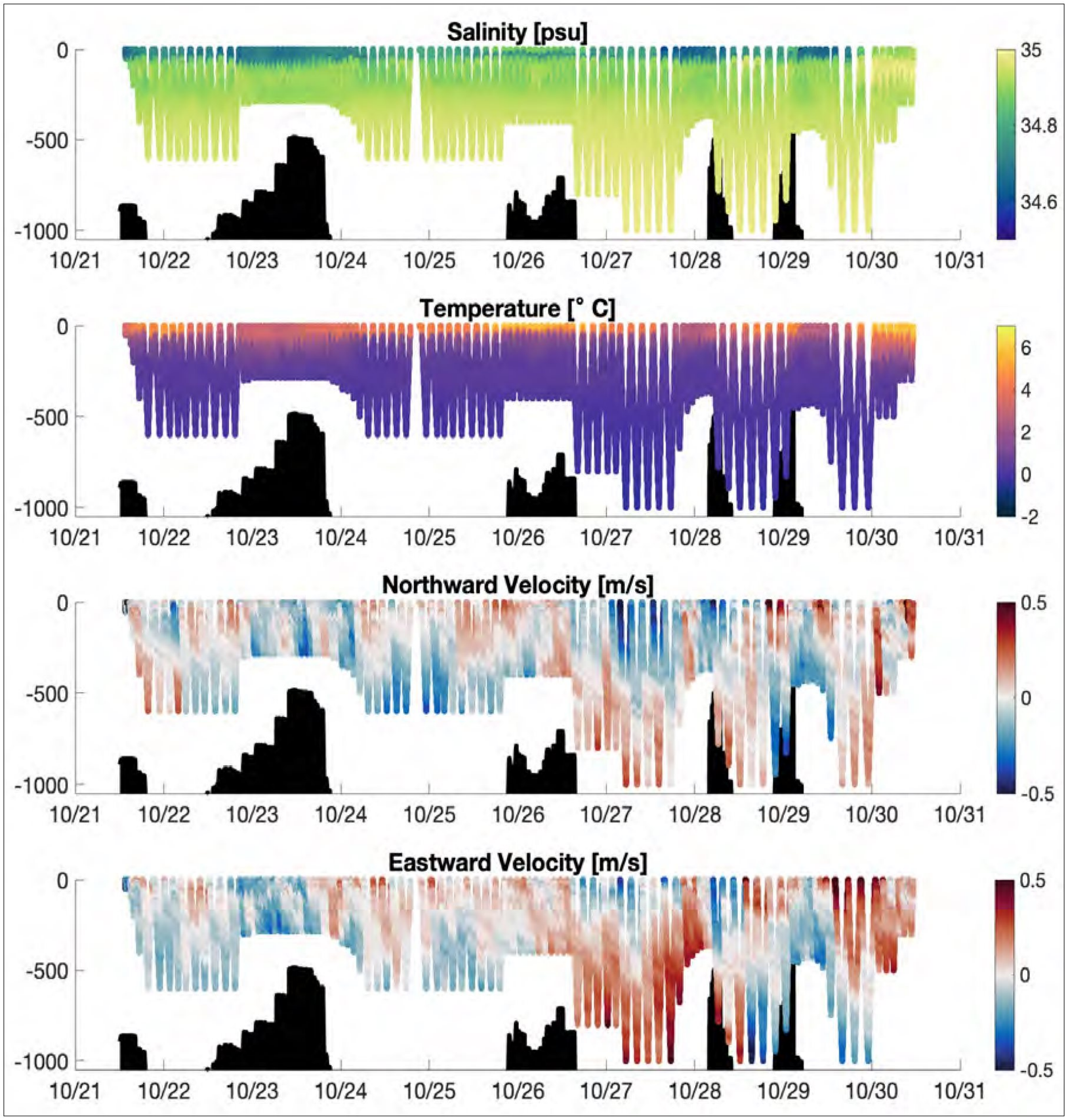


Figure 7: Jan Mayen data sections collected by SEA064 French Lady. Showing telemetered salinity, temperature, northward absolute velocity, and eastward absolute velocity. Bathymetric from Smyth & Sandwell (1997) is overlaid.

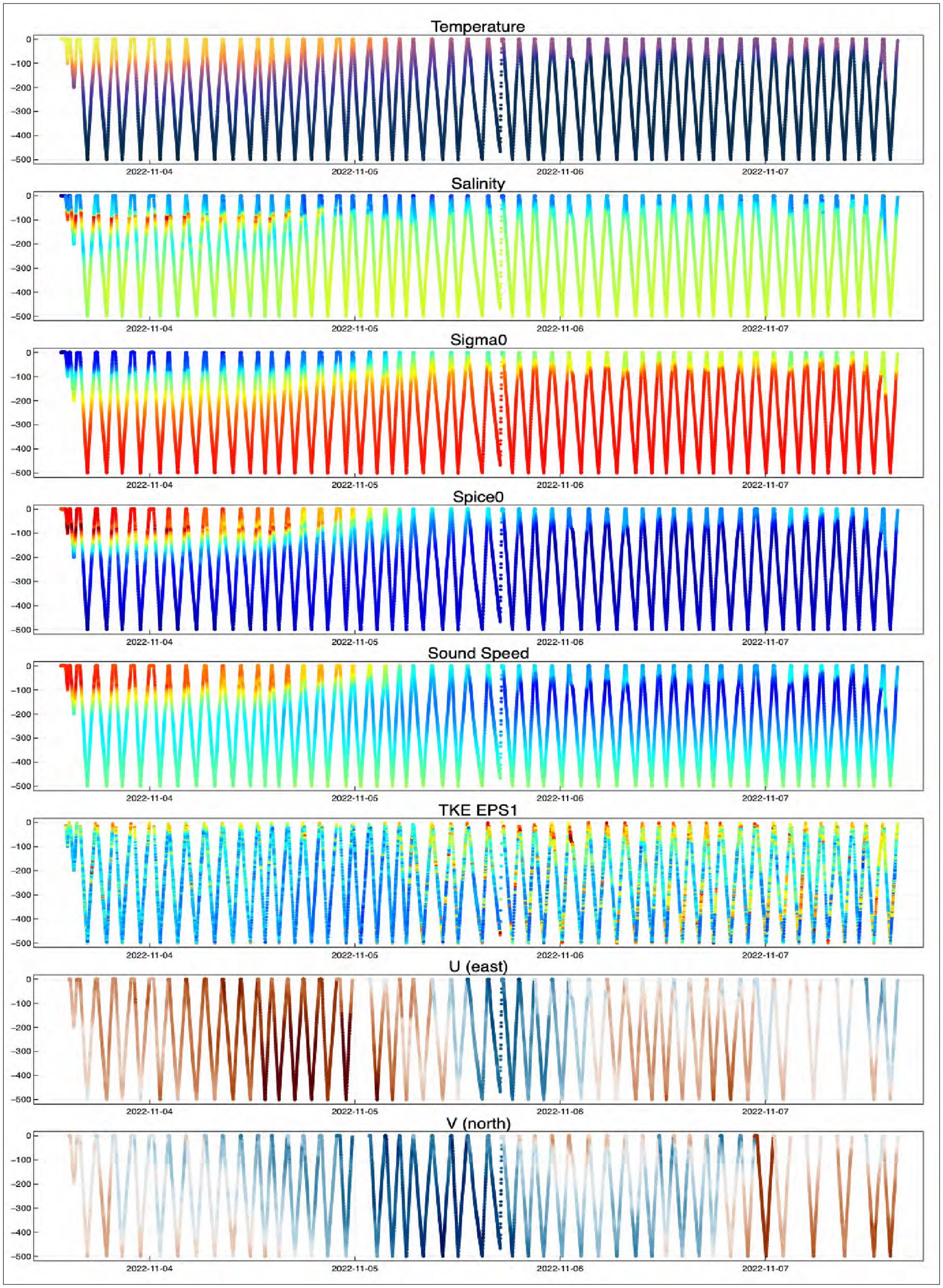


Figure 8: Lofoten Basin Eddy sections collected by SEA064 French Lady as of 07 Nov. Showing telemetered temperature, salinity, potential density, spiciness, sound speed, TKE dissipation, northward absolute velocity, and eastward absolute velocity.

APL-UW Turbulence processing glider Freya - Shapiro, Simmons (APL-UW)

Freya, was deployed in Jan Mayen on 21 October at 1310 UTC from the aft A-frame and winch. The glider is a 1000-meter Slocum G2 equipped with a Rockland MicroRider and in-situ turbulence processing. The MicroRider was equipped with the following shear and temperature probes: S1: M2450 S = 0.0848, S2: M2449 S = 0.0817, T1: T2213, T2: T2214. The glider is piloted by Justin Shapiro and Laur Ferris (APL-UW) and remains deployed (Fig. 9 left & right panels); it is scheduled to cross the Norwegian Atlantic Front Current (NwAFC) for recovery by the Norwegian vessel *RV Johan Hjort* on its 2022 November – December hydrography cruise in the Lofoten region.

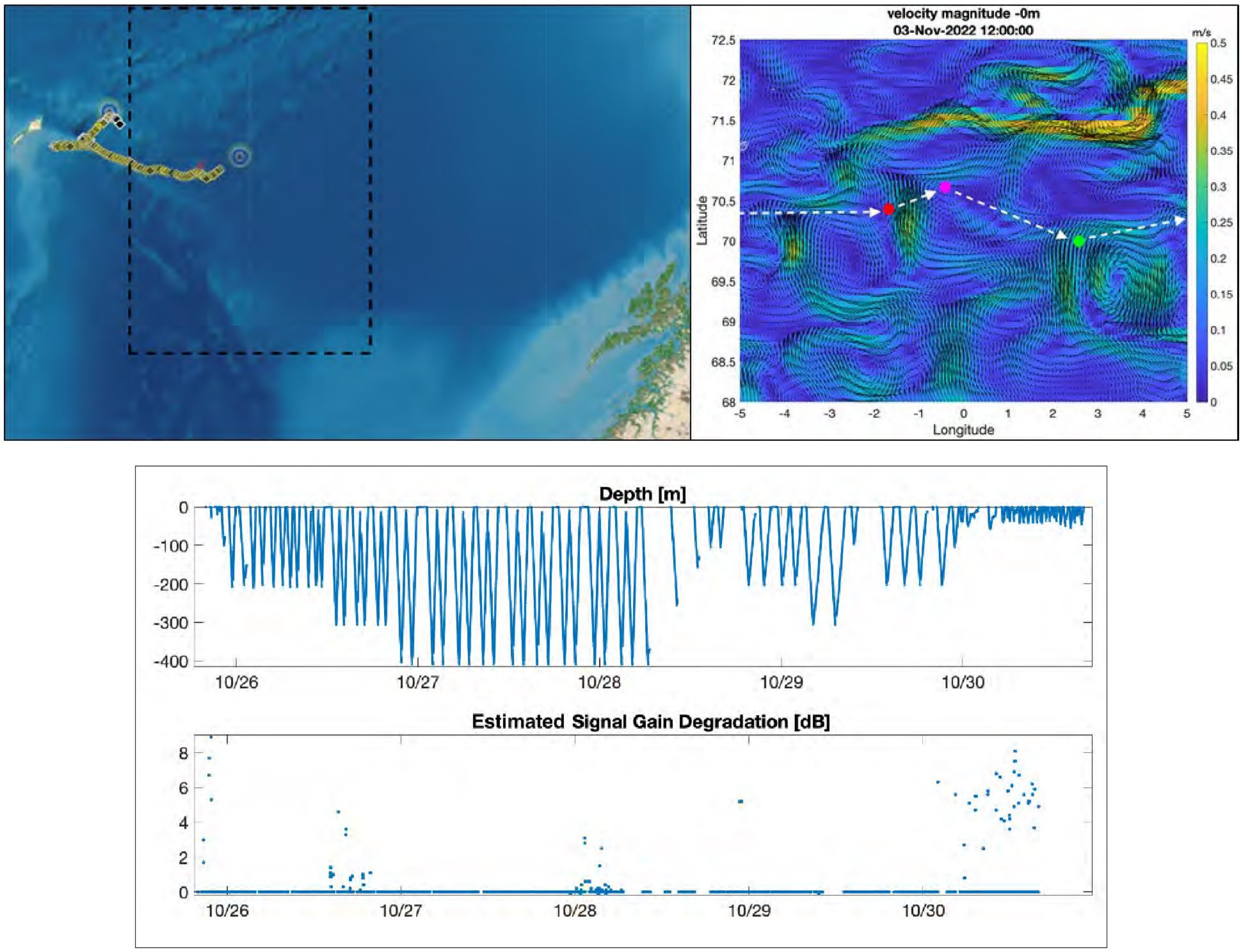


Figure 9: (left) Trajectory of Freya (bottom fork) and Apollo (top fork). (right) Freya planned mission (white arrows), with position on 06 Nov (red dot) and next two waypoints (purple and green dots) over Operational Mercator surface currents on 03 Nov. (bottom) Depth of Apollo dives and estimated signal gain degradation (nonzero during encounters with the DBASIS 1 source).

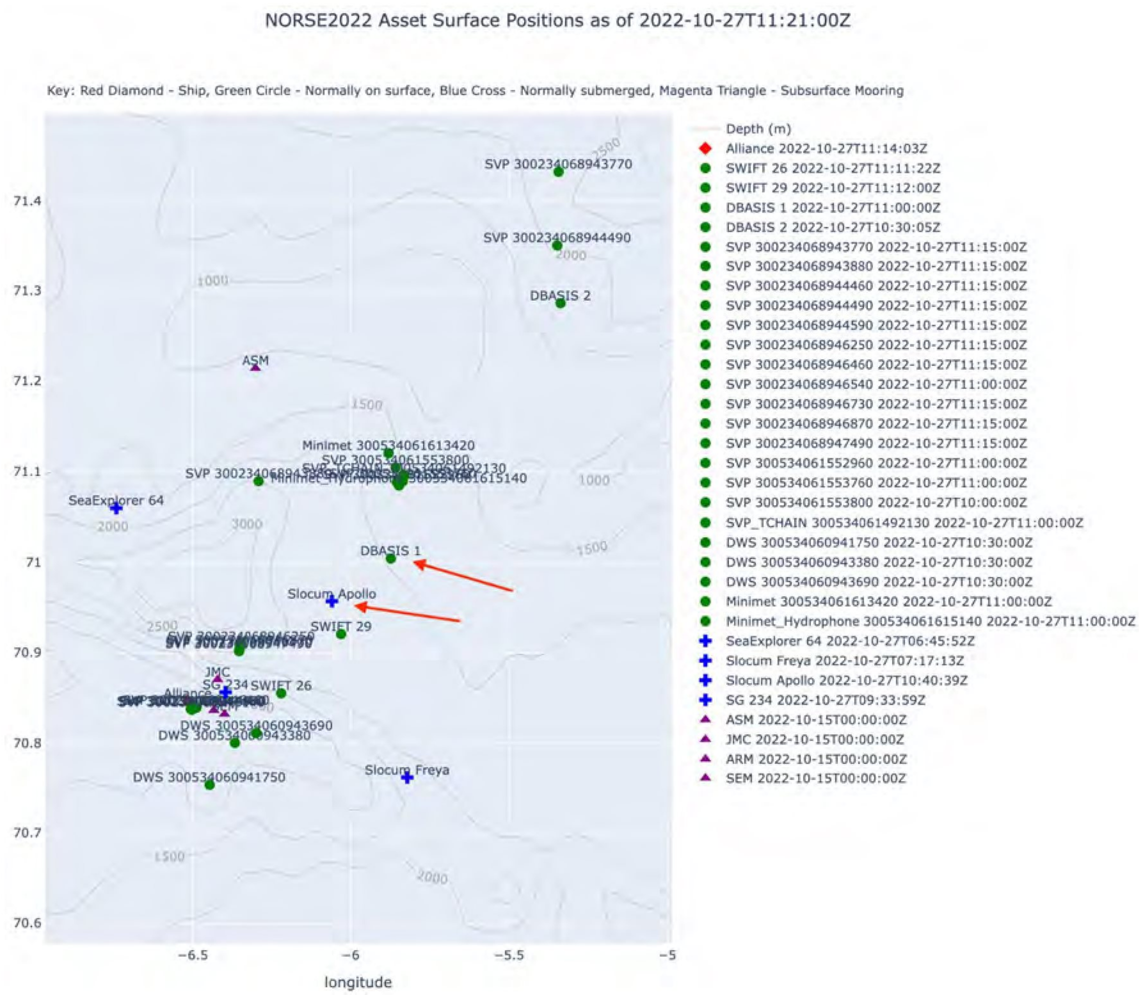


Figure 10:Situational awareness map of asset locations on 27-Oct-2022 at 1100 UTC. Apollo (blue "+" sign) follows the DBASIS 1 mobile acoustic source (green circle), annotated with red arrows (Map prepared by Geoff Schilling, APL-UW)

APL-UW & OASIS Towed array glider Apollo - (Abbot, Shapiro)

Apollo was deployed in Jan Mayen on 25 October at 2120 UTC from the aft A-frame and winch. The glider is a Slocum G2 glider equipped with a stock thruster, 32-hydrophone towed array, and in-situ acoustics processing. The glider was piloted by Justin Shapiro and Laur Ferris (APL-UW) and was commanded to follow the DBASIS NORSE1 (acoustics source) buoy as it advected northeast from Jan Mayen (Fig. 9 left panel). The glider successfully obtained several encounters with the DBASIS NORSE1 source (Fig. 9 bottom panel, Fig. 10). After a failed recovery attempt on 29 October (attributable to the ship's nonfunctional bow thruster), Apollo was recovered via small boat operation on 30 October during a calm weather window.

Slocum G3 glider 883 (''Urd'') – Brakstad, Våge, Fer, Elliott (UiB)

Urd was deployed near Jan Mayen on 21 October 2022 at 10:30 UTC from the aft A-frame and winch. The glider is rated to 1000-m depth and equipped with a pumped SBE CTD sensor. During the cruise Urd occupied two transects across the Jan Mayen Channel and ridge southeast of Jan Mayen (Fig. 11, left). The glider will remain deployed for one year, measuring the development of the surface mixed layer in the Iceland Sea during cold-air outbreaks. Urd will transit into the Iceland Sea on the southern side of Jan Mayen, hopefully capturing the dense water flowing along the Jan Mayen slope.

Slocum G3 glider 884 ("Verd") - Brakstad, Fer, Våge, Elliott (UiB)
Verd was recovered from small boat on 7 November 2022 at 19:00 UTC. The glider has been deployed since 7 August 2022, occupying the Gimsøy monitoring section across the Norwegian Atlantic slope Current (Fig. 11, right). Verd has rechargeable batteries and a pumped SBE CTD sensor. During the NORSE cruise Verd occupied a transect from the Norwegian slope to the center of the Lofoten Basin. The glider reached the outer edge of the Lofoten Basin Eddy before recovery.

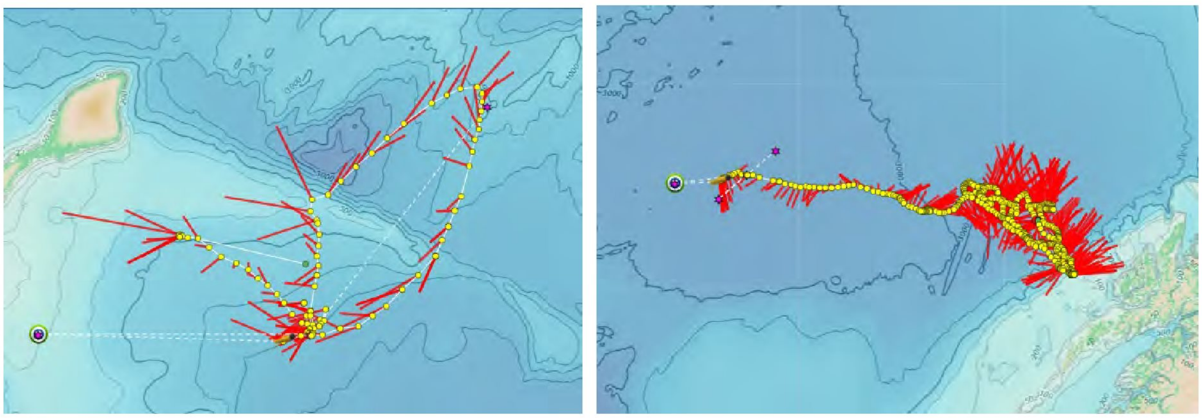


Figure 11:(left) Urd's track from deployment until 7. Nov with depth average current indicated in red. (right) Position and depth average current (red) for Verd's entire mission.

The Drogued Air-Sea Interaction System (DBASIS)
Under previous ONR funding, a SIO/WHOI collaboration led to the successful integration of an air/sea flux buoy with a Wirewalker ocean-wave-powered vertical profiling vehicle. The Drogued Air-Sea Interaction System (DBASIS) buoys were deployed in the Bay of Bengal in 2018 (1) and 2019 (3), where they simultaneously measured the bulk air-sea fluxes and the response of the ocean boundary layer in real-time and in high resolution. The drogued drifting design allowed for a process-study deployment at much lower cost than that of several deep-water moorings. Cost savings were also achieved in design changes to the surface buoy, and by the reduction in subsurface instrumentation facilitated by the vertical profiling vehicle. The deployments indicated our capacity to field such systems, and demonstrated their ability to resolve the processes at work in the open ocean during strong monsoon forcing in the context of very shallow ocean mixed layers. Measurements gathered by a 1-MHz profiling ADCP mounted on the Wirewalker showed the ocean's complicated shear response to strong atmospheric forcing, with frequency resolution of many cycles per hour and vertical resolution of <2 m through the upper ocean and ocean mixed layer. Optical data indicated strong changes in attenuation over the course of the deployment due to both biological processes and the entrainment and export of sediment-laden coastal water by the mesoscale eddy field. These data are crucial to test assumptions in the 1-D and submesoscale parameterizations used in operational forecast models. Additionally, the property evolution that arises as a consequence of the sheared ocean response to wind forcing directly impacts the acoustical characteristics of the upper ocean.

NORSE 2022 Deployment
The DBASIS buoys were deployed in the vicinity of Jan Mayen Island due to challenges in reaching the Lofoten Eddy region at the beginning of the cruise. NORSE2 was deployed first, at ~0900 on 23 October 2022 and recovered on 2 November 2022 at ~1200 UTC (see Fig. 12). NORSE 1, carrying the WHOI

sound source, was deployed on ~1900 25 October 2022 and recovered on 2 November 2022 at roughly 1600 UTC. NORSE1 was deployed nearby the PECOS acoustic array, which was configured for three hours of continuous recording, the OASIS Apollo Slocum glider with a towed acoustic array, and the CMRE acoustic drifters. The autonomous acoustic assets stayed relatively close to the NORSE1 source, and as such sound have several days of recording of the source at changing ranges. The as-deployed NORSE1 and NORSE2 DBASIS systems included in Appendix B.

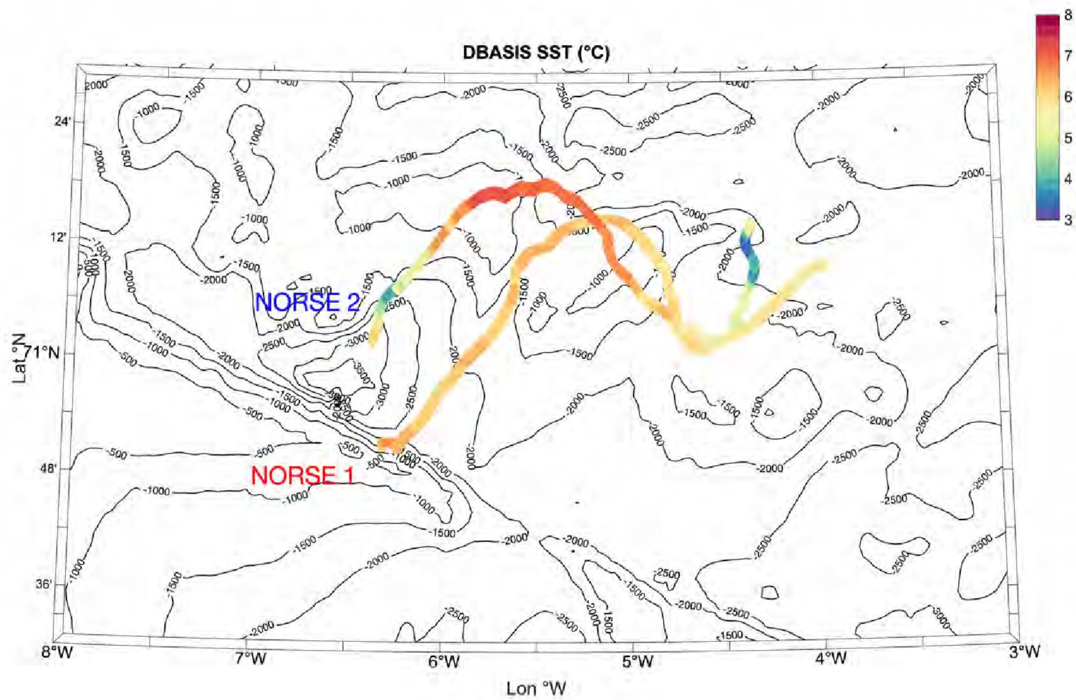


Figure 12. Map showing sea surface temperature measured by NORSE1 (25 October 2022 through 2 November 2022) and NORSE2 (23 October 2022 through 2 November 2022).

NORSE1 DBASIS included several innovations relative to previous systems. The buoy was fitted with a high-resolution IMU system, 3-D wind sensor, and downward-looking 500 kHz Nortek ADCP, in addition to other atmospheric sensors that are detailed in the diagrams in Appendix B. Example data from the MET system onboard the buoys for NORSE1 is plotted in Fig. 13. Below the surface, a “dual Wirewalker” combination was implemented for the first time. These Wirewalkers carried essentially the same instrumentation: CTD, bio-optics (chla, CDOM, 532 nm), 4-band radiometer (removed from the lower Wirewalker) and Nortek Signature 1000 downlooking ADCP. These Wirewalkers profiled above and below a sound-source installed at ~100 m depth, provided by Tim Duda of WHOI.

A WHOI-built sound source based on WHOI Micromodem electronics, from the WHOI ACOMM group, was placed at 100-m depth on DBASIS NORSE1. This source transmitted sound to the various autonomous platforms with hydrophones deployed in NORSE to study sound propagation paths. A few of these devices have been built, and for now they are called the WHOI ACOMM sources. The system operated autonomously while deployed because it was built as a transmit-only device. This system drove a Geospectrum Technologies Inc. M21-family transducer with 750 Hz resonance frequency. Output circuitry on the system gave the system a maximum SPL of 178 dB re 1 micropascal at 1 m, with -3db points at approximately 610 and 890 Hz. The system was programmed to transmit at 19 dB below max level to remain below the allowed level of 160 dB. A CSAC clock kept the system time.

Coded pulses, to be compressed by correlation analysis, were 610-890 Hz upsweep linear frequency modulation (LFM) chirps of 4.1 s duration. In 20-min time windows, starting at 5 and 35 minutes past the hour, pulses were emitted at times 0 and 5 sec in 20-sec subwindows. This gave pulses spaced at 5 s, 15 s, 5 sec, 15 sec, and so on. There were 240 pulses emitted per hour (2*20*3*2), for a 27.3% duty cycle, 41% in the 20-minute windows. The CSAC clock kept time to high accuracy, exceeding the needs of this project.

The upper Wirewalker was installed on a 100-m wire and was connected to the surface buoy via inductive communication. This Wirewalker collected 1,045 100-m profiles over the nearly eight-day deployment. The lower Wirewalker was installed on a 200-m wire spanning ~105-305 m depths. That unit collected 756 200 m profiles. Both Wirewalkers profiled continuously for the entirety of the deployment and yielded a complete data record from all sensors. These data are shown in Fig. 14, 15, and 16 of the physical properties and sound speed, bio-optical properties, and velocity/velocity shear, respectively. Several interesting processes are apparent, including near-inertial and submesoscale frontal dynamics, which appear to be impacting the bio-optical and acoustic properties of the ocean.

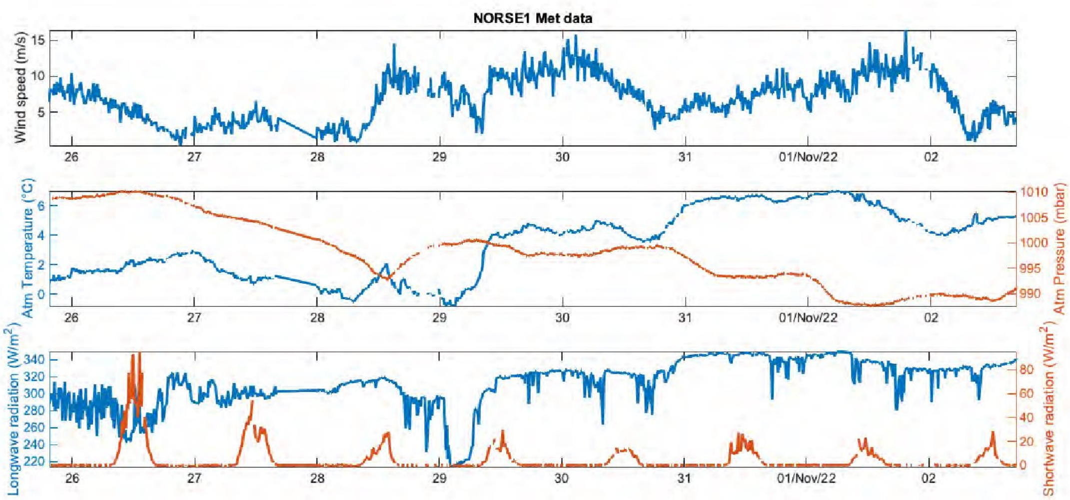


Figure 13. Meteorological data recorded by NORSE1.

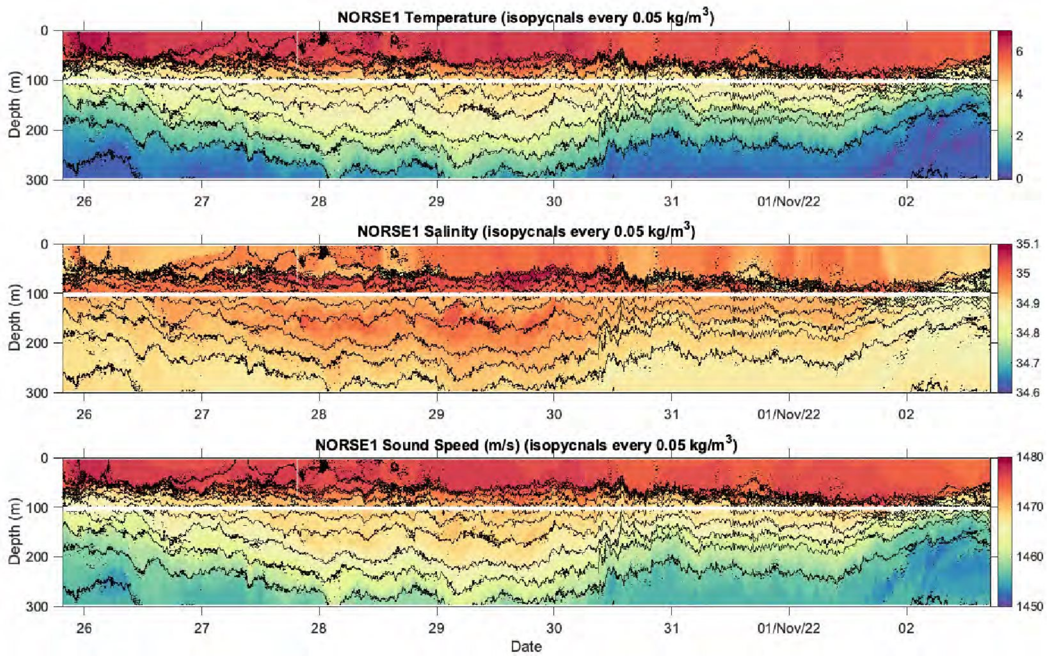


Figure 14. Temperature, salinity, and sound speed measured by NORSE1 with isopycnals every 0.05 kg/m³.

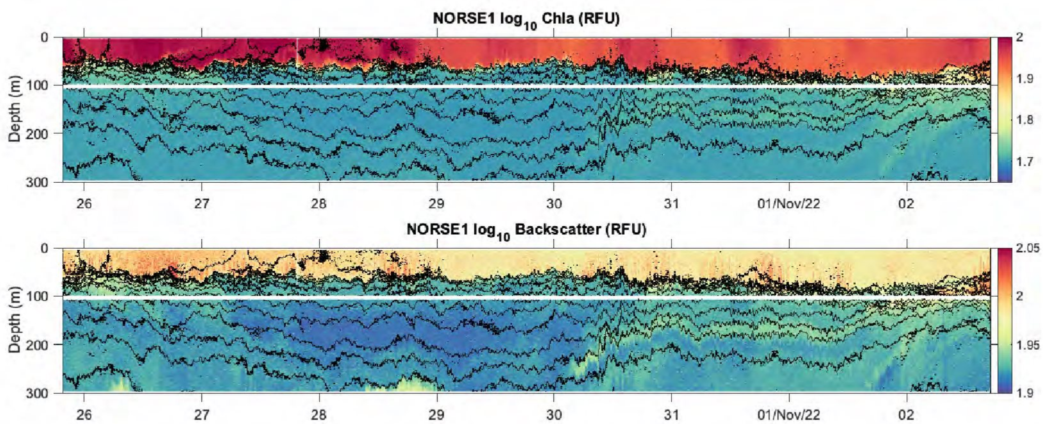


Figure 15. Optical parameters measured by NORSE1 with isopycnals every 0.05 kg/m³.

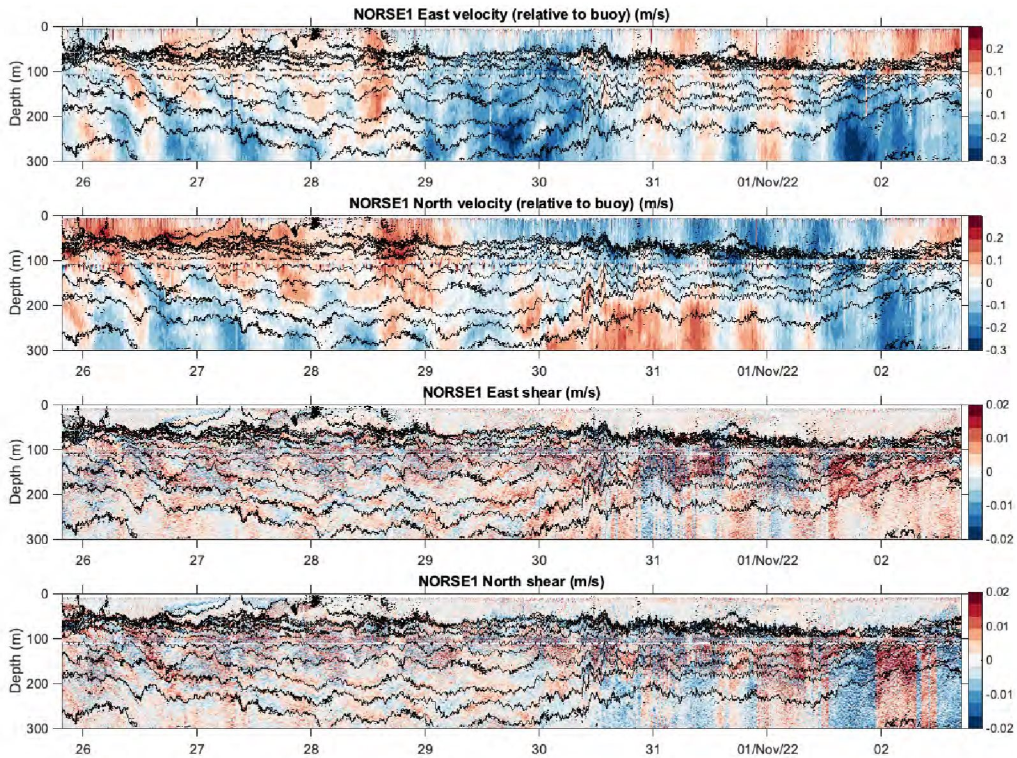


Figure 16. Velocity and shear measured by NORSE1 with isopycnals every 0.05 kg/m³.

NORSE2 was deployed in a similar configuration to the systems used on the MISO-BOB DRI, with the exception of using a 500-m Wirewalker profiling wire, and IMUs installed on the surface MET package. An example of MET data from the NORSE2 buoy is shown in Fig. 17. Below the surface, the Wirewalker profiled continuously, collecting 324 round-trip profiles to 500 m over the ~10 day deployment. The sensor payload of the Wirewalker was similar to those carried by NORSE1, with the inclusion of a dissolved oxygen sensor, which proved useful for water mass tracking.

While the velocity data were recorded continuously and returned a full record, the data collection on the CTD logger suffered an outage, described in the challenges section below, that led to the loss of ~26h of data in the CTD, bio-optical, irradiance, and dissolved oxygen channels. These data are shown in Figs. 18, 19, and 20.

Challenges

Our initial goal of deploying the DBASIS systems in the Lofoten eddy was scrapped early in the cruise due to the NRV Alliance Captain and crew choosing to operate closer to Jan Mayen island, which offered shelter in the case of the occurrence of extreme weather (which never, in fact, eventuated). While a thorough QA/QC of the MET and Wirewalker data is still ongoing, it does appear that we have a reasonably complete data record. The one exception is a 26-hour gap in the NORSE2 Wirewalker record. We are still diagnosing this issue, but at present it appears that the surface buoy controller for the Wirewalker telemetry, supplied by RBR, Inc. decided for unknown reasons to turn off the Wirewalker CTD logging system during the deployment, and, just as mysteriously, turn it on again 26 hours later. Very fortunately, the full bandwidth data of the first seven days was recorded in the surface buoy, because upon restarting the subsurface logger, the data in the subsurface logger was deleted. This near-catastrophic loss of data is an unacceptable failure-mode for the telemetry system and this has been clearly communicated to RBR. It also motivates us to implement our own buoy controllers to avoid this "black box" issue in the future. Finally, ship handling was a serious issue, and while the Captain and crew did their best, without DP or function bow-thrusters, the buoy approach was extremely rapid (>3 knots) and both buoys suffered damage to the atmospheric sensors during recovery. This had little impact on the mission, outside of precluding the possibility of a short three-day deployment at Lofoten Basin Eddy. Apart from these relatively minor challenges, the DBASIS deployments were overall quite successful.

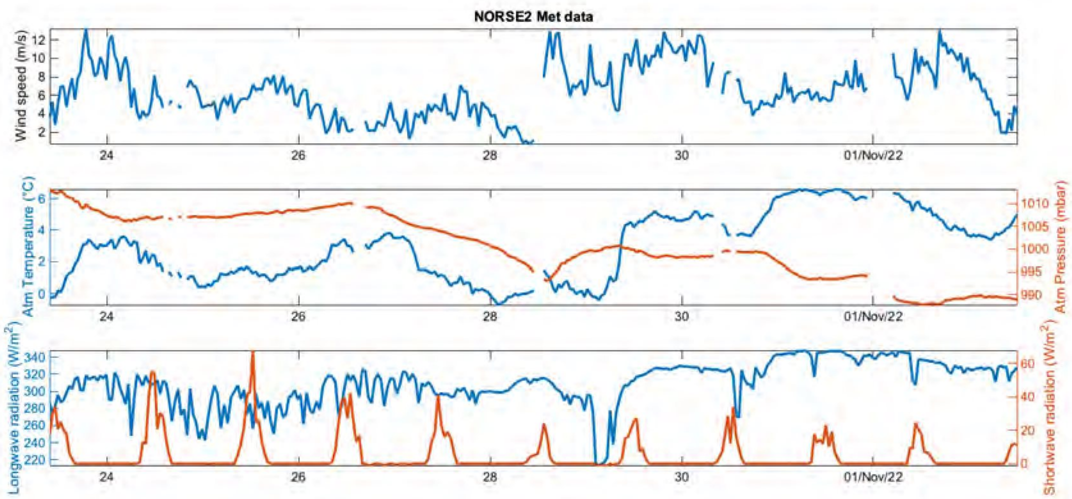


Figure 17. Meteorological data recorded by NORSE2.

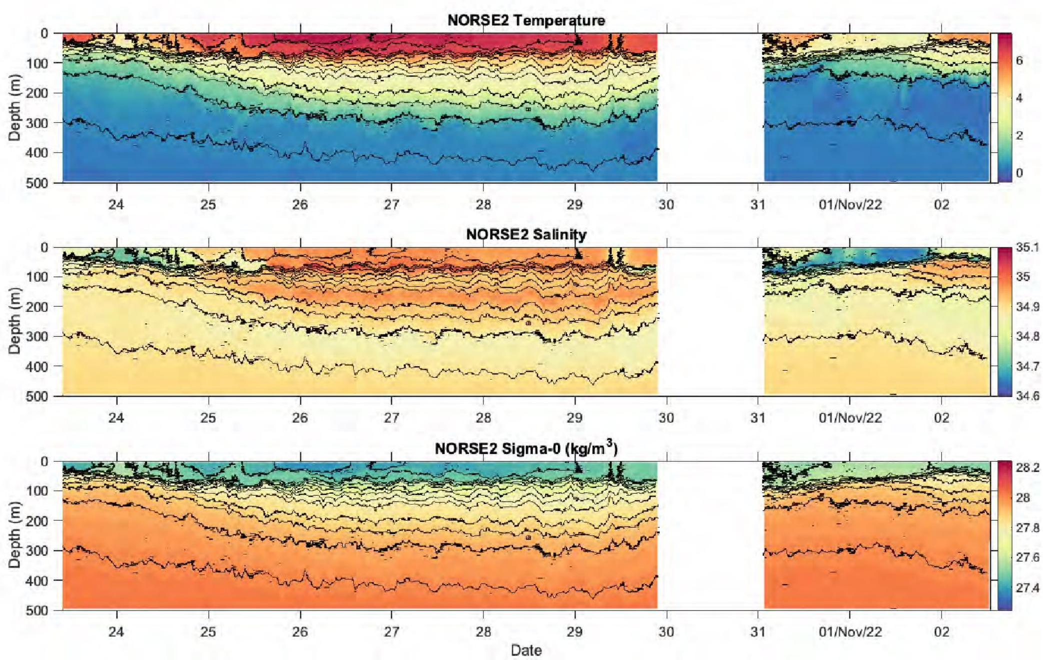


Figure 18. Temperature, salinity, and sound speed measured by NORSE2 with isopycnals every 0.05 kg/m³.

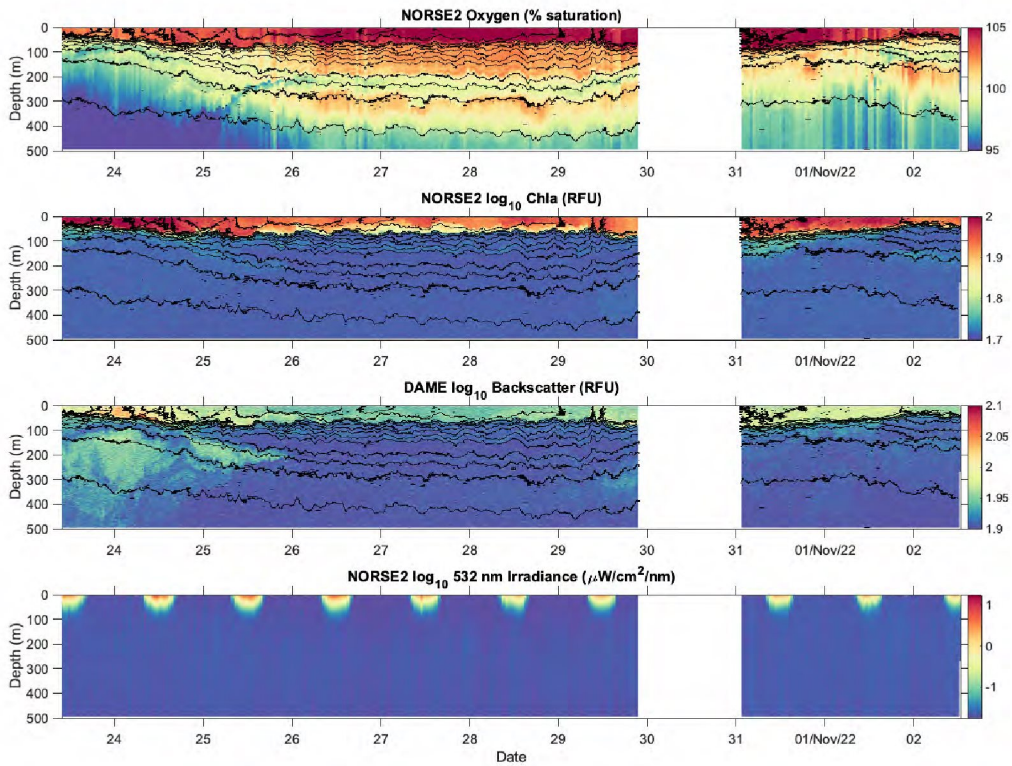


Figure 19. Optical parameters measured by NORSE1 with isopycnals every 0.05 kg/m³.

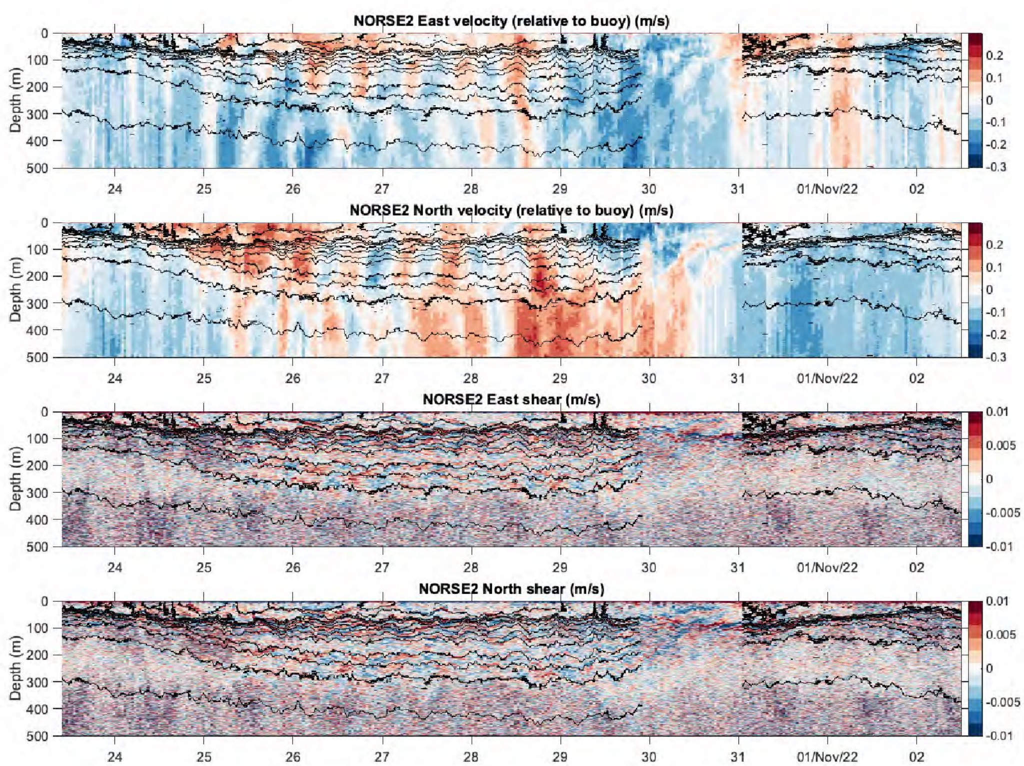


Figure 20. Velocity and shear measured by NORSE1 with isopycnals every 0.05 kg/m³.

Surface Drifters (SVP/MiniMet/DWSB)

Deployments at Jan Mayen

Several SVP drifters and their variants, the MiniMet and DWSB, all drogued at 15-m depth and equipped with sea surface temperature (SST) sensors were deployed in at the Jan Mayen site. Figure 21 shows the trajectories of the drifters between 25 October and 2 November in the Jan Mayen area. Currents transported the instruments to the north, and then east and finally to the south. An additional 13 SVP drifters were deployed at different times to act as scouts to assess the overall drift pattern for the recoverable assets. See Appendix C for the complete list of deployment times and locations.

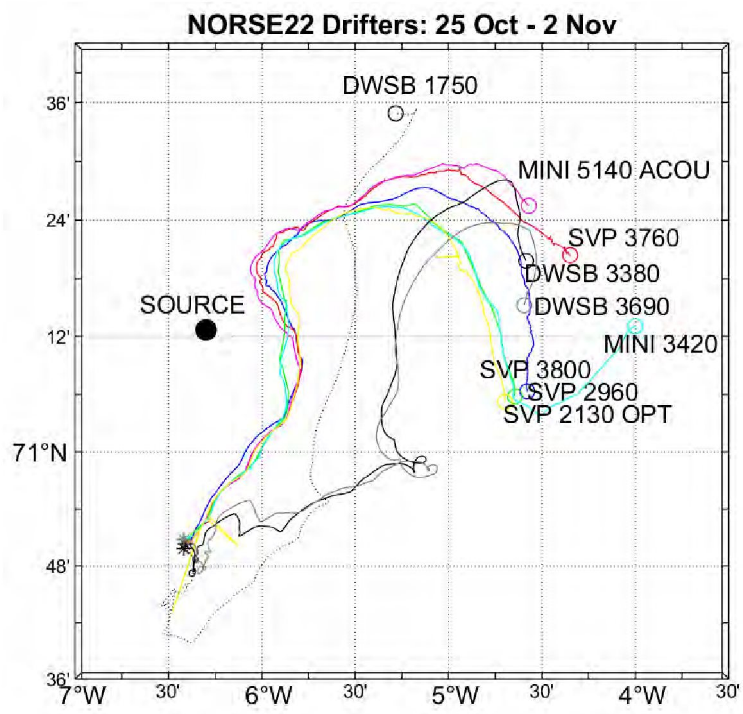


Figure 21. Tracks of the drifters: deployment and last positions are shown with star and open circle symbols, respectively. The position of the moored source is shown with a big black dot.

In addition to the standard SVP, Minimet, and DWSB drifters, five specialized drifters were also deployed. Three of these specialized drifters were SVP drifters that had been modified by CMRE to include an array of three hydrophones (see Fig. 22). These systems recorded signals from the moored acoustic source (see Fig. 5) and the drifting acoustic source on DBASIS NORSE1 as well as ambient sound. There were also two specialized drifters from SIO, including an Minimet drifter equipped with hydrophones and an SVP drifter equipped with optical sensors.

Deployments at the Lofoten Basin Eddy

Data from the nine-piece SVP (Surface Velocity Program, www.ldl.ucsd.edu) drifter array that was deployed in the Lofoten Basin Eddy during the NORSE pilot in 2021 suggest that there are energetic but small scale (1 – 10 km) irregular patterns of vorticity at the surface. These patterns seem to impact the amount of energy put into inertial motions and thus also what is transferred from the surface to below. Hence, for the 2022 cruise, the plan was to do clustered drifter deployments in the eddy to do more advanced computations of vorticity and dispersion.

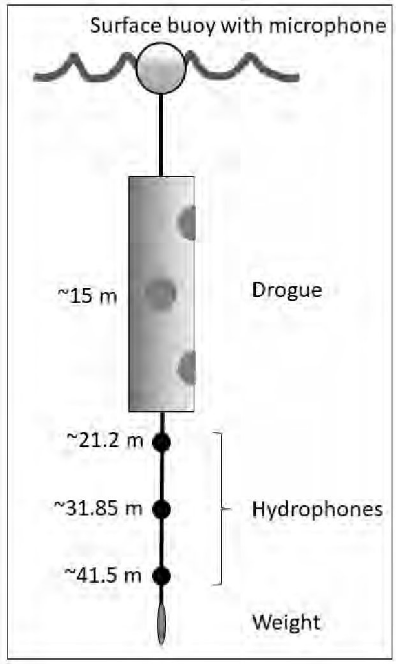


Figure 22. Schematic representation of the CMRE acoustic drifter.

The original sampling plan for the Lofoten Basin Eddy included deploying the DBASIS buoys and a few gliders in the eddy, together with the drifters, on the way to the mooring deployments at Jan Mayen. This would allow us to reseed the drifter array on the way back when picking up the buoys and gliders. The combination of drifters and buoys/gliders would provide high resolution velocity data from the surface as well as temperature, salinity, and velocities in the vertical dimension at least for the duration of the buoy and glider deployments. However, with the change of plans due to weather, the Alliance went straight from Tromsø to Jan Mayen where all the buoys and gliders were deployed.

The adjusted LBE sampling plan became to deploy clusters of drifters in the eddy together with four SWIFTS (recovered) and four ALAMO floats (expendable). In addition, one SeaExplorer (VIMS) was deployed to the west of the LBE during the transit, and set to sample the eddy in a few passes before leaving to meet up with glider FREYA and be recovered by a Norwegian vessel at the end of November.

In the afternoon of 4 November 2022, a total of 35 drifters were deployed in the LBE in six clusters of five drifters each. The clusters mainly consisted of SVPs (27) together with a few minimets (three). In addition, there were five DWSB (directional wave spectra buoys) deployed in between the clusters.

- SVP: drouged at 15m, measures temperature
- Minimet: drogued at 15m, measures temperature, wind speed, wind direction
- DWSB: un-drouged, measures wave period/height/direction

All drifters are set to sample every 5 minutes for the first month of their deployment and then to sample every 15 minutes.

The six clusters were deployed in the following way: two clusters at 10 km radius from the eddy center but on opposite sides, three clusters at 5 km radius evenly spaced around the center, and one cluster at the center. The clusters at 5 km and the center were each deployed together with a SWIFT and an ALAMO float, and all DWSB were deployed inside the 5 km radius. At the time of writing, the first few days of data from the drifters suggest that there is a lot of dynamic activity in the center of the eddy, and the drifters are tracing out inertial loops. All individual clusters remain coherent, and 30 out of the 35 drifters are still within an 18 km radius of the eddy center. Figure 23 shows the gliders trajectories up to through 7 November 2022. In addition to ALAMO, SWIFT, and SeaExplorer data, the drifter data will be complemented with the ADCP/fast-CTD transects that were made in a bowtie pattern in the center of the eddy as well as into its cyclonic neighbor to the southwest.

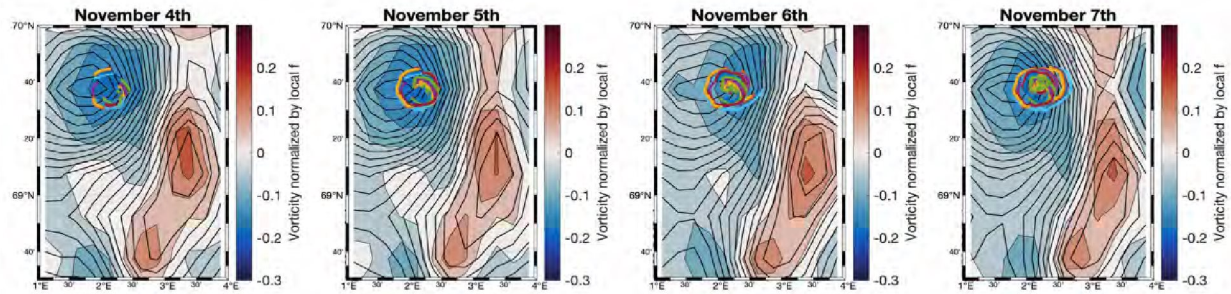


Figure 23. Geostrophic vorticity with sea surface height contours and drifter tracks in the Lofoten Basin Eddy.

SWIFTS

APL-UW brought 4 SWIFTv4 buoys to deploy as drifting assets during the NORSE 2022 cruise aboard Alliance. Each buoy is equipped with an Airmar WX200 Meteorological sensor, SBG Ellipse AHRS-IMU, Nortek Signature ADCP, Aanderaa 4319 Conductivity/Temperature sensor and serial jpeg camera. The drifter also has a 3 m drogue and auxiliary tracking via Iridium beacon and AIS transponder. These assets were intended to deploy and capture rapid surface evolution as well as provide accessory measurements with other assets. The buoys are deployed by hand with a slip line over the side of the ship and recovered by hand with a grappling hook or boat hook.

Initially the plan was to deploy the 4 SWIFTs in the Lofoten Basin Eddy with the other SIO drifting assets for ~14 days and recover after returning from the Jan Mayen area. With the evolving conditions and itinerary, we opted for a shorter deployment near Jan Mayen to capture surface conditions and evolution at the moored array. Later, there was an opportunity to conduct a four-day deployment within the LBE. The trajectories of the drifters near Jan Mayen, and later within the LBE are shown in Figure 24.

Jan Mayen Deployments

Two SWIFTs were deployed in the Jan Mayen Channel on 23 October once DBASIS NORSE2 was deployed. These drifted north along the line of the acoustic array and were recovered on the north side of the channel after 24 hours. These were the first assets recovered on the cruise with some concern about maneuverability without a bow thruster. The recovery went well with the ship able to approach and maintain heading.

On 25 October, two SWIFTs were deployed again in conjunction with the CMRE drifter array. SWIFT 27 and 28 were deployed on October 28 and 29 respectively, in proximity to DBASIS NORES1. SWIFT 28 was recovered the next day due to hardware issues and missed telemetry. The remaining buoys remained deployed through 2 November, capturing surface conditions during multiple weather events over the week.

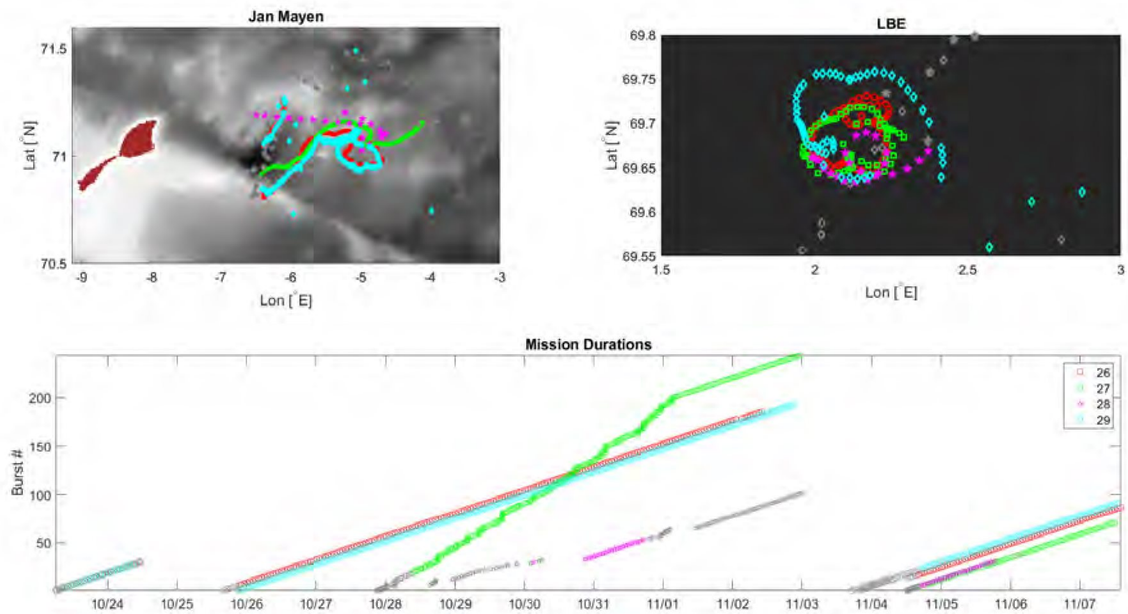


Figure 24. (top left) SWIFT drifter trajectories near Jan Mayen, (top right) as well as drifter trajectories while deployed inside the Lofoten Basin Eddy. (bottom) Mission duration for each SWIFT deployment. Colors indicate specific drifters in all plots.

SWIFT #	Deploy	2022			Recovery	2022		
	Year Day	Time UTC	Latitude	Longitude	Year Day	Time UTC	Latitude	Longitude
SWIFT 26	296	9:19	71.043117	-6.395883	297	1148	71.267432	-6.133627
SWIFT 29	296	9:30	71.05455	-6.39405	297	1017	71.272208	-6.09658
SWIFT 26	298	22:00	70.847533	-6.415583	306	2045	71.0539	-5.184
SWIFT 29	298	22:00	70.847533	-6.415583	306	2115	71.05375	-5.187733
SWIFT 27	301	15:07	70.899293	-6.448428	306	2330	71.1524	-4.1107
SWIFT 28	302	5:25	70.980645	-6.071187	303	1830	71.0748	-4.957117

Table 2. Summary of SWIFT deployments in the Jan Mayen area.

Lofoten Basin Eddy Deployments

With the successful mooring deployments finished and repairs made to the main generator we were now able to allot more time for measurements at the Lofoten Basin Eddy. We decided to position the four SWIFTs in the array of 35 drifters and four ALAMOs set up as six clusters. SWIFT 26, 28, and 29 were deployed with the 3 clusters at the 5 km radius from the LBE center. One cluster was positioned in the predicted center with SWIFT 27. The SWIFTs would spend four days in the eddy while the ship continued to run FCTD transects and the Sea Explorer did a fly through. All four buoys were recovered on 7 November without incident.

SWIFT#	Deploy	2022			Recovery	2022		
	Year Day	Time UTC	Latitude	Longitude	Year Day	Time UTC	Latitude	Longitude
SWIFT 26	308	15:28	69.73381	2.2328383	311	15:50	69.713829	2.2222661
SWIFT 27	308	15:48	69.683044	2.234536	311	14:05	69.679482	2.3021159
SWIFT 28	308	16:12	69.68	2.368597	311	15:20	69.724892	2.30479
SWIFT 29	308	16:50	69.641113	2.1802742	311	14:40	69.633003	2.408128

Table 3. Summary of SWIFT deployments in the Lofoten Basin.

Preliminary Telemetry Data

SWIFT drifters transmitted burst-averaged data via satellite throughout the cruise, providing a preview of the observations and potential analysis avenues. Detailed results will be made available upon further post-processing of the onboard raw data and subsequent analysis. Telemetry data show near-surface (i.e. at the height of the MET sensor, 0.4 m) wind speeds ranged from 2-12 ms (Figure 25). During the deployment near Jan Mayen Ridge, surface wind speeds exceeded 10 m/s beginning Oct 28 and persisted until Nov 03, except for a lull on the 31st. This decrease in wind speed coincided with a local maximum in air temperature with the potential for net positive (albeit likely weak) heat flux. At all other times, the air-sea temperature difference suggests net negative heat flux (from ocean to atmosphere). Winds rotated counterclockwise during this high-wind period. Significant wave heights reached 3 m coincident with the strongest winds, but decreased to 1 m during the warm atmospheric lull. Wave directions were predominantly aligned with the wind. These combined observations suggest ocean-atmospheric coupling. This inference is supported by concurrent wave spectra, which exhibit the distinct f^(-4) slope predicted by theories of wind-wave equilibrium (Figure 26, top). Surprisingly, wave energy spectra are not particularly well sorted by wind speed despite the large range of wind speeds observed during the passage of this storm. Investigating this uniformity in wave energy will be a priority for our post-processing analysis. Later within the LBE (deployment after the vertical dashed line in Figure 25), SWIFTs completed approximately one full rotation around the eddy within the 5 day deployment period. Surface wind speeds were weaker (~ 5 m/s), but significant wave heights appear to have been similarly up to 3 m and wave spectra suggest wind-wave equilibrium within the LBE as well (Figure 26, bottom). The wave spectra here display some weak wind speed dependence, although the range of wind speeds was smaller. Additional planned analysis includes computation of atmospheric fluxes with bulk formula and comparison of those results with flux estimates from other instruments/platforms, which may differ due to the close proximity of the SWIFT observations to the surface.

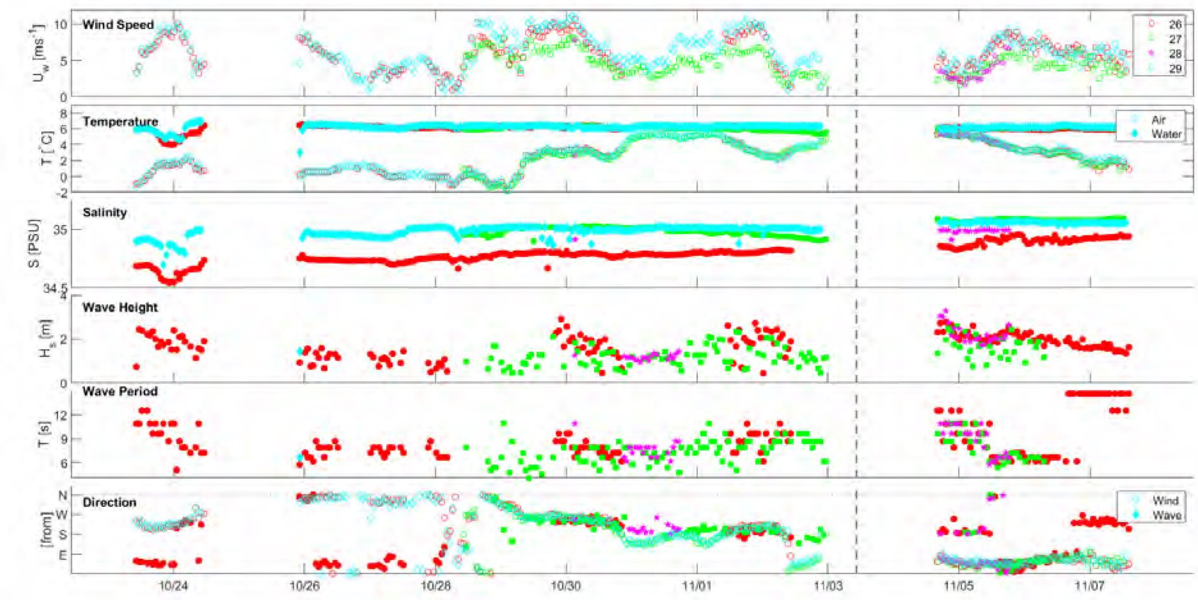


Figure 25. SWIFT observations of (from top to bottom) wind speed, air and sea temperature, salinity, wave height, wave period and wind and wave directions. Observations to the left of the dashed vertical line were obtained during sampling near Jan Mayen, while observations to the right were obtained in the Lofoten Basin Eddy.

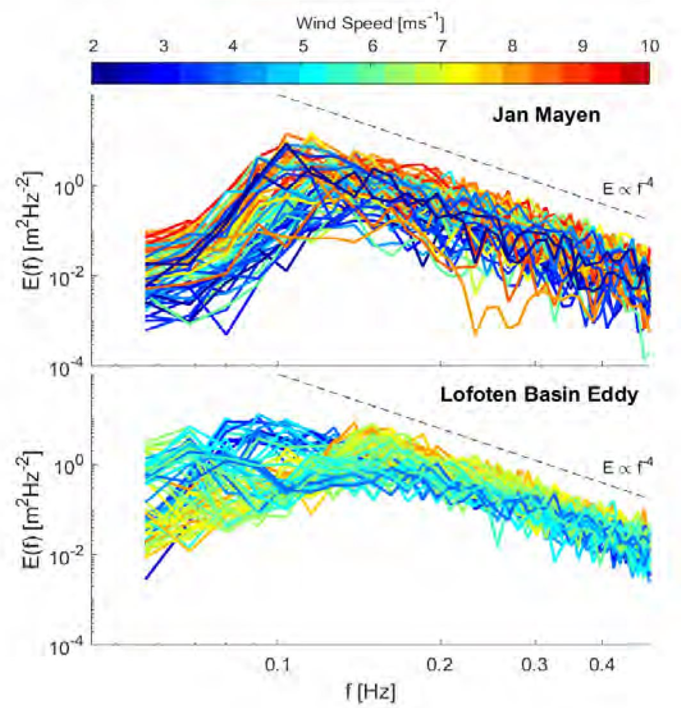


Figure 26. Example wave energy spectra from SWIFT 26, during sampling (top) near Jan Mayen and (bottom) within the Lofoten Basin Eddy. Spectra are colored by wind speed.

SPOTTERS

Three SOFAR Spotters were deployed during the transit from Tromsø to Jan Mayen at longitudes of 3° E, 4° E, and 5° E. These are solar powered drifters that went dormant soon after deployment. They are designed to reactivate once there is enough sun to power them in the spring.

CMRE Acoustic Float

The CMRE acoustic float is the commercial PROVOR float manufactured by NKE in Hennebont, France (https://nke-instrumentation.com/). A compact Volumetric Acoustic Sensor (cVAS) developed at CMRE was fitted to the PROVOR in a stand-alone configuration. The cVAS is a compact volumetric array of six hydrophones that allows directional sound field estimations. The PROVOR float equipped with cVAS was deployed three times during the cruise, twice in the Jan Mayen area and once in the Lofoten Basin Eddy. The float performed only one profile during each deployment. Due to buoyancy problems, it overshot the prescribed parking depth and reached the security maximum depth, followed by emergency ascent to the surface. See appendix C for detailed information on deployment times and locations.

Alamo Profiling Floats

Four Alamo profiling floats were deployed in the Lofoten Basin Eddy with the drifter clusters. See appendix C for detailed information on deployment times and locations.

Shipboard Sampling

Fast CTD, T-PADS

The SIO/MOD shipboard profiling systems use a deck mounted direct-drive winch built on a frameless motor platform. For NORSE 22, two winch systems were mounted on the port and starboard quarters, with the control station just forward and inboard of each. The boom, 32' long, rests directly forward when the system is not in use. In each case, the instrument was over boarded by swinging the boom outboard manually with taglines.

From the starboard winch we deployed the FCTD fish (Fig. 27). It rapidly profiles at vertical speeds of 5 m/s, both up and down, allowing for very high-resolution measurements while the ship is underway. For this cruise we conducted FCTD profiling while the ship was steaming at 3-4 knots. We complete 2254 vertical profiles with the FCTD, covering a wide range geography and targeted processes. Profiling depths ranged from 50 to 1100 m, depending on the processes of interest in each region. Several examples are described in the results section below, with all data shown in Appendix D.

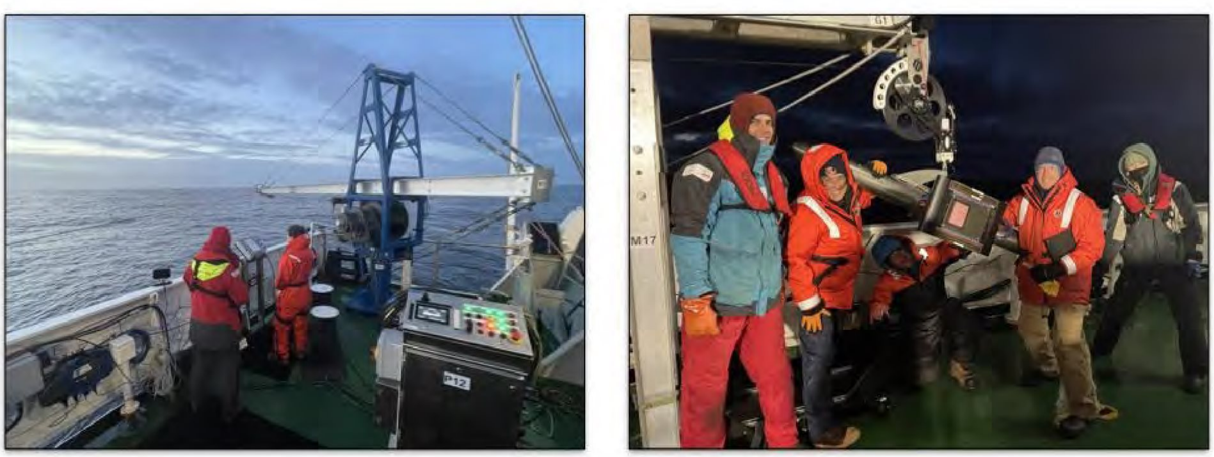


Figure *27. NORSE deployments of the Fast CTD system (left) and inaugural TPADS (right).*

From the portside winch we deployed the new Towed Phased Array Doppler System (TPADS, Fig. 27); this was the first deployment of this system. TPADS is a 200 kHz phased array doppler sonar system mounted in a towed body that is designed to be deployed behind a ship. The system records on 32 parallel staves which are formed into 31 beams spanning a ~100° fan using time delay beamforming. This allows radial velocities to be measured over a 3D swath of the ocean as the 2D fan is towed behind the ship, scanning the beam pattern through the along-ship dimension. The main goal of TPADS deployment on the NORSE 22 cruise was to qualify the performance of the new instrument and test processing and deployment strategies. TPADS was first deployed at 17:14UTC on 28 October for a two-hour shakedown test with the array oriented at a 0° angle and the beampattern in a cross-ship orientation. Shakedown testing proceeded quickly, and the fish was deployed to 100 m. Over the course of the deployment several horizontal shear layers were imaged evolving in time and space. Following a short recovery to change the array orientation, the TPADS was redeployed with the array oriented directly downwards for a one-hour test. This test revealed significant back lobe contamination of the velocity signal resulting from the downwards looking array orientation. Attempts followed to block the back lobe emitted from the transmitters with sound absorbing material. Following a successful checkout, the TPADS was deployed overnight on 29 – 30 October for approximately 12 hours. This deployment featured a downward facing array and a shallow tow depth of ~20 m. This allowed FCTD operations to continue as normal. The shallow tow depth and rough conditions resulted in significant platform motion which may degrade the instrument performance when used in this mode. On 30 October, the TPADS was deployed again for a ~2 hour period with a side looking array and a beampattern oriented along-ship. During this period a mixed layer front was surveyed, and an equi-tension winch mode was trialed to stabilize platform motion. The final TPADS deployment was on 1 November for approximately 5 hours with the array in a 10° downwards looking array oriented cross-ship. During this survey, the TPADS was deployed at 70 – 90 m and the FCTD was concurrently deployed to 60 m. The target of this survey was again a strong mixed layer front. Over the course of the cruise the TPADS was deployed for approximately 22 hours over four deployments, often concurrently with the FCTD. TPADS performed extremely well, with range mostly controlled by sidelobe contamination from the surface. Good velocity signal was seen out to 100 m range and shear layers of 5 – 10 m vertical scale were well resolved. Co-deployments between the FCTD and TPADS, especially the final frontal transect, have the potential to produce unique 3D views of velocity and density in frontal zones that are beyond the scope of traditional instrumentation.

Bow Chain

A bow chain system was deployed from the ship to measure fine scale structure at fronts. One of the forward ship mounted winches was be used to lower the 200 lb weight through the forward A-frame. The sensors themselves are attached to a clip-in-clip-out separate line, which was tied off near the bow and becomes load bearing underway. The deployed chain was 30 meters long, with 56 sensors (52 RBR solos and 4 RBR duets). The system was deployed twice, Nov 1, 18:00UTC – Nov 1, 23:50UTC and Nov 6st, 17:00UTC – Nov 7 09:00UTC. An example of bow-chain data is shown in Figure 26 and Figure 27.

Other ship-board instruments

We also appreciated the ship-provided hull mounted ADCP and throughflow data. The 300 kHz and 75 kHz ADCP data were provided by the ship in VMDAS files, without ship motion correction. Science party processing removed ship motion to make processed files for each. Ship-board throughflow and meteorological data were very useful for adaptive sampling.

Ship-board sampling results

Driven by the motivation described above, through a coordinated set of observations we sought to observe and understand the complex set of processes that set upper ocean structure and sound speed in this region, particularly during and in the after math of strong surface forcing events. Given the time of year, there was a surprising dearth of very strong surface forcing events, but we did see some appreciable wind forcing in the form of several storms as well as shorter wind bursts.

The first two weeks were spent measuring near Jan Mayen. In this region the defining feature is the presence of the Atlantic Front separating warm and saltier Atlantic Water and colder fresher Arctic water. A snapshot from the operational Norwegian model (Fig. 28) shows the modeled surface temperature ad upper ocean currents on 31 October, overlaid with sea-surface temperature as measured by the ship throughflow system for two days before and after. During the period of ship sampling in this region, warm meanders came and went, showcasing a variety of interleaving processes at their edges.

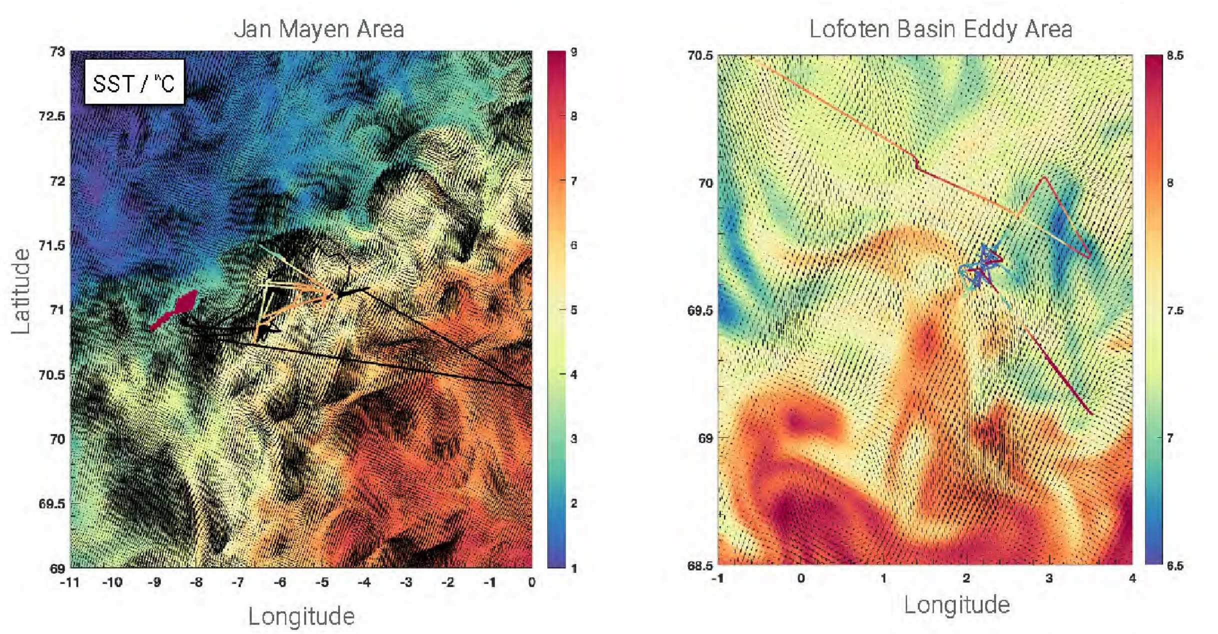


Figure 28: Norwegian high-resolution Barents model snapshots from Oct 31 (left) and Nov 6 (right). In each panel, the color is modeled sea surface temperature (SST), and the arrows are near-surface model velocity. Superimposed are our ship sampling tracks for a few days surrounding each period, with color indicating measured throughflow temperature.

The boundary between these two water masses is rife with meanders and filaments at a wide variety of scales, many of which we sampled through. Several common features of this transition can be seen in Fig. 29. The Atlantic water meander visible in Fig. 29 has a broader vertical structure, characteristic of mesoscale features in this region. On the other side, the coldest Arctic water is trapped in a shallow surface boundary layer (SBL), typically of order 50 m deep. Interestingly, even after wind events, the SBL shoaled rapidly back to this depth, particularly in the presence of strong lateral density gradients. The bow chain data (Fig. 29, upper-most panel), reveals a very sharp front, with intriguing regularly spaced features, that may represent submesoscale instabilities or Langmuir cells. Strong shear layers at the base of the SBL were imaged by the TPADS (Fig. 30). Ongoing analysis of TPADS will explore lateral variability of upper ocean shear and coherent velocity structures on 10-100 m scales, especially near sharp fronts. The temperature-salinity scatter plot showcases the variability of salinity and temperature in the surface across the channel (Fig. 31). In the north side of the JM channel, we measured the freshest water in the region.

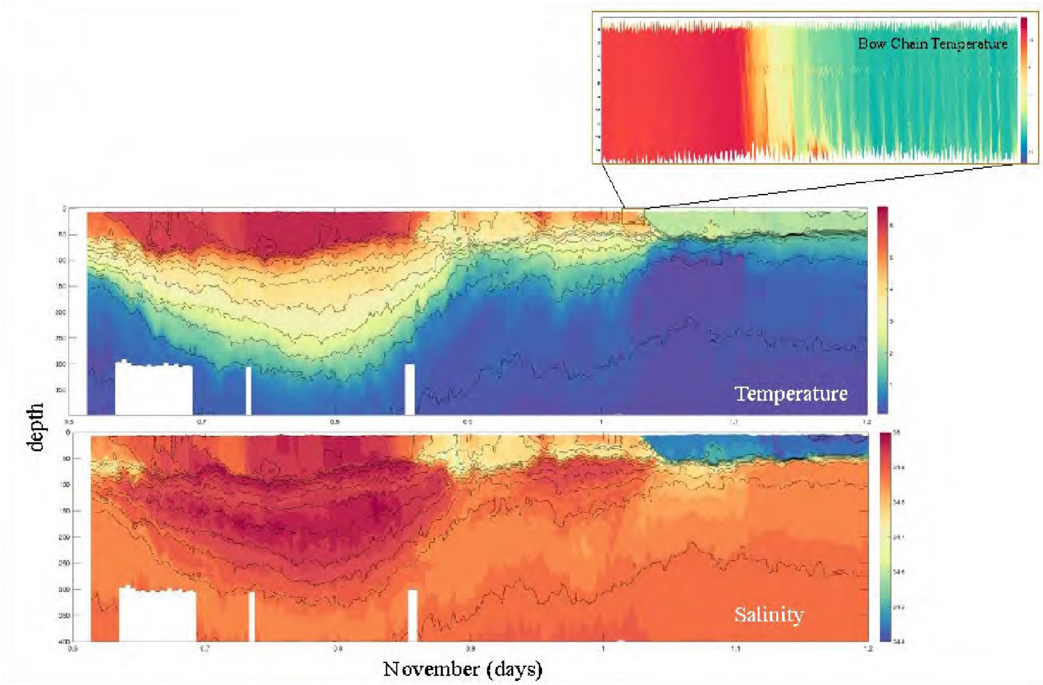


Figure 29: FCTD temperature and salinity sections on the north side of the Jan Mayen channel (line 6 in Figure xx3). In the top figure, a 15-minute temperature section from the 4-hour bow chain deployment is shown, highlighting the high frequency variability at the sharp front.

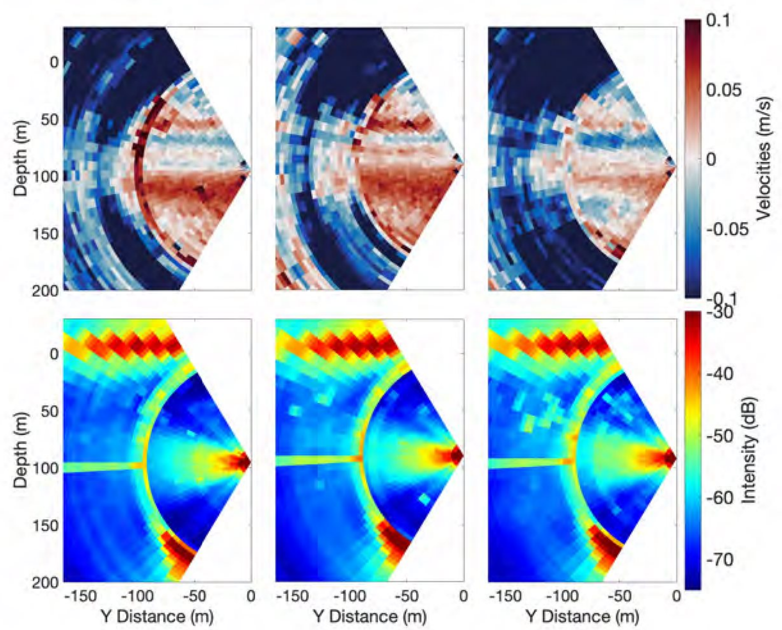


Fig. 30. A series of images captures the evolution of a shear layer over 4 minutes (350m along track distance) imaged by the side looking towed phased array doppler sonar (TPADS). Top panels show radial velocity at successive timesteps highlighting a series of horizontal shear layers. Velocities are good up to the sidelobe reflection at ~100m range, after which they are contaminated by the surface velocities. The bottom panels show corresponding backscatter intensity. In these plots the main lobe of the beam pattern is visible, followed by a curved region of high intensity corresponding to the sidelobe from the surface hit. At 0 m depth a region of high intensity indicates the surface refection from the steered beams.

Deeper in the water column, around the channel ridges, a subsurface salinity was observed which is characteristic of water influenced by the North Atlantic front current, the only source of spicy water in the region. Below 400 meters, water T-S values are less variable (Fig. 32), and we capture deep water, as denser than 28 kg/m^3, in the channel and over the ridge. For deeper water masses, internal tide sloshing and mixing may play an important role in water mass modification. Figure 31 shows 24 hours of sampling across Jan Mayen ridge. Variability at both diurnal and semi-diurnal periods is evident, with beam-like structures in velocity radiating up and off the ridge. Many features of the flow observed here are reminiscent of other internal tide studies, for example near Kaena Ridge in Hawaii or Luzon Strait. One important difference here is that the diurnal internal tide may not propagate as a free internal wave, and even the semi-diurnal internal tide is very close to inertial / turning latitude. It may be that the internal tide here exists more as a topographically trapped wave than a freely propagating one. The thick black line in Figure 28 represents the 28.03 kg/m^3 isopycnal, typically taken to be the boundary of Greenland Basin deep water. Previous work has argued that this water mass may be transiting through Jan Mayen channel into the Icelandic basin, though the exact route is unclear. Here we show the first evidence that it is sloshing all the way up and over the ridge. The water masses sloshing back and forth over the ridge also are home to a sound speed minimum/duct, which is significantly distorted by the internal tide activity here. This variability may play into the signals measured by the acoustic moorings in this region.

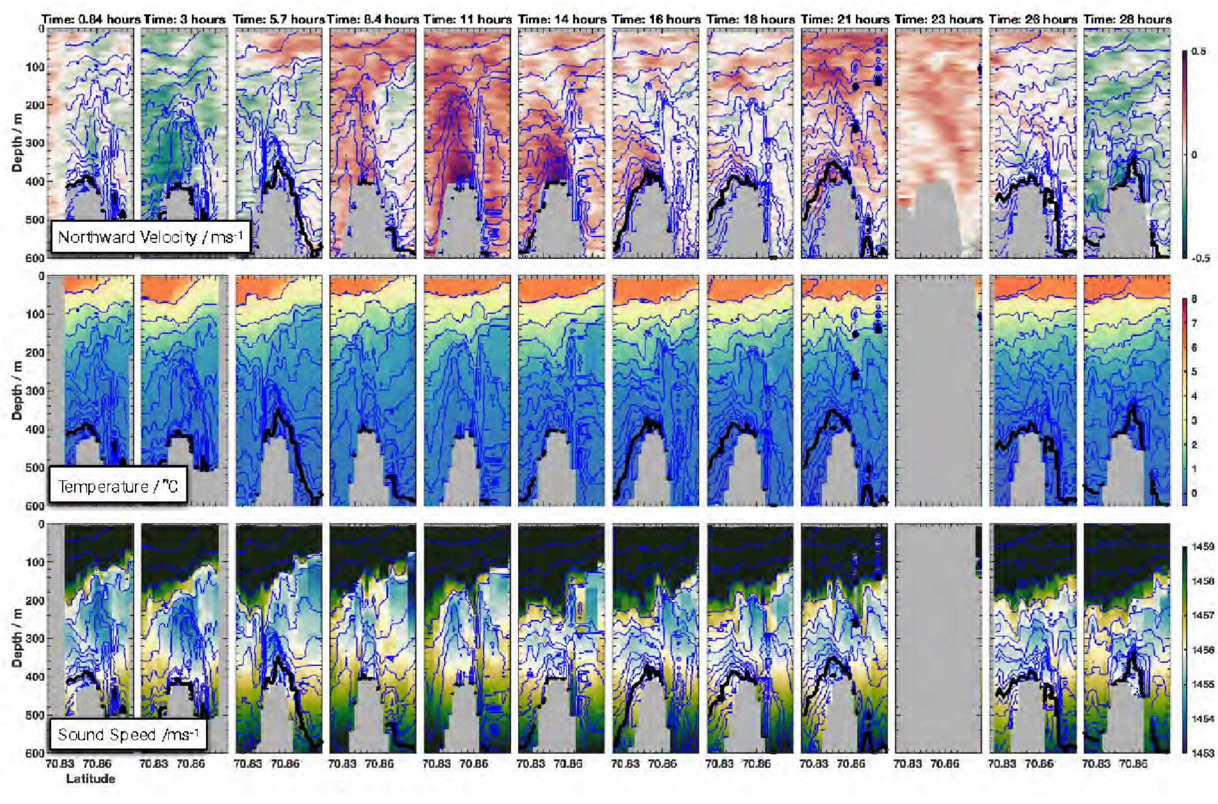


Figure 31: 24 hours of FCTD sampling across Jan Mayen ridge. From top to bottom row are norward velocity from the hull-mounted 75 kHz ADCP, FCTD temperature, and sound speed as calculated from FCTD data. In each panel isopycnals are contoured, with the 28.03 isopycnal in thicker black.

The last portion of sampling took place in the Lofoten Basin Eddy (LBE). We completed two different types of surveys, a higher resolution observation of the center of the eddy, and a long section across the eddy front with its neighboring cyclonic eddy to its south. Within the LBE, the flow generally displays the expected anti-cyclonic tendency (Fig. 33). However, superimposed on that broad flow are much smaller-scale variations in velocity, on the order of a few kilometers wide. Some of these appear to line up with sharp depressions of the surface boundary layer base. It is yet unclear whether these are high frequency internal waves or submesoscale instabilities or some combination thereof.

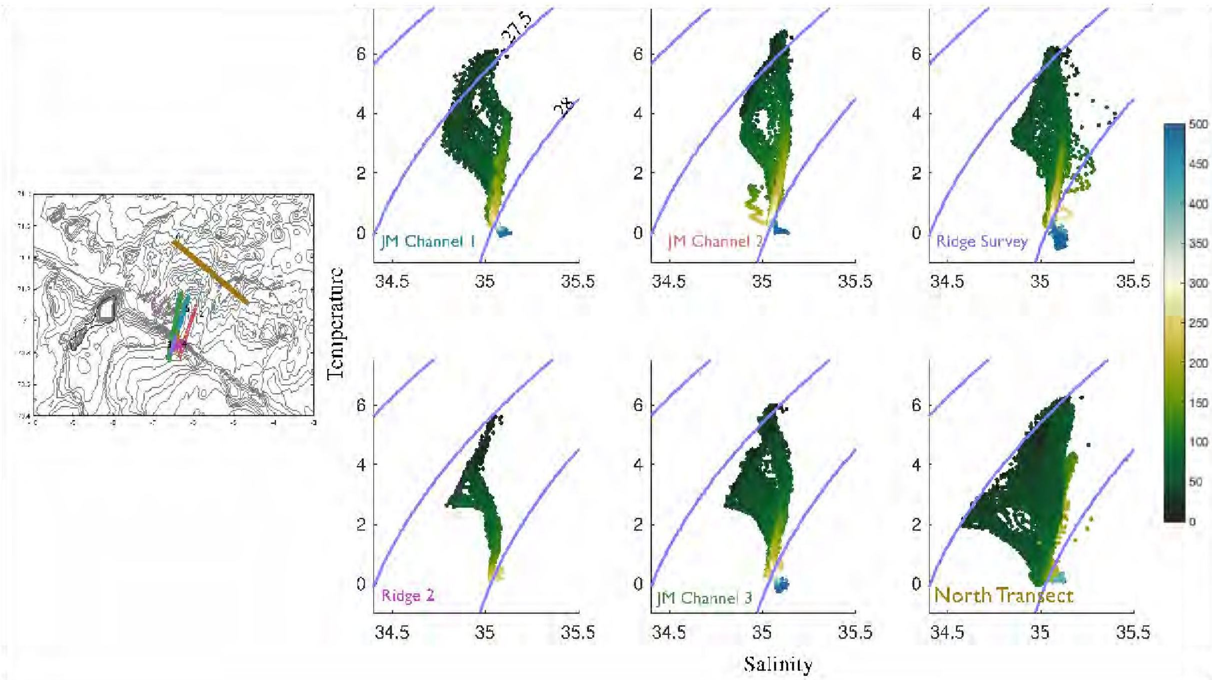


Figure 32. Map on the left highlights the fast CTD surveys carried out in the Jan Mayen channel and nearby ridges. On the right, temperature, and salinity scatter plots from the different fast CTD cast show the variability of the water mass characteristics in the surrounding areas of the JM Channel. The scatter plot is colored by depth and the contours represent isolines of same potential density.

Below the surface boundary layer, there is a large-scale mesoscale gradient between the LBE and the anticyclonic eddy to the south (Fig. 34). The vertical structure appears to be closer to mode 2 than mode 1, as isopycnal slopes above and below 400 m have mirror images. In the surface ocean however, the gradient is not monotonic. Instead, the temperature gradient consists of a series of sharper frontlets. A zoom in with bow chain data shows the gradient at each frontlet to be very sharp.

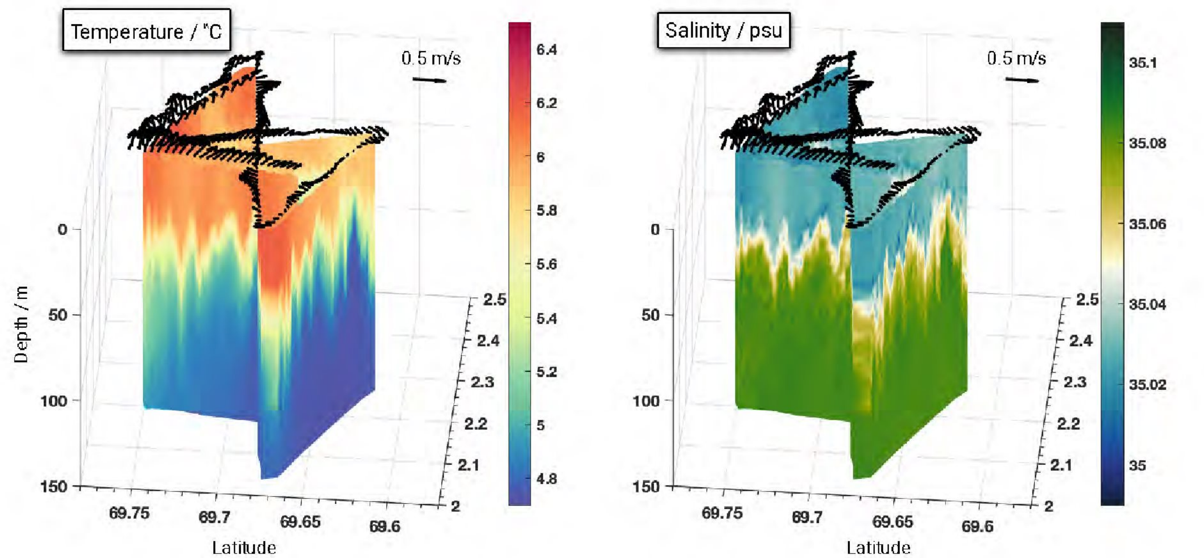


Figure 33. Left panel is FCTD temperature data through one butterfly-shaped sampling pattern through the Lofoten Basin Eddy, zoomed in on the top 150 meters. Arrows at the top show the velocity from the 75kHz ADCP averaged over this same depth range. Right panel is salinity.

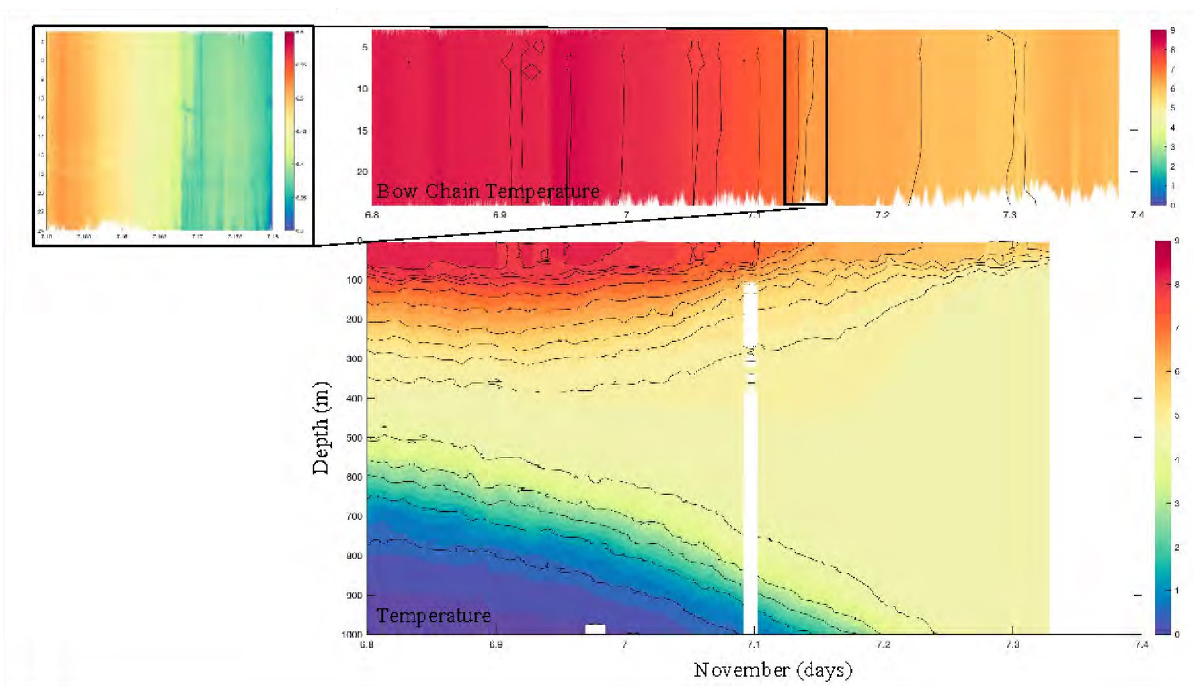


Figure 34: FCTD temperature section on the bottom panel of the cyclonic eddy south of the Lofoten Basin eddy. In the top panel concurrent bow chain data is shown with the isopycnals from the FCTD overlayed. To the left, a close up of the bow chain data is presented to show the fine-scale structure of the front at the edge of the front.

Science Personnel

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18	Emerson Hasbrouck	WHOI	ehasbrouck@whoi.edu	DBASIS
19	Joe Talbert	APL-UW	jtalbert@apl.washington.edu	SWIFTs
20	Ailin Brakstad	UIB	Ailin.Brakstad@uib.no	UIB gliders and Env. Mooring

Appendix A. Day by Day Summary of Actions

18.10.2022	We left Tromsø around 1500.
19.10.2022	Transit to Lofoten Basin Around 630 changed course to Jan Mayen
20.10.2022	Continued transit to JM 344 SOFAR SPOTTER 1967 deployed 557 SOFAR SPOTTER 1381 deployed 812 SOFAR SPOTTER 1891 deployed
21.10.2022	Arrived at Jan Mayen and deployed two gliders 1008 APL-UW Seaglider deployed 1028 UIB Slocum deployed Transited further into JM's shadow and deployed two more gliders 1258 APL-UW Slocum (turbulence) deployed 1313 VIMS SeaExplorer deployed Transited to shallow-water mooring location 1500 Multibeam survey of the mooring locations on the south side of JMCh ~2400 Began sheltering near JM
22.10.2022	0900 began transit to test FCTD outside Norwegian territorial waters 1100 FCTD shake down test 1300 Set up for DBASIS 1600 FCTD shake down test #2 1900 begin ADCP survey to determine DBASIS deployment location
23.10.2022	0500 completed ADCP survey. Data reviewed by Drew and deployment location identified. 0700 DBASIS buoy team on deck for final preparations 0907 DBASIS (Dame) deployment completed 0919 Deployed SWIFT 26 0930 Deployed SWIFT 29 1000 Transit to begin FCTD survey 1200 Crane mooring components from boat deck 1430 Begin FCTD survey 2245 Deployed three SVP drifters
24.10.2022	0045 FCTD recovered at the end of the line. 0700 Begin set up on deck for source mooring deployment, ship on location practicing running the deployment track 0830 Tangled mooring line delays source mooring preparations as well as broken wench (down for 3.5 hours) 0900 Transit to recover two SWIFTS 1017 SWIFT 29 recovery complete 1148 SWIFT 26 recovery complete Transit to PECOS array deployment location 1600 Begin PECOS deployment 1950 PECOS sled on the seafloor 2138 PECOS recovery mooring on the seafloor 2225 Begin FCTD survey
25.10.2022	0830 complete FCTD survey 0830 Winch repair begins 1100 Begin source mooring deployment 1358 Complete source mooring deployment Transit to south side of channel 1800 Begin DBASIS (Dude) deployment 1924 Complete DBASIS (Dude) deployment 2029 Deployed the APL-UW Slocum with towed array 2200 Deployed three clusters of drifters and 2 SWIFTS 2249 Put PECOS in continuous record mode (3 hour duration) 2300 FCTD survey between mooring and Jeff Bridges DBASIS

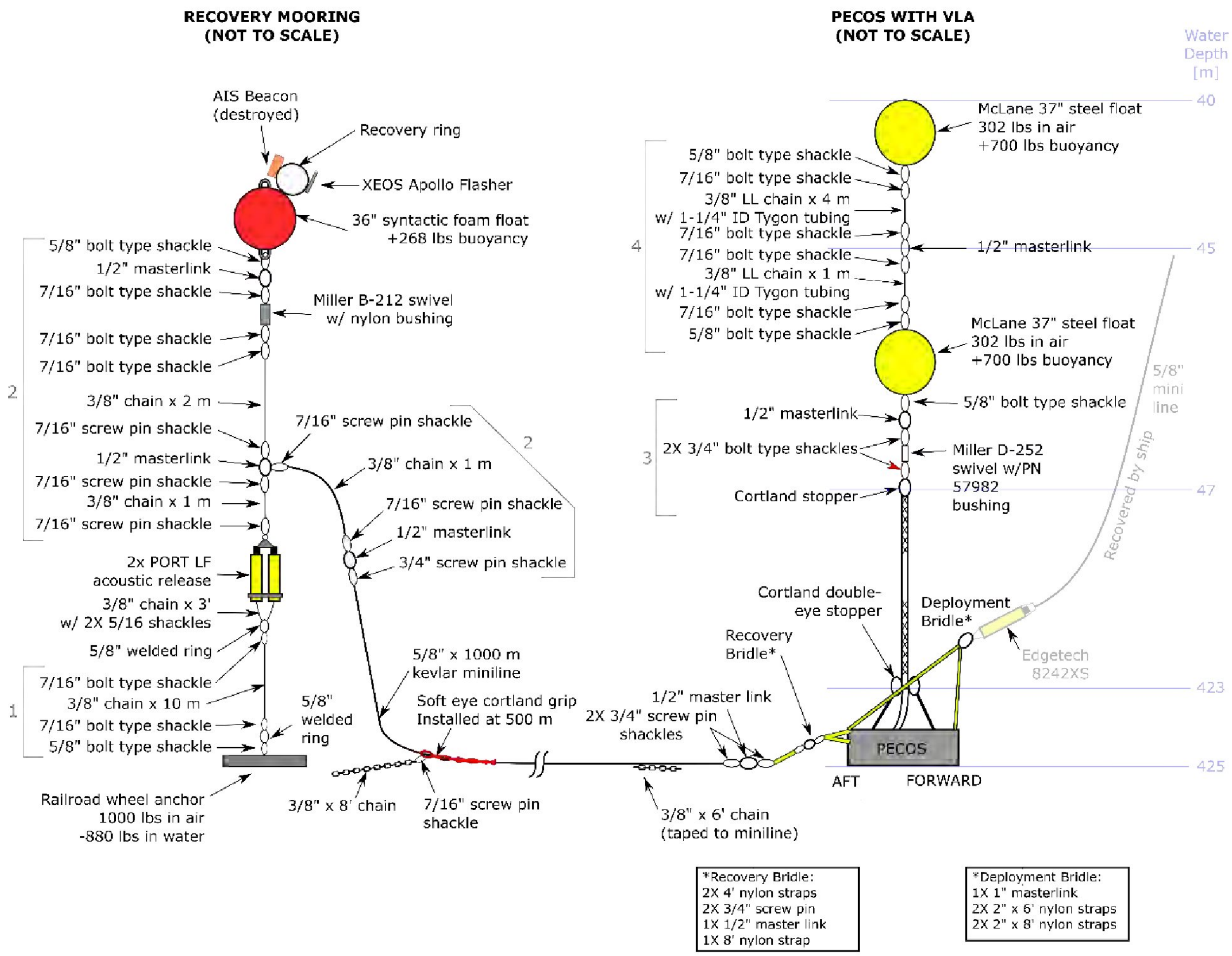
26.10.2022 299	0200 FCTD out of the water 0200 Started ADCP survey over the ridge 0730 Arrived at Deep Water Environmental Mooring site, 1 hour delay for winch problems 0800 Put the small boat in the water to deploy the CMRE float 0815 Small boat is back 1407 Completed Deep Water Environmental Mooring 1430 Recovered the CMRE Float 2213 Completed Shallow Water Environmental Mooring
27.10.2022	FCTD
28.10.2022	FCTD
29.10.2022	0525 SWIFT 28 deployed 0630 Attempted J-13 from drifting Alliance, tried for 3 hours but could not get it working 0800 Recorded signal from the moored source using the vessel's hydrophone 0930 Transit to Apollo glider with towed array, planning small boat pick up 1030 Arrive at glider location to recover from Alliance (too rough/windy for small boat) 1240 Abandon attempt to recover the glider; too windy for ship to come along side it 1530 Localization of the source mooring and recording the source transmission 1700 FCTD survey
30.10.2022	0000 Continuing FCTD survey; Fish was lost at 0620, running PADS only 1200 Launch small boat to recover SeaExplorer 1230 Recovered SeaExplorer 1330 Launch small boat to recover Seaglider 1400 Recovered Seaglider (was not functioning properly) 1630 Launch small boat to recover Slocum with towed array and deploy Pierre's float 1700 Recovered Slocum (it had stopped communicating) 1830 Recovered SWIFT 28 (it had stopped communicating) 1900 FCTD survey
31.10.2022	0720 Begin transit to collect CMRE float 0920 Recover CMRE float 1052 Recover CMRE drifter 1331 Recover another CMRE drifter 1400 FCTD survey
01.11.2022	0000 Continued FCTD survey 1800 Deployed the bow chain
02.11.2022	0030 Recovered bow chain 0200 FCTD needed re-termination; switched to ADCP survey only 0830 Recovered Minimet with hydrophones 1030 Recovered SVP with hydrophones 1230 Recovered DBASIS Dame 1400 Recovered SVP with hydrophones 1700 Recovered DBASIS Dude
03.11.2022	1340 Deployed the VIMS SeaExplorer on the outer edge of the Lofoten Basin Eddy 1430 ADCP survey
04.11.2022	0200 FCTD survey 1400 completed FCTD survey 1400 deployed the CMRE float 1445 deployment of drifters (27 SVP, 5 DWSB, 3 Minimet, 4 SWIFTS, and 4 ALAMO) 1700 FCTD survey
05.11.2022	0800 Stopped FCTD survey and transit to recover CMRE float 1030 Recovery of CMRE Float 1100 FCTD
06.11.2022	FCTD survey all day 1800 Deployed bow chain
07.11.2022	0900 Recovered bow chain and FCTD 1000 CTD cast with LADCP, calibration cast to 300 m, full depth cast to ~3000 m

	1400 Recovered SWIFTS 1800 Recovered UIB glider
08.11.2022	Transit
09.11.2022	1500 Arrival in Tromsøtextlab

Appendix B. Mooring Diagrams

NORSE 2022 PECOS Mooring

Revised: 27 Oct 2022 by Sagers



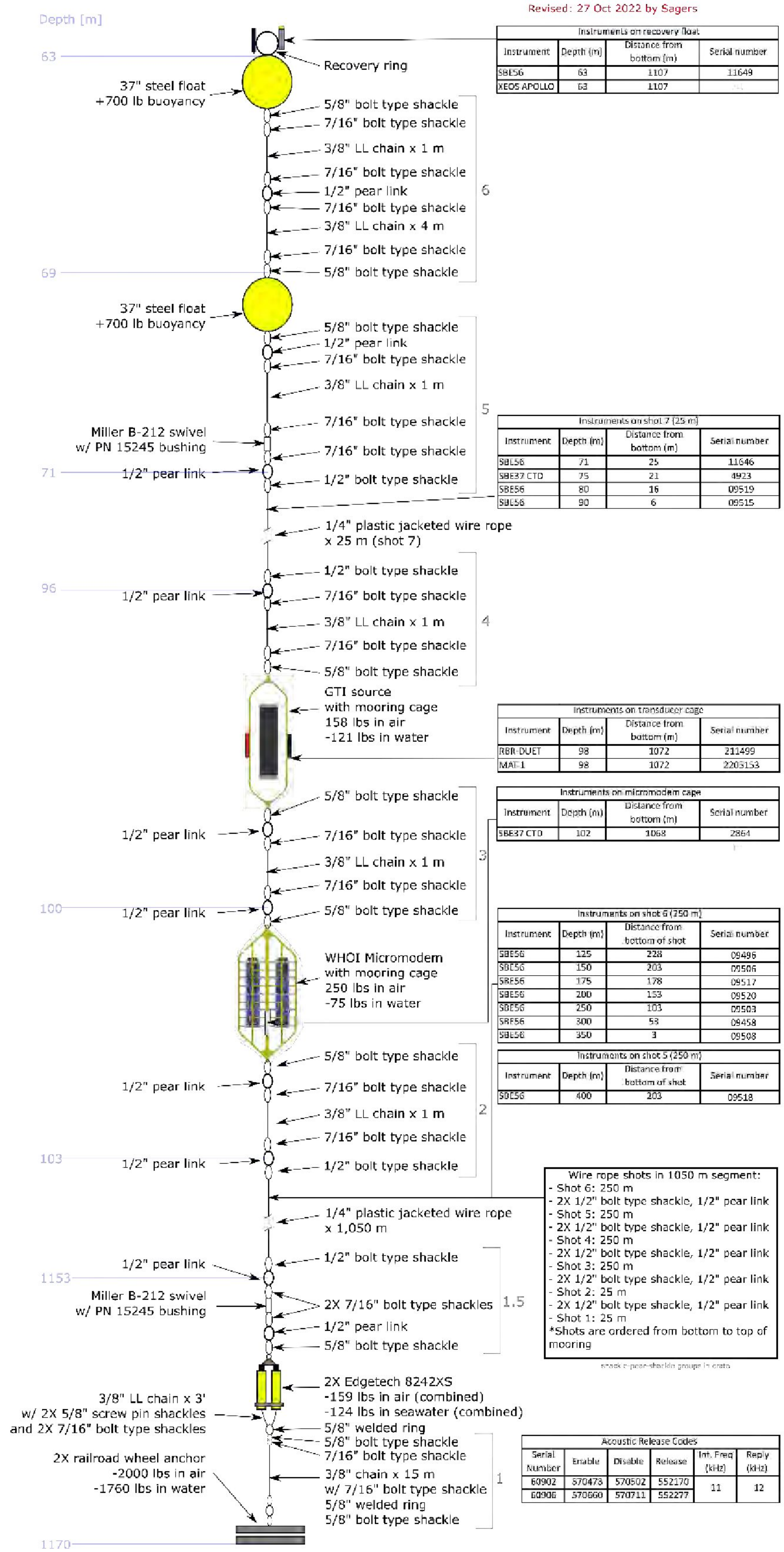
Acoustic Release Codes					
Serial Number	Enable	Disable	Release	Int. Freq (kHz)	Reply (kHz)
52152	357060	357111	343631	11	12
52154	357174	357216	343677		

Instrument Position on PECOS Array						
Instrument	Serial Number	Depth (m)	Distance from seabed (m)	Distance above hydrophone 52 (m)	Closest hydrophone number	Distance above closest hydrophone (m)
RBR duet	211502	47	378	372	1	2.25
Mat-1	2205152	125	300	294	12	4
Mat-1	2205150	225	200	194	26	5.5
RBR duet	211498	225	200	194	26	5.5
RBR duet	211501	285	140	134	34	3.5
Mat-1	2205154	305	120	114	37	5.25
RBR duet	211497	345	80	74	42	1.5
Mat-1	2205151	385	40	34	48	5

Photos of Recovery Bridle

NORSE 2022 Acoustic Source Mooring

Revised: 27 Oct 2022 by Sagers



Instruments on recovery float			
Instrument	Depth (m)	Distance from bottom (m)	Serial number
SBE56	63	1107	11649
XEOS APOLLO	63	1107	

Instruments on shot 7 (25 m)			
Instrument	Depth (m)	Distance from bottom (m)	Serial number
SBE56	71	25	11646
SBE37 CTD	75	21	4923
SBE56	80	16	09519
SBE56	90	6	09515

Instruments on transducer cage			
Instrument	Depth (m)	Distance from bottom (m)	Serial number
RBR-DUET	98	1072	211499
MAT-1	98	1072	2203153

Instruments on micromodem cage			
Instrument	Depth (m)	Distance from bottom (m)	Serial number
SBE37 CTD	102	1068	2864

Instruments on shot 6 (250 m)			
Instrument	Depth (m)	Distance from bottom of shot	Serial number
SBE56	125	228	09496
SBE56	150	203	09506
SBE56	175	178	09517
SBE56	200	153	09520
SBE56	250	103	09503
SBE56	300	53	09458
SBE56	350	3	09508

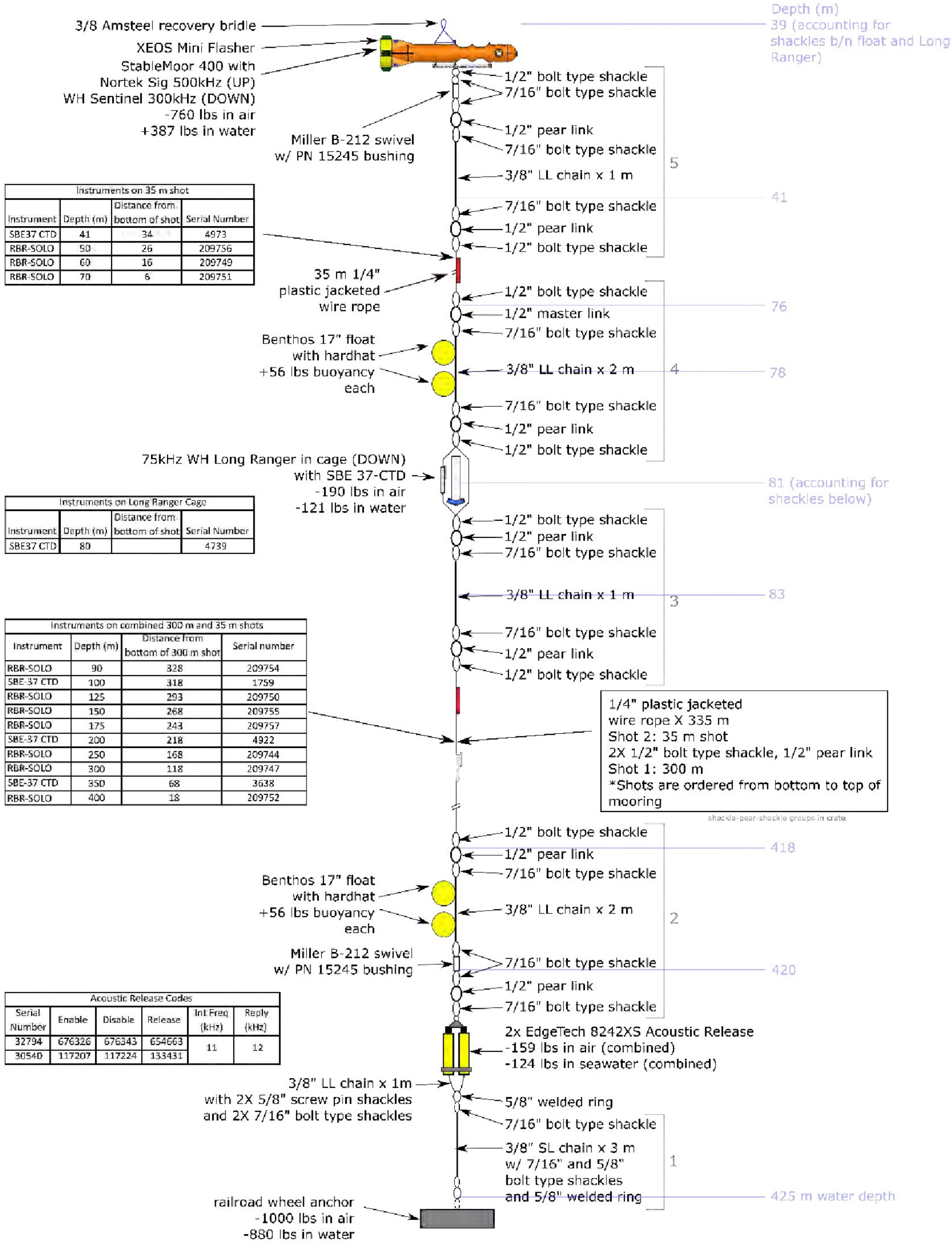
Instruments on shot 5 (250 m)			
Instrument	Depth (m)	Distance from bottom of shot	Serial number
SBE56	400	203	09518

Wire rope shots in 1050 m segment:
- Shot 6: 250 m
- 2X 1/2" bolt type shackle, 1/2" pear link
- Shot 5: 250 m
- 2X 1/2" bolt type shackle, 1/2" pear link
- Shot 4: 250 m
- 2X 1/2" bolt type shackle, 1/2" pear link
- Shot 3: 250 m
- 2X 1/2" bolt type shackle, 1/2" pear link
- Shot 2: 25 m
- 2X 1/2" bolt type shackle, 1/2" pear link
- Shot 1: 25 m

*Shots are ordered from bottom to top of mooring

Acoustic Release Codes					
Serial Number	Enable	Disable	Release	Int. Freq (kHz)	Reply (kHz)
60902	570473	570502	552170	11	12
60906	570660	570711	552277		

NORSE 2022 Shallow Water Environmental Mooring



Instruments on 35 m shot			
Instrument	Depth (m)	Distance from bottom of shot	Serial Number
SBE37 CTD	41	34	4973
RBR-SOLO	50	26	209756
RBR-SOLO	60	16	209749
RBR-SOLO	70	6	209751

Instruments on Long Ranger Cage			
Instrument	Depth (m)	Distance from bottom of shot	Serial Number
SBE37 CTD	80		4739

Instruments on combined 300 m and 35 m shots			
Instrument	Depth (m)	Distance from bottom of 300 m shot	Serial number
RBR-SOLO	90	328	209754
SBE-37 CTD	100	318	1759
RBR-SOLO	125	293	209750
RBR-SOLO	150	268	209755
RBR-SOLO	175	243	209757
SBE-37 CTD	200	218	4922
RBR-SOLO	250	168	209744
RBR-SOLO	300	118	209747
SBE-37 CTD	350	68	3638
RBR-SOLO	400	18	209752

Acoustic Release Codes					
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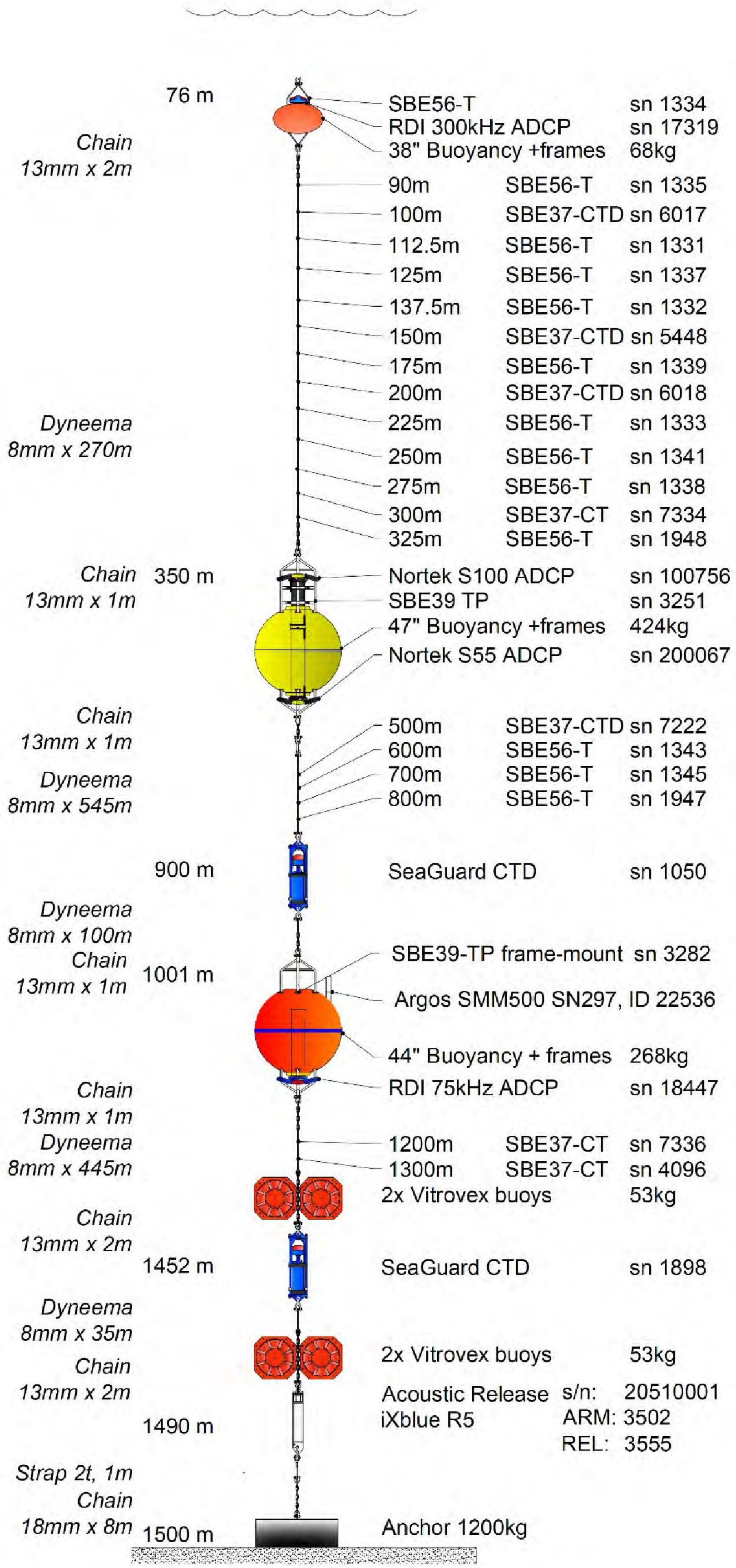
32794	676326	676343	654663	11	12
30540	117207	117224	133431		

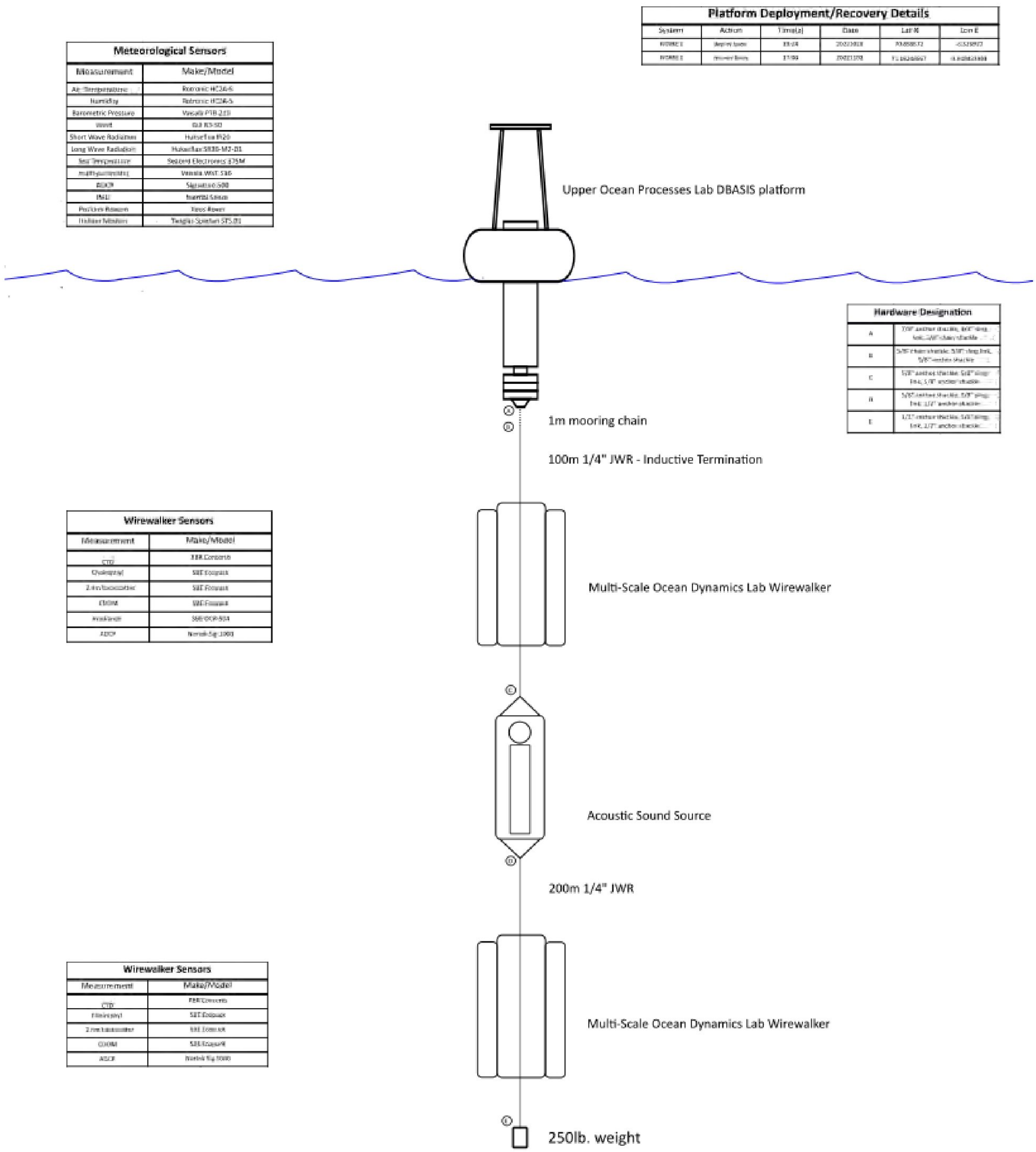


UNIVERSITETET I BERGEN
Geofysisk Institutt

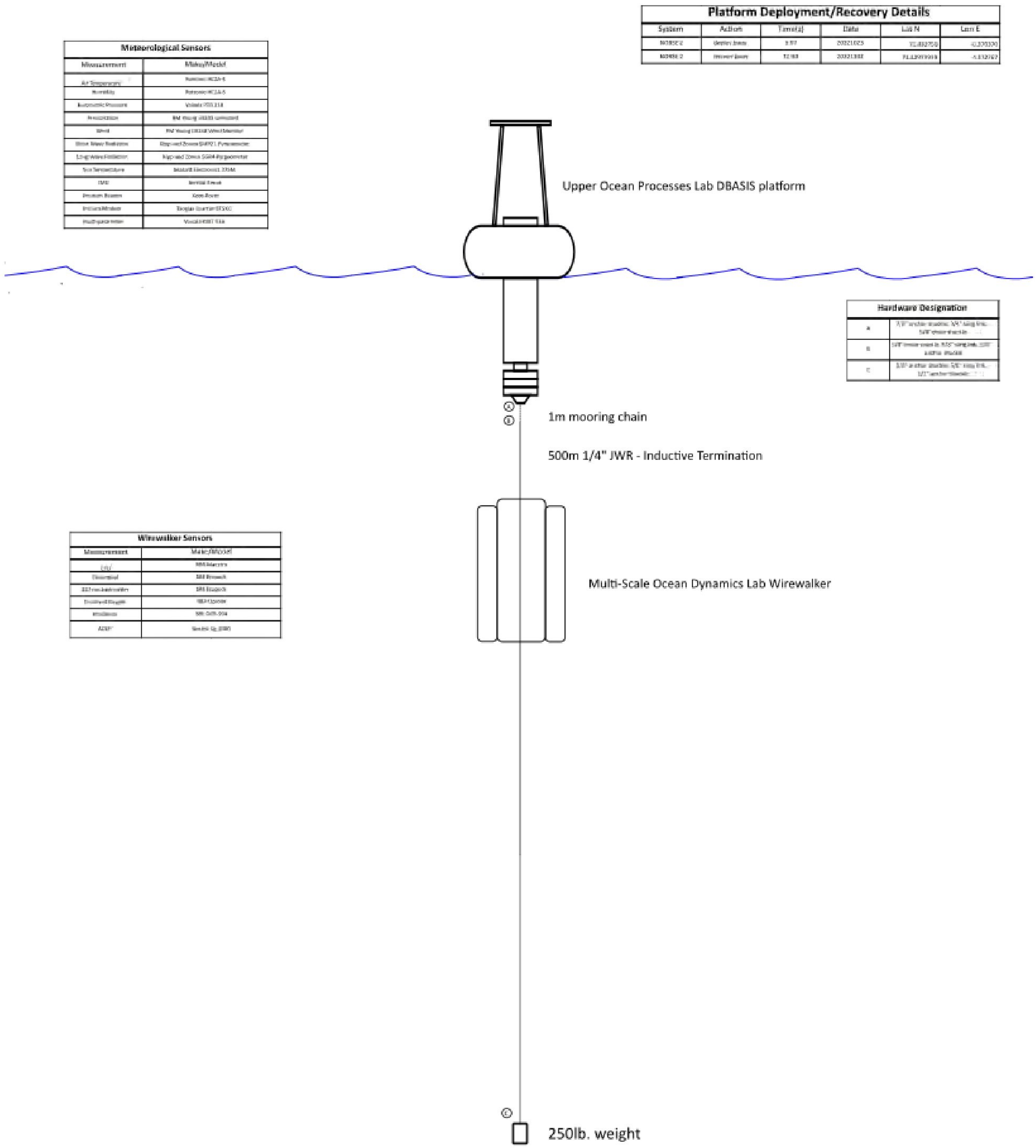
Mooring name:	JMC
Project:	ONR-GLOBAL
Location:	Jan Mayen Channel
Position:	Lat 70.869161N
	Lon 6.4115010W
Depth:	1505 m
Deploy:	2022-10-26 14:07 UTC
	RV Alliance
Recover:	
Notes:	

Latest update: 07/12/2022

NORSE 1


Platform Deployment/Recovery Details
Meteorological Sensors
Measurement
Make/Model
Upper Ocean Processes Lab DBASIS platform
Hardware Designation
1m mooring chain
100m 1/4" JWR - Inductive Termination
Wirewalker Sensors
Measurement
Make/Model
Multi-Scale Ocean Dynamics Lab Wirewalker
Acoustic Sound Source
200m 1/4" JWR
Wirewalker Sensors
Measurement
Make/Model
Multi-Scale Ocean Dynamics Lab Wirewalker
250lb. weight

NORSE 2


Platform Deployment/Recovery Details
Meteorological Sensors
Upper Ocean Processes Lab DBASIS platform
Hardware Designation
1m mooring chain
500m 1/4" JWR - Inductive Termination
Wirewalker Sensors
Multi-Scale Ocean Dynamics Lab Wirewalker
250lb. weight

Appendix C. Deployments and Recoveries

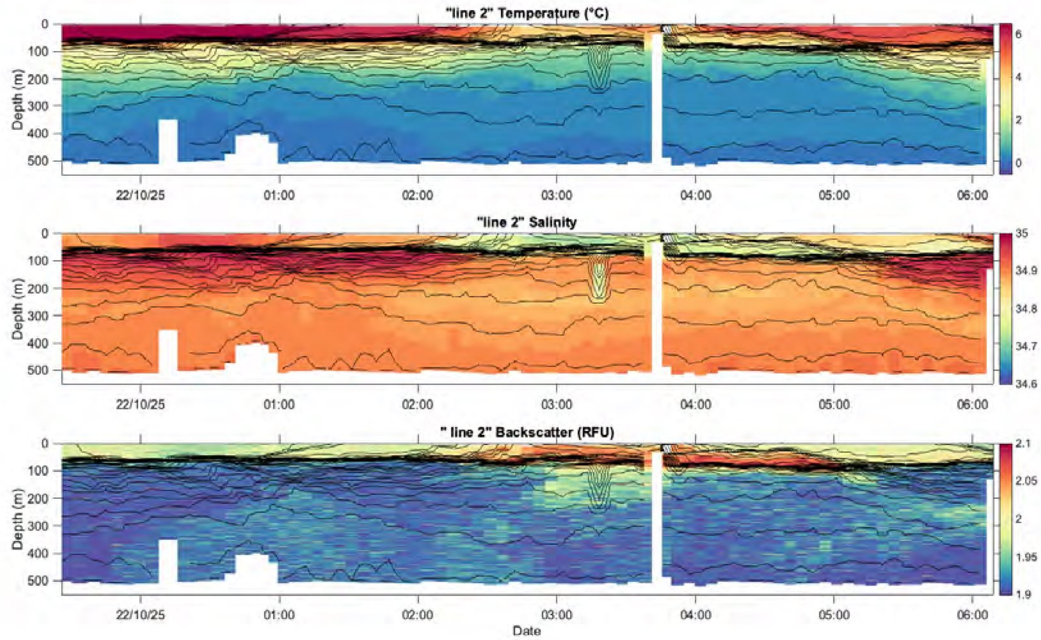
	DEPLOYMENT				RECOVERY			
ITEM	YEAR-DAY 2022	TIME [UTC]	LATITUDE [DEG N]	LONGITUDE [DEG E]	YEAR-DAY 2022	TIME [UTC]	LATITUDE [DEG N]	LONGITUDE [DEG E]
SOFAR SPOTTER 1967	293	3:44	70.138557	4.998446	Expendable			
SOFAR SPOTTER 1381	293	5:57	70.189547	3.999972	Expendable			
SOFAR SPOTTER 1891	293	8:12	70.240388	3.000000	Expendable			
APL-UW Seaglider	294	10:08	70.787063	-7.529825	303	1335	70.9546	-6.0849
UIB Slocum	294	10:28	70.793318	-7.556008	To be recovered by another vessel			
APL-UW Slocum (turbulence)	294	12:58	70.799927	-7.965580	303	17:00	71.074800	-4.957117
VIMS SeaExplorer	294	13:13	70.800703	-7.967595	303	1236	70.913644	-6.274630
DBASIS (Dame)	296	9:07	71.032750	-6.370370	306	1230	71.228733	-4.372767
SWIFT 26	296	9:19	71.043117	-6.395883	297	1148	71.267432	-6.133627
SWIFT 29	296	9:30	71.054550	-6.394050	297	1017	71.272208	-6.096580
SVP 68943880	296	22:45	70.888500	-6.410200	Expendable			
SVP 68943770	296	22:45	70.888500	-6.410200	Expendable			
SVP 68944490	296	22:45	70.888500	-6.410200	Expendable			
PECOS Array	297	19:50	70.836847	-6.411678	To be recovered in 2023			
PECOS Recovery float	297	21:38	70.841858	-6.401289	To be recovered in 2023			
Source Mooring	298	13:58	71.211565	-6.298711	To be recovered in 2023			
DBASIS (Dude)	298	19:24	70.858572	-6.326910	306	1700	71.162467	-3.94843
APL-UW Slocum (array)	298	20:28	70.895824	-6.374157	303	1700	71.06815	-4.94797
300534061552960 (CMRE SVP acoustical)	298	21:36	70.830883	-6.418083	306	1400	71.103917	-4.57355
300534060941750 (SIO DWS)	298	21:36	70.830883	-6.418083	Expendable			
300534061553760 (CMRE SVP acoustical)	298	21:49	70.838800	-6.415350	306	1030	71.335267	-4.3393333
300534061615140 (SIO Minimet acoustical)	298	21:49	70.838800	-6.415350	306	830	71.425983	-4.5672667
300534061492130 (SIO SVP optical)	298	21:49	70.838800	-6.415350	304	1208	71.088933	-4.6947833
300534060943380 (SIO DWS)	298	21:49	70.838800	-6.415350	Expendable			

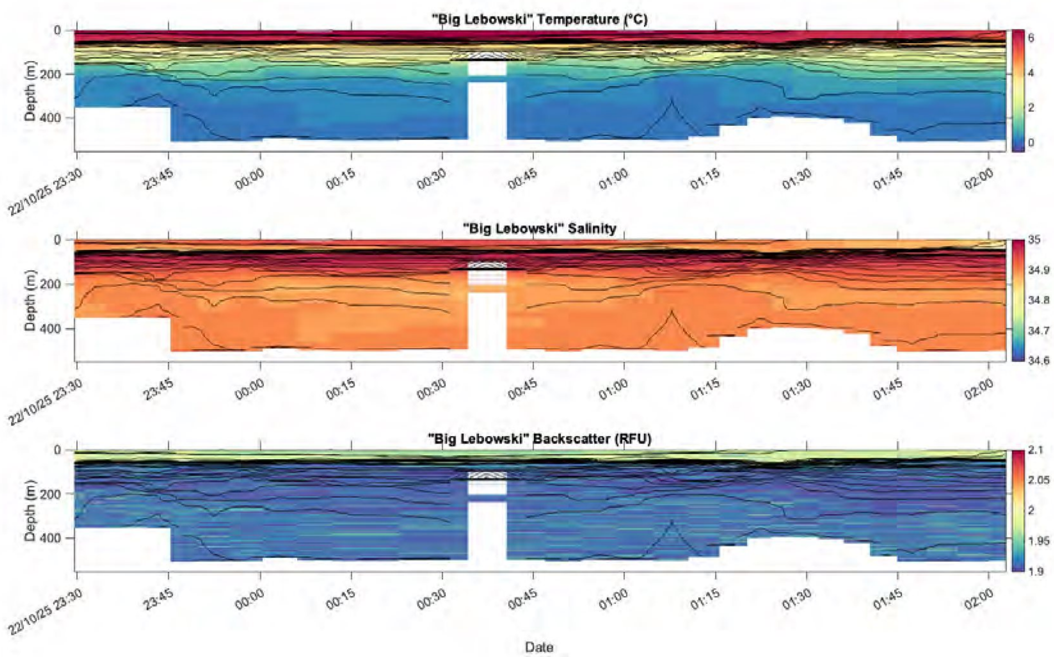
300534061553800 (CMRE SVP acoustical)	298	22:05	70.847533	-6.415583	304	1331	71.100267	-4.643550
300534061613420 (SIO SVP minimet)	298	22:05	70.847533	-6.415583	Expendable			
300534060943690 (SIO DWS)	298	22:05	70.847533	-6.415583	Expendable			
SWIFT 26	298	22:00	70.847533	-6.415583	306	2045	71.0539	-5.184
SWIFT 29	298	22:00	70.847533	-6.415583	306	2115	71.05375	-5.1877333
CMRE Float	299	8:00	70.8764	-6.457600	299	1430	70.8752	-6.4703
Deep Environmental Mooring	299	14:07	70.811433	-6.078000	To be recovered in 2023			
Shallow Environ. Mooring	299	22:13	70.831946	-6.399105	To be recovered in 2023			
SWIFT 27	301	15:07	70.899293	-6.448428	306	2330	71.1524	-4.1107
SWIFT 28	302	5:25	70.980645	-6.071187	303	1830	71.0748	-4.9571167
CMRE Float	303	17:00	71.074800	-4.957117	304	920	71.024733	-4.9926333
VIMS SeaExplorer	307	13:40	70.0849	-1.393667	To be recovered by another vessel			
CMRE Float	308	14:00	69.80165	2.518515	309	1030	69.59525	2.65346667
SVP - 300234068945810	308	15:25	69.716383	2.135667	Expendable			
SVP - 300234068945230	308	15:26	69.715133	2.139333	Expendable			
Minimet - 300534061613120	308	15:27	69.714167	2.142133	Expendable			
SVP - 300234068945490	308	15:28	69.613233	2.145033	Expendable			
SVP - 300234068944880	308	15:29	69.71231	2.148017	Expendable			
SWIFT 26	308	15:29	69.71231	2.148017	311	1550	69.71115	2.49822
Alamo 9110	308	15:29	69.71231	2.148017	Expendable			
SVP - 300234068945770	308	16:09	69.67993	2.371383	Expendable			
SVP - 300234068945760	308	16:10	69.67982	2.374550	Expendable			
Minimet – 61614370	308	16:11	69.67965	2.378533	Expendable			
SWIFT 28	308	16:11	69.67965	2.378533	311	1520	69.71115	2.49822
Alamo 9110	308	16:11	69.67965	2.378533	Expendable			
SVP - 300234068947500	308	16:12	69.679467	2.38240	Expendable			
SVP - 300234068945540	308	16:13	69.679317	2.38645	Expendable			
SVP - 300234068949240	308	16:47	69.64415	2.18630	Expendable			
SVP - 300234068947730	308	16:48	69.64268	2.18415	Expendable			
SVP - 300234068948710	308	16:49	69.64162	2.18265	Expendable			

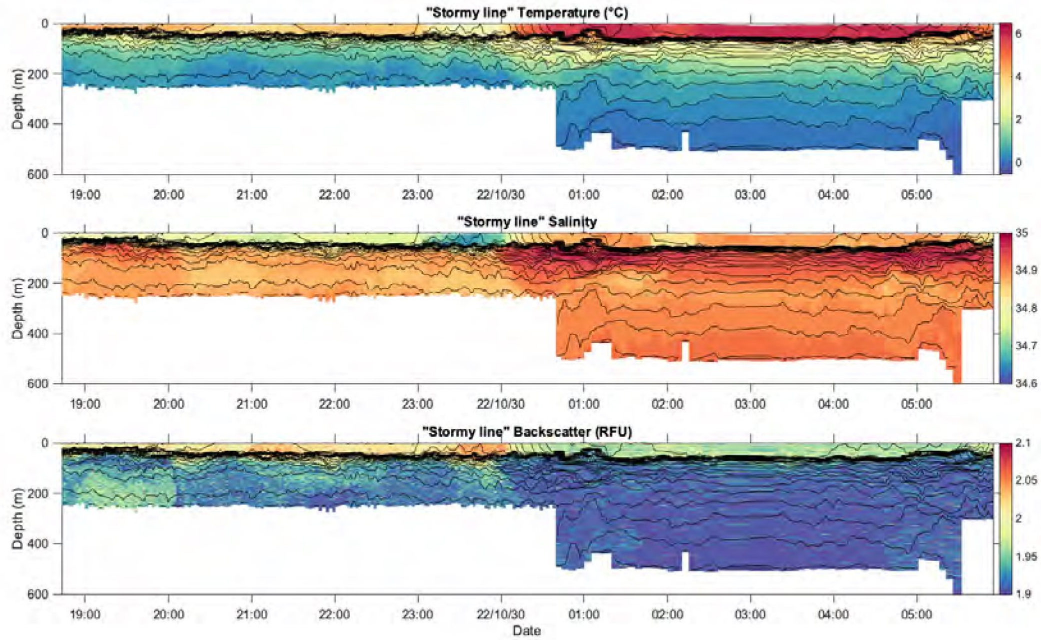
SWIFT 29	308	16:49	69.64162	2.18265	311	1440	69.71115	2.49822
Alamo 9112	308	16:49	69.64162	2.18265	Expendable			
SVP - 300234068949230	308	16:50	69.64035	2.18065	Expendable			
SVP - 300234068948880	308	16:51	69.63913	2.17873	Expendable			
SVP - 300234068543320	308	14:46	69.76263	2.38787	Expendable			
SVP - 300234068543190	308	14:47	69.76027	2.38307	Expendable			
SVP - 300234068543240	308	14:48	69.75825	2.37882	Expendable			
SVP - 300234068543420	308	14:49	69.75592	2.37427	Expendable			
SVP - 300234068948900	308	14:59	69.75353	2.36958	Expendable			
SVP - 300234068947710	308	17:09	69.59927	2.12725	Expendable			
SVP - 300234068947580	308	17:10	69.59643	2.12355	Expendable			
SVP - 300234068948630	308	17:11	69.59395	2.11873	Expendable			
SVP - 300234068948250	308	17:12	69.59163	2.11687	Expendable			
SVP - 300234068948250	308	17:13	69.58932	2.11337	Expendable			
SVP - 300234068944600	308	15:45	69.68728	2.22222	Expendable			
SVP - 300234068944720	308	15:46	69.68621	2.22563	Expendable			
Minimet - 300534061604120	308	15:47	69.68530	2.22852	Expendable			
SWIFT 27	308	15:47	69.68530	2.22852	311	1400	69.670928	2.309762
Alamo 9114	308	15:47	69.68530	2.22852	Expendable			
SVP - 300234068945710	308	15:48	69.68412	2.23223	Expendable			
SVP - 300234068944710	308	15:49	69.68320	2.23475	Expendable			
DWSB - 300534060945720	308	15:37	69.69992	2.18467	Expendable			
DWSB - 300534060943430	308	15:43	69.68772	2.22085	Expendable			
DWSB - 300534060944440	308	15:59	69.68033	2.29405	Expendable			
DWSB - 300534060943750	308	16:01	69.68033	2.31338	Expendable			
DWSB - 300534060942730	308	16:33	69.66382	2.27142	Expendable			
UIB Glider	Deployed from another vessel				311	1800	69.70581	3.28954

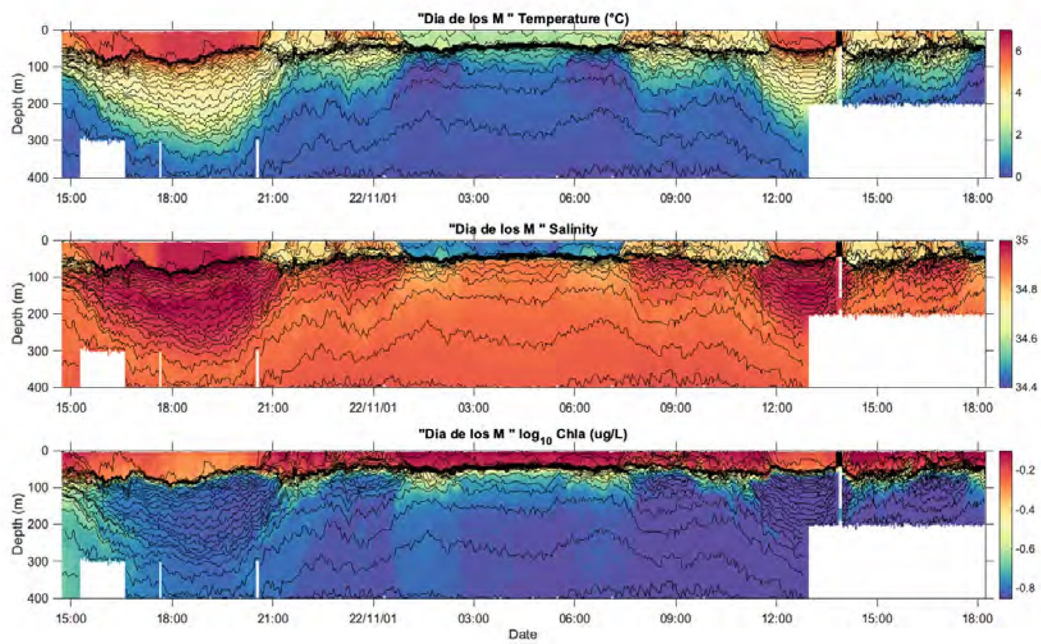
Appendix D. FCTD Transects

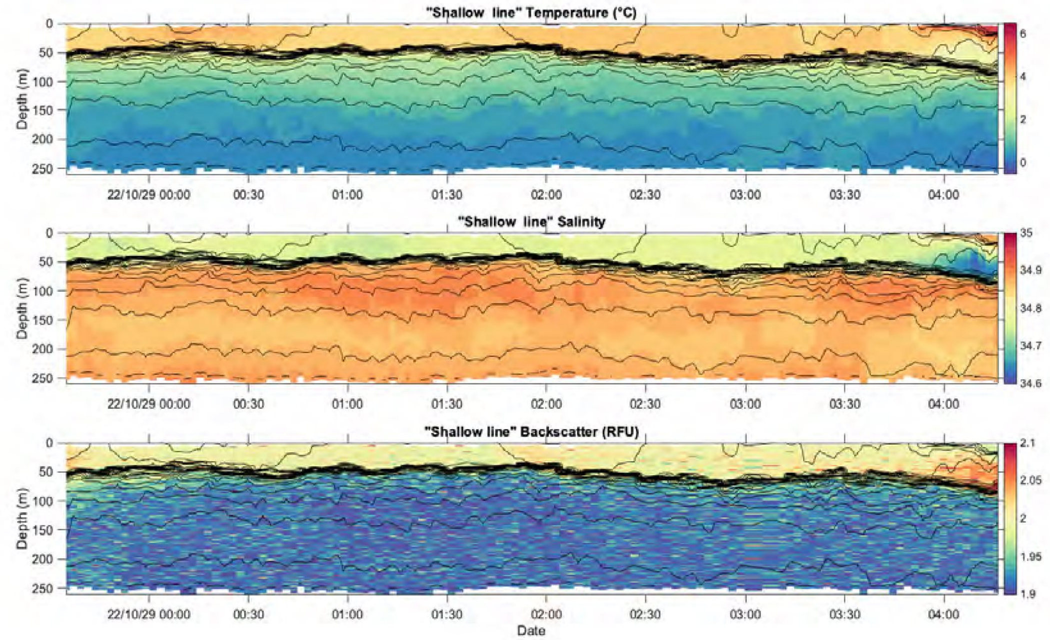
FTCD Transects in the Jan Mayen Area

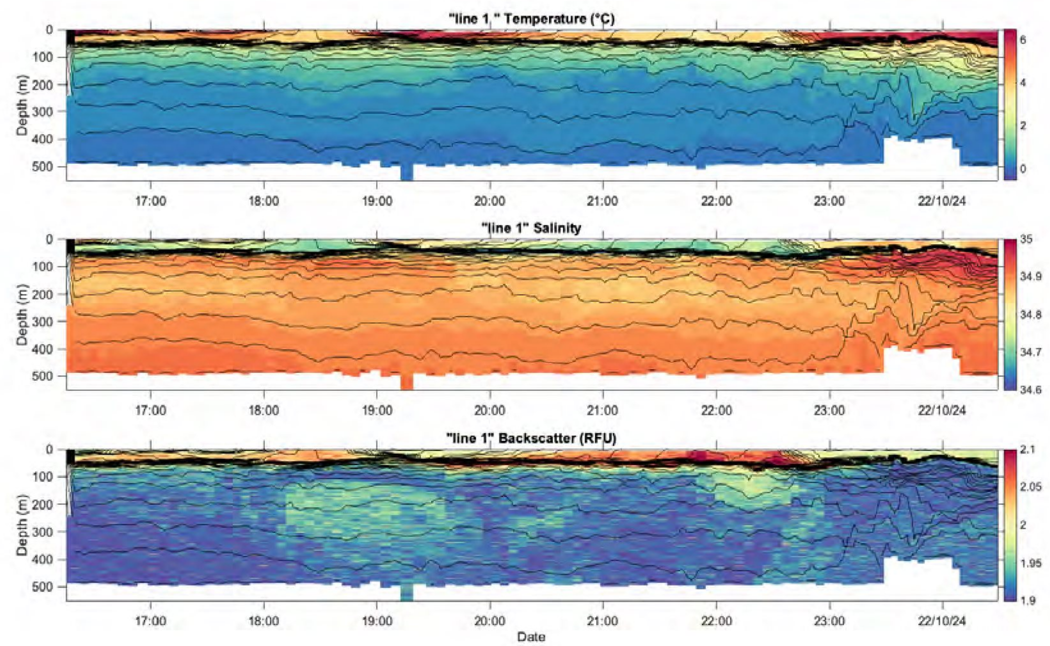




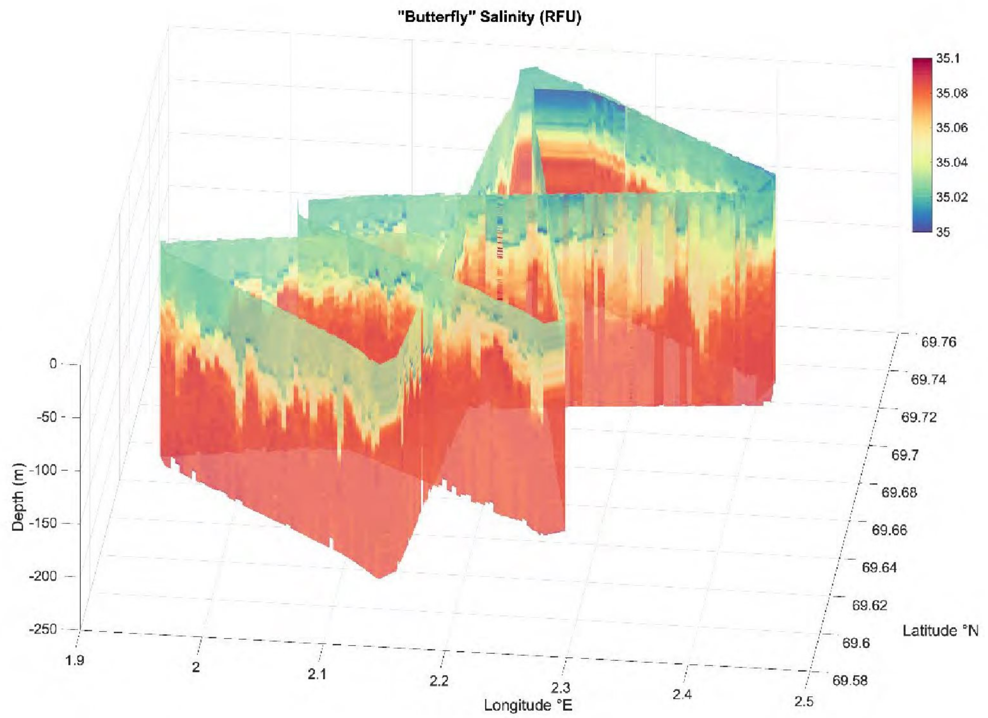

"Stormy line" Temperature (°C)
"Stormy line" Salinity
"Stormy line" Backscatter (RFU)
Depth (m)
Date
19:00
20:00
21:00
22:00
23:00
22/10/30
01:00
02:00
03:00
04:00
05:00

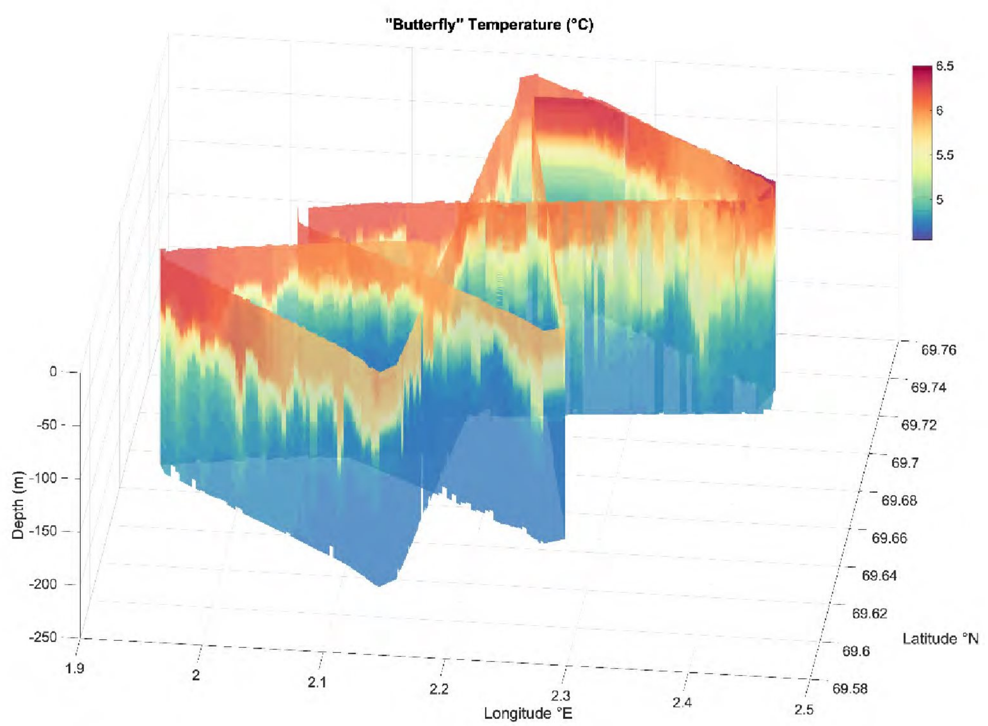

"Dia de los M " Temperature (°C)
"Dia de los M " Salinity
"Dia de los M " $\log_{10}$ Chla (ug/L)
Depth (m)
Date
15:00
18:00
21:00
22/11/01
03:00
06:00
09:00
12:00
15:00
18:00

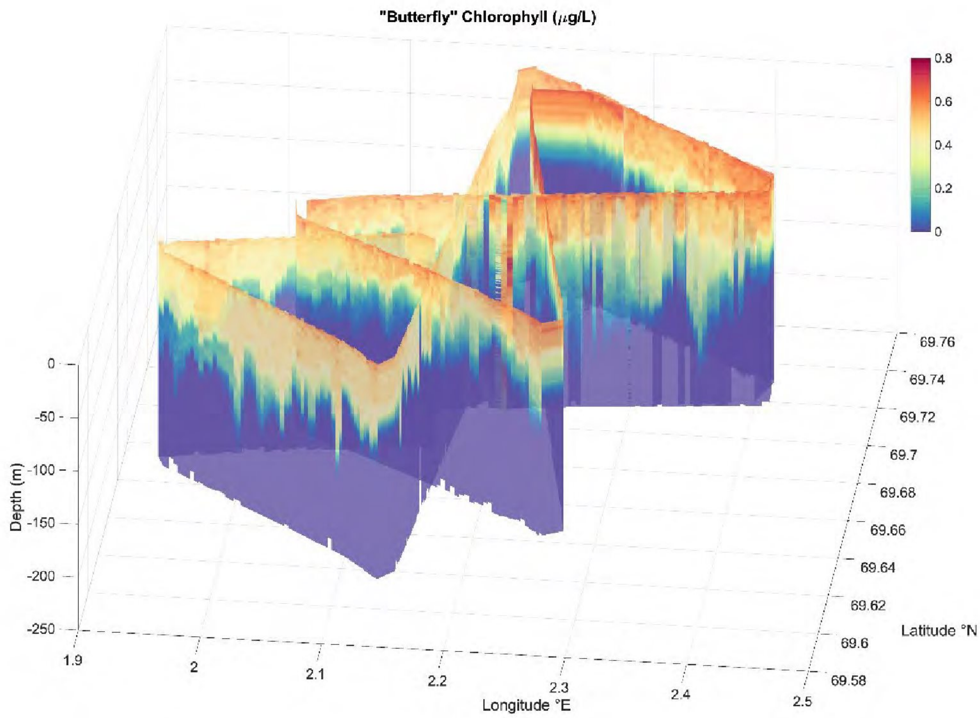

"Shallow line" Temperature (°C)
"Shallow line" Salinity
"Shallow line" Backscatter (RFU)
Depth (m)
Date
22/10/29 00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00

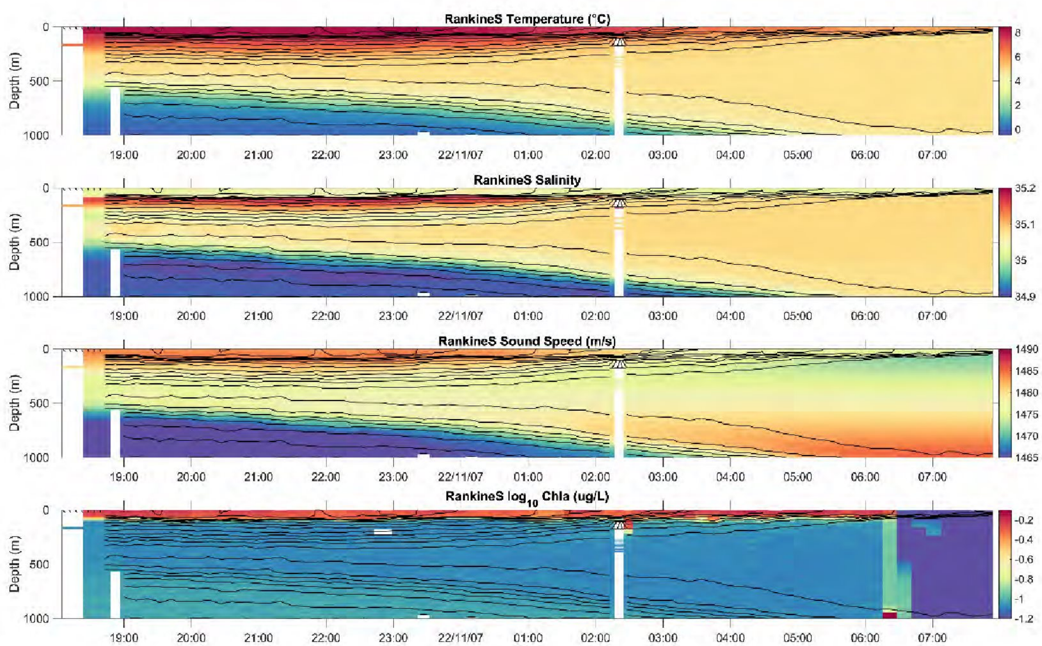

"line 1 " Temperature (°C)
"line 1" Salinity
"line 1" Backscatter (RFU)
Depth (m)
Date
17:00
18:00
19:00
20:00
21:00
22:00
23:00
22/10/24

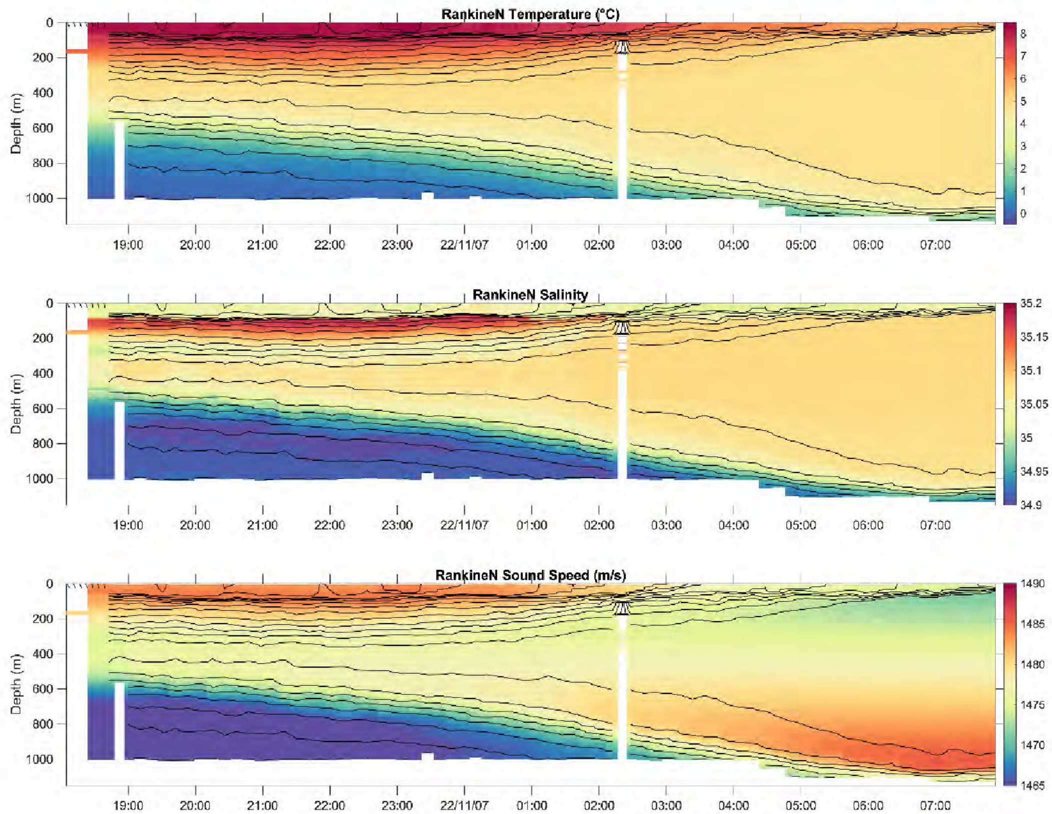
FTCD Transects in the Lofoten Basin






"Butterfly" Chlorophyll (μg/L)
Depth (m)
Longitude °E
Latitude °N


RankineS Temperature (°C)
RankineS Salinity
RankineS Sound Speed (m/s)
RankineS log10 Chla (ug/L)
Depth (m)
Date
22/11/07


RankineN Temperature (°C)
RankineN Salinity
RankineN Sound Speed (m/s)
Depth (m)
19:00
20:00
21:00
22:00
23:00
22/11/07
01:00
02:00
03:00
04:00
05:00
06:00
07:00