CRUISE REPORT
FARDWO-DS1

RV Sarmiento de Gamboa

19/07/2023 Reykjavik (Iceland)
12/08/2023 Reykjavik (Iceland)

LIBERTAS PERFVNDET · OMNIA LVCE
UNIVERSITAT DE BARCELONA

FAR-DWO
FAR-reaching impacts of Dense Water Overflows in the North Atlantic and the Mediterranean

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1. Summary

The Denmark Strait (DS), situated between Iceland and Greenland, serves as a compelling study area for researchers in various fields of oceanography. This strait acts as a critical gateway, connecting the Arctic and Atlantic Oceans. Its unique geographic location and complex oceanographic dynamics make it an ideal location for investigating a wide range of phenomena related to ocean circulation and climate patterns. In DS the dense water being formed at the Nordic Seas, consisting of the Norwegian, Greenland, and Iceland Seas, overflows the strait's central sill and the East Greenland Shelf (EGS), eventually reaching the Irminger Basin in the North Atlantic Ocean. The Denmark Strait Overflow (DSO) is the main focus of the FAR-DWO DS1 cruise onboard RV Sarmiento de Gamboa (CSIC).

Despite extensive studies on the DSO by the physical oceanography community, its sediment transport capacity and far-reaching effects on seafloor relief, as well as its signature in bottom water geochemistry and sedimentary records, remain largely unexplored. Furthermore, the effects of flow constriction caused by the DS sill and the complex topographic features in the EGS have received limited attention, despite their crucial role in understanding DSO dynamics and their significance in the broader ocean circulation system. To address these research gaps, the FAR-DWO DS1 cruise employed a combination of multidisciplinary observational analyses, sampling strategies and continuous monitoring of dense water overflows (DWOs). This report presents the technical aspects and the preliminary results of the cruise.

The scientific research conducted during the cruise has been made possible by the grant PID2020-114322RB-I00, funded by the Spanish MCIN/AEI/ 10.13039/501100011033.

2. Goals of the cruise and methodological setup

The research objectives and the methodological setup of the cruise has consisted on:

(i) the deployment of mooring lines to gain insights into the changing hydrography and sedimentation related to DWOs, covering both short-term (days) and mid-term (one year) perspectives.

ii) the acquisition of CTD casts, suspended matter and sADCP and LADCP data to gather comprehensive data of the water masses within the Denmark Strait (DS) and the nearby region of the Kangerlussuaq Trough, allowing for an intricate analysis of the distribution, structure, and biogeochemical properties of the study area with particular emphasis on capturing detailed insights into DSO.

(iii) the obtention of high-resolution bathymetric and very shallow seismic data to determine the physical imprint of DWOs on the seafloor and subseafloor in the DS sill and the Kangerlussuaq Trough Mouth Fan.

(iv) the extraction of seafloor sediment samples for a detailed characterization of the DWOs geochemical and sedimentological imprint in the sedimentary record.

Furthermore, throughout the cruise we have conducted real-time analyses of both forecasted and hindcasted water mass behaviours using outputs from oceanic models. These insights proved immensely valuable in guiding the on-site decision-making process.

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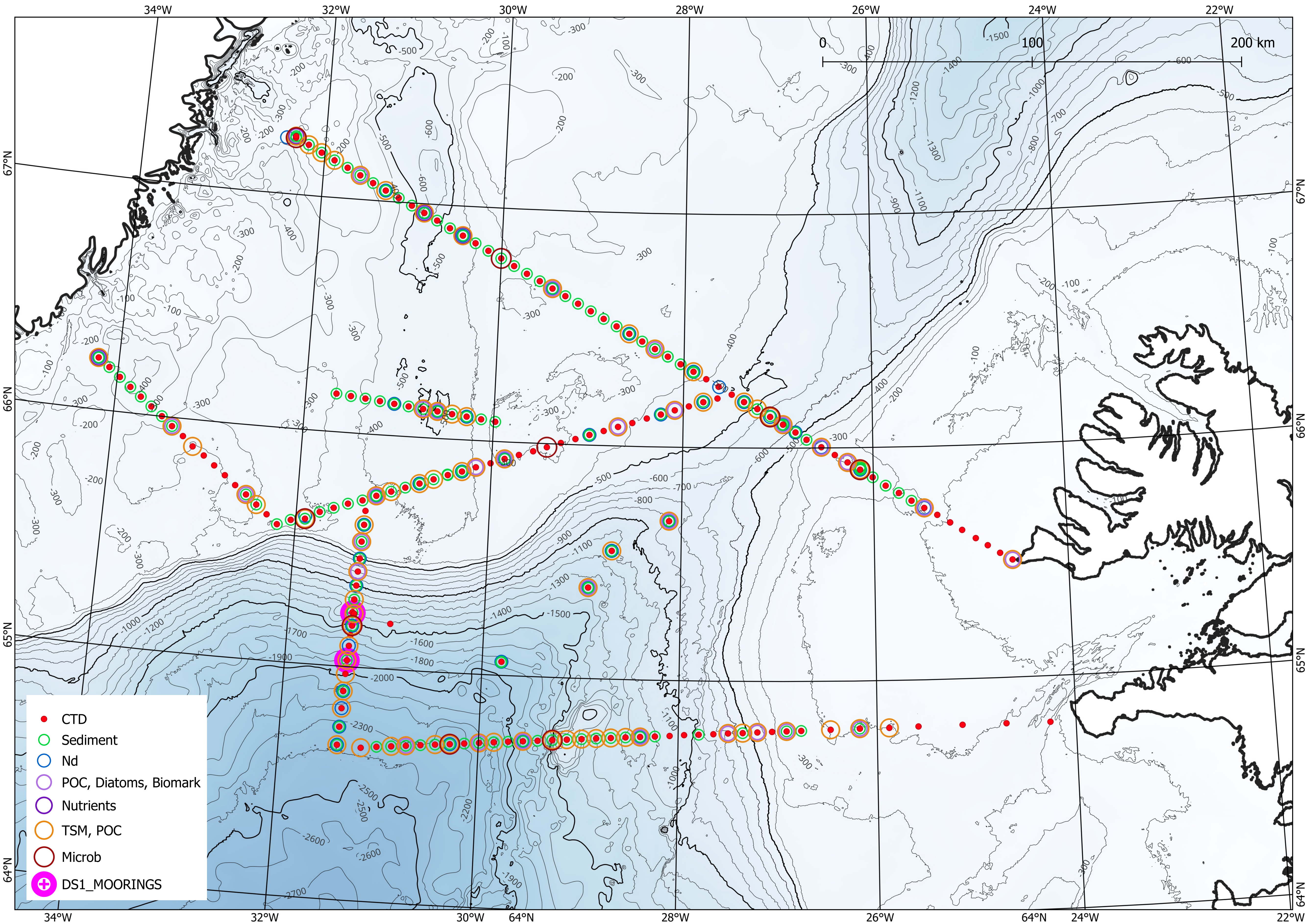
INTRODUCTION

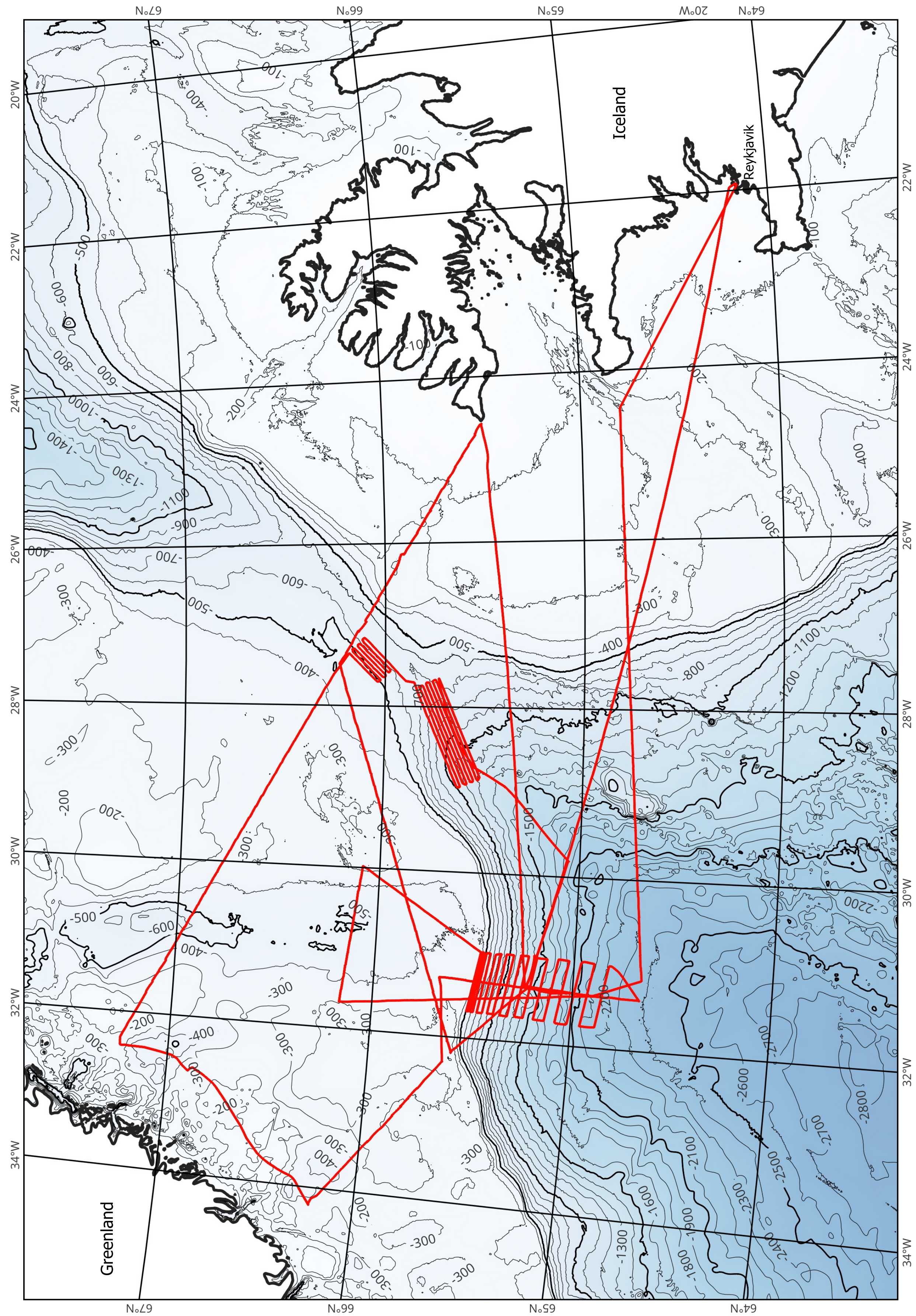


3. Numbers of cruise

Water column		
Moorings deployed	3 moorings	
Thermosalinograph	22 days	
CTD/LADCP profiles	185 profiles	238 km of measures
Nd and REE samples	236 samples	
Suspended matter, organic C & biomarkers	323 filters	
Diatom communities	60 samples	
Microbial communities	26 samples	
Nutrients	18 samples	
Seafloor		
Mono Core	92 out of 115	9.4 m of sediment
Gravity Core	17 out of 20	19.6 m of sediment
Multi Core	13 out of 14	1.7 m of sediment
Van Veen	18 out of 23	
Multibeam and parasound lines	32 lines + transits	4539 line-km

Figure 1. Photography of the cruise FAR-DWO DS1 research team.

Figure 2. Navigation map of the FARDWO-DS1 cruise.



4. Participants and external collaborations

The FAR-DWO DS1 cruise onboard research team consisted of 18 scientists and 8 technicians from Spain, France and Iceland. Throughout the expedition, we received invaluable technical support from the Unidad de Tecnología Marina (UTM-CSIC).

Comprising the on-board team are:

Name	Surname	Organisation	Role
David	Amblas	Universitat de Barcelona (Spain)	Chief Scientist
Anna	Sanchez-Vidal	Universitat de Barcelona (Spain)	Chief Scientist
Marta	Arjona Camas	CEFREM/UB (France, Spain)	Scientist
Antonio M.	Calafat Frau	University of Barcelona (Spain)	Scientist
Sara	Campderrós Serra	Universitat de Barcelona (Spain)	PhD Student
Marc	Cerdà Domènech	Universitat de Barcelona (Spain)	Scientist
Sara	Espinosa Paz	Universitat de Barcelona (Spain)	PhD Student
Audria	Faith Dennen	University of Iceland (Iceland)	Graduate Student
Anthony	Ferrant	IFREMER (France)	Technician
Helena	Fos Serdà	Universitat de Barcelona (Spain)	PhD Student
Jaime	Frigola Ferrer	Universitat de Barcelona (Spain)	Scientist
Luisa	Gonçalves de Freitas	Universitat de Barcelona (Spain)	PhD Student
Galderic	Lastras Membrive	Universitat de Barcelona (Spain)	Scientist
Irene	Llamas Cano	Universitat de Barcelona (Spain)	PhD Student
Jacobo	Martin de Nascimento	Universitat de Barcelona (Spain)	Scientist
Mara	Navarro Buigues	Universidad de La Palmas (Spain)	PhD Student
Leopoldo D.	Pena González	University of Barcelona (Spain)	Scientist
Jesús	Peña Izquierdo	Lobelia Earth (Spain)	Scientist
Ricardo	Silva Jacinto	IFREMER (France)	Scientist
Jose Luis	Pozo Blasco	UTM (Spain)	Technician
Joaquin	Salvador Castiella	UTM (Spain)	Technician
José Alberto	Serrano Mayo	UTM (Spain)	Technician
Ivan	Mouzo Bellino	UTM (Spain)	Technician
Joaquim	Rabadà Manuel	UTM (Spain)	Technician
Samuel	Álvarez Martínez	UTM (Spain)	Technician
Gabriel	Campos Pereira	UTM (Spain)	Technician

Before and during the oceanographic cruise, we greatly benefited from the invaluable assistance provided by external collaborators and remote support. These collaborators, hailing from various institutions and expertise areas, played a key role in enhancing the success of the cruise. Their contributions ranged from sharing specialized knowledge to offering equipment. This collaborative approach significantly enriched the cruise's scientific output and contributed to a comprehensive understanding of the complex oceanographic processes under investigation.

Name	Surname	Organisation
Maria Dolores	Pérez Hernández	ULPGC (Spain)
Rut	Pedrosa Pámies	MBL (USA)
Elisenda	Ballesté Pau	Universitat de Barcelona (Spain)
Sólveig	Ólafsdóttir	HAFRO-MFRI (Iceland)
Andreas	Macrander	HAFRO-MFRI (Iceland)
Steinunn	Ólafsdóttir	HAFRO-MFRI (Iceland)
Angel	Ruiz Angulo	University of Iceland (Iceland)
Anna	Wahlin	University of Gothenburg (Sweden)
Karl	Adam Ulfsbo	University of Gothenburg (Sweden)
Eleanor	Frajka-Williams	University of Hamburg (Germany)
Wilken-Jon	von Appen	AWI (Germany)
Xavier	Durrieu de Madron	CEFREM (France)

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5. Daily operations (narrative)

July 19, 2023:

Initiation of the survey, departing from the port of Reykjavik at 11:30, with navigation to the first CTD station, with good weather. At 12:14, data recording initiated for multibeam mapping. Following this, from 14:03 until midnight, the parasound system was connected.

July 20, 2023:

Navigation and recovery of water samples at the first CTD station, with SVP measurements to correct the multibeam bathymetric data. At 12:00, operations encompassing CTD measurements and Monocore (MoC) sediment sampling commenced. Following this, navigation directed the vessel to the designated mooring position from 13:14 to 14:30, leading to the successful deployment of the mooring at 2:47 PM. The mooring was named “FD-DS-HR”, as it had to monitor the DSO during 12 days at high resolution. Subsequently, the vessel changed course towards the FDDS1_001_CTD location. At 15:46, the multibeam echosounder and parasound systems were restarted. Unfortunately, due to potential positional and date inconsistencies, the reliability of previously recorded data was compromised. At 09:00 we are informed that the Dynamic Positioning of the vessel is not operative. Additionally, the slave LADCP attached to the CTD rosette failed. Experiments were also conducted to enhance the data quality of the sADCPs by adjusting their position with respect to the vessel hull, but the results were not conclusive. Good weather.

July 21, 2023:

At 07:42, CTD operations commenced with CTD_001, followed by navigational transitions to successive CTD stations, separated 7 km apart. Noteworthy moments include the occurrence of aborted CTD_008 due to sensor discrepancy. Furthermore, consecutive MoC operations did not successfully retrieve sediment. As a result, the decision was made to employ a VanVeen (VV) grab for seafloor sampling (the velocity of cable deployment for VV stations was set to 40 m/min). This effort yielded coarse sediment and rounded large pebbles containing abundant fauna. We were notified that we lacked permission from the Spanish Dirección General de la Marina Mercante to navigate north of the latitude 66.283ºN. This posed a challenge to certain aspects of the cruise objectives. In response, the chief scientists communicated with the vessel operator to address this issue and explore options for rectifying this limitation, aiming to proceed with the original plan (the permit was obtained in 26/07). Good weather.

July 22, 2023:

Continued CTD deployments, water sampling, and transits to different stations. We identified and resolved the issue with the multibeam echosounder at 15:56. The problem was attributed to a synchronization mismatch of clocks. 18:30 UTM technicians figured out that the configuration of the CTD is not updated and they fix it. Good weather but with dense fog.

July 23, 2023:

CTD operations are ongoing. At 19:00, the UTM technicians identified an issue with the winch revolution counter calibration and initiated efforts to rectify it. By 23:00, the gravity core (GC) FDDS1-043-GC became bent because of sampling in overconsolidated mud (the velocity of cable deployment for GC stations was set to 80 m/min). Good weather but with dense fog.

July 24, 2023:

At 09:00, the first iceberg was sighted. By 16:50, we conducted a transition to reach the location of mooring A (high-resolution) for the purpose of performing a CTD operation to calibrate the sensors. Following that, our course was directed towards the deeper regions in the southern end of the Denmark Strait, with plans to execute three successive CTD stations along the DSO route. Good weather.

July 25, 2023:

CTD deployments were ongoing, accompanied by multiple successful Van Veen (VV) and gravity core (GC) sediment sampling operations. At 18:00, we received news that the vessel's Dynamic Positioning system had been restored to working condition. Good weather.

July 26, 2023:

CTD stations persisted until 19:00, at which point deployment had to be halted due to inclement weather. Our focus shifted to the multibeam survey zone situated in the deep region near the outlet of the DS sill. The objective was to create a high-resolution bathymetric map of an area that displayed remarkably substantial sediment bedforms, some reaching heights of up to 90 meters. A small part of the area was mapped a few days before at centimetric resolution by the AUV Kongsberg Hugin Ran of the University of Gothenburg, onboard RV Skagerak, in the framework of a collaboration with FAR-DWO DS1. We obtained the permission from the Spanish Dirección General de la Marina Mercante to navigate north of the latitude 66.283ºN.

July 27, 2023:

The bad weather persisted and we continued the multibeam survey. Our mapping area expanded to encompass the central area of the Denmark Strait sill.

July 28, 2023:

Weather improved and we concluded multibeam survey operations and resumed CTD deployments. To accommodate a pH sensor, one of the two Seapoint turbidity sensors on the rosette was disconnected.

July 29-31, 2023:

Favourable weather conditions prevailed as we caught sight of Greenland for the very first time. The occurrence of icebergs and occasional fog banks forced to decrease our navigation speed and relocate stations and transits nearer to the Greenland coastline. In CTD 080 anomalies in the Seapoint turbidity sensor data exhibited spikes in the recorded graph. The wiring configuration was scrutinized, connectors underwent re-lubrication, and subsequent reconnection was executed. In CTD093 a corrupted file stopped from LADCP Slave, preventing data collection. Also file 059 was identified as corrupt and was removed. In CTD097 the Slave file 065 displayed a discrepancy of 20 minutes in recorded data, indicating malfunctioning of the header. The problem remained in the successive casts, so it was decided to remove the Slave transducer. In CTD113 the Slave module was reinstalled after comprehensive verification of surface equipment functionality, with positive results.

Unfortunately, the multibeam .s7k files were unintentionally erased from the acquisition data folder, causing the omission of transit lines from the last surveyed area towards the Greenland coast, spanning from approximately 29/07 around 20:00 to 01/08 around 00:00.

August 01, 2023:

We proceeded as scheduled with the CTD stations, traversing the East Greenland Shelf under favorable weather conditions. However, two stations (see annexes) encountered again acquisition issues with the LADCP and was removed from the rosette. Regrettably, the problems with the gravity core winch persisted, and despite seeking remote support from the supplier, the issue could not be resolved.

August 02, 2023:

Recuperation of the mooring FD-DS-HR, starting at 08:30. We did two CTD stations prior to the release of the mooring to calibrate the sensors. To avoid problems Once the mooring was onboard we continued with CTD deployments, with good weather, followed by a multibeam survey across the slope in front of the Kangerlussuaq Trough.

August 03, 2023:

At 09:00 deployment operations for FD-DS-B (UB) commenced under favorable weather conditions, achieving successful deployment at a water depth of 1870 meters. The mooring's final position was established at coordinates 65°01.610'N, 31°22.209'W. Following the accomplished deployment, our trajectory directed us towards the location of FD-DS-A (IFREMER+UB) and water depth of 1370 m, reaching the site at 11:44. The mooring's final position was confirmed at coordinates 65°14.637'N, 31°19.060'W. Subsequently, we directed towards resuming multibeam echosounder and parasound survey activities.

August 4-5, 2023:

Continuing under favorable weather conditions, we proceeded with the multibeam echosounder and parasound surveys, ultimately concluding these operations on the 05/087 at 03:24. At this point, we initiated the transit towards CTD station 130. In tandem with the CTD water sampling activities, we achieved successful retrievals of both gravity cores and multi cores.

August 6, 2023:

By 06:30, the CTD section crossing Kangerlussuaq Trough had been successfully completed, prompting our transition to the deeper sector of the study region. Subsequently, we conducted a gravity core operation at station 126, a task previously hindered by winch-related issues. Although sediment recovery proved successful, the process was very slow due to ongoing winch challenges. Following this, we started the final CTD section, focusing on the deep end of the southern segment of the Denmark Strait.

August 7-8, 2023:

CTD deployments were ongoing with good weather. After a long journey of repairing the UTM technicians managed to fix the problem with the winch and we could do a gravity core sampling station at 2300 m water depth, at 22:15. In 08/08 we noticed that the two MiliQ systems in the lab stopped working.

August 9, 2023:

We proceeded with the CTD operations towards the Icelandic coast and set 21:00 as the determined time to finalize the scientific tasks and begin the transit to Reykjavik. Unfortunately, due to an unfavorable weather forecast in the study area that impeded further work, we had to adjust the cruise's end date from August 12th to August 10th.

August 10, 2023:

We reached the Reykjavik port at 09:00 AM, successfully completing all tasks, including the proper packaging of instruments and samples, as well as tidying up the laboratories.

6. Methodology and preliminary results

6.1. Lowered CTD (rosette)

6.1.1. System and operations

During the FARDWO-DS1 cruise we conducted hydrographic measurements using a CTD SBE 9plus System. In total, 190 CTD stations were carried out at the Denmark Strait area. The SBE9plus CTD unit was mounted on a rosette with a carousel of 24 x 12L Niskin bottles for seawater sampling.

The CTD stack was equipped with dual sensors for temperature and conductivity, as well as one sensor for oxygen and pressure. Additional sensors mounted on the CTD were: 3x turbidimeters, 1x transmissometer, 1x fluorometer, and a PAR/irradiance sensor. Details of the sensors with serial numbers and calibration dates can be found in Table 5.1.1.1. In addition, ocean current velocities were measured using two ADCPs attached to the CTD frame, one upward-looking (slave) and the other downward-looking (master). Also, a downward-looking altimeter with a range of about 100 m measured the distance to the bottom for safe handling the CTD. Distance from bottom ranged between 7-10m depending on weather conditions and deep-sea current velocities.

For data logging and triggering of the water samples, the vessel's CTD deck unit was used. Data was recorded and displayed in the SeaSaveV7.26 software. Time and ship's location were taken from the ship's navigational system (NMEA). CTD file naming convention included the cruise identifier (FDDS1), the station number (XXX, three digits), and type of

Table 1. Serial number and calibration dates of all CTD sensors attached to the rosette.

Device	Type	SN and calibration date
CTD	SBE 9plus	S/N 09P44540-0851
CTD-Sensors	Temperature 1	4669, Cal. Date 06-Oct-21
	Conductivity 1	3289, Cal. Date 07-Oct-21
	Pressure, Digiquartz with TC	0852, Cal. Date 09-Nov-21
	Temperature 2	4747, Cal. Date 17-Mar-23
	Conductivity 2	3361, Cal. Date 21-Feb-23
Oxygen	SBE43	1980, Cal. Date 25-Mar-23
Turbidity	SeaPoint 1	11107, Gain 100x
	SeaPoint 2	T004 (UB), Gain 20x
	WET Labs ECO-NTU	6268, Cal. Date 04-Jun-20
Transmissivity	Transmissometer WET Labs C-Star	1013, Cal. Date 25-Jul-22
Fluorescence	WET Labs ECO-AFL/FL	6268, Cal. Date 04-Jun-20
PAR/Irradiance	Biospherical/Licor	70676, Cal. Date 16-Sep-19
pH	AMT	0339, Cal. Date 06-Nov-19
Altimeter	PSA-900	40396, Cal. Date 14-Jun-19
Rosette	SBE Carousel	24 bottles of 12L

operation (CTD), leading to FDDS1_XXX_CTD. All CTD stations and the samples taken at the respective stations are listed in Table 3.

Incidences during the CTD stations:

- Between CTD_000 and CTD_013, we observe very noisy and spiky turbidity data from the two SeaPoint turbidity sensors, which were attached to the CTD with 100x gain cables. We decide to check the cables of both turbidity sensors.
- At station CTD_014, after changing the gain cables, the new configuration is gain 100x for the SeaPoint 2 sensor, and gain 20x for the SeaPoint 1 sensor.
- After station CTD_019, the conductivity sensor 2 with S/N 3302 is changed by a new conductivity sensor 2 with S/N 3361.
- Between station CTD_023 and station CTD_024, the temperature sensor 2 with S/N 4721 is replaced by a new temperature sensor with S/N 4747. So that, the new dual temperature and conductivity sensor package from station CTD_024 states as following: Temperature 2 (S/N 4747) and Conductivity 2 (S/N 3361).
- At station CTD_066, the SeaPoint sensor 2 (owned by the GRCGM-UB) is removed from the CTD to be deployed in mooring FD-DS-B and is replaced by a pH sensor (S/N 0339).

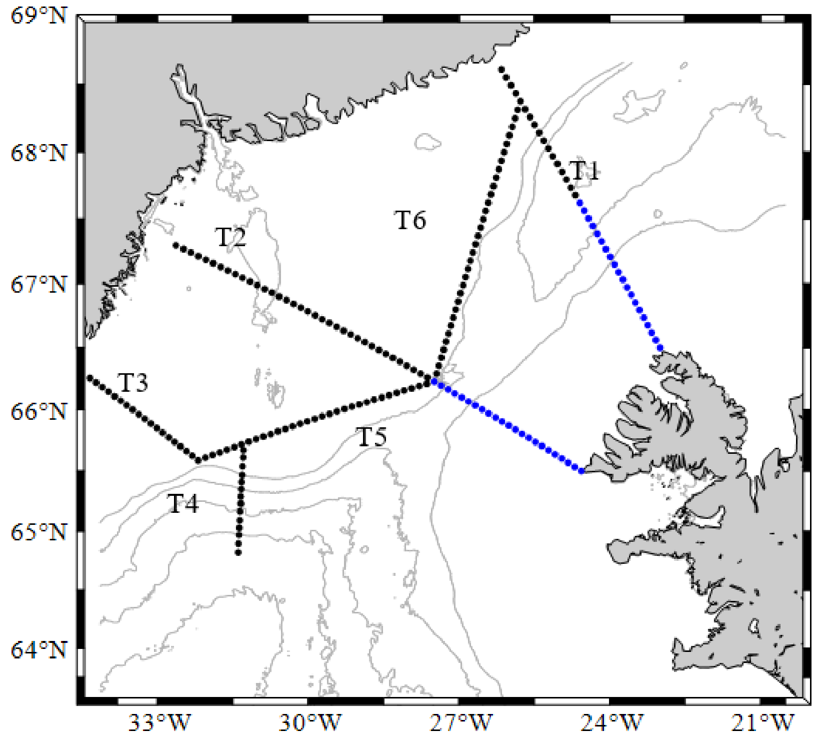


Figure 3. Original plan of the stations location. Blue dots represent the stations that match with the hydrographic sections carried out by MFRI. T1: Transect 1. T2: Transect 2. T3: Transect 3. T4: Transect 4. T5: Transect 5. T6: Transect 6.

6.1.2. Stations design

Figure 3 shows the location of the different CTD stations corresponding to the original cruise planning, designed with a spatial resolution of ~7 km in order to resolve mesoscale features. Blue dots indicate CTD stations that correspond with the hydrographic sections carried out by the Marine and Freshwater Research Institute (MFRI). This institute surveys different sections around Iceland every 3 months to monitor territorial waters. This will allow for great intercomparability of the results in FARDWO-DS1 cruise with the data collected by the MFRI.

Among the main scientific goals is the use of an inverse box model and to estimate geostrophic transports. That requires “closed boxes” in the CTD station design, closing both with Iceland and Greenland coasts. In this way, we obtain a kind of box in which we can study the inflows of the North Icelandic Irminger Current (NIIC), the flux towards lower latitudes of the East Greenland Current (EGC) and the outflow of the DSO.

Transect T4 (Figure 3) is of interest because it corresponds to the moorings deployment zone in order to study the overflow of dense shelf waters, particle transports and erosional features on the seabed. For this reason, another box is closed with the T3 and T5, so that the inverse model can be used to study the flow coming from the Greenland continental shelf and continuing southwards. It will also show how much of these dense waters flow in the direction of the mooring arrays.

Shortly after cruise departure on 19/07/2023 we were informed that we do not had the appropriate permits to sail north of 66º17’N. Therefore, the CTD sampling plan was modified according to Figure 4. The transects T5 and T6 from Figure 3 are relocated in Figure 4. A new transect across the Kangerlussuaq Trough will allow to study further bathymetric

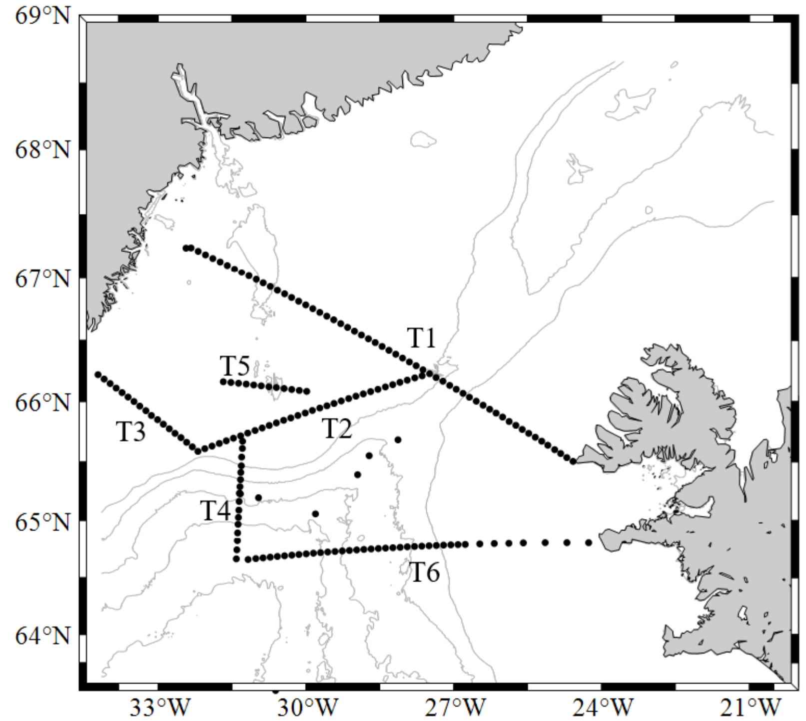


Figure 4. Final CTD station location. T1: Transect 1. T2: Transect 2. T3: Transect 3. T4: Transect 4. T5: Transect 5. T6: Transect 6.

constraints in the dense shelf water transport. With the new transect T6, both the NIIC and the DSOW are crossed both on a northern and a southern section. In addition, it will also be possible to study the directionality of the DSOW once ~65ºN is reached.

6.1.3. CTD data processing and performance assessment

6.1.3.1. Routines for CTD raw data processing

Once the raw files (.btl, .hex, .hdr, .xmlcon) have been obtained at each CTD station, raw data are processed so that they have a suitable format for their treatment and analysis. For this we use the Sea-Bird SEASOFT software package (SBEDataProcessing_Win32) from which a .cnv file with the corresponding processed data will be obtained. In turn, this .cnv file can be split into two files:

- One with the data only (.asc)
- Another one with the header (.hdr) which now contains the final information of the CTD and the processing.

The processing of the data will depend on the CTD used during the cruise. During the FARDWO-DS1 cruise, the SBE9plus was used, so the processing was carried out in the following way:

1. Data Conversion: converts raw data (.hex) into physical data (engineering data .cnv).

    a. Output format: ASCII output

    b. Convert data from: Upcast and downcast

    c. Create file types: Create converted data (CNV) file only

    d. Source of start time in output .cnv header: Instrument's time stamp

    e. Select Output Variables: choose the variables corresponding to the sensors present in the CTD (e.g. Pressure, Digiquartz [db]; Temperature [ITS-90, deg C]; Salinity, Ptractical [PSU]; Oxygen, SBE 43 [mmol/kg]; ...) In the case of oxygen, a window will open to apply the Tau and hysteresis correction.

2. Filter. Filtering is done for two reasons; the first is to match the time constants of temperature and conductivity. The second is to smooth the pressure signal to remove 'loops' in the data using the loopedit module. The values used depend on the CTD used.

    a. Low pass filter A: 0.15 s, applied to pressure only.

    b. Low pass filter B: 0.00 s, not applied to any constant.

3. Align the CTD sensors. Not all sensors measure at the same rate and there may be small gaps between the readings of one instrument and another at the same pressure level (due to the placement of the sensors in the CTD). It is therefore useful to carry out a series of filtering operations to eliminate or smooth out this type of inconsistency and odd peaks by applying an advance of the variables with respect to the pressure from:

    a. Temperature: 0s

    b. Conductivity: 0.1s
    c. Oxygen: 2-5s

4. Cell thermal mass. Correct the thermal mass of the conductivity cell.
    a. Alpha= 0.03
    b. 1/beta= 7.0
5. Loop Edit. To eliminate small loops consisting of rising and falling pressures.
    a. Minimum CTD velocity (m/s): 0.25
    b. Surface soak depth: 10
    c. Minimum soak depth: 5
    d. Maximum soak depth: 20
6. Derive. Calculate potential temperature, density and other oceanographic parameters.

    a. Choose the parameters of interest for the study.

7. Derive TEOS-10. Calculation of oceanographic parameters using the TEOS-10 (2010) algorithms of the equation of state of seawater.

    a. Parameters of interest for the study are chosen (e.g. absolute salinity, conservative temperature...).

8. Bin Average. To make an interpolation and calculation of the data every x meters of depth, allowing us to have certain data at a certain depth in all the stations. The interval (in meters) that is chosen depends on the vertical spatial scale of the process to be studied. For the preliminary data shown below bin average was calculated every 1m depth. For other puposes bin average was calculated in pressure every 10db, both for downcast and upcast.

9. Bouyancy. Used for the calculation of stability (10-8 rad2/m) and Brünt-Väisälá Frequency, (N, cycles/hour). Typically calculated with pressure interpolated data.

10. ASCII Out. Used to split the file into two files, one with the header information (.hdr extension) and one with the data (.asc extension).

6.1.3.2. Assessment of CTD sensor performance and stability

In order to quantify sensor stability and potential drifts in the measurements we compare two pairs of sensors for temperature and conductivity mounted at the bottom of the rosette frame. Both pairs of sensors are located at identical positions into the rosette, therefore no large differences are expected due to sensor location and differences will be likely attributed to sensor instability and/or measurement drift. Comparisons are only done at the Niskin bottle stops during the upcast (for bottle depth details see Table 2).

In Figure 5 the temporal evolution of the differences between the two temperature, conductivity and salinity values is shown. For temperature, we find a standard deviation of 0.06 ºC around the mean value of 0.004 ºC. For conductivity, the behaviour is quite similar with a mean value of -0.0014 mS/cm and a standard deviation of 0.0484 mS/cm. The computed salinity differences yield a standard deviation of 0.0211 psu around the mean difference of -0.0054 psu. There are no significant evidences of sensor drifts during the monitored period.

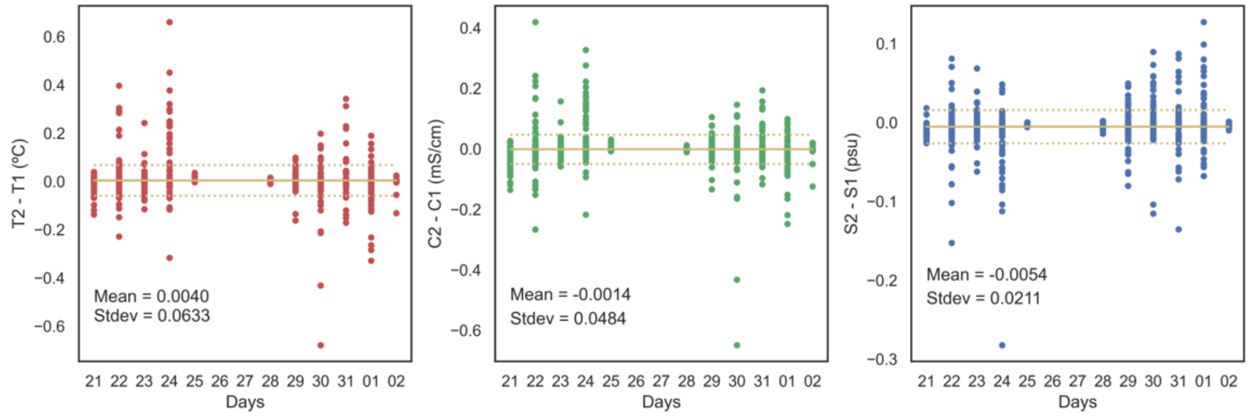


Figure 5. Differences between sensor measurements of temperature (red), conductivity (green) and calculated salinity (blue) at bottle stops during the cruise. No significant sensor drifts are observed. Mean sensor differences and standard deviations (1σ) are indicated in each case.

In Figure 6 the behavior of the same sensor differences is shown as a function of water depth. It is clear that the largest differences appear at small depths (<300 m). These differences could be attributed to different factors such as the steeper vertical hydrographic gradients at shallow waters (see preliminary results section) and small differences in the response times of the paired sensors. Offsets cannot be attributed to sensor positioning as each pair is mounted at exactly the same height in the rosette frame.

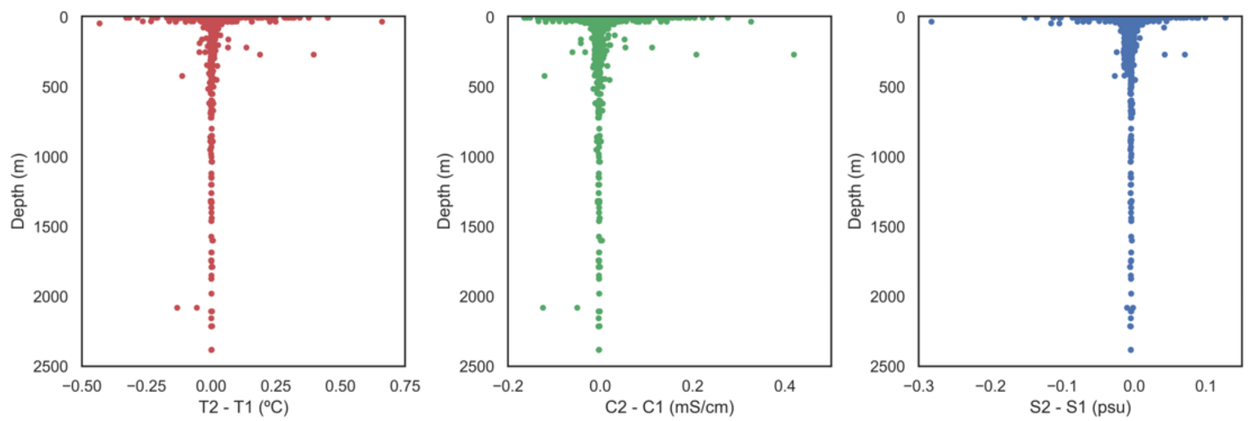


Figure 6. Differences between sensor measurements of temperature (red), conductivity (green) and calculated salinity (blue) at bottle stops versus water depth. Sensor differences are more evident in shallow waters (<300 m) than at greater depths. Very low and high values are not shown.

6.1.3.3. Salinity and Oxygen calibrations

No calibrations with in-situ seawater samples were performed for conductivity and/or dissolved oxygen content measurements during the cruise. Measurements rely entirely on the instrumental calibrations performed for each sensor as reported in the System and Operation section 5.1.1.

6.1.3.4. pH sensor

As requested during the cruise planning a dedicated pH sensor was mounted in the CTD frame replacing a redundant Seapoint turbidity sensor. This swap took place at Station 066. After a few casts it was evident that the default factory calibration of the pH sensor was not working properly, therefore we recorded systematically the CTD voltage output #2 (0 – 5V) to be calibrated at a later time. During a cruise transit on Aug 4th we attempted to calibrate the pH sensor following the AMT manual procedure with the UTM technical staff and using certified pH standard solutions (3.00, 4.01, 7.01) provided by L. Pena (UB). Calibrations calculations are shown below and linear regression line in Figure 7.

However, at most stations, the voltages measured by the pH sensor(4 – 5 V))(Figure 7) were much higher than the expected values corresponding to a typical seawater pH ~ 8.1 – 8.3. In some cases, the pH sensor saturated at voltages of 5 during the entire cast. Therefore we

Formulas for calibration, measurement and temperature compensation:

$U = a_1 (pH-7) + a_0$ (1, linear regression calibration)

$a_1(20°C) = a_1(T) \times f(T)$ (2, sensor slope at 20°C)

$pH = \frac{f(T)(U-a_0)}{a_1(20°C)} + 7$ (3, pH-value calculation)

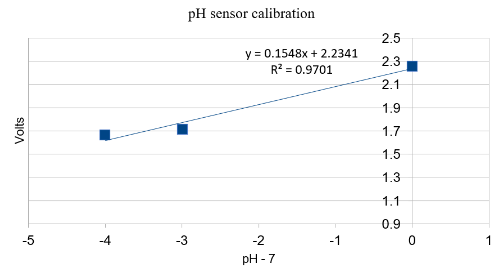
$f(T) = A_0+A_1T+A_2T^2$ (4, temperature correction factor)

with: $A_0 = 1.0732$

$A_1 = -3.9093 \times 10^{-3}$

$A_2 = 1.2333 \times 10^{-5}$

T measuring temperature in °C
U measured voltage (output signal of pH-sensor)
a_1 coefficient of linear regression (slope), equation 1
a_0 coefficient of linear regression, equation 1
f(T) temperature correction factor (Nernst factor)
$A_0...A_2$ coefficients for f(T) equation



pH	Volt	Temp
3	1.6618	17.7
4.01	1.7082	16.6
7.01	2.2515	16.7

f(T)	Ai(20)	pH-7
1.0078691956	0.1560625607	-4
1.0117041015	0.1566563731	-2.99
1.0113542404	0.1566021992	0.01

Figure 7. Linear fit of the pH sensor calibration as measured onboard in order to try to obtain reliable pH measurements.

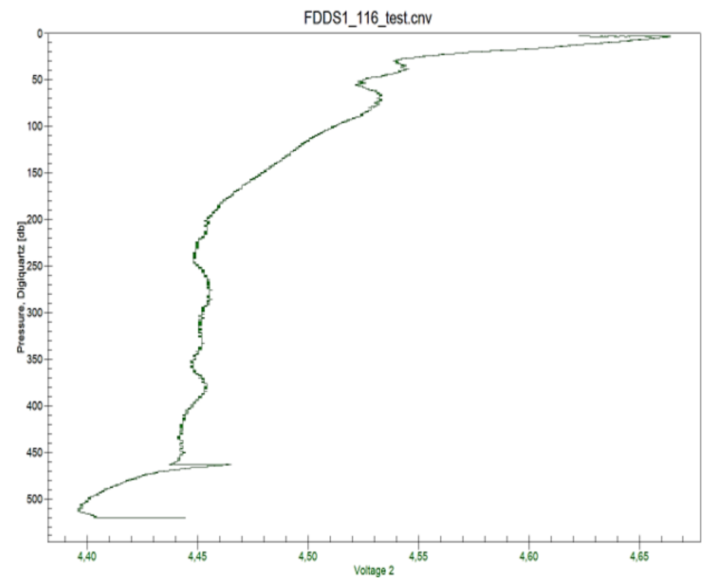


Figure 8. pH sensor voltage profile at Station 116 as an example of voltage outputs to be compared with calibration.

concluded that the pH sensor was malfunctioning and it was disconnected from the CTD array in Aug 4th.

6.1.4. Lowered Acoustic Doppler Current Profiler (LADCP)

Two Acoustic Doppler Current Profilers (ADCP) were mounted on the CTD rosette in order to obtain full-depth current profiles at each oceanographic station. The ADCPs used were 300 kHz Workhorse Monitor (Teledyne RD Instruments). The two ADCPs were configured to sample in master/slave mode to ensure synchronization. The master ADCP was the down-looker (serial number 15016) and the slave was the up-looker (s/n 24479). An external battery case supplied energy to both units.

Communication with the instruments, start-and-stop data acquisition and data download were carried out by means of the BBTalk software.

The vertical bin size was set to 8 m for both ADCPs. Single ping data were recorded in narrow bandwidth to increase range. Data was acquired in beam coordinates, with blank distance set to 8 m. More details about the configuration can be found in the scripts sent to the ADCPs before every cast, which were unaltered throughout the cruise and are shown as annexes.

Due to frequent technical problems with the upward-looking unit, the respective CTD, master and slave numbers do not necessarily match. The equivalences between them are detailed in Table X1.

L-ADCP data was processed with the LDEO_IX. 14 implementation of the velocity inverse method [1, 2]. For each master/slave profile data, synchronized time series of CTD and navigation data were added during ADCP processing as 1-second bin averages. Relevant LADCP processing steps of the CTD data include the following steps in SBE Data Processing software: Data Conversion, Wild Edit, and Bin Average (1 s). Data from the Vessel-Mounted

Figure 9. Locations (blue arrows) of the upward and downward looking ADCPs installed in the CTD-rosette ensemble. The external battery canister is marked with an orange arrow.

ADCP were also used for additional constraint on the processing of the LADCP data. These were obtained using the CODAS software [3] departing from the .LTA files output by VmDas. The LDEO software package comprises a set of Matlab® routines which output velocity data and up to 14 figures providing data visualization and diagnostics. From these, Figure 10, which offers a comprehensive summary of the velocity profile and its associated errors, is shown for every L-ADCP profile conducted during the survey (see annexes). Preliminary sections of zonal and meridional transects during the survey using L-ADCP data are shown in annexes.

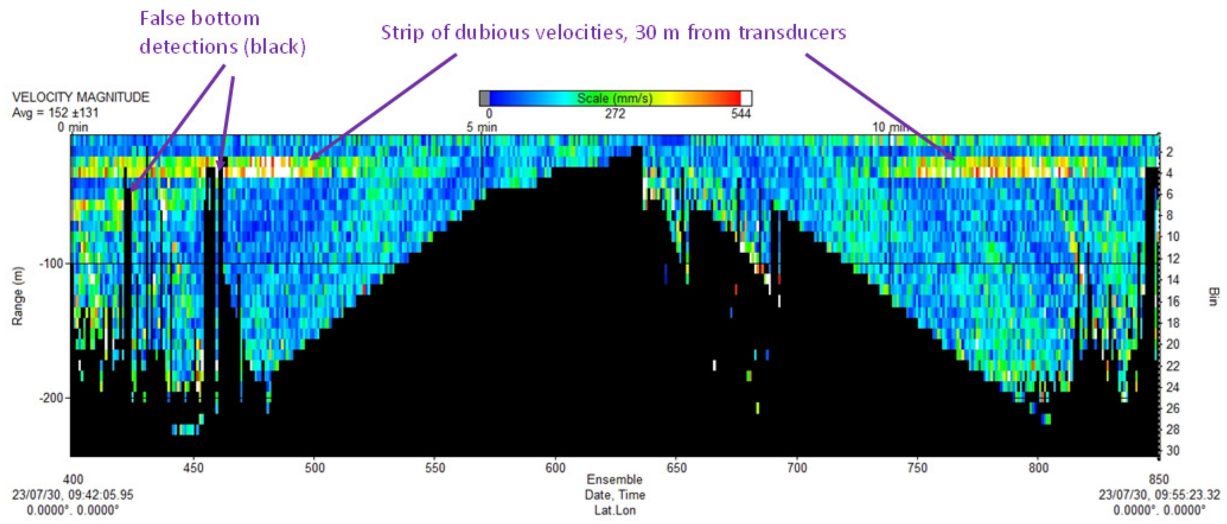


Figure 10. Example of Master ADCP preliminary data (contour of unfiltered, non-referenced velocity magnitude), corresponding to CTD station #93 and Master ADCP file #99.

6.1.4.1. Caveats and incidents

- From the first profiles, Master ADCP had a weak beam #3 (as recurrently reported by the LDEO software diagnostics). Although the ADCP can and will automatically calculate velocities from 3-beam solutions (fourth beam is redundant), this is a technical issue, most probably related to the hardware, that should be checked for future surveys.
- The slave (upward-looking) ADCP presented frequent technical problems and was detached several times from the rosette for maintenance. The usability of slave profiles from stations 0-10 is limited due to noisy and often, to prematurely interrupted and/or split cast files profiles (acquisition failed and resumed abruptly due to unknown reasons). Valid L-ADCP slave profiles are available mostly for stations 59-95 (according to CTD number reference, see Table 2).
- NMEA GPS data embedded within hexadecimal CTD data files was in certain cases too sloppy and impaired the results. It is recommended to use, or at least consider where necessary, the original navigation data which the SADO (the ship's real-time data compiler system) makes available both as raw data and as daily reports of 1-second averaged intervals.

- Caution should be taken while processing/interpreting master ADCP data from stations where the monocorer was used (check the general survey logsheet). The presence of the monocorer is not straightforward from some echo/correlation profiles, while in other stations it is evident as a band of incoherent relative velocities and false bottom detections at the approximate distance of the object from the transducers (Figure 9). Acoustic beams might be affected beyond the actual distance of a large artificial scatterer placed in its path (TRDI Application Note FSA-019, 11/2002) and there are no post-processing instructions from the manfacturer.

6.1.5. Preliminary results

Preliminary CTD hydrographic information is shown here using the CTD processed data described in section 6.3.1. In order to construct the hydrographic sections CTD station data is interpolated linearly following a custom gridding based on section length (km) and maximum depth (m). Given the steep isopycnal gradient in this region it is necessary to perform a further isopycnal gridding that estimates more reliably the isopycnal mixing of the different water parcels at each section. Gridding and plotting of the sections has been carried out using custom Python language scripts.

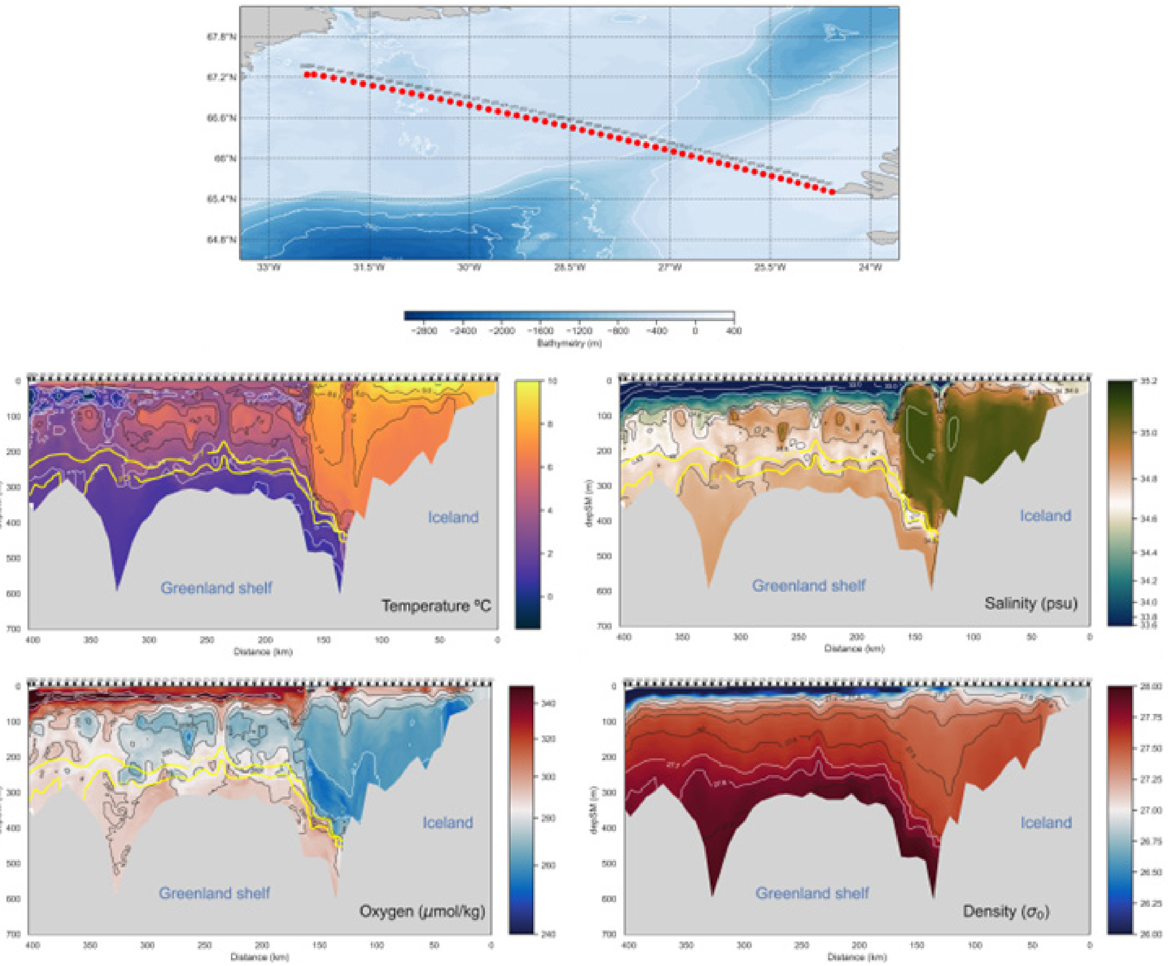


Figure 11. Section 1 Hydrographic parameters. CTD station numbers are indicated. Top-left: Temperature; Top-right: Salinity; Bottom-left: Oxygen; Bottom-right: Density annomaly. σ0 = 27.7 and 27.8 isopycnals are highlighted in yellow.

6.1.5.1. Section 1

This section (Figure 11) was completed in SE – NW direction stretching two separate legs:

- Leg 1: St_001 to St_023 (21-22/07/2023, 65º30,17'N, 24º34,57'W - 66º13,74'N, 27º29,33'W)
- Leg 2: St_061 to St_095 (28-30/07/2023, 65º15,63'N, 27º37,39'W - 67º14,42'N, 32º25,93'W)

Section 1 main features: Hydrographic work across the Denmark Strait (DS) focused on capturing and describing the dense waters descending into the Atlantic Ocean from the Denmark Strait sill as well as the Greenland shelf dense water jets. CTD sampling resolution (~7km) is enough to capture detailed hydrographic features. Relatively warm and saline northward flowing water from the Icelandic sector of the Irminger Current (IC) is found at the eastmost part of the section. The IC is separated by a sharp hydrographic front in T, S and Oxygen content around km 160 in the section. On the NW side of the front, southward flowing waters from the Nordic Seas are clearly described as colder, fresher and oxygen rich values. At the deepest sector of the sill and over a large extension in the Greenlad shelf the core of the overflow water are clearly seen with cold waters (-1.5 to 0ºC), intermediate salinity (>34.9psu) and oxygen rich (>300µmol/kg). The isopycnals σ0=27.8 and 27.7 kg/m3 are shown in yellow, the first one typically marking the upper limit of the DSO and the second one the "fresh water" cap that is typically described in this region above the DSO.

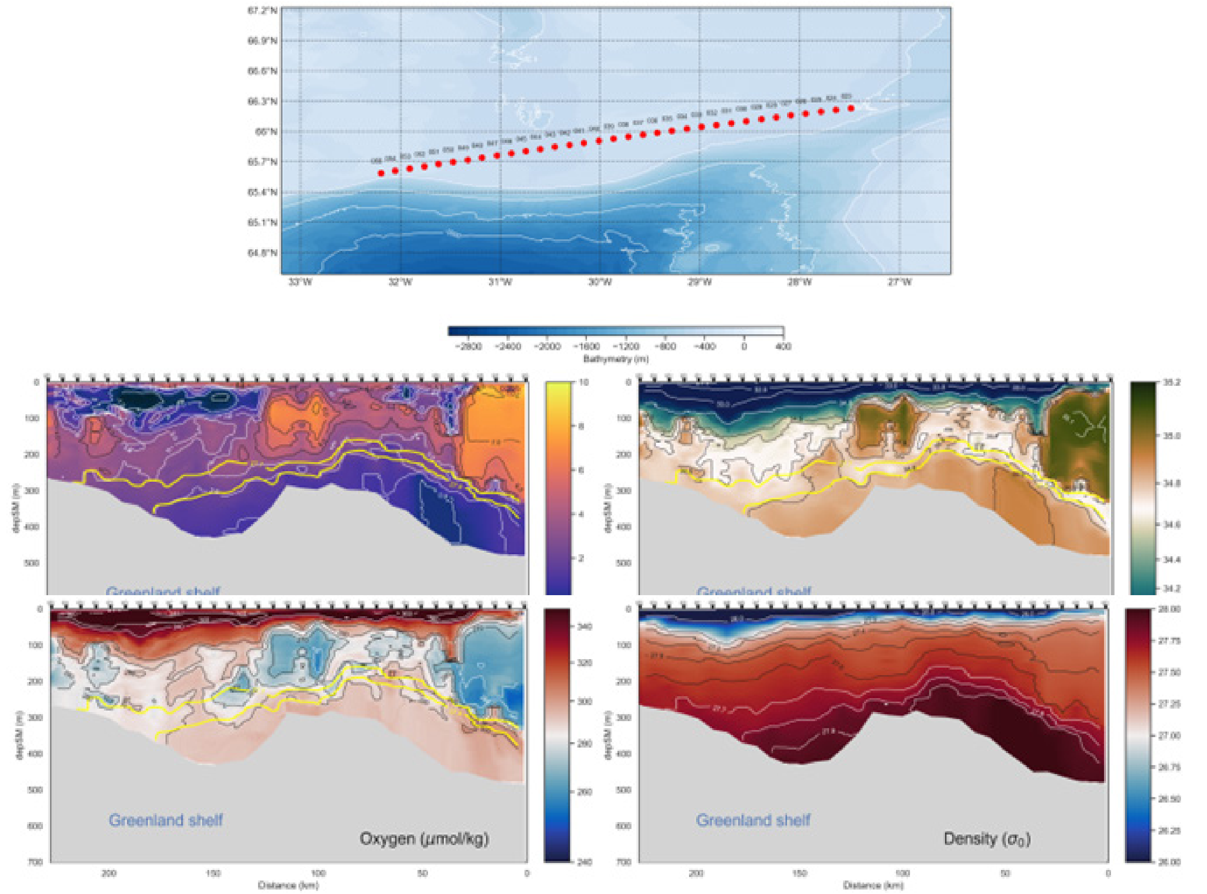


Figure 12. Section 2 Hydrographic parameters. CTD station numbers are indicated. Top-left: Temperature; Top-right: Salinity; Bottom-left: Oxygen; Bottom-right: Density annomaly. σ0 = 27.7 and 27.8 isopycnals are highlighted in yellow

In the upper water column, on the Greenland shelf, a lens of colder waters (temperatures below 2°C) are found at depths shallower than 100 m, which is characterized by low salinities. In between those colder, subsurface waters and the dense plume, there are patches of increased temperature and salinity, corresponding possibly to diluted, recirculating branches of the warm Irminger waters.

6.1.5.2. Section 2

This section (Figure 12) was completed in NE – SW direction and comprises CTD stations St_023 to St_055 (22-24/07/2023, 66º13,74'N, 27º29,33'W – 65º36,23'N, 32º11,43'W)

Section 2 main features: Hydrographic work along the Greenland Shelf (GS) focused on capturing and describing the shallow dense water jets that eventually spill into the DSO along its southward path. Section 2 clearly shows a large volume of dense overflow waters (σ0 > 27.8) on the shelf as well as into the DSO. A stronger fresh water lens between 150 -20m is clearly seen at the SW sector, followed by patches of warm-salty and less oxygenated waters likely from recirculated IC branches.

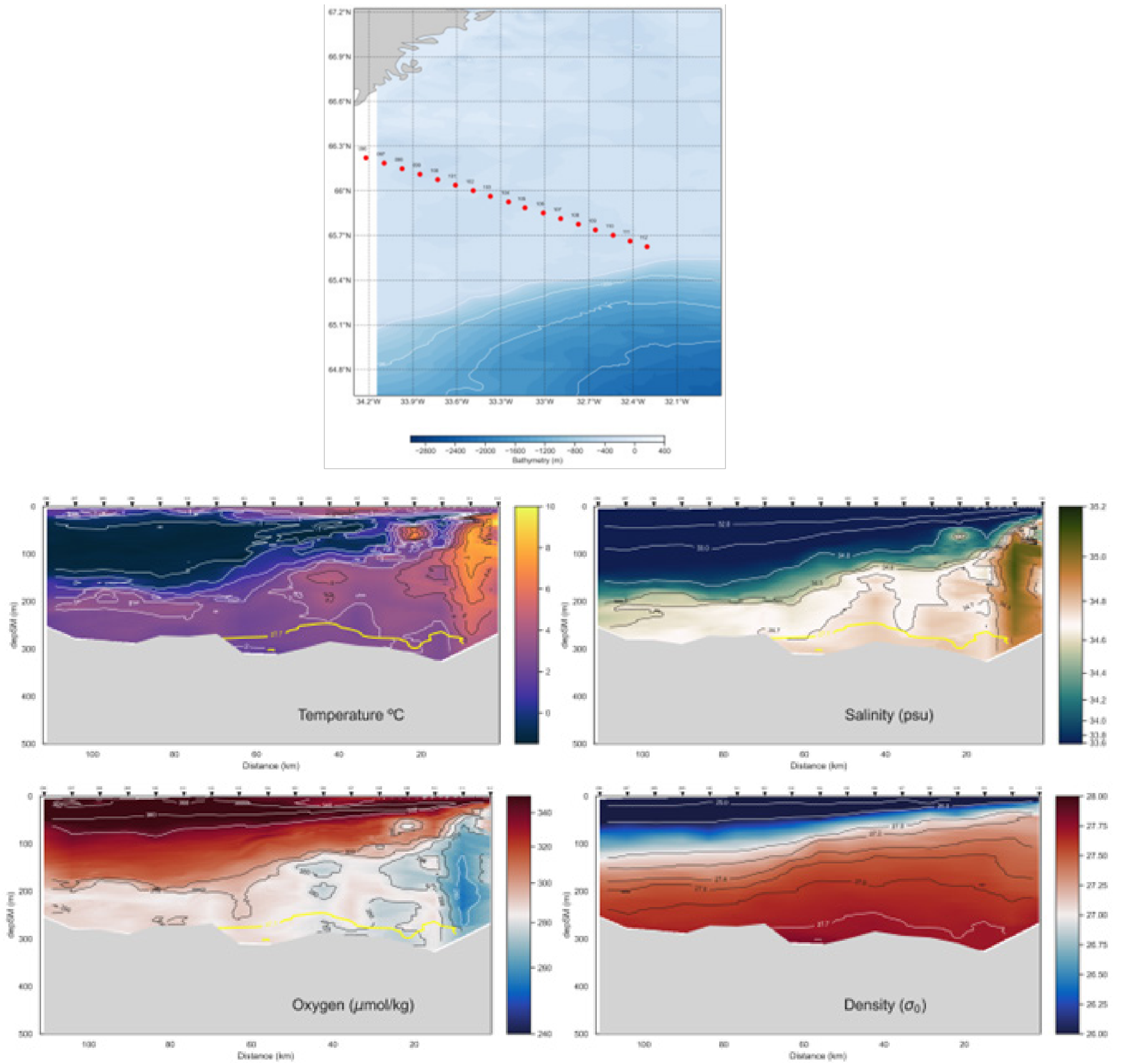


Figure 13. Section 3 Hydrographic parameters. CTD station numbers are indicated. Top-left: Temperature; Top-right: Salinity; Bottom-left: Oxygen; Bottom-right: Density annomaly. σ0 = 27.7 and 27.8 isopycnals are highlighted in yellow

6.1.5.3. Section 3

This section (Figure 13) was completed in NW – SE direction and comprises CTD stations St_096 to St_112 (30-31/07/2023, 66º13,27'N,34º13,14'W – 65º37,48'N, 32º18,30'W).

Section 3 main features: Hydrographic work across the Greenland Shelf (GS) already defined a thick (150m) and extended fresh (<32psu) and cold (< -1ºC) water tongue. The southernmost sector depicts a hydrographic front with the northward flowing IC branch, as shown in temperature, salinity and oxygen.

6.1.5.4. Section 4

This section (Figure 14) was completed in N – S direction and comprises CTD stations St_113 to St_129 (31/07/2023 - 02/08/2023, 65º40,28'N, 31º17,10'W - 64º39,82'N, 31º24,66'W).

Section 4 main features: This hydrographic section is located along the two mooring lines deployed and it has helped to define the final position of the different sensors in the mooring arrays. The overflow waters mixes along on its southward path and DSO generally freshens

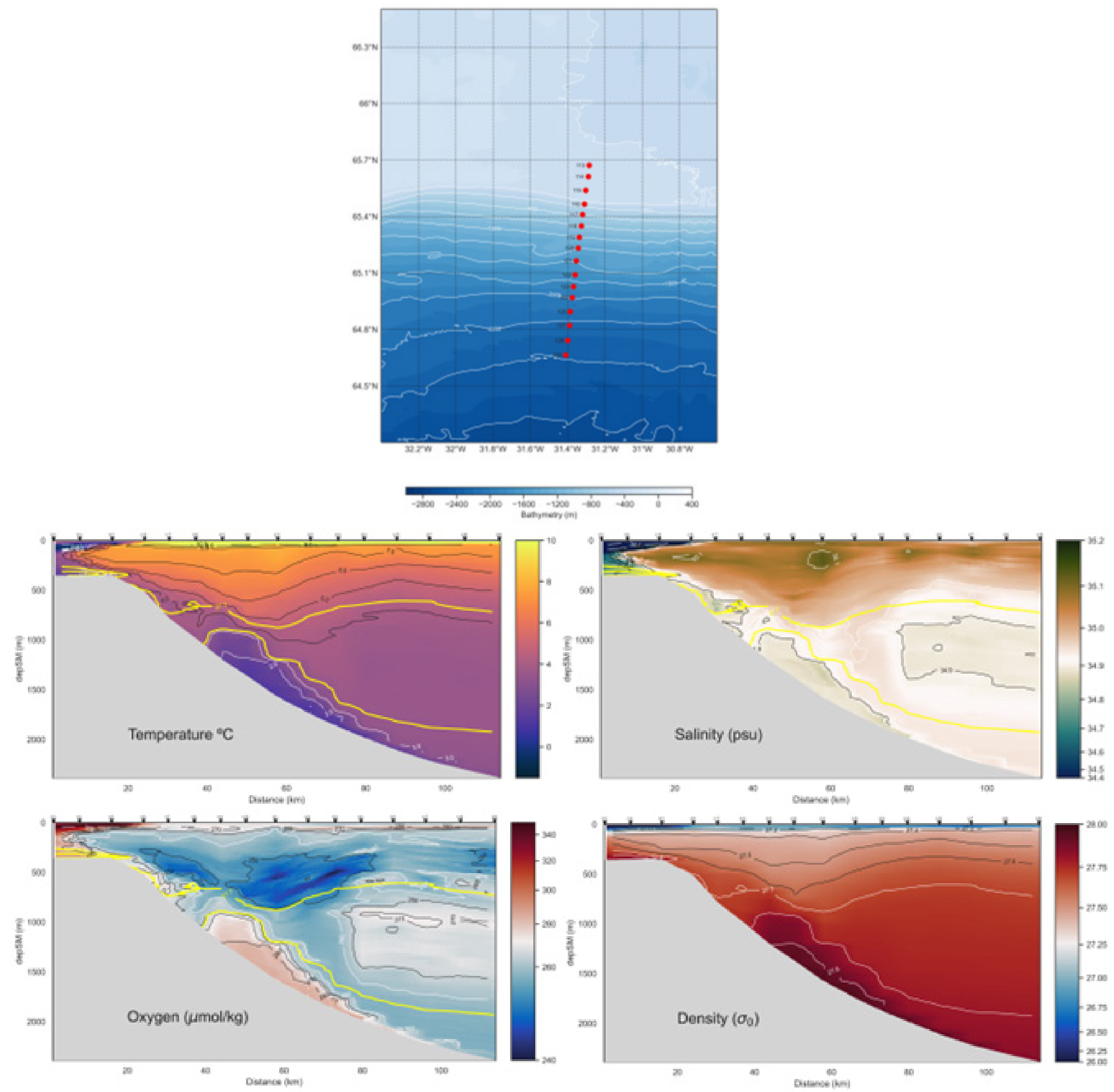


Figure 14. Section 4 Hydrographic parameters. CTD station numbers are indicated. Top-left: Temperature; Top-right: Salinity; Bottom-left: Oxygen; Bottom-right: Density annomaly. σ0 = 27.7 and 27.8 isopycnals are highlighted in yellow.

and warms but also increases in thickness. A dense water jet is clearly depicted on the shelf break and indications of downslope mixing transport are easily identified in this section. Over the DSO there is now a large body of Labrador waters (LSW) between 900 -1800m aproximately, which is colder, fresher and with more oxygen than overlying Irminger waters.

6.1.5.5. Section 5

This section (Figure 15) was completed in E – W direction directly across the Kangerlussnaq Trough, and comprises CTD stations St_130 to St_141 (05-06/08/2023, 66º05,07'N, 29º58,93'W -66º09,81'N, 31º40,55'W).

Section 5 main features: A well developed fresh water lens between 150 -20m is clearly seen at the W sector, spreading eastward and underlayed by patches of warm-salty and less oxygenated waters likely from recirculated IC branches. This section likely captures the IC branch moving northward (East core) and recirculating southward (West core) into the Kangerlussuaq Trough. At the bottom of the DSO there is an homogeneous parcel of dense (σ0 > 27.8), cold and relatively salty water with intermediate oxygen levels, clearly indicating dynamic renewal of these waters.

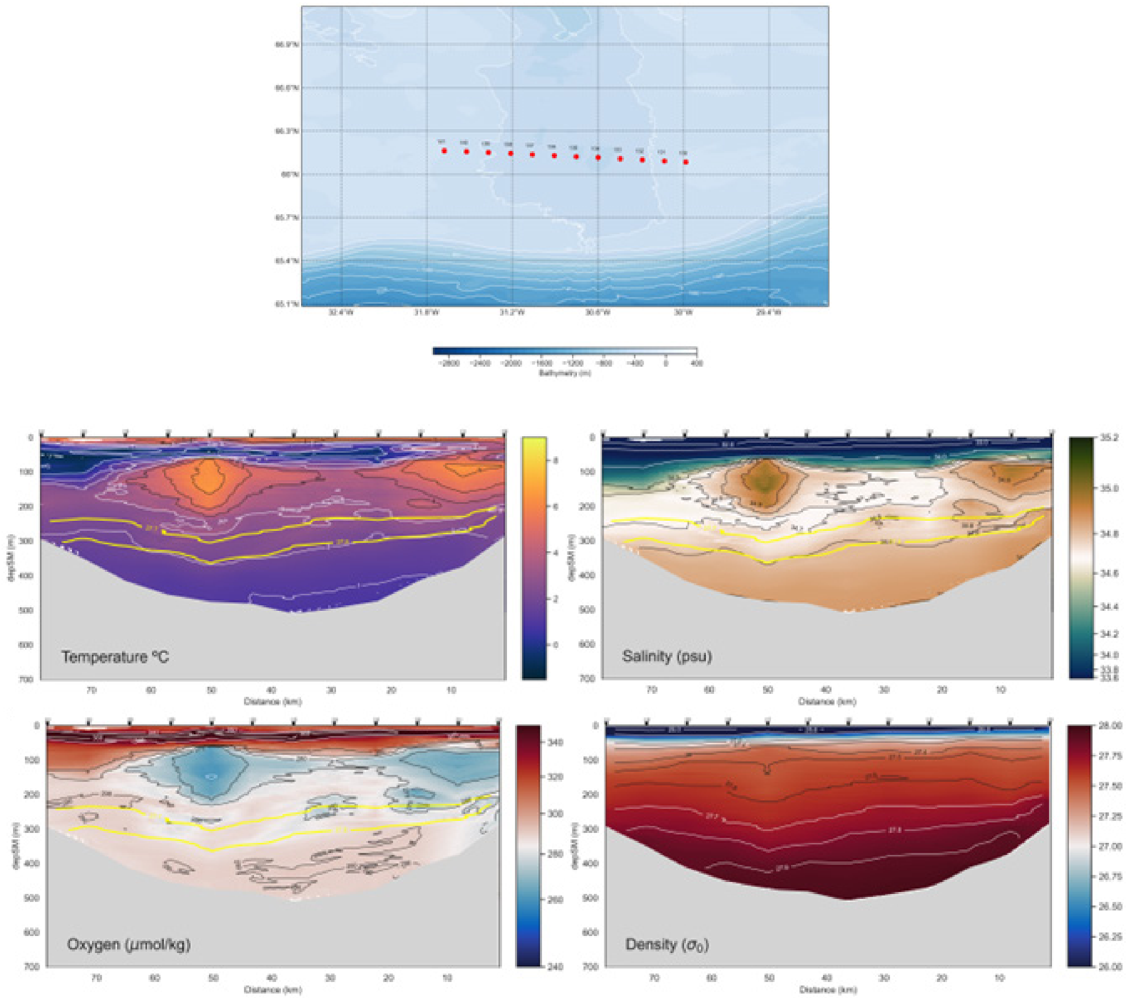


Figure 15. Section 5 Hydrographic parameters. CTD station numbers are indicated. Top-left: Temperature; Top-right: Salinity; Bottom-left: Oxygen; Bottom-right: Density annomaly. σ0 = 27.7 and 27.8 isopycnals are highlighted in yellow.

6.1.5.6. Section 6

This section (Figure 16) was completed in E – W direction directly across the Kangerlussuaq Trough, and comprises CTD stations St_130 to St_141 (dates, coords).

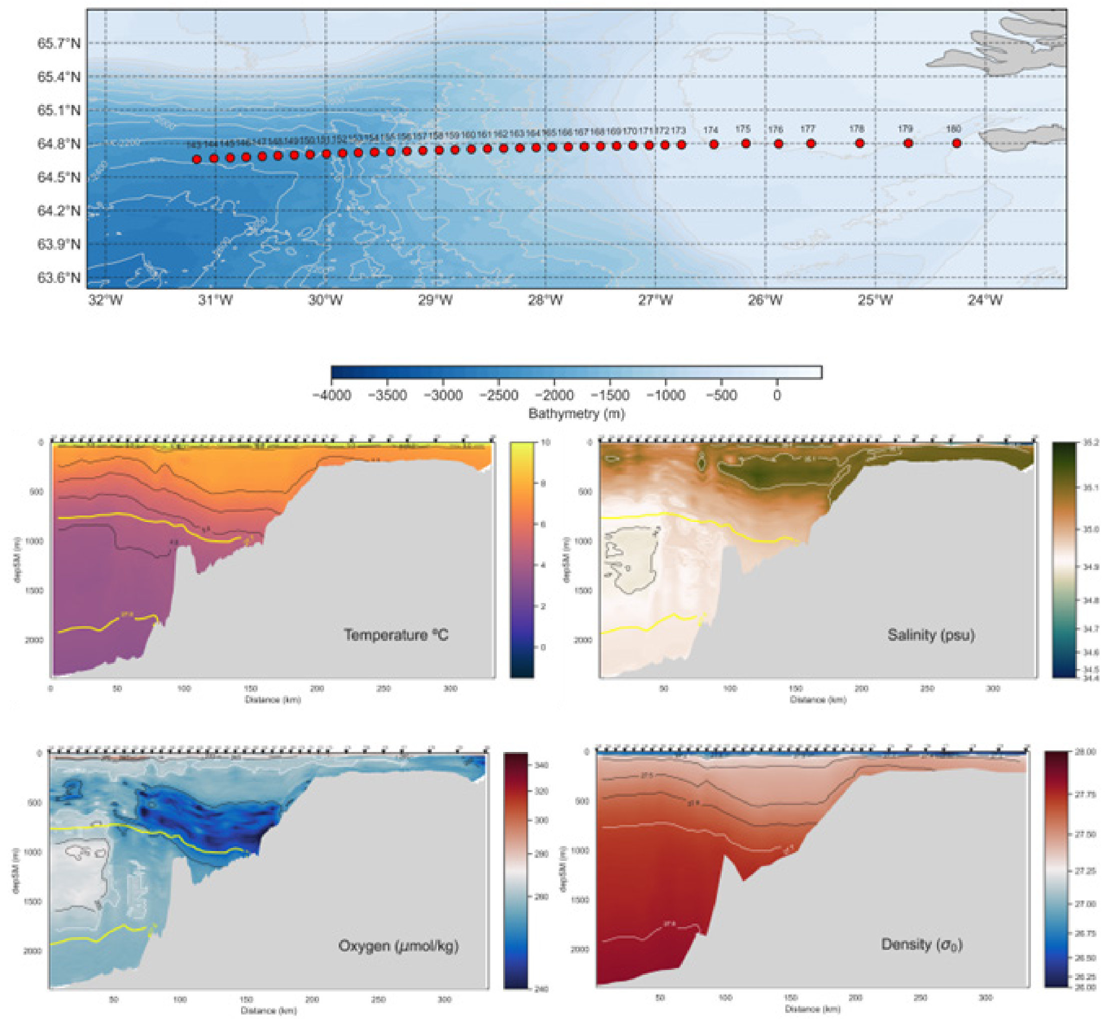


Figure 16. Section 6 Hydrographic parameters. CTD station numbers are indicated. Top-left: Temperature; Top-right: Salinity; Bottom-left: Oxygen; Bottom-right: Density annomaly. σ0 = 27.7 and 27.8 isopycnals are highlighted in yellow.

6.2. Water sampling

6.2.1. Water sampling for Nd isotopes (ƐNd) and rare earth element (REE)

Water samples are collected directly from 12L Niskin bottles. The number of samples taken at each station goes from 4 in the shallower stations to 10 at the deepest stations (Table 2). Once the rosette is on board samples are immediately filtered through 0.85 - 0.45µm Acropak Supor capsule filters into acid-cleaned 500ml LDPE bottles for REEs and 10L cubitainers for Nd. Each sample is immediately acidified with 500µl of concentrated hydrochloric acid (HCl) for REE samples and with ~10 mL of 50% HCl for Nd samples to obtain pH < 2. This step is necessary so the dissolved cations present in seawater do not adhere on the walls of the bottles/cubitainer as well as to prevent further biological activity during sample storage. Once the samples are acidified, they can be stored waiting for the pre-concentration step (see below). Acidified REE samples are stored in the refrigerator to be processed back in land. See Figure 4 for detailed location of the CTD stations sampled for Nd and REE.

Table 2. List of CTD stations, Niksin bottles and depths sampled for Nd and REE

CTD Station	Niskin bottles	Depth (m)	Sample
FDDS1-008	1, 3, 5, 13	181, 118, 69, 4	Nd, REE
FDDS1-013	1, 5, 7, 13	273, 180, 105, 7	Nd, REE
FDDS1-016	1, 3, 5, 7, 9, 15	268, 230, 180, 150, 100, 5	Nd, REE
FDDS1-018	1, 3, 5, 7, 9, 11, 13, 15	362, 340, 300, 240, 200, 151, 101, 5	Nd, REE
FDDS1-019	1, 3, 4, 5, 6, 7, 8, 9, 10, 15	418, 386, 363, 348, 323, 276, 231, 181, 53, 6	Nd, REE
FDDS1-020	3, 4, 7, 8, 10, 11, 13, 15, 16, 19	603, 550, 491, 444, 421, 391, 310, 202, 101, 5	Nd, REE
FDDS1-022	1, 3, 5, 7, 9, 23	477, 423, 400, 300, 151, 6	Nd, REE
FDDS1-025	1, 3, 7, 9, 11, 13, 23	470, 403, 291, 243, 192, 101, 6	Nd, REE
FDDS1-028	1, 3, 5, 7, 9	446, 400, 151, 84, 5	Nd, REE
FDDS1-033	1, 5, 9, 13	301, 240, 101, 6	Nd, REE
FDDS1-039	2, 3, 5, 13	281, 210, 80, 4	Nd, REE
FDDS1-042	3, 5, 7, 9	414, 187, 131, 5	Nd, REE
FDDS1-045	1, 3, 5, 7, 9	426, 291, 151, 44, 5	Nd, REE
FDDS1-048	1, 5, 7, 13	363, 201, 50, 6	Nd, REE
FDDS1-053	5, 6, 8, 12	276, 161, 83, 5	Nd, REE
FDDS1-057	1, 3, 5, 7, 9, 11, 13, 15	1790, 1260, 860, 720, 640, 550, 200, 5	Nd, REE
FDDS1-058	3, 5, 8, 10, 12, 14, 20	1327, 900, 544, 404, 260, 72, 5	Nd, REE
FDDS1-059	3, 5, 7, 9, 11, 13?, 15	1142, 1035, 720, 500, 230, 25?, 5	Nd, REE
FDDS1-060	1, 3, 5, 7, 9, 14	890, 670, 450, 272, 90, 5	Nd, REE
FDDS1-061	1, 3, 5	476, 250, 131	Nd, REE
FDDS1-063	3, 5, 7, 9, 15	332, 282, 190, 106, 5	Nd, REE
FDDS1-068	3, 5, 7, 11	315, 191, 103, 5	Nd, REE
FDDS1-074	5, 7, 9, 15	304, 201, 95, 5	Nd, REE
FDDS1-081	5, 7, 9, 23	399, 161, 91, 5	Nd, REE
FDDS1-084	1, 3, 5, 9, 11, 23	596, 500, 351, 130, 50, 3	Nd, REE
FDDS1-087	5, 7, 9, 15	350, 101, 45, 5	Nd, REE
FDDS1-095	5, 7, 9, 17	344, 185, 75, 5	Nd, REE
FDDS1-096	3, 5, 7, 13	251, 218, 100, 5	Nd, REE
FDDS1-114	3, 5, 7, 9, 11, 15	350, 252, 197, 146, 75, 5	Nd, REE
FDDS1-116	1, 3, 5, 7, 9, 11	515, 417, 291, 150, 40, 5	Nd, REE
FDDS1-118	1, 3, 5, 7, 9, 11, 14, 15, 17	981, 881, 799, 670, 619, 451, 212, 78, 3	Nd, REE
FDDS1-121	1, 3, 5, 7, 9, 11, 13, 15, 17, 19	1572, 1440, 1316, 1120, 930, 880, 700, 400, 225, 5	Nd, REE
FDDS1-122	6, 7, 9, 11, 13, 15, 17, 19, 21, 23	1742, 1685, 1461, 1001, 721, 617, 400, 241, 60, 2	Nd, REE
FDDS1-125	3, 5, 7, 9, 11, 13, 15, 17, 19, 21	2107, 2081, 1851, 1600, 1151, 850, 630, 351, 125, 5	Nd, REE
FDDS1-129	3, 5, 7, 9, 11, 13, 15, 17, 19, 21	2383, 2156, 1749, 1400, 1200, 950, 688, 450, 179, 6	Nd, REE
FDDS1-132	3, 5, 7, 13	416, 84, 42, 5	Nd, REE
FDDS1-134	3, 5, 7, 9, 11	490, 390, 260, 125, 51	Nd, REE
FDDS1-137	1, 3, 5, 7	477, 144, 40, 5	Nd, REE
FDDS1-149	3, 5, 6, 7, 8, 9, 10, 11, 12, 15	2224, 2000, 1600, 1400, 1000, 900, 700, 450, 200, 5	Nd, REE
FDDS1-154	3, 5, 7, 9, 12, 13, 15, 24	1832, 1500, 1250, 910, 740, 510, 213, 5	Nd, REE
FDDS1-162	1, 3, 5, 7, 9, 11, 13, 24	1144, 960, 710, 590, 450, 290, 75, 5	Nd, REE

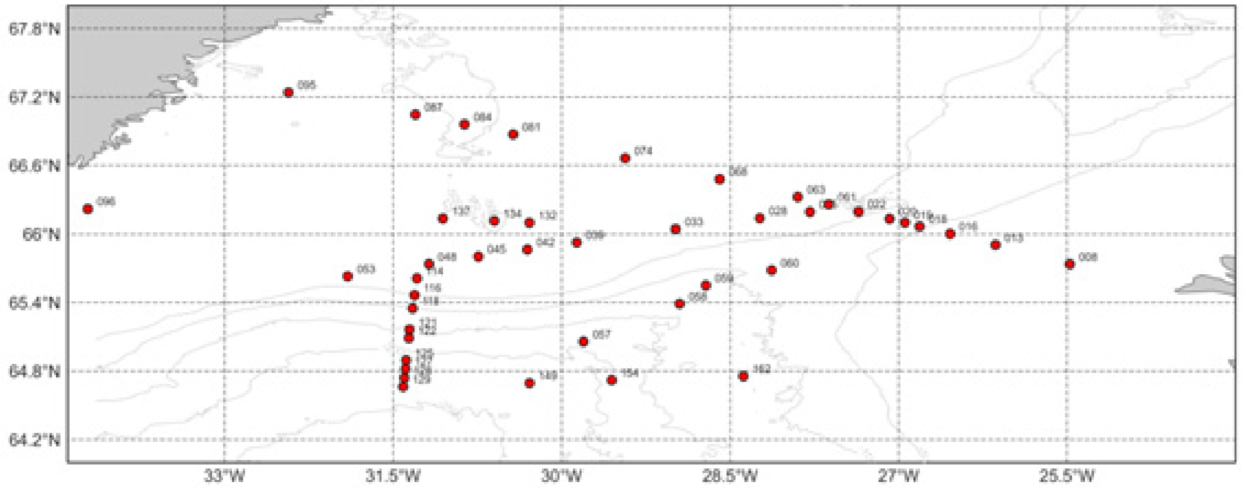


Figure 17. Map with the location of CTD stations where seawater was taken for Nd isotope and REE analysis.

Pre-concentration of Nd using SEP-PAK C18 cartridges

The objective of this step is to eliminate the complex matrix of major elements found in seawater and concentrate the Nd in a C18 cartridge. The pH of the samples must be brought between 3.6 and 3.9. The pH of the acidified samples is increased stepwise using ultrapure ammonium hydroxide. Every sample requires a different volume of ammonia. Usually between 3.5 and 4.5 ml are necessary to rise the pH to the needed value. The ammonia is added in small quantities into the cubitainer and the pH measured with a benchtop pH-meter (Hanna Lab, Bench Blue) each time. PH-meter is calibrated daily prior to sample processing. Samples must be well homogenized before measuring the pH with a pH-meter. If the pH of the sample rises above 3.9, concentrated HCl is used to lower it again. Once the pH is adjusted between the optimum values, the water sample is ready for the pre-concentration.

The pre-concentration of Nd consists of pumping the seawater with a peristaltic pump

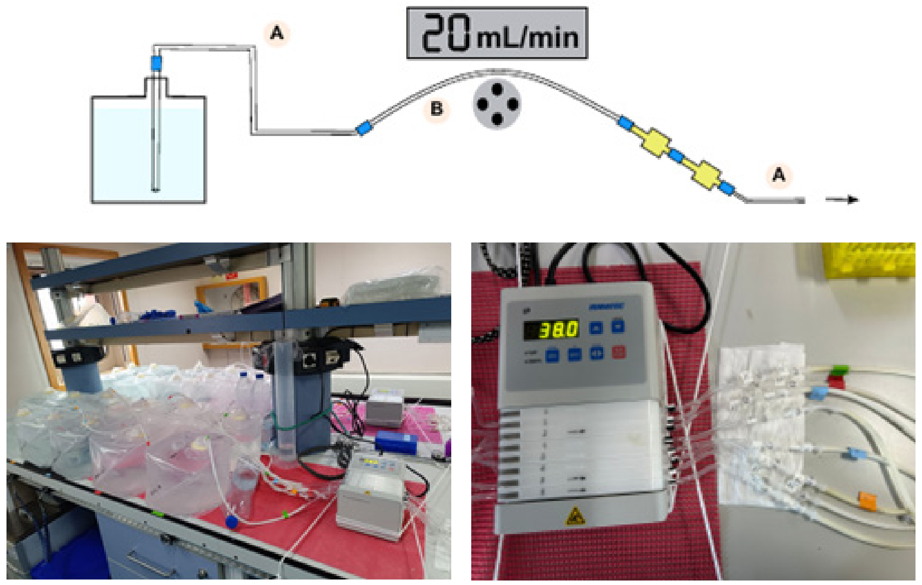


Figure 18. (top) Schematic diagram of seawater pumping through C18 cartridges to preconcentrate Nd isotope samples; (left) Two cubitainer pumping stations with double 8-way peristaltic pumps allowing for 16 samples to pre-concentrate simultaneously; (right) Detail of the C18 cartridges mounted in series that will be stored for further analysis in the laboratory.

through the C18 cartridge previously loaded with a complexing agent. The loading of the C18 cartridge can be done before the sampling and consists of adding 300µl (2 x 150µl) of 2-ethylhexyl-phosphate, a complexing agent with great affinity for the trivalent cations. For 10L seawater samples 2 x C18 cartridges are needed, connected to the peristaltic bomb in series (see Figure 18). Using 2 cartridges in tandem prevents the loss of Nd if the first cartridge gets saturated. Seawater samples from the cubitainers must be pumped through the C18 cartridge with a constant flow of 20ml/min. At this flow rate samples take approximately 10h to preconcentrate completely. After preconcentration, cartridges are stored covered in parafilm in the refrigerator.

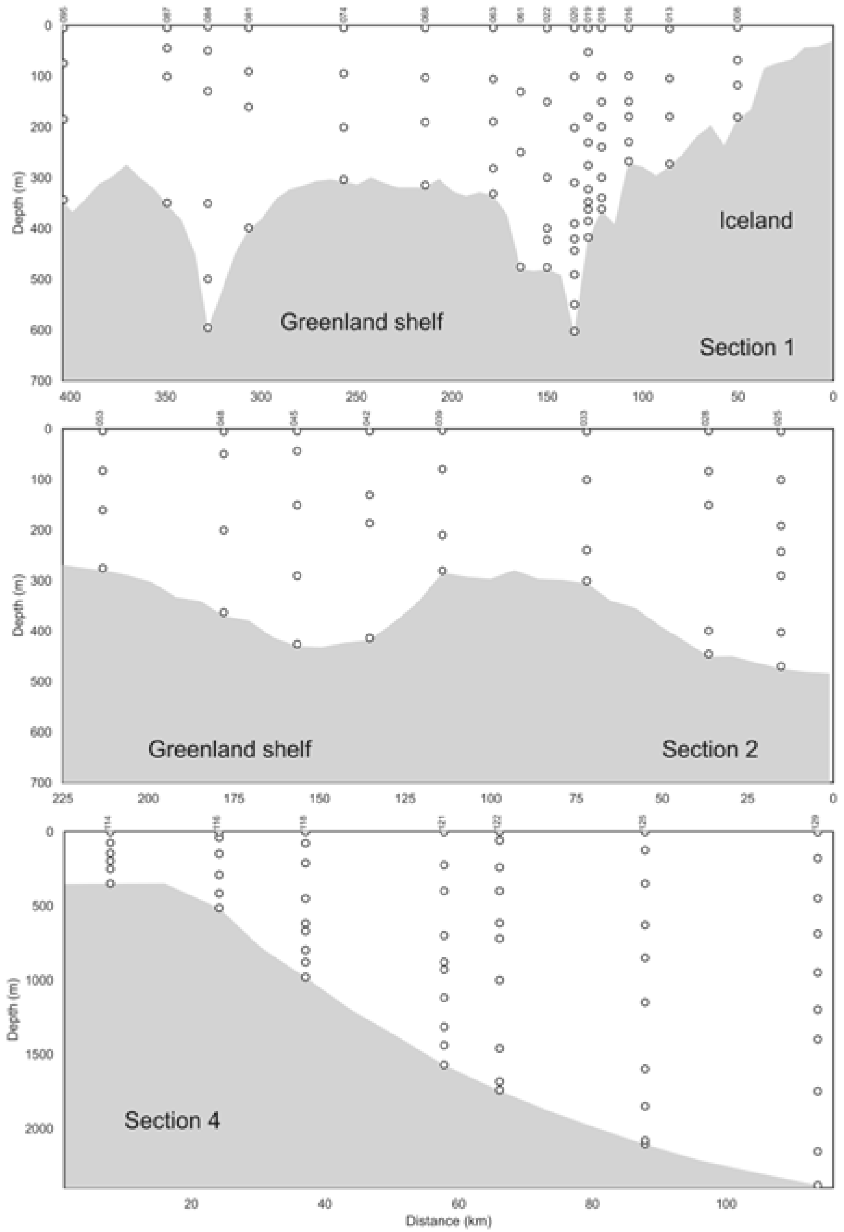


Figure 19. Show the main seawater sampling distribution for Nd and REE vs. depth along the main sections during the FARDWO-S1 cruise.

6.2.2. Water sampling for TSM, POC, Biomarkers, nutrients & microbiology

6.2.2.1. TSM, POC and Biomarkers

Samples for Total Suspended Matter (TSM), Particulate Organic Carbon (POC) and Biomarkers were filtered onboard onto preweighted 0,4µm nucleopore (TSM) and precombusted GFF (POC, Biomarkers) filters. Samples for TSM and POC were dried onboard (24h at 45ºC) and kept at air temperature, samples for biomarkers were frozen at -80ºC.

Table 3. List of CTD stations and depths sampled for Diatoms, POC, Biomarkers, TSM.

STATION	OPERATION	DATE	Depth	Depth sample	Comments
FDDS1-003-CTD	CTD	21/07/2023	54	5	Diatoms, POC, Biomarkers
				32	Diatoms, POC, Biomarkers
FDDS1-008-CTD	CTD	21/07/2023	190	5	Diatoms, POC, Biomarkers
				35	Diatoms, POC, Biomarkers
FDDS1-013-CTD	CTD	21/07/2023	280	7	POC, Biomarkers
FDDS1-014-CTD	CTD	22/07/2023	302	5	Diatoms, POC, Biomarkers
				14	Diatoms, POC, Biomarkers
FDDS1-016-CTD	CTD	22/07/2023	276	5	Diatoms, POC, Biomarkers
FDDS1-019-CTD	CTD	22/07/2023	450	5	Diatoms, POC, Biomarkers
				26	Diatoms, POC, Biomarkers
				415	TSM, POC, Biomarkers
FDDS1-020-CTD	CTD	22/07/2023	425	5	TSM, POC, Biomarkers
				35	TSM, POC, Biomarkers
				390	TSM, POC
				442	TSM, POC
				490	TSM, POC
				605	TSM, POC
FDDS1-021-CTD	CTD	22/07/2023	507	340	TSM, POC
				487	TSM, POC
FDDS1-022-CTD	CTD	22/07/2023	488	5	TSM, POC, Biomarkers
				25	TSM, POC, Biomarkers
				478	TSM, POC
FDDS1-025-CTD	CTD	22/07/2023	478	16	TSM, POC
				320	TSM, POC
				472	TSM, POC
FDDS1-027-CTD	CTD	22/07/2023	461	4	Diatoms, POC, Biomarkers, TSM
				11	Diatoms, POC, Biomarkers, TSM
				270	TSM, POC
				380	TSM, POC
FDDS1-032-CTD	CTD	23/07/2023	350	5	Diatoms, POC, Biomarkers
				24	Diatoms, POC, Biomarkers
FDDS1-039-CTD	CTD	23/07/2023	292	5	Diatoms, POC, Biomarkers, TSM
				33	Diatoms, POC, Biomarkers, TSM
				283	POC, TSM
FDDS1-041-CTD	CTD	23/07/2023	391	5	Diatoms, Biomarkers

				25	Diatoms, POC, Biomarkers
				43	Diatoms
				51	Diatoms
FDDS1-042-CTD	CTD	23/07/2023	425	413	TSM, POC
FDDS1-044-CTD	CTD	23/07/2023	442	5	POC, Biomarkers
				33	POC, Biomarkers, TSM
FDDS1-045-CTD	CTD	24/07/2023	442	5	POC
FDDS1-047-CTD	CTD	24/07/2023	391	375	TSM
FDDS1-048-CTD	CTD	24/07/2023	377	5	Diatoms, POC, Biomarkers
				37	Diatoms, POC, TSM
				355	TSM
FDDS1-053-CTD	CTD	24/07/2023	291	5	POC, TSM
				275	POC, TSM
FDDS1-058-CTD	CTD	25/07/2023	1325	5	Diatoms, POC, Biomarkers, TSM
				20	Diatoms, POC, Biomarkers, TSM
				544	POC, TSM
				1327	POC, TSM
FDDS1-059-CTD	CTD	25/07/2023	1145	1142	POC, TSM
FDDS1-060-CTD	CTD	25/07/2023	898	5	Diatoms, Biomarkers
				31	Diatoms, Biomarkers
FDDS1-063-CTD	CTD	28/07/2023	345	5	POC, TSM
				30	POC, TSM
				335	POC, TSM
FDDS1-066-CTD	CTD	28/07/2023	333	5	Diatoms, POC, Biomarkers
				27	Diatoms, POC, Biomarkers
FDDS1-068-CTD	CTD	28/07/2023	322	5	POC, TSM, Biomarkers
				30	POC, TSM, Biomarkers
				315	POC, TSM
FDDS1-074-CTD	CTD	29/07/2023	304	5	Diatoms, POC, Biomarkers
				29	Diatoms, POC, Biomarkers
				304	POC, Biomarkers
FDDS1-081-CTD	CTD	29/07/2023	414	5	POC, TSM
				35	POC, TSM
				400	POC, TSM
FDDS1-084-CTD	CTD	29/07/2023	611	5	Diatoms, POC, Biomarkers
				32	Diatoms, POC, Biomarkers
FDDS1-087-CTD	CTD	30/07/2023	361	5	POC, TSM
				30	POC, TSM
				350	POC, TSM
FDDS1-089-CTD	CTD	30/07/2023	310	5	Diatoms, POC, Biomarkers
				31	Diatoms, POC, Biomarkers
				297	TSM
FDDS1-091-CTD	CTD	30/07/2023	294	286	TSM
FDDS1-092-CTD	CTD	30/07/2023	321	160	POC, TSM
				311	POC, TSM
FDDS1-093-CTD	CTD	30/07/2023	350	75	POC, TSM
				340	POC, TSM
FDDS1-095-CTD	CTD	30/07/2023	358	5	Diatoms, POC, Biomarkers, TSM

				55	Diatoms, POC, Biomarkers, TSM
				344	POC, TSM
FDDS1-096-CTD	CTD	30/07/2023	262	5	Diatoms, POC, Biomarkers, TSM
				39	Diatoms, POC, Biomarkers, TSM
				61	POC, TSM
				251	POC, TSM
FDDS1-103-CTD	CTD	31/7/2023	319	5	Diatoms, POC, Biomarkers, TSM
				35	Diatoms, POC, Biomarkers, TSM
				70	POC, TSM
				306	POC, TSM
FDDS1-105-CTD	CTD	31/7/2023	309	5	POC, TSM
				40	POC, TSM
				295	POC, TSM
FDDS1-110-CTD	CTD	31/7/2023	337	5	Diatoms, POC, Biomarkers
				23	Diatoms, POC, Biomarkers
FDDS1-111-CTD	CTD	31/7/2023	302	295	TSM
FDDS1-114-CTD	CTD	31/7/2023	361	32	TSM, POC
				116	TSM, POC
				350	TSM, POC
FDDS1-115-CTD	CTD	01/08/2023	352	5	Diatoms, POC, Biomarkers
				30	Diatoms, POC, Biomarkers
				40	POC
FDDS1-117-CTD	CTD	01/08/2023	782	5	Diatoms, POC, Biomarkers
FDDS1-119-CTD	CTD	01/08/2023	1189	5	POC, Biomarkers, TSM
				20	POC, Biomarkers, TSM
				1199	TSM, POC
FDDS1-120-CTD	CTD	01/08/2023	1359	5	POC, Biomarkers, TSM
				30	POC, Biomarkers, TSM
				1365	POC, TSM
FDDS1-122-CTD	CTD	01/08/2023	1746	1743	TSM, POC
FDDS1-123-CTD	CTD	01/08/2023	1876	5	POC, Biomarkers, TSM
				21	POC, Biomarkers, TSM
				1873	POC, TSM
FDDS1-124-CTD	CTD	01/08/2023	1986	1980	POC, TSM
FDDS1-125-CTD	CTD	02/08/2023	2112	2106	POC, TSM
FDDS1-126-CTD	CTD	02/08/2023	1386	1366	POC (4), TSM
FDDS1-127-CTD	CTD	02/08/2023	2213	2214	POC, TSM
FDDS1-129-CTD	CTD	02/08/2023	2377	5	POC, TSM
				2382	POC, TSM
FDDS1-132-CTD	CTD	5/8/2023	420	5	POC, TSM
				30	POC, TSM
				466	TSM
FDDS1-133-CTD	CTD	5/8/2023	484	470	POC, TSM
FDDS1-134-CTD	CTD	5/8/2023	505	5	Diatoms, POC, Biomarkers
	CTD			36	Diatoms, POC, Biomarkers
	CTD			490	POC, TSM
FDDS1-135-CTD	CTD	5/8/2023	519	5	Diatoms, POC, Biomarkers
	CTD			40	Diatoms, POC, Biomarkers

	CTD			505	POC, TSM
FDDS1-143-CTD	CTD	6/8/2023	2356	2361	POC, TSM
FDDS1-145-CTD	CTD	6/8/2023	2325	2327	POC, TSM
FDDS1-146-CTD	CTD	6/8/2023	2314	5	Diatoms, POC, Biomarkers
	CTD			36	Diatoms, POC, Biomarkers
FDDS1-148-CTD	CTD	7/8/2023	2252	2244	POC, TSM
FDDS1-149-CTD	CTD	7/8/2023	2229	2244	POC, TSM
FDDS1-151-CTD	CTD	7/8/2023	2201	5	Diatoms, POC, Biomarkers
				42	Diatoms, POC, Biomarkers
				2202	POC, TSM
FDDS1-152-CTD	CTD	7/8/2023	2186	2185	TSM
FDDS1-154-CTD	CTD	8/8/2023	1834	5	Diatoms, POC, Biomarkers
				14	Diatoms, POC, Biomarkers
				1832	POC, TSM
FDDS1-156-CTD	CTD	8/8/2023	1500	1522	POC, TSM
FDDS1-157-CTD	CTD	8/8/2023	1046	1038	POC, TSM
FDDS1-158-CTD	CTD	8/8/2023	1147	1141	POC, TSM
FDDS1-159-CTD	CTD	8/8/2023	1318	1315	POC, TSM
FDDS1-160-CTD	CTD	8/8/2023	1249	1243	TSM
FDDS1-161-CTD	CTD	8/8/2023	1164	1160	TSM
FDDS1-162-CTD	CTD	8/8/2023	1150	5	Diatoms, POC, Biomarkers
				28	Diatoms, POC, Biomarkers
				1144	TSM
FDDS1-168-CTD	CTD	8/8/2023	646	5	Diatoms, POC, Biomarkers
				34	Diatoms, POC, Biomarkers
				640	TSM, POC
FDDS1-169-CTD	CTD	8/8/2023	538	531	POC, TSM
FDDS1-170-CTD	CTD	8/8/2023	429	5	Diatoms, POC, Biomarkers
				13	Diatoms, POC, Biomarkers
				429	TSM
FDDS1-172-CTD	CTD	9/8/2023	243	5	TSM, POC, Biomarkers
				15	TSM, POC, Biomarkers
				138	POC, TSM
				235	POC, TSM
FDDS1-174-CTD	CTD	9/8/2023	200	187	POC, TSM
FDDS1-175-CTD	CTD	9/8/2023	203	5	Diatoms, POC, Biomarkers
				22	Diatoms, POC, Biomarkers
				196	POC, TSM
FDDS1-176-CTD	CTD	9/8/2023	206	198	POC, TSM
FDDS1-177-CTD	CTD	9/8/2023	190	184	POC, TSM
FDDS1-177-CTD	CTD	9/8/2023	174	166	POC, TSM

6.2.2.2. Nutrients

Water samples were taken for nutrient analyses (Table 4 In each station a falcon tube was filled with 50 mL of filtered water at 0.45 mm from an Akropack (0.45 mm).

Table 4. Stations sampled for nutrients.

Station	Bottle	Depth (m)
FD-DS1-081-CTD	5, 7, 9, 23	400, 160, 90, 5
FD-DS1-084-CTD	1, 3, 5, 9, 11, 23	595, 500, 350, 130, 49, 5
FD-DS1-095-CTD	5, 7, 9, 17	344, 185, 75, 5
FD-DS1-096-CTD	3, 5, 7, 13	251, 218, 100, 5

6.2.2.3. Microbiology

Water samples were taken for microbial community analyses (Table 5). Due to a failure of the autoclave filter holders were sterilized with UV light. In each station sampled, 4 litres of water were taken at surface, chl-a maximum and maximum depth. The system (peristaltic pump + tube) was cleaned with MQ water and then 2 litres of sample and 2 litres of sample were filtered onto 0.22 µm filters. Filters were placed into a 2 ml tube and frozen at -80ºC. The milli-Q system died on 8/8/2023 and distilled water was used since then. 3 blanks were performed the last day (filtering 2000 ml distilled water in a filter).

Table 5. Stations sampled for microbial communities in seawater.

Station	Code	Depth	Volume filtered
FD-DS1-013-CTD	MC	7 m	1700 ml
	F	273 m	1400 ml
FD-DS1-020-CTD	S	5 m	2000 ml
	MC	35 m	2000 ml
	F	605 m	2000 ml
FD-DS1-036-CTD	S	4 m	2000 ml
	MC	36 m	2000 ml
	F	270 m	1200 ml
FD-DS1-053-CTD	S	5 m	2000 ml
	MC	43 m	2000 ml
	F	275	2000 ml
FD-DS1-078-CTD	S	5 m	2000 ml
	MC	31 m	2000 ml
	F	320 m	2000 ml
FD-DS1-094-CTD	S	5 m	2000 ml
	MC	50 m	2000 ml
	F	365 m	1500 ml
FD-DS1-120-CTD	S	5 m	2000 ml
	MC	30 m	2000 ml
	F	1364 m	2000 ml
FD-DS1-149-CTD	S	5 m	2000 ml
	MC	31 m	2000 ml
	F	2224 m	2000 ml
FD-DS1-156-CTD	S	5 m	2000 ml
	MC	28 m	2000 ml
	F	1522 m	2000 ml

6.2.3. Diatoms

Note that for all samplings the material was rinsed 3 times with water from the Niskin before each station.

6.2.3.1. Microanalysis

Samples were taken to analyse the elemental composition of diatoms.

9-10 L of water were filtered by a 200 µm mesh to remove large zooplankton and collected in 1 or 2 carboys from Niskin bottles. 4 mL to a 5 mL were sampled into a cryovial and the rest of the water was reverse filtered with a 20 µm mesh, until around 100-200 mL remained. This volume was filtered through a 47 mm diameter 10 µm porus polycarbonate filter, which was placed in the cryovial containing 4 mL of sample and vortexed some seconds to detach cells. Cryovials were flashed freeze and stored at -80ºC.

Figure 20. Details of the different steps of the microanalysis sampling.

6.2.3.2. Citometry

Samples were taken for enumerating pikoeukaryotes in the seawater.

Sampling

1.5 mL of water filtered by 200 µm mesh were pipetted into a 2 mL sterile cryovial, using sterile tips. Then, 150 µL of glutaraldehyde were added to the cryovial under a fume hood, mixed by inversion and kept for 30 min in dark and cold. Finally, cryovials were flashed freeze and stored at -80ºC.

6.2.3.3. Counting

Samples were taken for quantification and identification of diatom diversity.

Water was filtered from Niskin bottles by a 200 µm mesh and 250 mL were measured and transferred into glass amber bottles. 1ml of lugol was added, then mixed by inversion and stored at 4ºC.

Figure 21. Sampled water was stored in 250 mL glass bottles.

Table 6. Stations sampled for microanalysis (5 mL cryovials), citometry (2 mL cryovials) and counting (250 mL glass bottles).

STATION	DATE	Depth (m)	Depth sample (m)	Microanalysis	Citometry	Counting
FDDS1-000-PROVA	7/20/2023			PROVA	PROVA	PROVA
FDDS1-003-CTD	7/21/2023	54	5	S1, S2	S1, S2	S
			32	M1, M2	M1, M2	M
FDDS1-008-CTD	7/21/2023	190	5	S1A, S1B, S2	S1, S2	S
			35	M1, M2	M1, M2	M
FDDS1-013-CTD	7/21/2023	280	7	M1, M2	M1, M2	M
FDDS1-014-CTD	7/22/2023	302	5	S1, S2	S1, S2	S
			14	M1, M2	M1, M2	M
FDDS1-016-CTD	7/22/2023	276	5	SM1, SM2	SM1, SM2	5m
FDDS1-019-CTD	7/22/2023	450	5	S1, S2	S1, S2	S
			26	M1, M2	M1, M2	M
FDDS1-022-CTD	7/22/2023	488	5	S1, S2	S1, S2	S, S5
			25	M1, M2	M1, M2	M, M25
FDDS1-027-CTD	7/22/2023	461	4	S1, S2	S1, S2	S
			11	M1, M2	M1, M2	M
FDDS1-032-CTD	7/23/2023	350	5	S1, S2	S1, S2	S
			24	M1, M2	M1, M2	M
FDDS1-039-CTD	7/23/2023	292	5	S1, S2	S1, S2	S

			33	M1, M2	M1, M2	M
FDDS1-041-CTD	7/23/2023	391	5	S1, S2	S1, S2	S
			25	M1, M2	M1, M2	M_25m
			43	M3, M4	M3, M4	M_43m
			51	M5, M6	M5, M6	M_51m
FDDS1-044-CTD	7/23/2023	442	5	S1, S2	S1, S2	S
			33	M1, M2	M1, M2	M
FDDS1-048-CTD	7/24/2023	377	5	S1, S2	S1, S2	S
			37	M1, M2	M1, M2	M
FDDS1-058-CTD	7/25/2023	1325	5	S1, S2	S1, S2	S
			20	M1, M2	M1, M2	M
FDDS1-060-CTD	7/25/2023	898	5	S1, S2	S1, S2	S
			31	M1, M2	M1, M2	M
FDDS1-066-CTD	7/28/2023	333	5	S1, S2	S1, S2	S
			27	M1, M2	M1, M2	M
FDDS1-074-CTD	7/29/2023	304	5	S1, S1.2, S2	S1, S2	S
			29	M1, M2	M1, M2	M
FDDS1-084-CTD	7/29/2023	611	5	S1, S2	S1, S2	S
			32	M1, M2	M1, M2	M
FDDS1-089-CTD	7/30/2023	310	5	S1, S2	S1, S2	S
			31	M1, M2	M1, M2	M
FDDS1-095-CTD	7/30/2023	358	5	S1, S2	S1, S2	S
			55	M1, M2	M1, M2	M
FDDS1-096-CTD	7/30/2023	262	5	S1, S2	S1, S2	S
			39	M1, M2	M1, M2	M_39m
FDDS1-103-CTD	7/31/2023	319	5	S1, S2	S1, S2	S
			35	M1, M2	M1, M2	M
FDDS1-110-CTD	7/31/2023	337	5	S1, S2	S1, S2	S
			23	M1, M2	M1, M2	M
FDDS1-115-CTD	8/1/2023	352	5	S1, S2	S1, S2	S
			40	M1, M2	M1, M2	M
FDDS1-117-CTD	8/1/2023	782	5	SM1, SM2	SM1, SM2	S_M
FDDS1-120-CTD	8/1/2023	1359	5	S1, S2	S1, S2	S
			30	M1, M2	M1, M2	M
FDDS1-123-CTD	8/1/2023	1876	5	S1, S2	S1, S2	S
			21	M1	M1, M2	M_21m
			33	M2, M3	M3, M4	M_33m
FDDS1-135-CTD	8/5/2023	519	5	S1, S2	S1, S2	S
			42	M1, M2	M1, M2	M
FDDS1-146-CTD	8/7/2023	2314	5	S1, S2	S1, S2	S1, S2, S3
			36	M1, M2	M1, M2	M1, M2, M3
FDDS1-151-CTD	8/7/2023	2201	5	S1, S2	S1, S2	S1, S2, S3, S4
			42	M1, M2	M1, M2	M1, M2, M3, M4
FDDS1-154-CTD	8/8/2023	1834	5	S1, S2	S1, S2	S1, S2, S3, S4
			14	M1, M2	M1, M2	M1, M2, M3, M4

FDDS1-162-CTD	8/8/2023	1149	5	S1, S2	S1, S2	S1, S2, S3, S4
			27.8	M1, M2	M1, M2	M1, M2, M3, M4
FDDS1-168-CTD	8/9/2023	646	5	S1, S2	S1, S2	S
			34	M1, M2	M1, M2	M
FDDS1-170-CTD	8/9/2023	429	5	S1, S2	S1, S2	S1, S2, S3, S4
			13	M1, M2	M1, M2	M1, M2, M3, M4
FDDS1-175-CTD	8/9/2023	204	5	S1, S2	S1, S2	S
			22	M1, M2	M1, M2	M

6.3. Sediment sampling

Sediment samples were recovered with different systems according to their different capabilities of sediment recovery: monocorer, Van Veen grab, multicorer and gravity corer.

6.3.1. Monocorer

A NIOZ monocorer system attached to the CTD-rosette was deployed in most CTD stations, but not all of them, since there were doubts about the effect it could have on the ADCP measurements (check it in the Daily Activity Report). The monocorer was hanged on the CTD-rosette with a 30 m long rope. For the operations, first the monocorer was manually deployed and then the rosette was lowered until the sea surface and started the CTD measurements. At 50 m above the sea floor the rosette stopped during a minute for the stabilization of the monocorer, and later was lowered until less than 10 m above sea floor, ensuring the penetration of the monocorer on the sea floor. For the recovery, first the rosette was introduced into the ship and later the monocorer was manually recuperated.

This system allows recovering up to 30 cm of well stratified sediment sample from the sea floor, including the more fluid water-sediment interphase.

Depending on the recovery the sediment sample was directly preserved within the polycarbonate tube (vertically, full tube) or sliced each 1 cm in plastic bags, and later stored in the fridge.

Sometimes the monocorer returned void onboard, likely related to coarse or rocky materials

Figure 22. Monocorer system, deployment operation and sample recovered in FDDS1_009_MoC station.

in the sea floor, difficult to sample, or maybe due to a bad triggering of the system. In those cases, it was important to recover the few material recovered (maybe few millimeters) to observe the nature of the sea floor (ex. Figure 22).

Finally, a total of 77 Monocorer samples were successfully recovered, 30 stored in the fridge as an undisturbed archive (full tube) and 47 sliced and stored in plastic bags in the fridge (see Table 7 for more details).

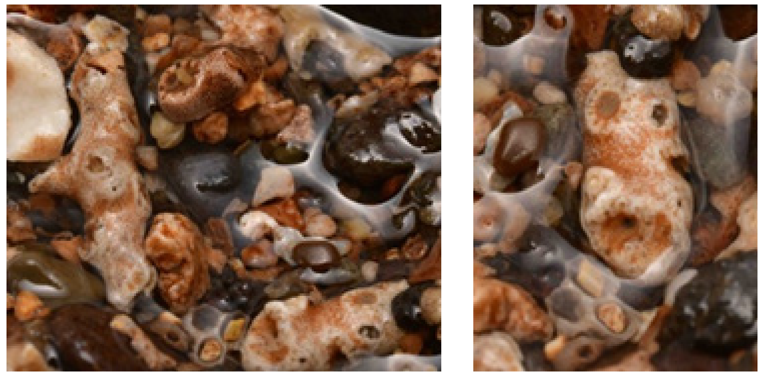


Figure 23. Example of materials recovered in station FDDS1_060_MoC, with sands, pebbles and carbonates fragments (likely corals).

Table 7. Summary of stations with monocorer sampling, total recovery, storage procedure and comments on the materials.

STATION	Depth (m)	Recovery (cm)	Stored	Comments
FDDS1-009-MoC	241	11	Sampled: 11 plastic bags	Grey sands with fibers and some rests of shells
FDDS1-010-MoC	200	5	Sampled: 2 plastic bags. 1 bag 0-3 cm. 1 bag 3-5 cm.	Dirty water, maybe a little bit washed. Grey sands with little gravels and carbonats rests.
FDDS1-011-MoC	224	4	Sampled: 4 plastic bags	Medium sands with carbonate fragments same gravels.
FDDS1-012-MoC	258	11	Sampled: 11 plastic bags	
FDDS1-013-Moc	280	27	Full tube	
FDDS1-017-MoC	396	0.1	Sampled: 1 plastic bag	Coarse sand, mostly carbonates. color light brown-orange (remembers to “cascajo”)
FDDS1-018-MoC	370	0		
FDDS1-019-MoC	450	0		
FDDS1-033-MoC	304	0	Sampled: 1 plastic bag	Something organic, soft. Sands with pebbles.
FDDS1-042-MoC	425	0		
FDDS1-043-MoC	435	7	Sampled: 7 plastic bags	
FDDS1-044-MoC	442	30	Full tube	
FDDS1-045-MoC	442	11	Sampled: 8 plastic bags	
FDDS1-046-MoC	423	4	Sampled: 4 plastic bags	
FDDS1-047-MoC	391	5	Sampled: 5 plastic bags	Sandy mud with small pebbles.
FDDS1-048-MoC	383	5	Sampled: 5 plastic bags	
FDDS1-049-MoC	348	13	Sampled: 13 plastic bags	No photo
FDDS1-050-MoC	342	16	Full tube	
FDDS1-051-MoC	304	5	Sampled: 3 plastic bags: 0-1 cm. 1-2 cm. 2-5 cm	
FDDS1-052-MoC	301	0		
FDDS1-053-MoC	291	0		
FDDS1-054-MoC	284	0		

FDDS1-055-MoC	269	0		
FDDS1-056-MoC	1353	0		
FDDS1-057-MoC	1780	0.5	1 plastic bag	Sands and pebbles. Likely washed
FDDS1-058-MoC	1325	0		
FDDS1-059-MoC	1145	0		
FDDS1-060-MoC	898	0.1	1 plastic bag	Coarse sands and biogenic carbonates, likely corals or briozoa (photos with magnifiying glass)
FDDS1-063-MoC	345	10	Sampled: 10 plastic bags	
FDDS1-064-MoC	344	4	Sampled: 1 plastic bag	Sandy
FDDS1-065-MoC	347	17	Full tube	
FDDS1-066-MoC	333	16	Full tube	
FDDS1-067-MoC	309	7	Sampled: 6 plastic bags	0-1 cm lost
FDDS1-068-MoC	322	20	Full tube	
FDDS1-069 MoC	325	15.5	Full tube	
FDDS1-070-MoC	325	18	Full tube	
FDDS1-071-MoC	315	3	Sampled: 1 plastic bag	Washed
FDDS1-072-MoC	309	4	Sampled: 4 plastic bags	
FDDS1-073-MoC	322	16	Full tube	Redox front at 12 cm (color change)
FDDS1-074-MoC	304	0		
FDDS1-075-MoC	310	9	Sampled: 9 plastic bags	
FDDS1-076-MoC	315	0.5	Sampled: 1 plastic bag	
FDDS1-077-MoC	323	0		
FDDS1-078-MoC	332	7	Sampled: 7 plastic bags	
FDDS1-079-MoC	352	0.5	Sampled: 1 plastic bag	
FDDS1-080-MoC	389	2	Sampled: 1 plastic bag	
FDDS1-081-MoC	414	19	Full tube	
FDDS1-082-MoC	462	17	Full tube	
FDDS1-083-MoC	538	22	Full tube	
FDDS1-085-MoC	458	14	Sampled: 14 plastic bags	
FDDS1-086-MoC	393	0		
FDDS1-087-MoC	361	21	Full tube	
FDDS1-088-MoC	328	11	Sampled: 11 plastic bags	
FDDS1-089-MoC	311	0		
FDDS1-090-MoC	282	7	Sampled: 7 plastic bags	Consolidated muds with pebbles
FDDS1-091-MoC	294	3	Sampled: 3 plastic bags	
FDDS1-092-MoC	321	0		
FDDS1-093-MoC	350	19	Full tube	
FDDS1-094-MoC	378	0		
FDDS1-095-MoC	346	19.5	Full tube	
FDDS1-096-MoC	262	19	Full tube	
FDDS1-097-MoC	284	20	Full tube	
FDDS1-098-MoC	287	20	Full tube	
FDDS1-099-MoC	297	0		
FDDS1-100-MoC	280	3	Sampled: 3 plastic bags	

FDDS1-101-MoC	283	0		
FDDS1-102-MoC	274	4	Sampled: 1 plastic bag	
FDDS1-103-MoC	319	19.5	Full tube	
FDDS1-110-MoC	337	7	0-1 cm sampled for Diatoms: 2 vials and 1 plastic bag (freeze). 1-7 cm sampled: plastic bags	
FDDS1-111-MoC	302	0		
FDDS1-114-MoC	361	0		
FDDS1-115-MoC	352	0		
FDDS1-116-MoC	519	0		
FDDS1-118-MoC	978	0		
FDDS1-119-MoC	1189	0		
FDDS1-123-MoC	1876	10	Full tube	
FDDS1-125-MoC	2112	8	Sampled: 8 plastic bags	
FDDS1-128-MoC	2299	5	Sampled: 5 plastic bags	
FDDS1-129-MoC	2377	0		
FDDS1-130-MoC	290	0		
FDDS1-131-MoC	379	14	Full tube	
FDDS1-132-MoC	421	6	Sampled: 6 plastic bags	
FDDS1-133-MoC	484	21	Full tube	
FDDS1-134-MoC	505	20.5	Full tube	
FDDS1-135-MoC	519	0		
FDDS1-136-MoC	489	15	Full tube	
FDDS1-137-MoC	482	4	Sampled: 4 plastic bags	
FDDS1-138-MoC	461	8	Sampled: 8 plastic bags	
FDDS1-139-MoC	422	21	Full tube	
FDDS1-140-MoC	358	16	Sampled: 16 plastic bags	1 pebble of 5cm in the top
FDDS1-141-MoC	301	11	Sampled: 5 plastic bags (0-1 cm, 1-2 cm, 2-3 cm, 3-4 cm, 4-11 cm)	
FDDS1-144-MoC	2348	0		
FDDS1-145-MoC	2325	4	sliced in 4 plastic bags	
FDDS1-146-MoC	2314	13	Full tube	Light brown sandy muds, very rich in foraminifera, presence of dark minerals
FDDS1-147-MoC	2292	0		
FDDS1-148-MoC	2252	15	Full tube	
FDDS1-149-MoC	2229	17	Full tube	
FDDS1-150-MoC	2206	19	Full tube	
FDDS1-151-MoC	2201	19	sliced in 19 plastic bags	
FDDS1-152-MoC	2186	15	Full tube	
FDDS1-153-MoC	202	13	Sliced in 13 plastic bags	
FDDS1-154-MoC	1834	20	Sliced in 20 plastic bags	
FDDS1-155-MoC	1864	0		
FDDS1-156-MoC	1500	3	Stored in plastic bags	

FDDS1-158-MoC	1147	21	Full tube	
FDDS1-159-MoC	1318	11	Sliced in 11 plastic bags	
FDDS1-160-MoC	1249	11	Sliced in 12 plastic bags	
FDDS1-161-MoC	1164	0		
FDDS1-162-MoC	1149	15	Sliced in 15 plastic bags	
FDDS1-163-MoC	1086	3	1 plastic bag	no photo
FDDS1-166-MoC	840	0		
FDDS1-169-MoC	538	0		
FDDS1-172-MoC	243	0		
FDDS1-173-MoC	244	15	Sliced in 15 plastic bags	
FDDS1-175-MoC	205	21	Full tube	

Figure 24. Examples of Van Veen grab recovery with muddy sediments (FDDS1_043_VVb) and a mixture of mud with pebbles (FDDS1_020_VVb).

6.3.2. VanVeen Grab

A Feritech 0.1m2 Van Veen grab was used for the recovery of bigger volume of sediments from the sea floor (max. 16.6 L). It was used to sample and explore the nature of the sea floor especially in stations where the monocorer failed, normally covered by decimetric pebbles and large rocks mixed with mud, and sponges (Figure 24).

A total of 16 stations were successfully sampled with the Van Veen grab (Table 8).

Table 8. List of Van Veen operations and description of the sampling carried out.the materials.

STATION	Depth (m)	Sampling and comments
FDDS1-013-VV	290	Sampling 1st cm: Diatoms (2 vials) and Microbiology (1 vial), 1 bag frozen – 80ºC + 1 bag fridge
FDDS1-019-VV	455	Returned open, doesn't close
FDDS1-019-VV2	446	Returned open, doesn't close
FDDS1-020-VV	622	Graved, rounded black pebbles (basaltic), coarse sandy matrix and fauna (sponges, bryozoan, spiders? tunicates?). Sampling of 1st cm: Diatoms (2 vials), Microbiology (1 vial), 1 bag frozen – 80ºC + 1 bag fridge. A big bag with sediments.
FDDS1-021-VV	507	Semi-opened and washed sediment. Sampling 1st cm: Diatoms (2 vials) and Microbiology (1 vial), 1 bag frozen – 80ºC + 1 bag fridge, 1 big bag at fridge
FDDS1-022-VV	488	Semi-opened and washed sediment. Diatoms (1 vial), 2 bags at frigde
FDDS1-025-VV	481	Sampling 1st cm: Diatoms (2 vials) and Microbiology (1 vial), 1 bag frozen – 80ºC + 1 bag fridge. 5 plastic bags.
FDDS1-028-VV	463	Sampling 1st cm: Diatoms (2 vials) and Microbiology (1 vial), 1 bag frozen – 80ºC + 1 bag fridge.
FDDS1-033-VV	315	Semi-opened and washed. 3 stones (1 bag). 1 bag with something like a sponge
FDDS1-039-VV	293	1 plastic bag (fridge)
FDDS1-042-VV	431	Sampling 1st cm: Diatoms (2 vials) and Microbiology (1 vial), 1 bag frozen – 80ºC + 1 bag fridge (0-1cm). 3 bags (0-5 cm) at the fridge. Soft sands rich in foraminifera
FDDS1-043-VV	438	Sampling 1st cm: Diatoms (2 vials) and Microbiology (1 vial), 1 bag frozen – 80ºC + 1 bag fridge.
FDDS1-045-VV	440	Sampling 1st cm: Diatoms (2 vials) and Microbiology (1 vial), 1 bag frozen – 80ºC + 1 bag fridge.
FDDS1-048-VV-1	384	Empty
FDDS1-048-VV-2	370	Subsampling every cm (14 cm in 10 plastic bags?). 1 vial microbio. 1 bag surgace. 2 vial diatom
FDDS1-053-VV	291	Position from CTD; time and position aprox; 1 plastic bag
FDDS1-057-VV	1784	Empty
FDDS1-063-VV	345	1 plastic bag with pebbles
FDDS1-096-VV	264	Not closed
FDDS1-115-VV	352	Almost empty, large pebbles and coral
FDDS1-118-VV	979	Empty
FDDS1-119-VV	1189	Not closed
FDDS1-120-VV	1359	1 plastic bag

6.3.3. Multicorer

A KC Denmark multicorer with 6 tubes (100 mm diameter) was used for the sampling of the sea floor. This system allows recovering 6 replicates of very well preserved sea floor sediments up to 60 cm long, including the water-sediment interphase. Once on deck, the largest tube was marked with an A and the others with B, C, D, E and F in clockwise sense, consecutively (Figure 25). A picture of all them was also taken for the archive.

Later, each tube was stored or sampled following different procedures:

1. Subsampling with a PVC tube (75 mm diameter) for archive, stored in the fridge.
2. Full slicing each 1 cm, stored in the fridge.

3. 1st cm sampled for diatoms (2 vials)
4. Samples for microbiology at 0-1 cm, 5-6 cm, 10-11 cm and 20-21 cm
5. 1-5 cm slicing each 1 cm for grain-size analysis.
6. Subsampling with a PVC tube (75 mm diameter) for archive, stored in the fridge

Figure 25. Multicorer system used during FARDWO-DS1 cruise and an example of sediment recovery and sampling.

A total of 10 stations were successfully sampled with the Multicorer system (Table 9).

Table 9. List of Multicorer operations and description of the sampling carried out.the materials.

STATION	Depth (m)	Comments
FDDS1-013-MC1	281	Empty
FDDS1-013-MC2	288	A) 5cm: washed, sliced each 1 cm and stored in plastic bags. B) 7cm : washed, sliced each 1 cm in plastic bags. C) 1cm : mixed and washed, stored in 1 plastic bag
FDDS1-042-MC	431	Mostly empty: 1 plastic bag stored in fridge
FDDS1-066-MC	333	2 tubes stored as archive; 2 tubes sampled for diatoms; 1 tube sampled for microbiology.
FDDS1-081-MC	414	A) 47cm, stored as archive in PVC tube. B) 1st cm sampled for diatoms. C) 47 cm, sliced each 1 cm. D) sampled for microbiology (cm: 1, 5, 10, 20 in vials). E) 0-5 cm sliced each 1 cm for Grain-size . F) 42 cm, stored as archive in a PVC tube.
FDDS1-084-MC	611	A) 47cm, sliced each 1 cm. B) empty. C) 52cm, stored as archive in PVC tube. D) 50cm, stored as archive in PVC tube. E) 35cm, 1st cm sampled for diatoms. E) 48cm, sampled for microbiology.
FDDS1-087-MC	370	A) 46 cm, stored as archive in PVC tube. B) 38 cm, sliced each 1 cm. C) 43-50 cm, 1st cm sampled for diatoms. D) 42-48 cm, sampled for microbiology. E) 40-47 cm, top 5 cm sampled for grain size each 1 c.; F) 41 cm, stored as archive in PVC tube
FDDS1-095-MC	359	A) 26 cm, stored as archive in a PVC tube. B) 13 cm, sliced each 1 cm. C) 15 cm, sampled for diatoms and mircrobiology
FDDS1-096-MC-01	262	Empty
FDDS1-096-MC-02	263	Empty
FDDS1-132-MC	420	A) 12 cm, stored as archive in a PVC tube. B) 12 cm, sliced each 1 cm. C) 6 cm, washed, sampled for diatoms and microbiology. F) 5 cm, washed, 1 plastic bag. D and E empty
FDDS1-134-MC	506	A) 54cm, stored as archive as PVC tube. B) 48 cm, sliced each 1 cm. C) 39 cm, sampled for diatoms. D) 46 cm, sampled for microbiology. E) 48 cm, sampled for grain-size F) 49 cm, stored as archive in PVC tube.
FDDS1-137-MC	481	A) 8 cm, likely washed, sliced each 1 cm. B) 7 cm, washed, sampled for diatoms and microbiology

6.3.4. Gravity corer

A gravity corer with a weight of 1 Tn was also used for the recovery of long sediment sequences. Initially we used liners of 3 and 5 m long, but since one liner returned bent we could also re-arrange it as a 1.5 m long liner. The PVC liner used for the recovery of the sediment was of 75 mm diameter (Figure 25). The bottom of the liner was protected with a core-catcher, but it was also necessary to add a piece of plastic to avoid the washing of sandy particles, thus improving the recovery. Once on deck, the PVC liner was labelled and cut in 1 m long sections. At some stations the gravity corer totally penetrated into the sea floor thus allowing sediment to escape by the very top of the PVC liner (and the weight). Those sediments were stored in plastic bags or lost (check Table 10).

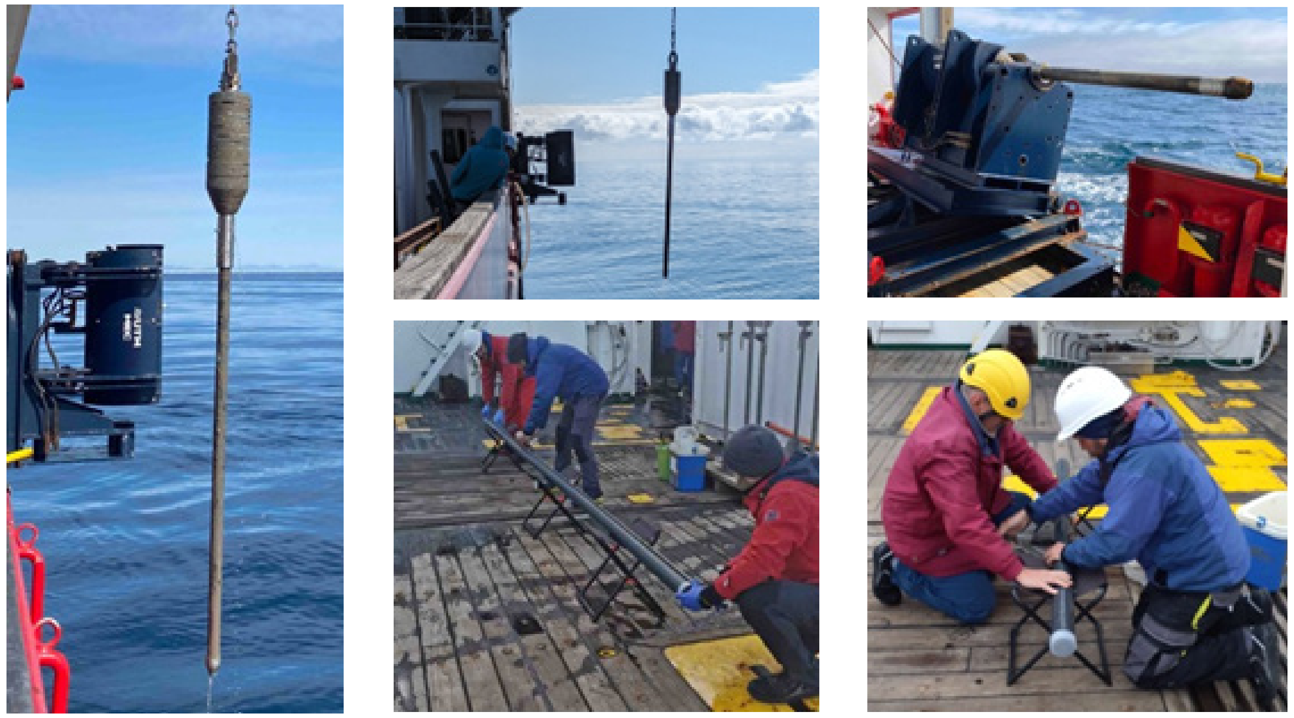


Figure 26. Gravity corer system during the FARDWO-DS1 cruise. Example of a 5 m sediment core recovering, labelling and cutting in 1 m long sections.

Finally, a total of 17 sediment cores and a total of 30 sections were recovered during the cruise.

Table 10. List of Gravity Corer operations and description of the sampling carried out.the materials.

STATION	Depth (m)	Lengtn (cm)	N. Sections	Samples in bags	Comments
FDDS1-013-GC	291	0	0	0	
FDDS1-042-GC	420	0	0	0	Aborted due to problems with the winch.
FDDS1-043-GC	437	54	1	2	Tube bent; 2 plastic bags (core catcher)
FDDS1-058-GC	1327	28	1	1	1 plastic bag with the core catcher
FDDS1-059-GC	1142	52	1	1	1 plastic bag with the core catcher
FDDS1-060-GC	898	0	0	1	<1 mm: 1 plastic bag with coarse sands and biogenic carbonates, likely corals or briozoa
FDDS1-065-GC	347	35	1	1	1 plastic bag (core catcher). Problems with winch
FDDS1-084-GC-A	610	3	3	3	3 core-catcher samples: Top core-catcher, Core-catcher, and Very bottom catcher. 1 m at the very top likely lost due to penetration>>>liner length.
FDDS1-084-GC-B	611	5	5	8	6 samples in bags at TOP: Very x 5 top, very x 4 top, very x 3 top, very very top, very top. 2 samples at CoreCatcher: CC-top, CC-bottom. 0.5 m at the very top likely lost due to penetration>>>liner length.
FDDS1-087-GC	361	149	1	1	
FDDS1-095-GC	358	72	1	1	
FDDS1-123-GC	1878	60	1		
FDDS1-132-GC	420	94	1	2	
FDDS1-134-GC-A	506	149	1	3	1 m at the very top likely lost due to penetration>>>liner length.
FDDS1-134-GC-B	505	498	5	2	498 cm (5 sections, 2 bags core catcher). 0.5 m at the very top likely lost due to penetration>>>liner length.
FDDS1-137-GC-A	482	149	1	2	
FDDS1-137-GC-B	481	244	2		Sec 1: 120 cm; Sec 2: 124 cm
FDDS1-142-GC	2107	66	1		Problems with the winch
FDDS1-152-GC	2212	300	3	1	Problems with the winch
FDDS1-157-GC	1046	55	1	1	

6.3.5. Sampling for diatom and microbiological analyses

Surface sediment samples were taken for diatom and microbial communities analyses. Sediment was put into a 5 ml (diatoms) or 2 ml (microbiology) tubes and frozen at -80ºC.

Table 11. List of station sampled by diatoms and microbiology.

Station	Depth	
FD-DS1-013-VV	290	Diatoms (2 vials, -80ºC)
		Diatoms (1 bag, -80ºC)
		Microbiology (1 vial, -80ºC)
FD-DS1-020-VV	621	Diatoms (2 vials, -80ºC)
		Diatoms (1 bag, -80ºC)
		Microbiology (1 vial, -80ºC)
FD-DS1-021-VV	507	Diatoms (2 vials, -80ºC)
		Diatoms (1 bag, -80ºC)
		Microbiology (1 vial, -80ºC)
FD-DS1-022-VV	488	Diatoms (1 vial, -80ºC)
FD-DS1-025-VV	481	Diatoms (2 vials, -80ºC)
		Diatoms (1 bag, -80ºC)
		Microbiology (1 vial, -80ºC)
FD-DS1-028-VV	463	Diatoms (3 vials, -80ºC)
		Diatoms (1 bag, -80ºC)
		Microbiology (1 vial, -80ºC)
FD-DS1-042-VV	431	Diatoms (2 vials, -80ºC)
		Diatoms (1 bag, -80ºC)
		Microbiology (1 vial, -80ºC)
FD-DS1-043-VV	438	Diatoms (2 vials, -80ºC)
		Diatoms (1 bag, -80ºC)
		Microbiology (1 vial, -80ºC)
FD-DS1-045-VV	440	Diatoms (2 vials, -80ºC)
		Diatoms (1 bag, -80ºC)
		Microbiology (1 vial, -80ºC)
FD-DS1-048-VV	374	Diatoms (2 vials, -80ºC)
		Diatoms (1 bag, -80ºC)
		Microbiology (1 vial, -80ºC)
FD-DS1-066-MC	333	Diatoms (2 vials, -80ºC)
		Diatoms (1 bag, -80ºC)
		Microbiology (1 vial at 0cm, 1cm, 5 cm, 10 cm, 20 cm, -80ºC)
FD-DS1-074-VV	316	Diatoms (2 vials, -80ºC)
		Diatoms (1 bag, -80ºC)
		Microbiology (2 vials, -80ºC)
FD-DS1-081-MC	414	Diatoms (2 vials, -80ºC)
		Diatoms (1 bag, -80ºC)
		Microbiology (1 vial at 0cm, 5 cm, 10 cm, 20 cm, -80ºC)
FD-DS1-084-MC	611	Diatoms (2 vials, -80ºC)
		Diatoms (1 bag, -80ºC)
		Microbiology (1 vial at 0cm, 5 cm, 10 cm, 20 cm, -80ºC)
FD-DS1-087-MC	361	Diatoms (2 vials, -80ºC)
		Diatoms (1 bag, -80ºC)

		Microbiology (1 vial at 0cm, 5cm, 10cm, 20cm, -80ºC)
FD-DS1-095-MC	358	Diatoms (2 vials, -80ºC)
		Microbiology (1 vial at 0cm, -80ºC)
FD-DS1-110-MOC		Diatoms (2 vials, -80ºC)
		Diatoms (1 bag, -80ºC)
FD-DS1-132-MC		Diatoms (2 vials, -80ºC)
		Diatoms (1 bag, -80ºC)
		Microbiology (2 vial at 0cm, 5 cm, -80ºC)
FD-DS1-134-MC		Diatoms (2 vials, -80ºC)
		Diatoms (1 bag, -80ºC)
		Microbiology (1 vial at 0cm, 5cm, 10 cm, 20 cm, -80ºC)
FD-DS1-137-MC		Diatoms (2 vials, -80ºC)
		Diatoms (1 bag, -80ºC)
		Microbiology (1 vial at 5 cm, 10 cm, -80ºC)
FD-DS1-149-MC		Diatoms (2 vials, -80ºC)
		Diatoms (1 bag, -80ºC)
		Microbiology (1 vial at 0cm, 5cm, 10cm, 20cm, -80ºC)

6.4. Moorings

Mooring was deployed and recovered after 12 days (FD-DS-HR), and 2 moorings were deployed (FD-DS-A and FD-DS-B) and left for over a year (expected recovery date: 20-27/9/2024). The following tables (Table 12) and figures (Figure 27 and Figure 28) include all information about recoveries and deployments.

The measurements obtained by mooring FD-DS-HR show several drops of bottom temperature from 3.7 to 0.6ºC, and peaks of current speed up to 1.0 m/s which would suggest the occurrence of boluses (that will spin up cyclones) of dense overflow waters on short time scales (2-3 days).

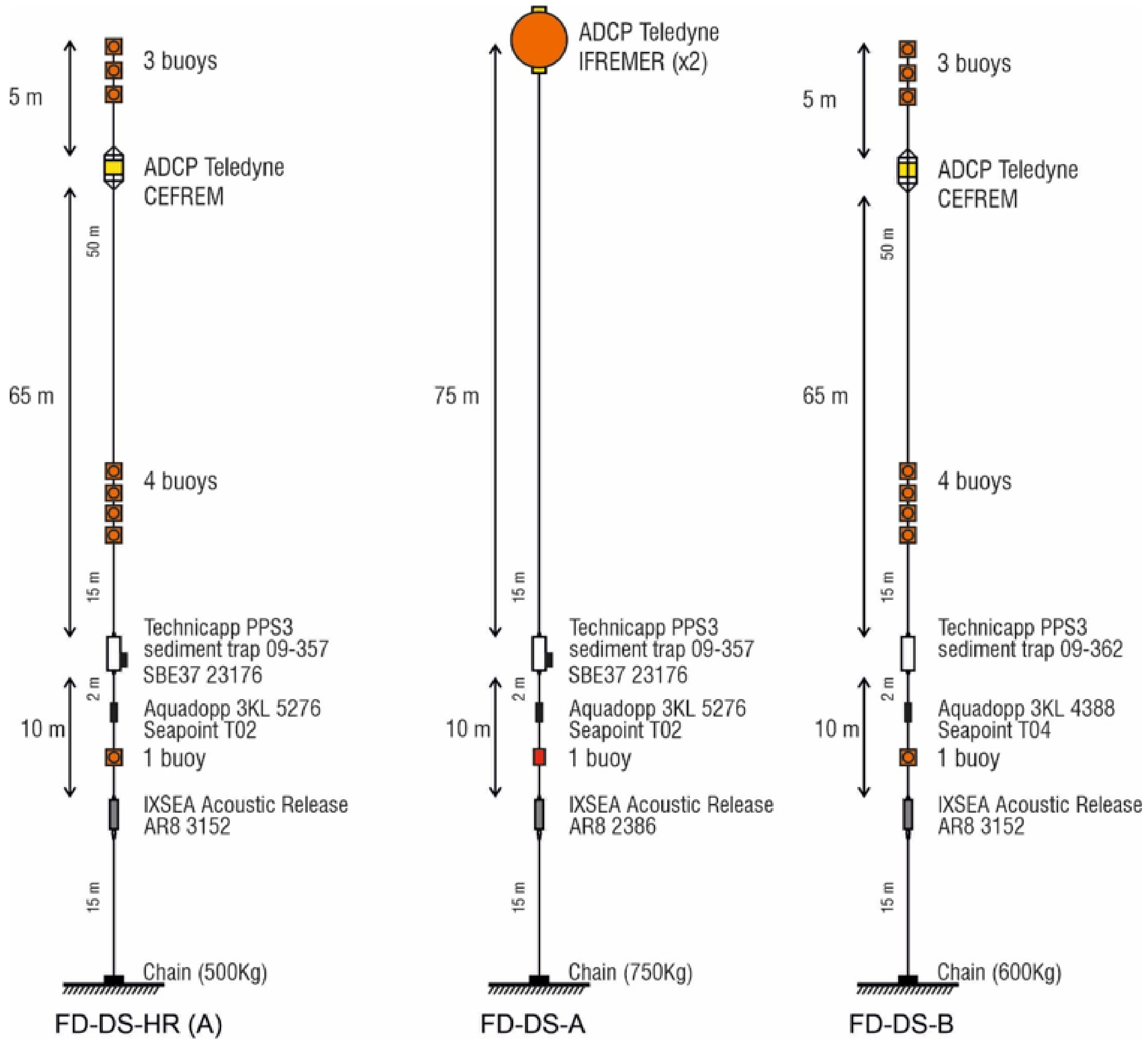


Figure 27. Moorings deployed in the Denmark Strait.

Table 12. Instruments deployed in the Denmark Strait.

Instrument	S/N	Details	Programming
Mooring FD DS HR Deployed 20/7/2023 14:47, Recovered 2/8/2023 11:00 65º14.674'N; 31º19.039'W; 1326 m			
Acoustic Release	AR8 3152	IC68 + IC49 (int)	
		IC68 + IC55 (rel)	
Single Point Currentmeter with Seapoint T002	3KL 5276		Measurement 120 sec Average interval 60 sec
			Start deployment 20/7/2023 08:00
SBE37	23176		Measurement 120 sec
			Start deployment 20/7/2023 08:00
Sediment trap	09-357		1 21/7/2023 00:00
			2 22/7/2023 00:00
			3 23/7/2023 00:00
			4 24/7/2023 00:00
			5 25/7/2023 00:00
			6 26/7/2023 00:00
			7 27/7/2023 00:00
			8 28/7/2023 00:00
			9 29/7/2023 00:00
			10 30/7/2023 00:00
			11 31/7/2023 00:00
			12 1/7/2023 00:00
			Close 2/7/2023 00:00
ADCP Teledyne Workhorse 300 KHz (CEFREM)	6424		Blanking distance 1.76 m
			Bin size 4 m (30 bins)
			30 pings/ensemble (120 sec)
			Magnetic test with bbtalk 17/7/2023: 3.9º (no calibration)
			Start deployment 20/7/2023 08:00
Mooring FD DS A Deployed 3/8/2023 11:42 65º14.6424'N; 31º19.0640'W; 1335 m			
Acoustic Release	AR8 2386	1BC9 + 1B49 (int)	
		1BC9 + 1B55 (rel)	
Single Point Currentmeter with Seapoint T002	3KL 5276		Measurement 600 sec Average interval 60 sec
			Start deployment 04/08/2023 00:00
SBE37	23176		Measurement 120 sec
			Start deployment 04/08/2023 00:00
Sediment trap	09-357		1 1/9/2023 00:00
			2 1/10/2023 00:00
			3 1/11/2023 00:00

			4 1/12/2023 00:00
			5 1/1/2024 00:00
			6 1/2/2024 00:00
			7 1/3/2024 00:00
			8 28/7/2024 00:00
			9 29/7/2024 00:00
			10 30/7/2024 00:00
			11 31/7/2024 00:00
			12 1/7/2024 00:00
			Close 2/7/2024 00:00
ADCP Teledyne (X2)	IFREMER		Data start 03/08/2023 12:00:00
			Measurement frequency: 6 mins
			Depth cells: 4m
			Ping per ensemble: 11
			Ping interval: 3sec
			Ambiguity velocity: 3m/s
			Blank: 1.76 m
			Magnetic variation: -17.4°
Mooring FD DS B Deployed 3/8/2023 9:43 65º01.610'N; 31º22.209'W; 1878 m			
Acoustic Release	AR8 3152	IC68 + IC49 (int)	
		IC68 + IC55 (rel)	
Single Point Currentmeter with Seapoint T004	3KL 4388		Measurement 600 sec Average interval 60 sec
			Start deployment 04/08/2023 00:00
Sediment trap	09-362		1 1/9/2023 00:00
			2 1/10/2023 00:00
			3 1/11/2023 00:00
			4 1/12/2023 00:00
			5 1/1/2024 00:00
			6 1/2/2024 00:00
			7 1/3/2024 00:00
			8 28/7/2024 00:00
			9 29/7/2024 00:00
			10 30/7/2024 00:00
			11 31/7/2024 00:00
			12 1/7/2024 00:00
			Close 2/7/2024 00:00
ADCP Teledyne Workhorse 300 KHz (CEFREM)	6424		Blanking distance 1.76 m
			Bin size 4 m (26 bins)
			17 pings/ensemble (600 sec)
			Magnetic test with bbtalk 2/8/2023: 6-11º (no calibration) (need to recalibrate after the cruise!)
			Start deployment 04/08/2023 00:00

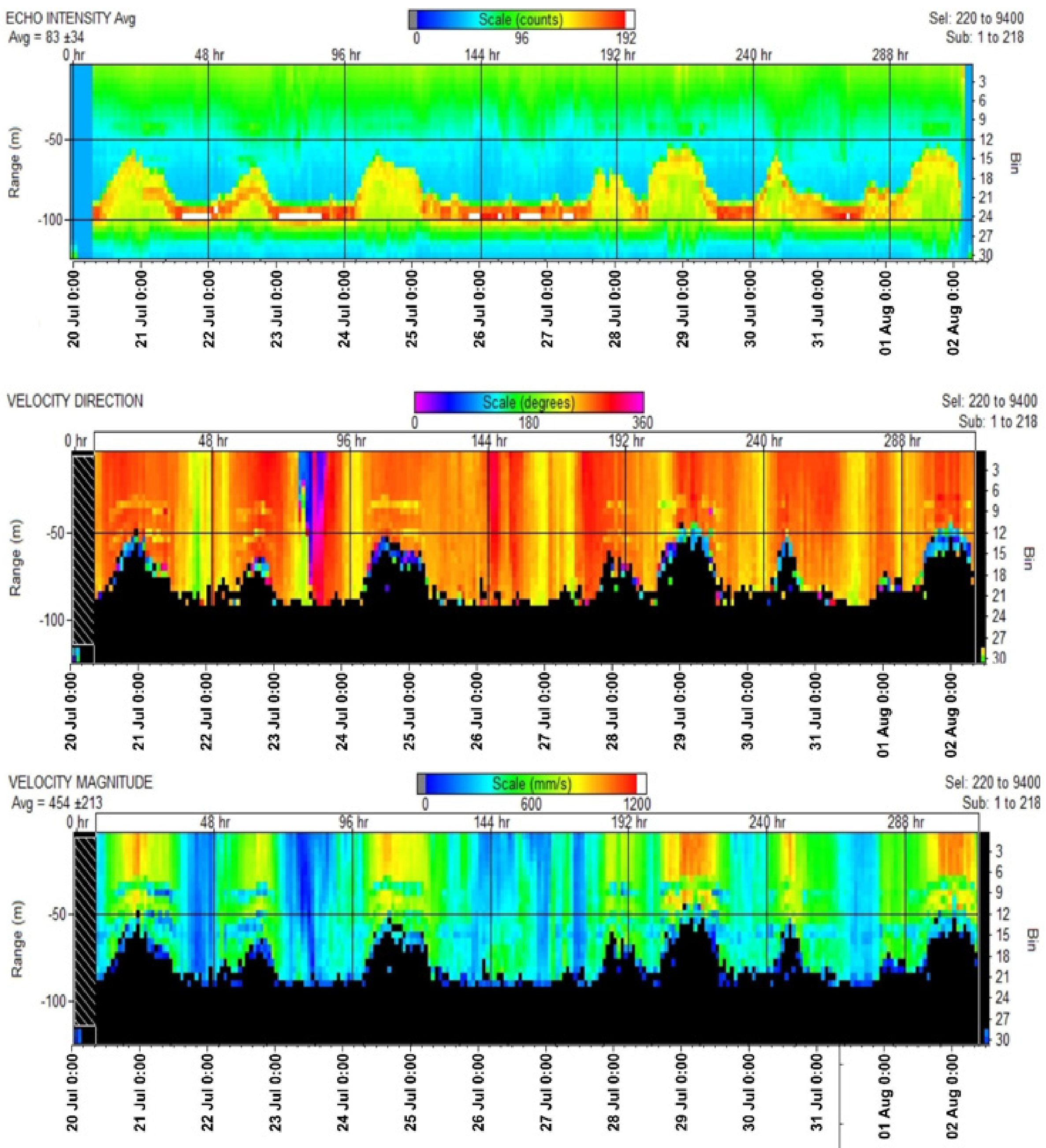


Figure 28. Backscatter, corrent speed and corrent direction as measured by the ADCP moored in the FD-DS-HR mooring.

6.5. Hull-mounted acoustic echosounders

6.5.1. Vessel-mounted Acoustic Doppler Current Profiler (sADCP)

Two Vessel-Mounted Acoustic Doppler Current Profilers (VM-ADCP, also referred to as ship-ADCP or sADCP) are installed on R/V Sarmiento de Gamboa to collect velocity profiles below the ship. The ADCPs, model Ocean Surveyor (TRDI, USA) 75 kHz and 150 kHz frequencies, are installed in the port retractable keel below the vessels' hull. Both ADCPs worked in narrowband mode to maximize range. Single-ping data was acquired following a synchronized routine, OS75 set as master and OS150 as slave. The transducer misalignments are 44.85 º for the 75 kHz ADCP and 45.89 º for the 75 kHz and 150 kHz ADCP respectively, which has been taken into account in the configuration files, together with transducer depth and other specifications (see annexes).

Data was acquired and pre-processed with the VmDas software ver. 1.50.19. This program continuously collects ADCP single ping data and merges it with navigation and attitude data from the ship's instruments. The files generated by VmDas are saved in the local hard disks of respective PCs devoted to this task. Every 12h the files also transferred to a read-only folder in the ship network. Most of the parameters are adjusted through the ADCP configuration file, while communications (ADCP, NMEA) are tuned in a separate menu. The ship's velocity (necessary to obtain absolute, current velocities) is monitored by both navigation (gyro/GPS) and bottom track (ADCP) data, the latter being restricted to the ADCP's range. VmDas rotates, references and averages the raw single-ping data, while applying quality control thresholds, and finally outputs STA (short term averages) and LTA (long term averages) files, which in this survey were set to 2 and 10 minutes averages respectively. These STA/LTA files were inspected with the WinADCP software during navigation to check acoustic and diagnostic data as well as preliminary current velocities.

Beyond this previsualization provided by WinADCP, a more dedicated processing of the raw data has been conducted through two complementary approaches:

a) Short Time Average (STA) files were processed using CASCADE 7.2 software (https://www.umr-lops.fr/en/Technology/Software/CASCADE-7.2). The reference layer from bins 3 to 5, and navigation from GPS are used. Data are also corrected for misalignment and amplitude Figure 30 and Figure 31. For the cleaning, the default parameters are used.

An example of FARDWO-DS1 SADCP data processed with CASCADE software is presented, i.e., the data collected during the cruise from July 19 to August 9, 2023, aboard the R/V Sarmiento de Gamboa (Figures 30 and 31). The velocity and the direction of the currents, as well as the echo intensity measured by the 75 kHz and the 150 kHz sADCPs are given.

b) Long term averages (LTA) were processed with the University of Hawaii software package CODAS (https://currents.soest.hawaii.edu/docs/adcp_doc/index.html). Contour_xy.mat and contour_uv.mat files were generated to support L-ADCP processing (see corresponding section).

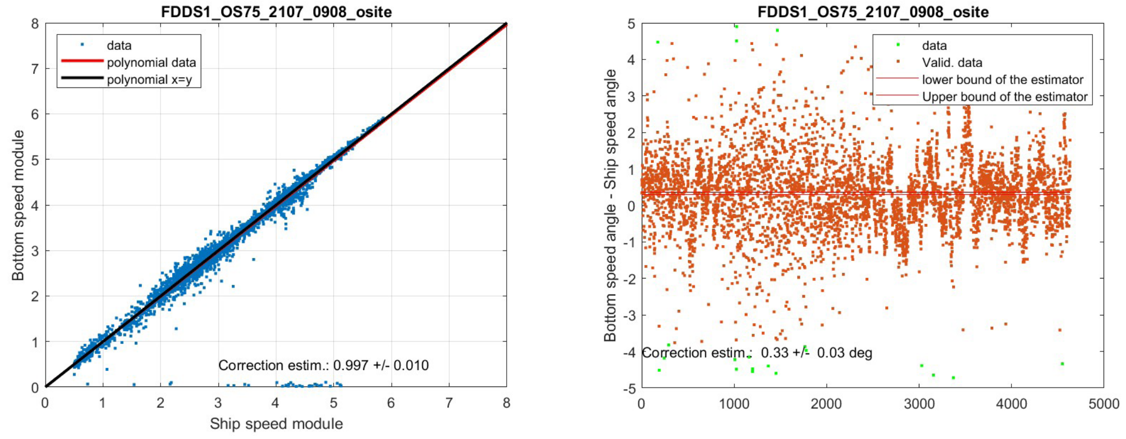


Figure 29. Misalignment and amplitude parameters obtained by the CASCADE processing software for the 75 kHz sADCP.

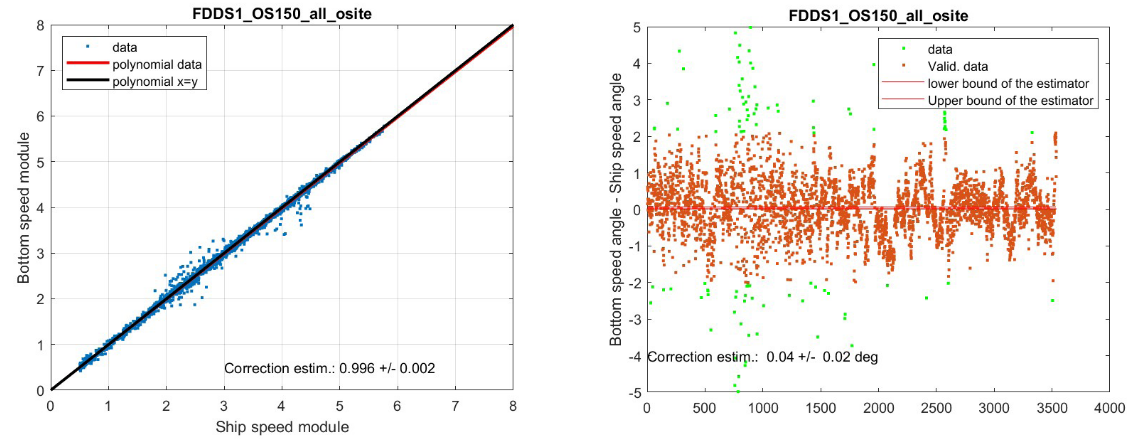


Figure 30. T Misalignment and amplitude parameters obtained by the CASCADE processing software for the 150 kHz sADCP.

6.5.1.1. Incidences and diary

- Both ADCPs, in particular OS75, evidenced technical problems that were already noticed and unresolved in the previous survey, as reported by technicians onboard. "Percent Good" and correlation profiles of the OS75 indicate noise or other problems and the backscatter of beam 4 was sensibly weaker than the other 3 beams throughout the cruise. Also, OS75 often loses large portions of its theoretical range at intermediate or surface levels; this happened in this cruise frequently in coincidence with topmost freshened water layers, and thus could be tentatively attributed to side-lobe reflections on a sharp pycnocline. Both ADCPs presented typical depth ranges of "good" data (as defined by reference thresholds such as echo amplitude > 64 counts; correlation >120 counts; PG4 > 25%) around 125/300m for the OS150 and OS75 respectively, which are clearly below their theoretical optima.
- It is worth noting that there was no ping synchronizer in the Sarmiento de Gamboa. This is a common asset in oceanographic vessels to avoid interferences between the different acoustic instruments (ADCPs, single and multi-beam echo sounders, etc.) working simultaneously.
- Until 21/07/2023 16:44h, the sADCPs are under investigation and different

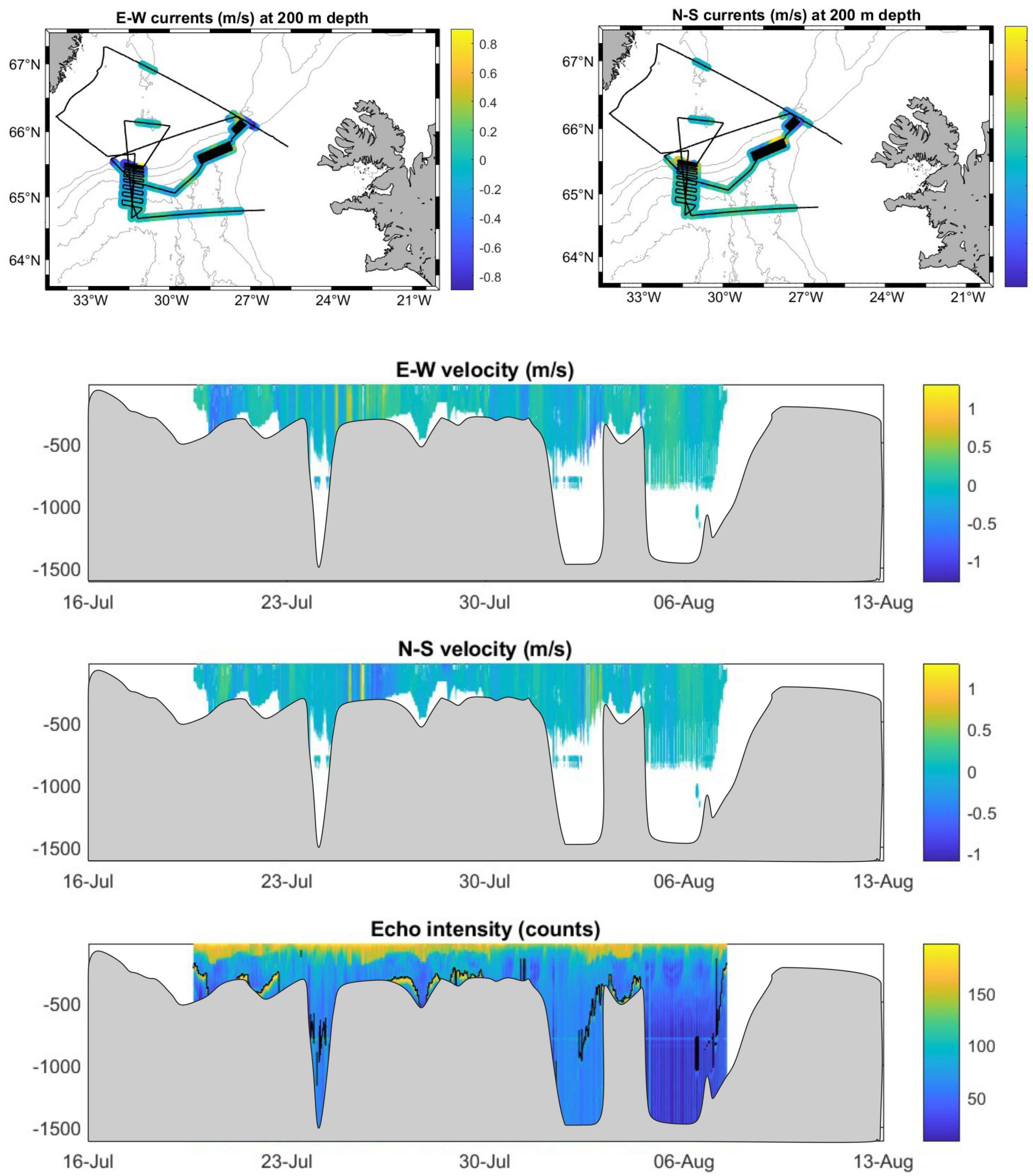


Figure 31. Track of the FARDWO-DS1 cruise at the Denmark Strait, showing the E-W and N-S velocity components (m/s) as a color scale, measured by the 75 kHz sADCP. Time-series of E-W and N-S velocity components (m/s) as well as echo intensity (counts).

configurations are tested (in the VmDas options menus rather than through ACDP config file). Prefixes for these early acquisition tests were “pruebas” and “ADCP”. During these early tests, bin size was 8m for both ADCPs and they were not synchronized. The mobile keel was set to its highest point and hence transducer depth was 5.5 meters. Use of sADCP files up to this point is possible but not encouraged.

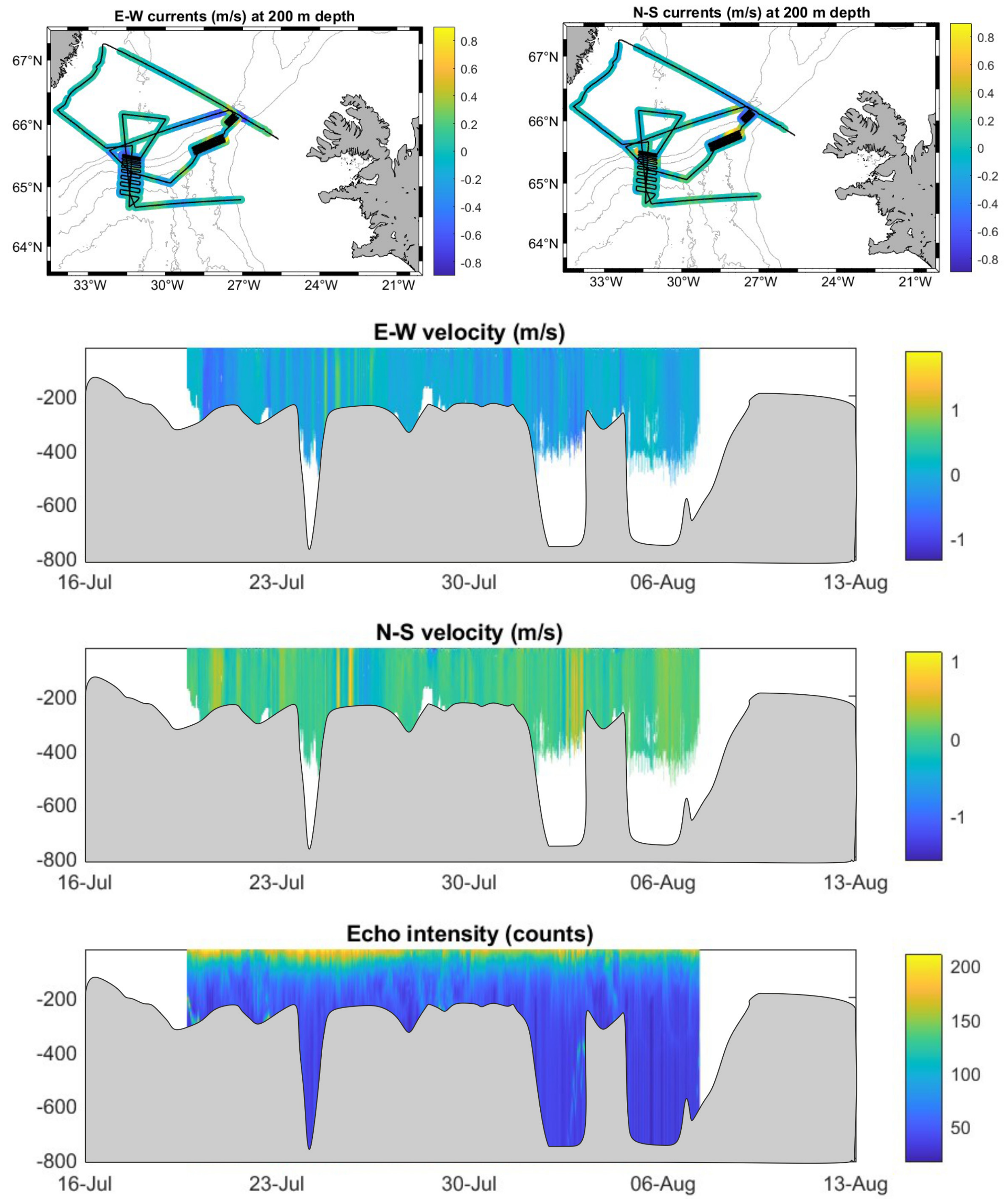


Figure 32. Track of the FARDWO-DS1 cruise at the Denmark Strait, showing the E-W and N-S velocity components (m/s) as a color scale, measured by the 150 kHz sADCP. Time-series of E-W and N-S velocity components (m/s) as well as echo intensity (counts).

- From 21/07/2023 16:44h onwards, the system works under the final configuration which was maintained till the end of the cruise, ADCP configuration files:

  FARDWODS1_OS75_NB_16m_QUILLABAJO.txt; FARDWODS1_OS150_NB_8m_v4_QUILLABAJO.txt

The content of these files is detailed in annexes.

The most important changes were:

- Bin size of OS75 changed to 16m (the optimum recommended by the manufacturer).
- Retractable keel was moved to its deepest range (port keel all the way down, while starboard keel at highest level) in an attempt to minimize noise and bad correlation issues. Consequently, transducer depth is now 10.5 meters. This implies a depth for the first velocity measurement of 18.5 and 22.5m for the OS150 and OS75 respectively.
- ACDPs synchronized (OS75 is master).
- From this point onwards, valid VmDaS files bear the following prefixes for the OS75 and OS150 respectively: FARDWO-OS75-NB8-006; FARDWO-OS150-NB8-037.
- On August 2nd the acquisition is interrupted again during mooring recovery operations to prevent interferences with the TT-801 releaser. On restart, the files have now these prefixes: FARDWO-OS75-NB8-007; FARDWO-OS150-NB8-038

And remain the same till the end of the cruise.

It is important to stress that OS150, in spite of its deceiving "NB8" label, is actually profiling 16-m bins.

6.5.2. Multibeam bathymetry

Bathymetry has been acquired using a hull-mounted Atlas Hydrosweep DS-3 multibeam echosounder. This model has a working frequency of 15.5 kHz (emission frequency between 14.5 and 16.0 kHz) and a full ocean depth range, creating 320 beams with a 1ºx1º beam opening. The typical range achieved at 700 m water depth is approximately 3000 m (4.2 times water depth), with an accuracy of 0.2% water depth. Beam forming mode selected has been equidistant throughout the cruise, with a swath opening of 130º. Data have been acquired at a speed of approximately 8 kt using the Teledyne PDS Suite (Acquisition, Figure 34; and Reason Sonar UI, Figure 35) and recorded in s7k format for an easy import to Caris HIPS & SIPS.

The first four days of the survey (July 19th to July 22nd) the system presented persistent acquisition and synchronization problems. Normal data recording started the afternoon of July 22nd and from then on, multibeam data was continuously acquired during all operations, also during stations, except when acquisition problems occurred and during mooring retrieval.

Raw data files acquired approximately between July 29th 20:30h and August 1st 00:30h were unfortunately lost. The unprocessed 10 m grid displayed in the Teledyne PDS Acquisition module was preserved.

Linear distance of multibeam acquisition during transits sums up 4855.090km (Figure 3). A part from data acquired during transits between sampling stations, three multibeam surveys were conducted in three separate areas (Figure 36, Table 13). CTD casts with temperature, salinity and depth values were used to calculate sound velocity profiles that were then applied during acquisition (Table 14). Nevertheless, obvious refraction problems were detected during

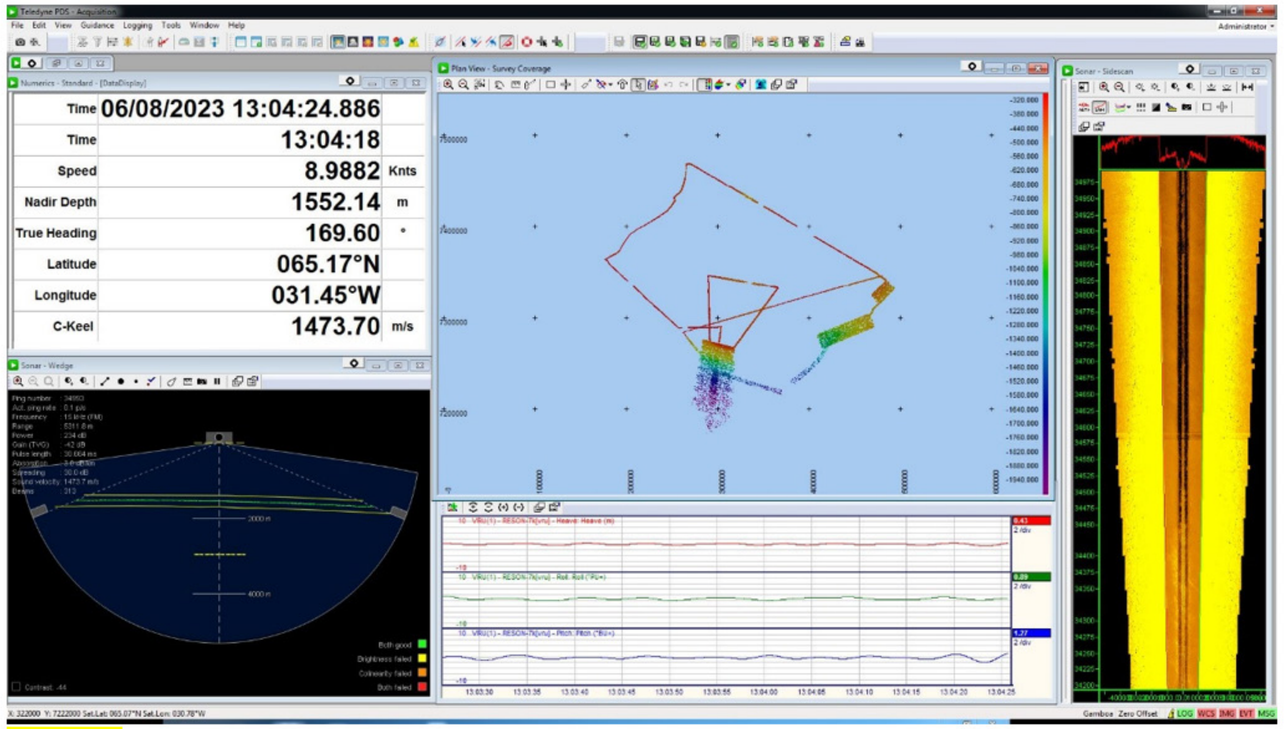


Figure 33. General view of the Teledyne PDS Acquisition window with the bathymetric grid obtained until August 6th.

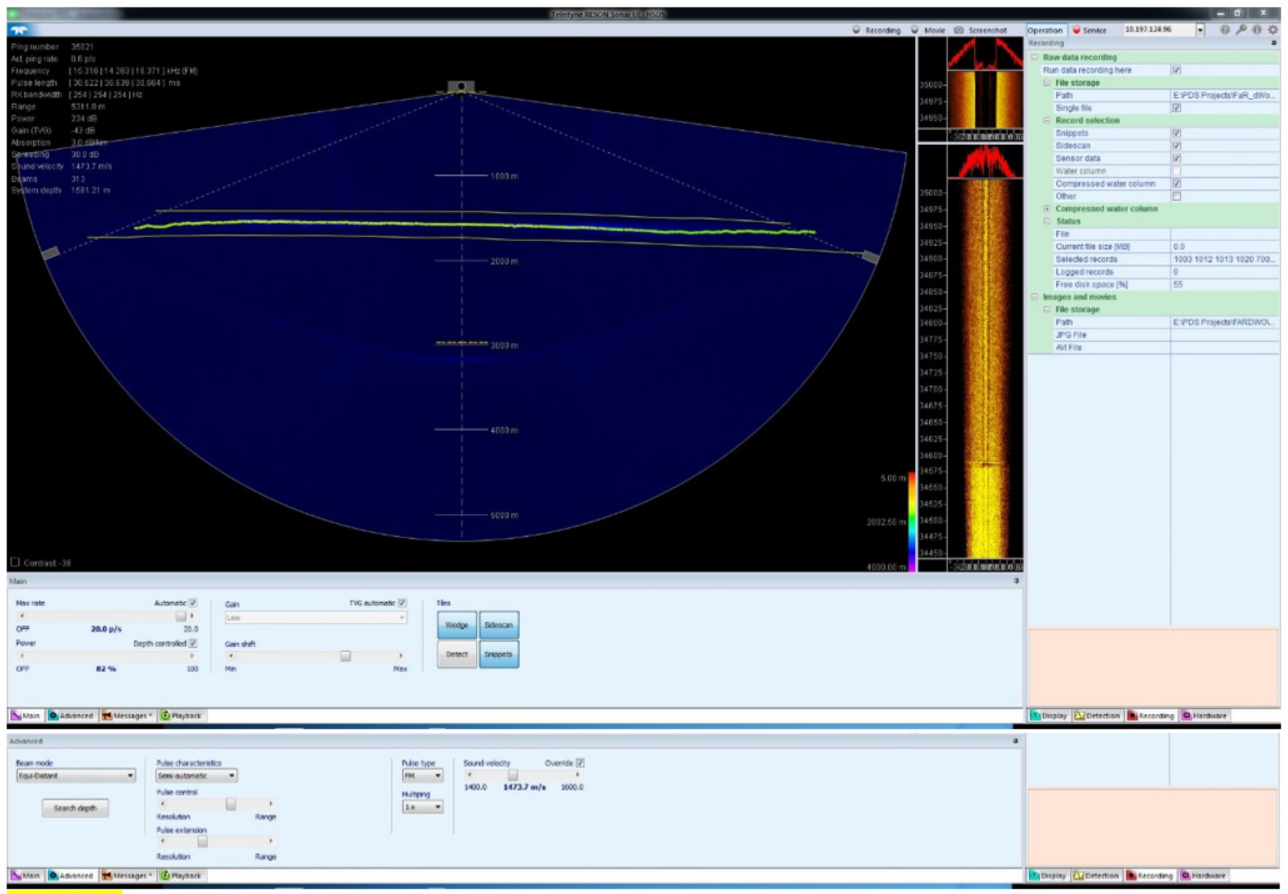


Figure 34. General view of the Teledyne RESON Sonar UI window with the selected acquisition parameters displayed below in the main and advanced tabs.

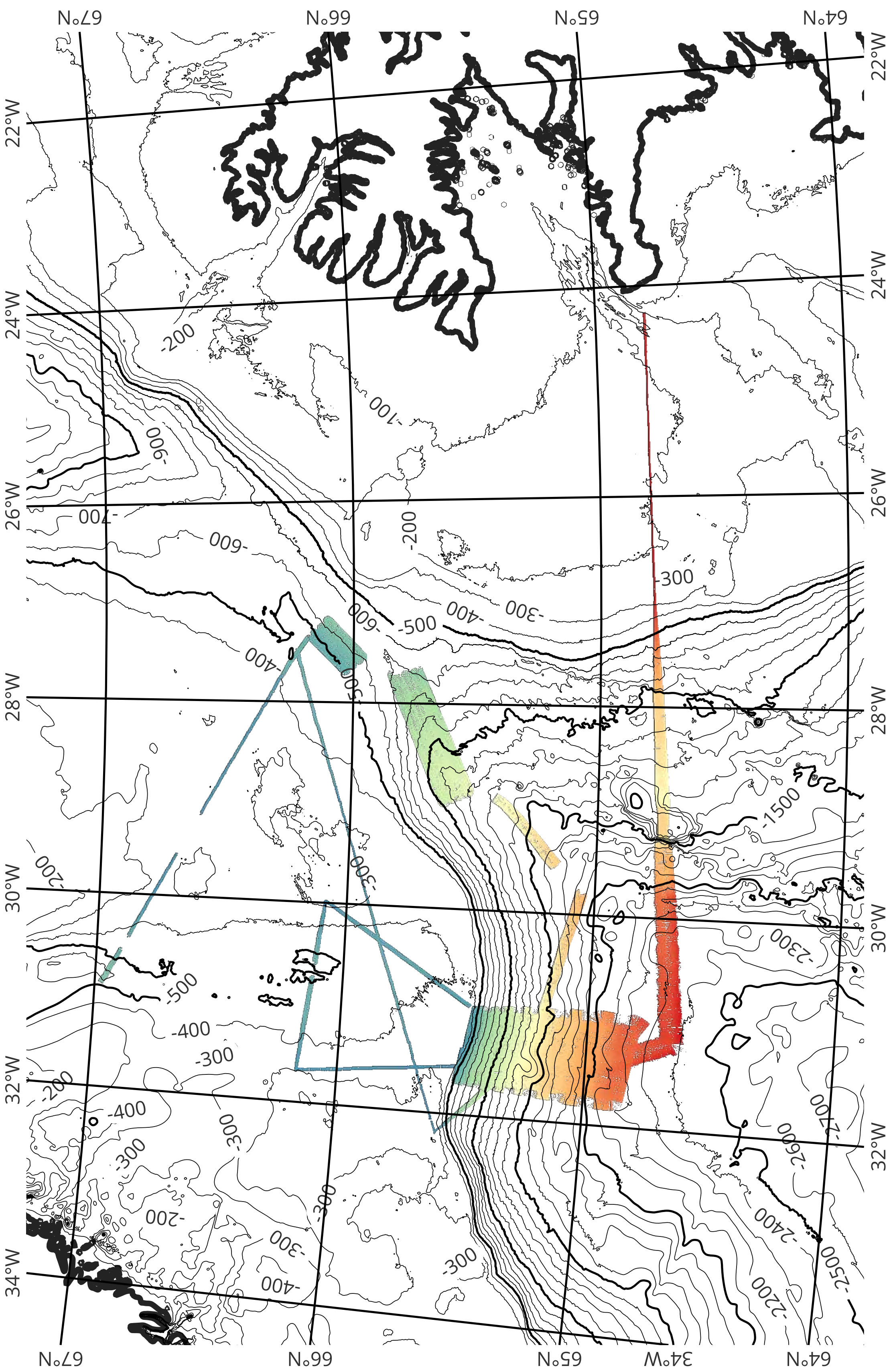


Figure 35. General map of all multibeam data.

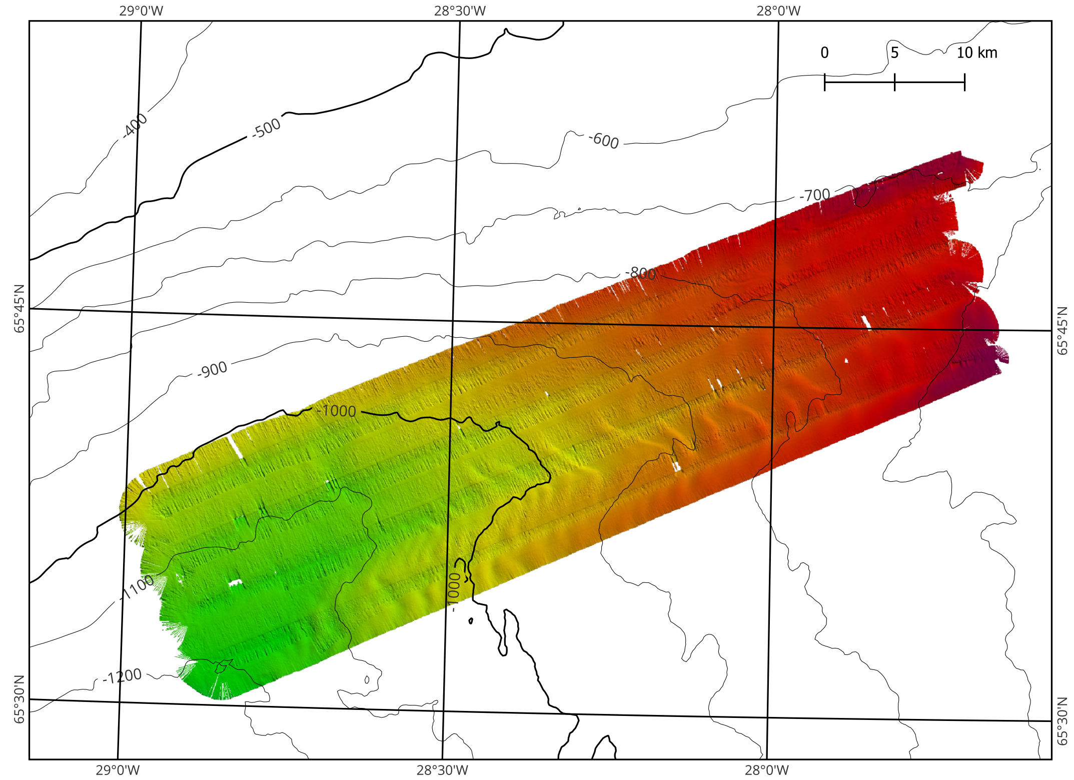


Figure 36. General map of all multibeam data.

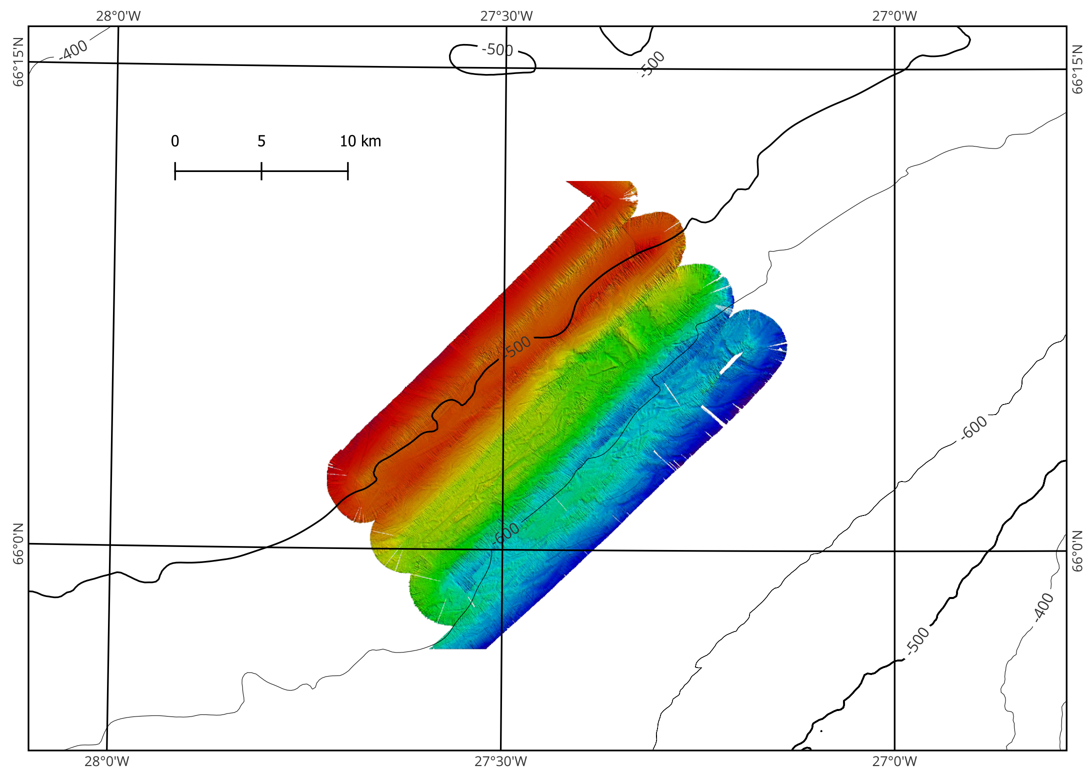


Figure 37. General map of all multibeam data.

some operations.

Multibeam data in s7K were imported to Caris HIPS & SIPS. A preliminary data processing was conducted onboard for the three areas, with automatic filtering and manual flagging of spurious soundings. The backscatter signal was not evaluated. Area 1 comprises water depths between 650m and 1180m of a region southeast of the axial part of the Denmark Strait, and displays large (51000 m long and 800m high) sediment waves (Figure 36). Area 2 is located northeast of Area 1, between 461m and 642m (Figure 36) water depth, whereas Area 3 comprises a wide corridor from the shelf (310 m) down to 20217 m water depth along the moorings transect (Figure 36).

Table 13. General data of the three multibeam surveys conducted.

Survey	Start date	End date	Line numbers	Area surveyed
Area 1	25/7 01:00	27/7 16:11	MB001 to MB008	60x17 km
Area 2	27/7 20:28	28/7 07:33	MB009 to MB015	23x14 km
Area 3	02/8 22:45	05/08 03:23	MB016 to MB032	77x35 km

Table 14. Sound velocity profiles calculated with CTD data and corresponding lines where they have been applied

Multibeam survey area 1					
LINE	START LAT	START LON	END LAT	END LON	SVP
MB001	65°43,75'N	27°39,59'W	65°31,12'N	28°50,67'W	CTD-059
MB002	65°32,11'N	28°51,54'W	65°44,76'N	27°40,44'W	CTD-059
MB003	65°45,70'N	27°40,85'W	65°33,09'N	28°53,21'W	CTD-059
MB004	65°33,98'N	28°53,24'W	65°46,68'N	27°42,61'W	CTD-059
MB005	65°47,60'N	27°44,15'W	65°35,03'N	28°54,88'W	CTD-059
MB006	65°36,10'N	28°55,16'W	65°49,32'N	27°44,46'W	CTD-059
MB007	65°49,79'N	27°45,40'W	65°37,06'N	28°56,83'W	CTD-059
MB008	65°38,04'N	28°57,41'W	65°50,63'N	27°46,46'W	CTD-059
Multibeam survey area 2					
LINE	START LAT	START LON	END LAT	END LON	SVP
MB009	66°06,48'N	27°13,41'W	65°58,55'N	27°33,32'W	CTD-059
MB010	65°59,30'N	27°34,51'W	66°07,66'N	27°14,14'W	CTD-059
MB011	66°08,14'N	27°16,62'W	66°00,18'N	27°36,27'W	CTD-059
MB012	66°00,63'N	27°38,41'W	66°09,04'N	27°18,19'W	CTD-059
MB013	66°09,72'N	27°20,35'W	66°01,56'N	27°40,23'W	CTD-059
MB014	66°02,49'N	27°41,61'W	66°10,93'N	27°21,23'W	CTD-059
Multibeam survey area 3					
LINE	START LAT	START LON	END LAT	END LON	SVP
MB015	64°49,55'N	31°02,53'W	64°52,81'N	31°45,17'W	CTD-125
MB016	64°57,17'N	31°44,27'W	64°53,89'N	31°00,93'W	CTD-125
MB017	64°57,89'N	31°00,91'W	65°01,18'N	31°44,46'W	CTD-125
MB018	65°04,72'N	31°43,07'W	65°01,53'N	30°59,82'W	CTD-122
MB019	65°04,78'N	30°59,37'W	65°08,00'N	31°42,75'W	CTD-122
MB020	65°11,24'N	31°41,96'W	65°08,67'N	30°59,11'W	CTD-121
MB021	65°11,28'N	30°89,46'W	65°14,46'N	31°42,32'W	CTD-120
MB022	65°16,88'N	31°41,27'W	65°13,87'N	30°58,02'W	CTD-120
MB023	65°16,10'N	30°58,95'W	65°19,24'N	31°42,05'W	CTD-119
MB024	65°21,34'N	31°40,69'W	65°18,39'N	30°57,77'W	CTD-118
MB025	65°20,47'N	30°58,05'W	65°23,53'N	31°41,05'W	CRD-118
MB026	65°25,15'N	31°40,59'W	65°22,41'N	30°57,63'W	CTD-117
MB027	65°23,76'N	30°58,93'W	65°26,89'N	31°41,01'W	CTD-117
MB028	65°28,28'N	31°40,51'W	65°25,29'N	30°58,18'W	CTD-116
MB029	65°26,48'N	30°58,01'W	65°29,47'N	31°40,50'W	CTD-116
MB030			65°27,38'N	30°57,21'W	CTD-116
MB031	65°27,83'N	30°59,05'W	65°30,85'N	31°40,45'W	CTD-116
MB032	65°31,03'N	31°35,14'W	65°28,76'N	30°56,28'W	CTD-116

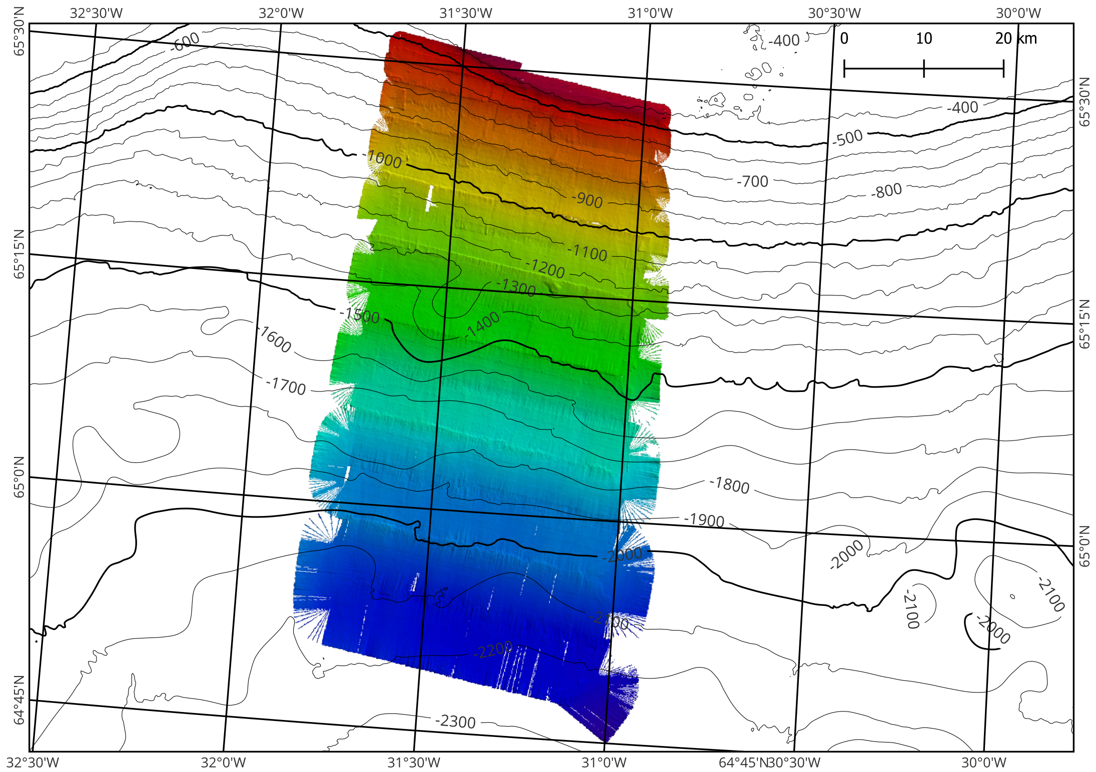


Figure 38. General map of all multibeam data.

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6.5. Acoustic echosounedrs

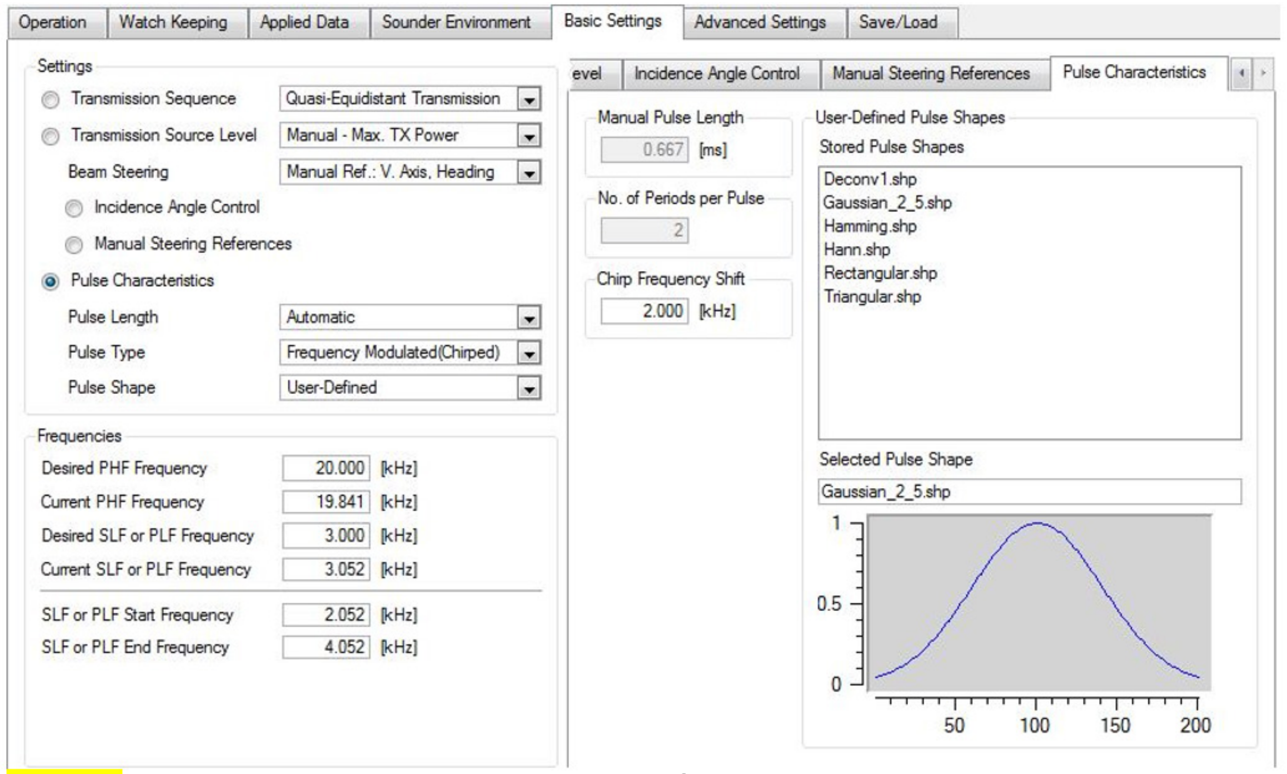

Figure 39. Pulse characteristics used during the FARDWO cruise.

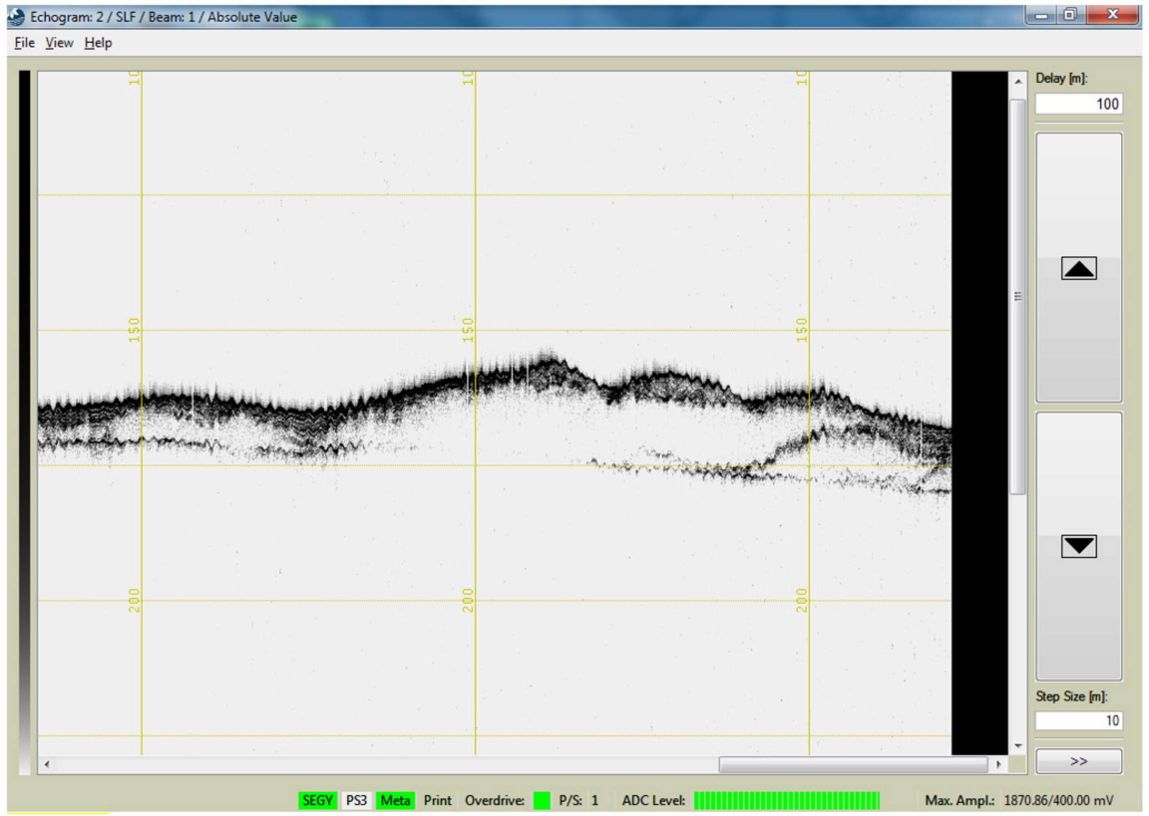

Figure 40. Screenshot during Parasound acquisition at 15:40 5 August, one of the few locations where some penetration was achieved.

Cruise Report FARDWO-DS1-2023
6.5. Acoustic echosounedrs

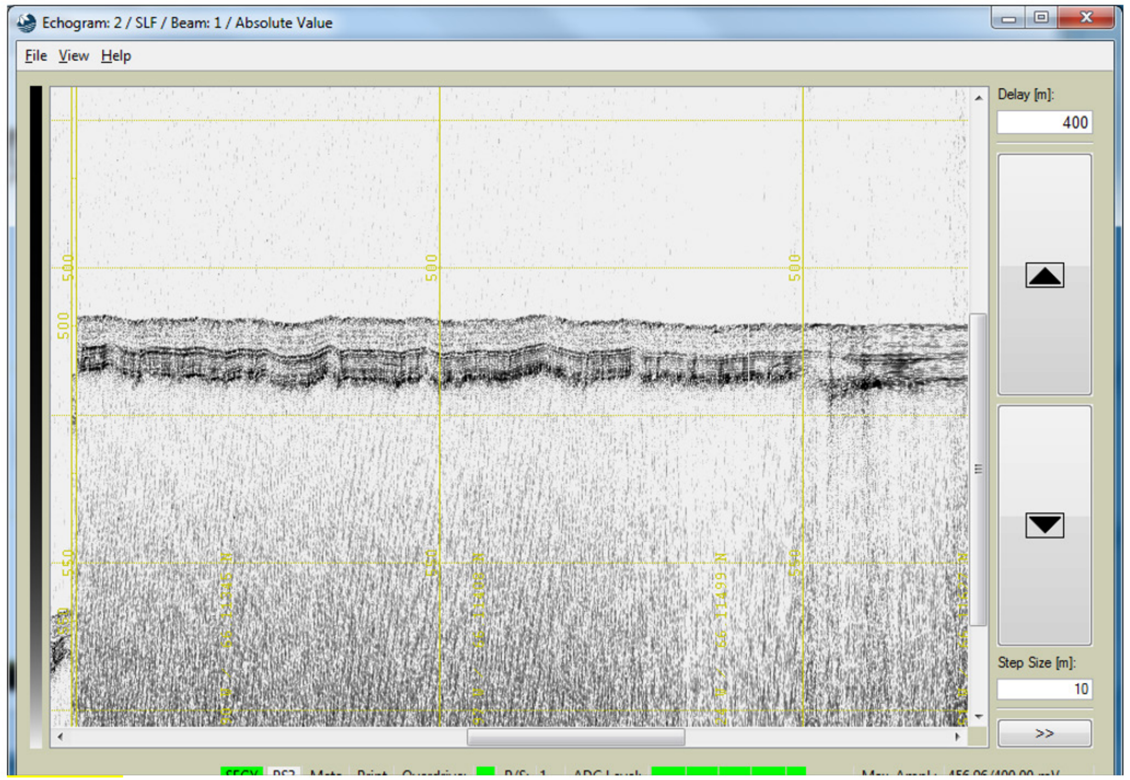

Figure 41. Screenshot during Parasound acquisition at 15:40 5 August, at approx. 500 m water depth in the axis of the Kangerlussuaq trough, one of the few locations where some penetration was achieved.

6.6. Thermosalinograph

6.6.1. TSG specifications

The RV Sarmiento de Gamboa is equipped with a thermosalinograph (TSG) that measures temperature and salinity from the seawater intake in the interior of the ship. The system was operated by the Unidad de Tecnología Marina (UTM) and consists of a Sea-Bird Electronics (SBE) 21. The accuracy of the temperature sensor is 0.001 ºC, the resolution is 10-4 ºC, and the response time is 0.065±0.01 s (Table 15). About the salinity sensor, it has a measurement range from 0.0 to 7.0 S/m with an accuracy of ±0.0003 S/m and a response time of 0.06 s (Table 16). The sampling frequency of the TSG is one measurement per 6 s, finally getting 22 days of data.

Table 15. Specifications of temperature sensor SBE21.

Calibration date	21 Oct 2021
Measurement range	-5 to +35ºC
Accuracy	±0.001ºC
Stability	Must demonstrate <0.001ºC drift during the 6 months prior to delivery
Resolution	0.0003ºC at 24 samples/s
Response time	0.065s ± 0.01 s (1.0 m/s water velocity)
Self-heating error	<0.0001ºC in still water
Settling time	<0.5s to within 0.001ºC

Table 16. Specifications of salinity sensor SBE21.

Calibration date	18 Apr 2023
Measurement range	0.0 to 7.0 S/m
Accuracy	±0.0003 S/m
Stability	0.0003 S/m per month
Resolution	0.00004 S/m at 24 samples/s
Response time	0.060 s (pumped)
Self-heating error	<0.0001ºC in still water

The cruise started with a TSG (Serial No. 3281) that stopped working on 23/07/2023. Thus, on 24/07/2023 the UTM members installed a new TSG (Serial No. 3288), which was calibrated on 04/18/2023 by Sea-Bird GmbH.

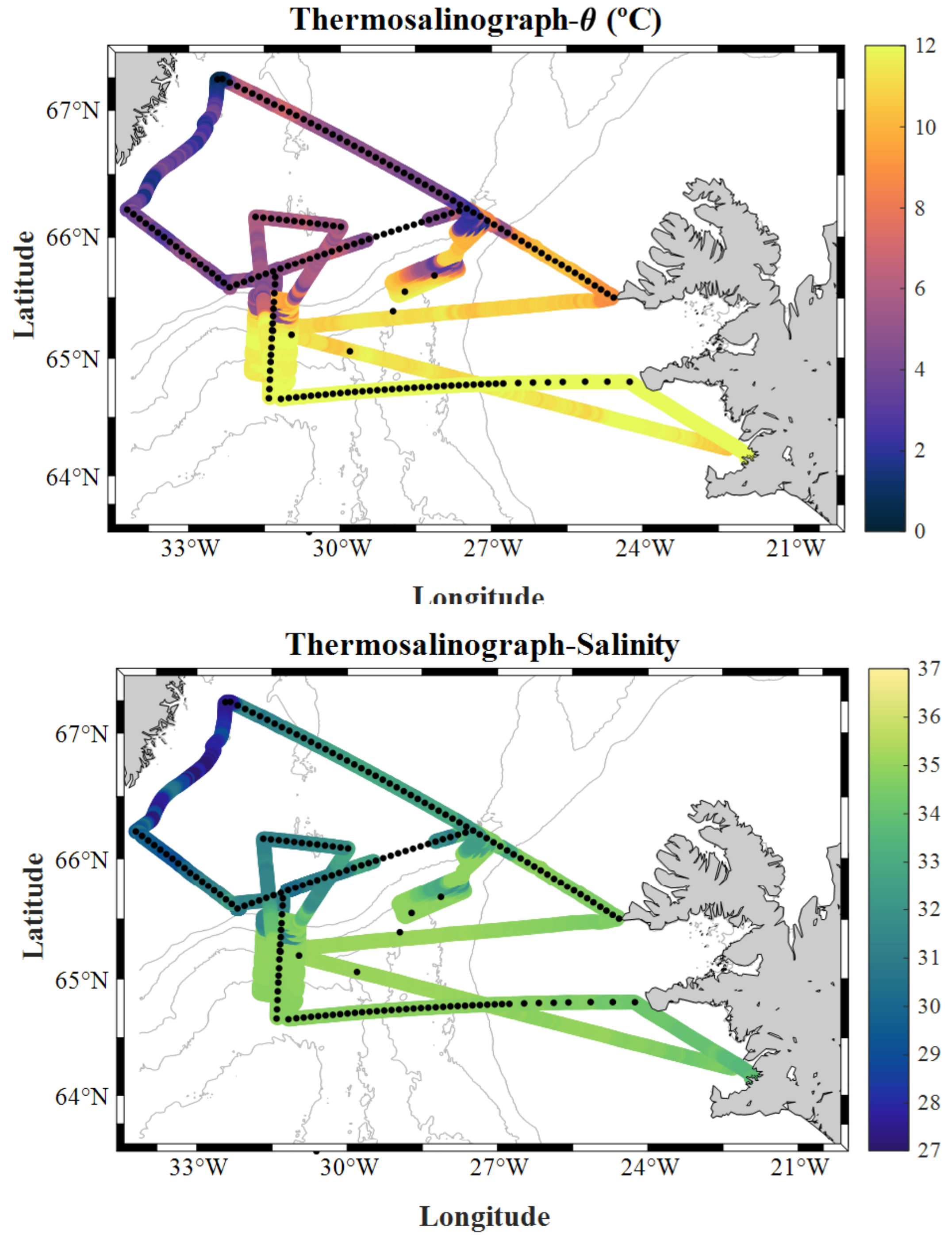

Figure 42. Salinity and temperature distribution on cruise transects.

FAR-DWO
FAR-reaching impacts
of Dense Water Overflows
in the North Atlantic
and the Mediterranean