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HYDROGRAPHIE

Scientific Cruise Report

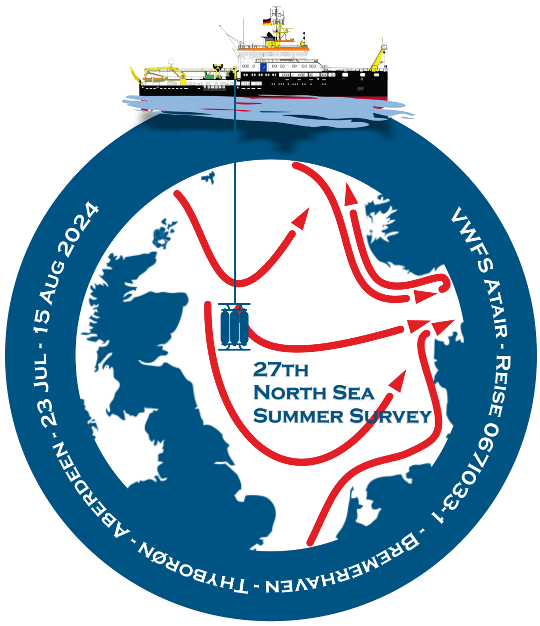
North Sea Summer Survey 2024
RV ATAIR, Cruise 067I033-1

23 Jul – 15 Aug 2024

Bremerhaven/Germany – Thyborøn/Denmark – Aberdeen/UK

Chief Scientist: Dr. Dagmar Kieke

Captain: Ulrich Klüber



Hamburg, November 2025

Suggested Citation:

Kieke, D., M. Köllner, M. Albinus, F. de la Granda Grandoso, N. Hempel, K. Heyer, S. Joswig, O. Klein, T. Kruschke, K. Latarius, F. Oestereich, C. Petrauskas, N. Römer, J. Sprenger, J. Sültenfuß, R. Velten, T. Zimmermann, A. Zonderman, T. Badewien, D. Pröfrock, H. Thomas (2025), North Sea Summer Survey 2024, RV Atair, Cruise 067I033-1, 23 July – 15 August 2024, Bremerhaven/Germany – Thyborøn/Denmark – Aberdeen/UK, *Scientific Cruise Report*, Bundesamt für Seeschifffahrt und Hydrographie (BSH), 58 pages, doi: 10.57802/9vev-j916.

Contact Information:

Dr. Dagmar Kieke

Federal Maritime and Hydrographic Agency (BSH)

Section M22 – Oceanographic Assessments
Bernhard-Nocht-Str. 78
20359 Hamburg
Germany

https://www.bsh.de

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1. Summary

English:

The scientific cruise *067I033-1* with the *Research Vessel (RV) ATAIR* aimed to investigate the physical and chemical state of the North Sea in summer 2024. The focus was on surveying a large-scale network of standard station locations at specific latitudes in order to observe the major inflow and outflow conditions into and out of the North Sea. The overall aim was to obtain suitable physical oceanographic data that serves to further extend already existing time series on the hydrographic properties of the North Sea's water column. Biological data obtained on selected stations with respect to chlorophyll-a and phytoplankton will be used to validate and compare satellite data. Chemical measurements address the carbon system of the North Sea and also serve to assess the concentrations of certain trace metals including mercury and its species as well as microplastic concentrations. Tritium measurements provide a North Sea-wide overview of present-day concentrations of this radionuclide. Data collected during this cruise consisted of hydrographic casts at the standard station locations as well as underway measurements to analyse the hydrographic conditions near the sea surface along the cruise track. Eight surface drifters were deployed in three different regions of the survey area, delivering information on the surface movement when exposed to the oceanic current field. The resulting data set from cruise *067I033-1* is of high quality. Of the intended 111 stations, 92 were surveyed, including a test station. Deteriorating weather conditions towards the end of the cruise prevented surveying the section along the 60°N latitude line. Data from 59°N is only available for the western part.

German:

Die Forschungsexpedition 067I033-1 mit dem Vermessungs-, Wracksuch- und Forschungsschiff (VWFS) ATAIR befasste sich mit der Untersuchung des physikalischen und chemischen Zustands der Nordsee im Sommer 2024. Der Schwerpunkt lag auf der Vermessung eines großflächigen Netzes von Standardmessstationen entlang verschiedener Breitengrade, die zur Beobachtung der wichtigsten Zu- und Abflussbedingungen in die und aus der Nordsee dienen. Das übergeordnete Ziel bestand darin, geeignete physikalisch-ozeanographische Daten zu gewinnen, um bereits vorhandene Zeitreihen zu den hydrographischen Eigenschaften der Wassersäule der Nordsee zeitlich fortzusetzen. Darüber hinaus sollen die an ausgewählten Stationen gewonnenen biologischen Daten hinsichtlich Chlorophyll-a und Phytoplankton zum Vergleich und zur Überprüfung von Satellitendaten herangezogen werden. Chemische Messungen befassen sich mit dem Kohlenstoffsystem der Nordsee und dienen der Bewertung der Konzentrationen bestimmter Spurenmetalle wie z.B. Quecksilber und dessen Spezies sowie Mikroplastikkonzentrationen. Tritiummessungen liefern einen Überblick über die aktuellen Konzentrationen dieses Radionuklids in der gesamten Nordsee. Die während der Fahrt gewonnenen Daten bestehen aus hydrographischen Messungen an Standardmessstationen und Messungen während der Fahrt zur Analyse der hydrographischen Bedingungen nahe der Meeresoberfläche entlang der Fahrtroute. Acht Oberflächendrifter wurden in drei verschiedenen Regionen des Untersuchungsgebiets ausgesetzt und lieferten Informationen über die Oberflächenbewegung, wenn sie dem Strömungsfeld der Nordsee ausgesetzt waren. Der aus der Fahrt 067I033-1 resultierende Datensatz ist von hoher Qualität. Von 111 geplanten Stationen konnten 92, darunter eine Teststation, realisiert werden. Schlechte Wetterbedingungen gegen Ende der Expedition verhinderten die Untersuchung des Abschnitts entlang des 60°N-Breitengrads. Daten von 59°N sind nur für den westlichen Teil verfügbar.

2. Participants

	Name	Institute	Field of Activity/Responsibility
1.	Kieke, Dagmar, Dr. *	BSH	chief scientist, data analysis
2.	de la Granda Grandoso, Francisco **	BSH	CTD watch, water sampling, chlorophyll filtration, plankton sampling, technics
3.	Hempel, Niklas **	Hereon	Hg, alkalinity/DIC, nutrients
4.	Köllner, Manuela *	BSH	CTD watch, VMADCP, thermosalinograph, CTD/VMADCP data processing, water sampling
5.	Klein, Ole, Dr. ***	Hereon	trace elements
6.	Kruschke, Tim, Dr. ***	BSH	CTD watch, water sampling, chlorophyll filtration, plankton sampling
7.	Petrauskas, Catharina ***	Hereon	alkalinity/DIC, nutrients
8.	Römer, Nadine *	BSH	CTD watch, water sampling, chlorophyll filtration, plankton sampling, salinometry
9.	Sprenger, Janina **	Hereon	trace elements
10.	Zimmermann, Tristan, Dr. ***	Hereon	microplastics, Hg
11.	Zonderman, Alexa **	Hereon	trace elements, microplastics

* Bremerhaven – Aberdeen ** Bremerhaven – Thyborøn *** Thyborøn – Aberdeen

BSH *Federal Maritime and Hydrographic Agency, Hamburg, Germany*
HEREON *Helmholtz-Center Hereon, Geesthacht, Germany*

Table 1.1. *Scientific participants of cruise 067I033-1, summer 2024.*

3. Purpose of the Cruise & Research Objectives

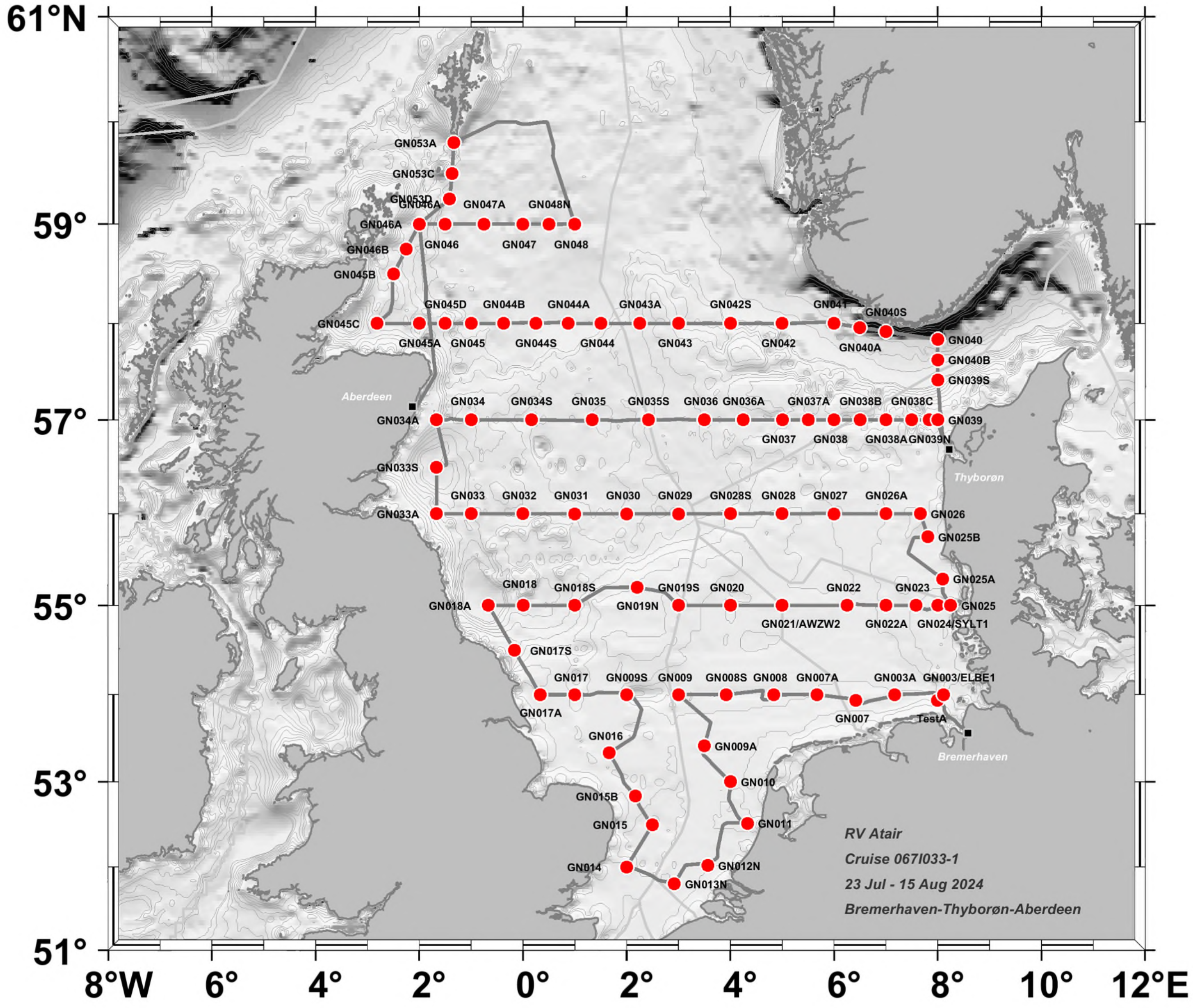

Figure 1.1 *Track of cruise 067I033-1 with RV ATAIR and locations of corresponding hydrographic stations shown as red markers. Text labels denote station names. Thin grey lines highlight the limits of the various Exclusive Economic Zones (EEZ) according to the Maritime Boundaries Geodatabase version 11.0 of Flanders Marine (2019).*

Cruise *067I033-1* with *RV ATAIR* served to conduct the annual large-scale *North Sea Summer Survey* (NSSS) of the BSH. Surveys similar to cruise *067I033-1* have been undertaken annually by the BSH since 1998. These surveys generally follow a predefined net of standard stations forming zonal sections crossing the North Sea at different latitudes between 54°N and 60°N. Additional stations are located to the south of 54°N forming a loop-like station pattern that stretches to about 52°N near the southern entrance to the North Sea. The annual *North Sea Summer Survey* is typically carried out at or close to the time of the expected maximum stratification and with phytoplankton productivity having passed its peak.

The particular cruise *067I033-1* of summer 2024 consisted of two legs, with leg 1 covering the southern to central part of the North Sea and leg 2 covering the central to northern part of the North Sea. Leg 1 with departure in Bremerhaven, Germany, on 23 July led to the port of Thyborøn, Denmark, where the vessel arrived on 4 August (compare Figure 1.1). The port stay during 4 and 8 August was used to exchange crew members and scientific participants (see Section 2). Due to a necessary repair of the vessel's X-band radar, the subsequent departure was delayed. The cruise was resumed on 8 August, when the vessel departed from Thyborøn in order to pursue leg 2 of cruise *067I033-1* in the northern part of the North Sea, which ended with the vessel arriving in Aberdeen, UK, on 15 August 2024.

Similar to summer 2023, the spatial resolution of the northern sections of cruise *067I033-1* was increased in summer 2024 in order to resolve smaller scale oceanic structures. Furthermore, two survey lines located to the west and east of the Orkney and Shetland Islands covering the inflow of Atlantic Water into the North Sea were planned.

The major purpose of cruise *067I033-1* based on respective measurement was to assess the state of the North Sea in summer 2024 with focus on the physical and chemical state. Respective large-scale data will contribute to investigating the hydrographic state of the water column in different regions of the North Sea. Furthermore, temporal hydrographic changes as they become obvious when bringing the data into context with data from previous cruises shall be addressed.

Particular objectives related to cruise *067I033-1* are the following:

- How far does the Atlantic Water (AW) that enters the North Sea at its northern limits propagate southward in summer 2024?
- Where does the main inflow take place?
- How far does AW entering the southern North Sea via the English Channel penetrate northwards in summer 2024?
- What is the respective regional sharpness and depth of the thermocline?
- What is the total salt and heat content of the North Sea in summer 2024?
- Where is the Baltic outflow located?
- What is the current distribution of trace metals and microplastics in the North Sea?
- What are major input pathways of mercury (Hg) to the North Sea, and how do Hg species vary within the North Sea?
- What is the state of the carbon system in summer 2024?
- What is the present-day concentration of the radionuclide tritium in the North Sea?
- What are typical drifter pathways at the sea surface, and what are the associated spreading time scales?

Overarching objectives that address temporal changes on different time scales are:

- How do changes in the Northeast Atlantic happening on time scales ranging from seasonal to decadal affect the North Sea?

- Which processes are linked to the variability in the North Atlantic Oscillation (NAO) and to what extent?

Chlorophyll-a and phytoplankton sampling carried during the cruise and analysis of selected samples will serve for improving remote-sensing products and satellite sensor validation by means of comparison with in-situ data.

4. Narrative of the Cruise

RV ATAIR left its berth at Kohlenkai in Bremerhaven/Germany on 23 July, 2024, at 11:00 UTC and subsequently passed the Bremerhaven sleuth in order to start its cruise *067I033-1*, the *North Sea Summer Survey* of 2024. The scientific mission of cruise *067I033-1* started in the late afternoon/early evening hours of the same day with a test station (#001/Test). Continuous acquisition of underway data was switched on after reaching station #002/GN003/ELBE1. The course was set to the west, initially following the latitude of 54°N. Having finished water sampling at station #004/GN007, the first out of eight surface drifters (EDDY 2089) was deployed. On 24 July, the vessel entered the Dutch EEZ and subsequently worked at nine hydrographic stations (#005/GN007A-#013/GN013N). At station #008/GN009, the vessel turned south to reach the southernmost station of the cruise near the southern entrance to the North Sea (station #013/GN013N, reached on 25 July).

The vessel entered UK waters for the first time on 26 July and worked on stations #014/GN014 to #018/GN009S on a northward course to return to 54°N and complete the measurements at this latitude (#020/GN017A, 27 July).

On 27 July, measurements started at the western end of the 55°N section at station #022/GN018A. Due to the construction of a large wind farm at Dogger Bank forcing the vessel to deviate from its intended cruise track, the location of the former station GN019 could not be reached anymore. Instead, a more northerly position was chosen and is now referred to as GN019N (station#025/GN019N, 28 July). UK waters were left shortly after the completion of station #026/GN019S on 28 July, and Dutch waters were reentered. On 29 July, the vessel reached the eastern end of the 55°N section (station #033/GN025) and headed north to continue measurements along 56°N in a westerly direction. The easternmost station #036/GN026 of the 56°N section was sampled on 29 July in Danish waters, and the westernmost station #046/GN033A in British waters was sampled on 31 July.

The 57°N section began at its western end (station #048/GN034A) on 1 August. The vessel headed east, crossing UK and Norwegian waters, and reached its eastern end at station #062/GN039 on 3 August. Recording of underway measurements was temporarily stopped after this station. So far prevailing general weather and sea state conditions had allowed to arrive quite early in the vicinity of the port of Thyborøn, Denmark. Thus, between the afternoon of 3 August and the noon hours of 4 August, the vessel dropped anchor about 20 nm off Thyborøn.

On 4 August at 13:00 UTC, *RV ATAIR* was towed to Nordre Mole in Thyborøn, Denmark, to complete Leg 1 of Cruise *067I033-1*. While in port, the crew and scientific participants were changed. The subsequent departure was delayed due to a malfunction in the vessel's X-band radar. As the continuation of the cruise without using the X-band radar was not permitted, a repair service had to be organised. On 8 August, a *Kongsberg* radar engineer arrived from Norway and carried out the necessary repairs and switch of radar components. The scientific mission was interrupted until 20:55 UTC on 8 August, when the vessel left Thyborøn to start leg 2 of cruise *067I033-1*. After leaving Thyborøn, recording of underway data was resumed after crossing the 3 nm-limits of Denmark, and station work followed the 8°E longitude towards the north. Three more surface drifters (EDDY) were deployed en route on the stations #063/GN039S to #065/GN040 while crossing the Norwegian Trench. The northernmost point of this section, located south of Norway, was reached at station #062/GN040 on 9 August. Afterwards, the vessel headed towards the west and followed the 58°N latitude from Norway towards the British coast (stations #066/GN040S to #079/GN045A). The western end of the section off the Moray Firth (#080/GN045C) was reached on 11 August.

After finishing the measurements at 58°N, the vessel took a north-eastern course to take measurements along a line from the Moray Firth to the Shetland Islands. This route passed the Orkney Islands to the east. The last four drifters (EDDY 2087, 2086, 2085 and 2083) were deployed at stations #082/GN046B to #085/GN053C on 11–12 August. On 12 August, the northernmost standard station of the cruise (#086/GN53A) was reached. This station is located directly to the south of the Shetland Islands and typically shows the strongest oceanic flow conditions at depth. While the CTD cast was being conducted, the crew of the *HM Coast Guard*'s search-and-rescue helicopter stationed on Shetland asked to carry out training manoeuvres directly above the vessel. The CTD cast was therefore interrupted, and the water sampler was brought back on deck. The cast was repeated once the manoeuvre had finished.

After completing its work at the station south of the Shetland Islands, the vessel reached 60°N on the eastern side of the islands. However, weather conditions had started to worsen significantly. Southeasterly winds of 8–10 Beaufort and high seas prevented any further station work. With the recording of underway measurements still switched on, the vessel attempted to follow 60°N until, on 12 August at 19:20 UTC, it was decided that it would be impossible to continue carrying out measurements at this latitude. Instead, the vessel changed course to head south again in order to reach latitude 59°N. Station work resumed at station #087/GN048 on 13 August. The final stations were surveyed along the 59°N line in a westerly direction. Station #092/GN046A was the last station to be surveyed and the only station visited twice during the cruise.

The continuous logging of underway data was stopped at around 19:30 UTC on 14 August, marking the end of the scientific mission of cruise *067I033-1* with *RV ATAIR*. The vessel arrived at the pilot station of Aberdeen at 13:15 UTC on 15 August and took on a pilot. The vessel was finally towed to Blaikies Quay No. 2 in the Port of Aberdeen, UK, at 13:22 UTC, marking the end of cruise *067I033-1*.

The port stay in Aberdeen was used for the disembarkation of the scientific participants and crew members of cruise *067I033-1*, as well as the embarkation of the participants of the subsequent cruise *067I033-2* (chief scienstist Dr. Torben Kirchgeorg, BSH) and the installation of the necessary laboratory equipment and instrumentation.

5. Scientific Tools & Methods

5.1 Overview

Scientific tools that were in use during the cruise comprised profiling of the entire water column using a Conductivity-Temperature-Depth (CTD) unit attached to a carousel water sampler system and equipped with a number of sensors that will be detailed in the following sections. Additional sensors attached to the CTD-unit involved a sensor measuring dissolved oxygen, a dual-wavelength sensor measuring simultaneously both turbidity and fluorescence, and an altimeter for determining the distance of the underwater unit to the sea bottom in order to avoid contact.

The carousel water sampler was equipped with a fixed number of 10 L sampling bottles to allow for taking water samples at discrete depths of the water column. Water sampling activities consisted of taking oxygen and salinity samples for the sake of calibrating the conductivity and oxygen sensors of the CTD unit. Further water samples addressed analysing water density, chlorophyll-a and phytoplankton, dissolved inorganic carbon (DIC), nutrients, trace metals including mercury and lead for shore-based laboratory analyses. In total, 92 stations involving the CTD/water sampler system were carried out. Secchi depth determination, water sampling for chlorophyll-a and phytoplankton were only performed on daylight stations.

A vessel-mounted Acoustic Doppler Current Profiler (VMADCP) system operating at 150 kHz and in narrow-band mode delivered oceanic velocity data of the upper water column during the cruise. Further underway measurements focused on standard meteorological data, water depth, near-surface values for water temperatures, salinity, fluorescence/chlorophyll and turbidity. An inert filtration cascade connected to the vessel's clean seawater system was active along several transects to obtain particulates in surface water for shore-based laboratory analysis of microplastics.

5.2 CTD Sensor Unit & Water Sampler Setup

During cruise *067I033-1* a profiling conductivity-temperature-depth (pressure) sensor unit (CTD) of type *Sea-Bird Electronics (SBE) 9plus* ("*CTD Sonde S6*") was in use. It was operated and powered from out of the vessel's hydrography lab via a deckunit of type *SBE11plus*. The CTD sensor package was mounted horizontally in the lower part of a water sampler frame (K7) of type *SBE32* potentially carrying up to 12 Niskin bottles of 10 L volume. The corresponding bottle release module is suitable for 24 bottles. Starting with position 1, every second bottle release position was chosen when closing any water sampler bottles. In addition to a set of Niskin bottles, the water sampler was equipped with one 10 L PTFE-coated Go-Flo bottle that was used for sampling of dissolved trace metals. All devices and sensors that were in use are listed in Table 5.1; the water sampler bottle set-up is listed in Table 5.2. The recording of the raw data was done using the BSH software *Seasave_Start* that internally calls the *SBE*-software *SeaSave*, version 7.26.7.121, and the data conversion software (from binary into ASCII) *SBEDataProcessing*, version 7.26.7.129.

Device	Serial Number	Calibration Date
CTD main housing with pressure sensor, SBE9plus	09P56228-1005, S6	20 Mar 2019
deckunit, SBE11plus	11P29178-0620, N1	---
temperature sensor 1, SBE3T, part of TC1	5254	29 Jun 2023
temperature sensor 2, SBE3T, part of TC2	5278	29 Jun 2023
conductivity sensor 1, SBE4C, part of TC1	3691	29 Jun 2023
conductivity sensor 2, SBE4C, part of TC2	3694	29 Jun 2023
oxygen sensor, SBE43	0153	16 Apr 2022
pump 1, SBE5	10061	---
pump 2, SBE5	10062	---
dual-wavelength sensor, WET Labs ECO-AFL/FL, fluorescence	4738	15 Jan 2018
dual-wavelength sensor, WET Labs ECO, turbidity	4738	15 Jan 2018
supplementary termperature sensor installed at the height of the Niskin bottles, SBE35	078	04 Jul 2016
altimeter, Valeport VA500	81276	11 Dec 2013
carousel water sampler with 12 positions for Niskin bottles, SBE32	3256228-0814, K7	---

Table 5.1. *Overview on CTD-related sensors or water sampler devices used during cruise 067I033-1.*

The CTD sensor package consisted of a primary and a secondary pair of temperature (T) and conductivity (C) sensors that were each connected to a particular pump and the main CTD housing carrying a pressure sensor. A through-flow oxygen sensor was connected to the primary T/C sensor pair. In addition, a dual-wavelength sensor of type *WetlabECO* delivering simultaneously fluorescence and turbidity data was attached to and powered by the CTD system. The distance to the sea bottom was estimated from an altimeter of type *Valeport VA500*. Inlets of the two T/C sensor pairs were soaked in distilled water before the start and after the end of each CTD cast. A supplementary temperature sensor was installed at the height of the Niskin bottles about 1 m above the CTD unit in order to record water temperature at the time of the bottle closing. All temperature and conductivity sensors were successfully recalibrated in the BSH's calibration laboratory prior to the cruise. In-situ temperatures are reported on the *ITS-90* scale. Derived salinities refer to the *Practical Salinity Scale* of 1978 (PSS-78). All respective densities have been inferred from the *EOS-80* equation.

The CTD system worked well during the whole cruise, and all sensors showed reliable measurements. The differences between redundant sensors were small and mostly within uncertainty range as given by the manufacturer and later calibration. Larger differences were observed under rough measurement circumstances or due to large numbers of particles within the water column clogging the sensor packs for short times.

Position	Bottle ID	Manufacturer	Volume	Nominal Closing Depth
1	S-ID181001	*General Oceanics*	10 L	bottom
3	S-ID181013	“ “	“	bottom
5	S-ID181005	“ “	“	Chl-a max
7	S-ID181006	“ “	“	Chl-a max
9	Go-Flo 179	*General Oceanics*	“	10 m
	S-ID181014	*General Oceanics*	“	10 m
11	S-ID181003	“ “	“	5 m
	S-ID181014	“ “	“	10 m
	Go-Flo 179	*General Oceanics*	“	10 m
13	S-ID181004	*General Oceanics*	“	5 m
	S-ID181003	“ “	“	5 m
15	S-ID181004	“ “	“	5 m

Table 5.2. *Overview on the Niskin bottle set-up and sampling scheme of cruise 067I033-1. Changes in the bottle set-up and thus changes to the bottle positions on the water sampler were made beginning with stations #002, #022 and #023.*

All Niskin bottles were checked at the beginning of the cruise and then closed during the upcast at the designated sampling levels. Before closing, a 3 min waiting time was applied to avoid entrained water from different depth levels being taken as a sample. Salinity samples were always taken from Niskin bottles closed near the bottom and at 5 dbar, see Table 5.2.

5.3 Water Sampling with respect to Salinity

Water samples were collected at all stations during cruise *067I033-1* for the purpose of checking the quality of the CTD-derived conductivity and, consequently, salinity. An exception was made at the test station at the start of the cruise. Water samples were taken from Niskin bottles closed at 5 dbar near the surface and at the bottom. The bottles were numbered and rinsed three times with seawater before being filled and sealed airtight. The water samples were analysed using an *OSIL AUTOSAL 8400B* salinometer, s/n 72273. Analysis of salinometer samples was partly done already during the cruise. For standardisation, *IAPSO* standard seawater batch P-167 was used. All samples were assigned a BSH sample identification number similar to a *Bedford* number.

5.4 Water Sampling with respect to Density

Water sampling with respect to density analysis was carried out on selected stations. Similarly to salinity, water samples were taken from the Niksin bottles that were closed near the surface at 5 dbar and close to the bottom. Numbered glass bottles were used and rinsed three times with seawater before finally filling the bottle. The sample was made air-tight by closing the bottle with a rubber plug and attaching a metal seal on top. All samples were given a BSH sample identification number similar to *Bedford* numbers. Back at the home lab, density samples were analysed with a densitymeter of type *Mettler Toledo Excellence D6*. In total, 38 samples taken from 19 station locations distributed all across the North Sea were analysed for density. Figure 5.2 presents the station locations with density sampling carried out during cruise *067I0331-1*. Sampling and analysis is done with respect to building up a density database for the North Sea for the sake of obtaining absolute salinity data, S_A. These should be based on density measurements that can be traced back to SI units, a prerequisite when considering the *Thermodynamic Equation of Seawater 2010* (TEOS-10).

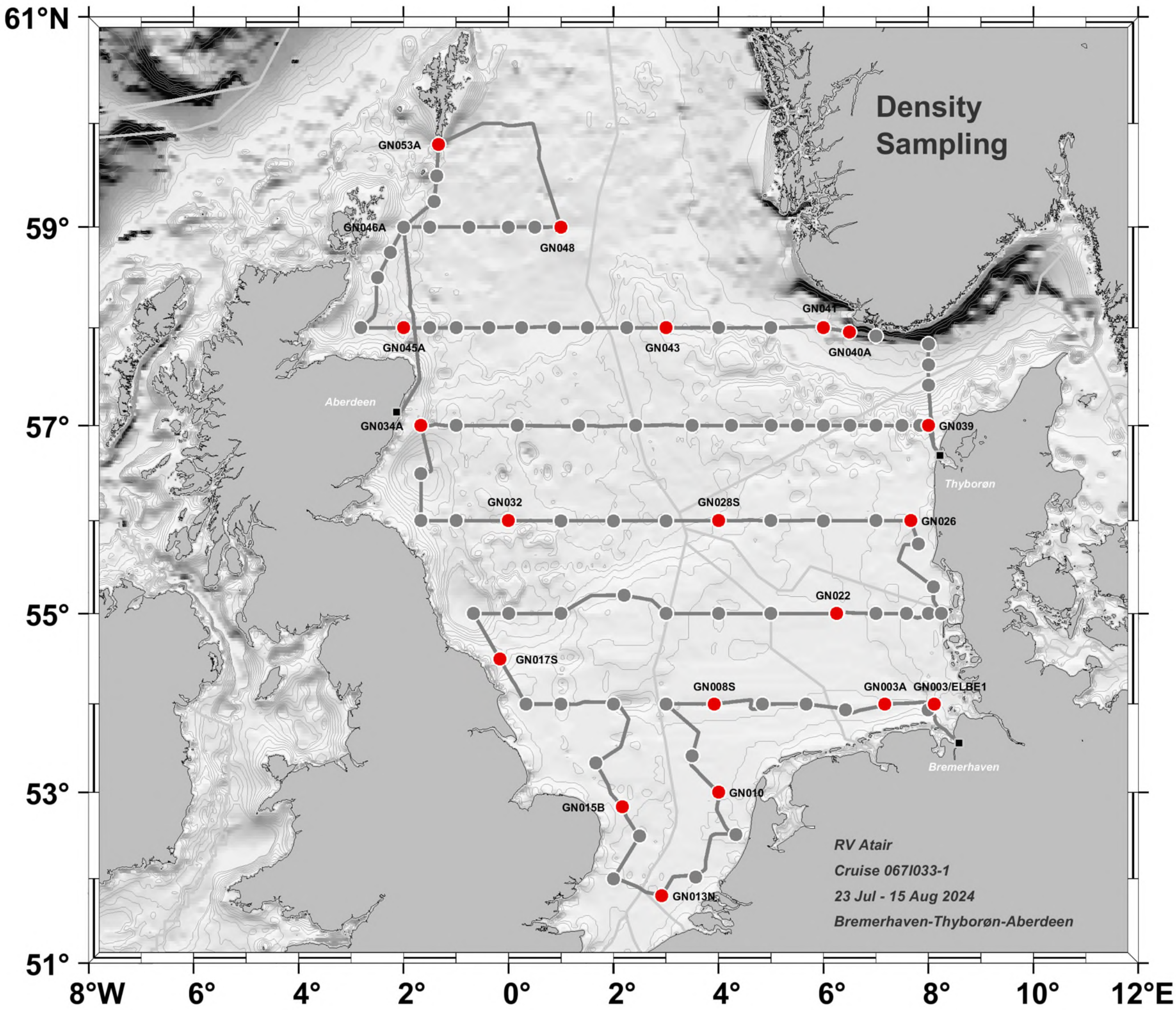

Figure 5.2. *Distribution of stations carried out during cruise 067I033-1 with density sampling (red dots).*

5.5 Near-Realtime Processing of CTD Data

All CTD data have been recorded at an original resolution of 24 Hz. Data have been checked and pre-processed during the cruise using the *SeaBird SBE Data Processing* software, version 7.26.7.129. The preliminary data taken from the downcast of each CTD profile were binned at 1 dbar resolution and sent on a daily basis during the cruise in near-real-time to the Maritime Data Centre at BSH, Hamburg, Germany and there were uploaded to the CrossDataPortal (https://cdp.srx.bsh.de), the open data portal of BSH, from where the data are available to the public. In total, near-realtime data for 92 CTD profiles were submitted and published during the cruise.

Pre-processing showed a better performance of the primary temperature/conductivity sensor pack (TC1) for most of the cruise. For station #086/GN053, the first CTD cast had to be cancelled during the upcast due to a search-and-rescue helicopter training manoeuvre of a *HM Coast Guard* helicopter directly above the vessel. A second CTD cast was later performed to collect the required water samples.

Overall, the performance of the CTD sensor unit during the cruise was good. Several profiles showed larger spikes most times within the gradients or layers of high biological activity, which might have let to clogging of one or both sensor packs.

The supplementary *SBE 35* temperature sensor was read out after every station and compared to CTD-derived temperature recorded at the time of closing the Niskin bottles during the up-cast. Data was downloaded directly from the sensor using the software *SeaTerm*, version 1.59.

5.6 Post-Cruise Processing of CTD Data

Post-cruise comparisons were made between CTD sensor packs TC1 and TC2 and between CTD temperatures and a supplementary temperature sensor of type *SBE35* installed at the height of the Niskin bottles. Furthermore, a comparison between CTD salinities and AUTOSAL-derived salinities was performed (compare Tables 5.3 and 5.4 and Figures 5.5 and 5.6).

The following correction procedure is applied to temperatue and conductivity/salinity measurements as well as oxygen data:

- Assumed measurement accuracy: T-CTD: ± 0.002, C-CTD: ± 0.003, S: estimated: ± 0.004
- A temperature correction will be applied in case the temperature difference (CTD vs. *SBE35*) exceeds 2x 0.002 and/or the difference between temperature sensors T1 and T2 exceeds 2x 0.002.
- A conductivity correction will be applied in case the salinity difference (AUTOSAL vs. CTD) exceeds 0.003 and/or the difference between conductivity sensors C1 and C2 exceeds 2x 0.003.
- The random error of oxygen samples obtained from titration is approximately 1%. Corrections are made if the oxygen difference (bottle vs. CTD oxygen) exceeds 1%.

Post-cruise quality control showed that the CTD data of cruise *067I033-1* were of high quality, and differences between TC sensor pairs were consistently small. When considering all data, all differences (at the latest after exclusion of outliers) are well within the error bounds. However, there are characteristic patterns in the sensor differences for conductivity and, even more clearly, for salinity when passing through a profile, especially at the deep profiles. Profiles that exceeded 200 dbar reveal a slight pressure dependence of the two sensors. All comparisons revealed small differences, which were within the error bounds and were slightly smaller for temperature, conductivity and salinity from the secondary sensors. Temperature differences between the T-sensors of the CTD-unit and the attached and external SBE35 sensor were within 0.0009 for 92% of the measurements when using temperature data from the primary sensor T1, and within -0.0001 for the secondary sensor T2. This is well within the uncertainty range of ± 0.004°C, see above.

In summary, any post-cruise correction of the data was not applied, and the temperature, conductivity and salinity data were made available with flag 1 (good data). The usage of the data from the secondary sensor pair (TC2) is recommended.

Sampling and titration of oxygen samples was not performed during cruise *067I033-1* to the North Sea, but was carried out on the subsequent cruise *067I033-2* to the German Bight. The same oxygen sensor was used on both cruises. The comparison between CTD oxygen and oxygen obtained from titrated water samples of cruise *067I033-2* unfortunately revealed a malfunction of the CTD oxygen sensor. Consequently, any correction of the sensor-derived oxygen data was not possible, and sensor-derived oxygen data from both cruises were made available with flag 4 (bad data).

Any quality control of fluorescence and turbidity data was not performed. Thus, the respective data were made available with flag 0 (no quality control applied).

Salinity Difference AUTOSAL-CTD	**All samples**	**All samples with differences < +/- 1 standard deviation**	**All samples with differences < +/- 1 standard deviation for the 2nd mean**
AUTOSAL - TSC1			
Number of data pairs	183	175	150
percentage		96%	82%
Mean difference	-0.0074	-0.0008	-0.0007
Median difference	-0.0012	-0.0011	-0.0010
Standard deviation	0.0466	0.0059	0.0021
AUTOSAL – TSC2			
Number of data pairs	183	175	111
percentage		96%	83%
Mean difference	-0.0064	-0.0007	-0.0005
Median difference	-0.00008	-0.00004	-0.00008
Standard deviation	0.0460	0.0065	0.0020

Table 5.3. *Results of the comparison between bottle salinity samples obtained from salinometer measurements (AUTOSAL) and conductivity/salinity recordings at the time of closing the Niskin bottles, the latter obtained from the two CTD sensor packs (TSC1 and TSC2).*

Temperature Difference **SBE35 - CTD**	**All samples**	**All samples at a pressure > 3.8 dbar**	**All** **± 1 standard deviation**
SBE35 - T1			
Number of data pairs	691	691	633
percentage		100%	92%
Mean difference	0.0039	0.0039	0.0009
Median difference	-0.0004	-0.0004	-0.0004
Standard deviation	0.0369	0.0369	0.0088
SBE35 – T2			
Number of data pairs	691	691	635
percentage		100%	92%
Mean difference	0.0030	0.0030	-0.0001
Median difference	-0.0008	-0.0008	-0.0009
Standard deviation	0.0417	0.0417	0.0102

Table 5.4. *Results of the comparison between temperature recordings from a supplementary SBE35 sensor installed at the height of the Niskin bottles at the time of closing the bottles, and from the two CTD-based sensors, T1 and T2.*

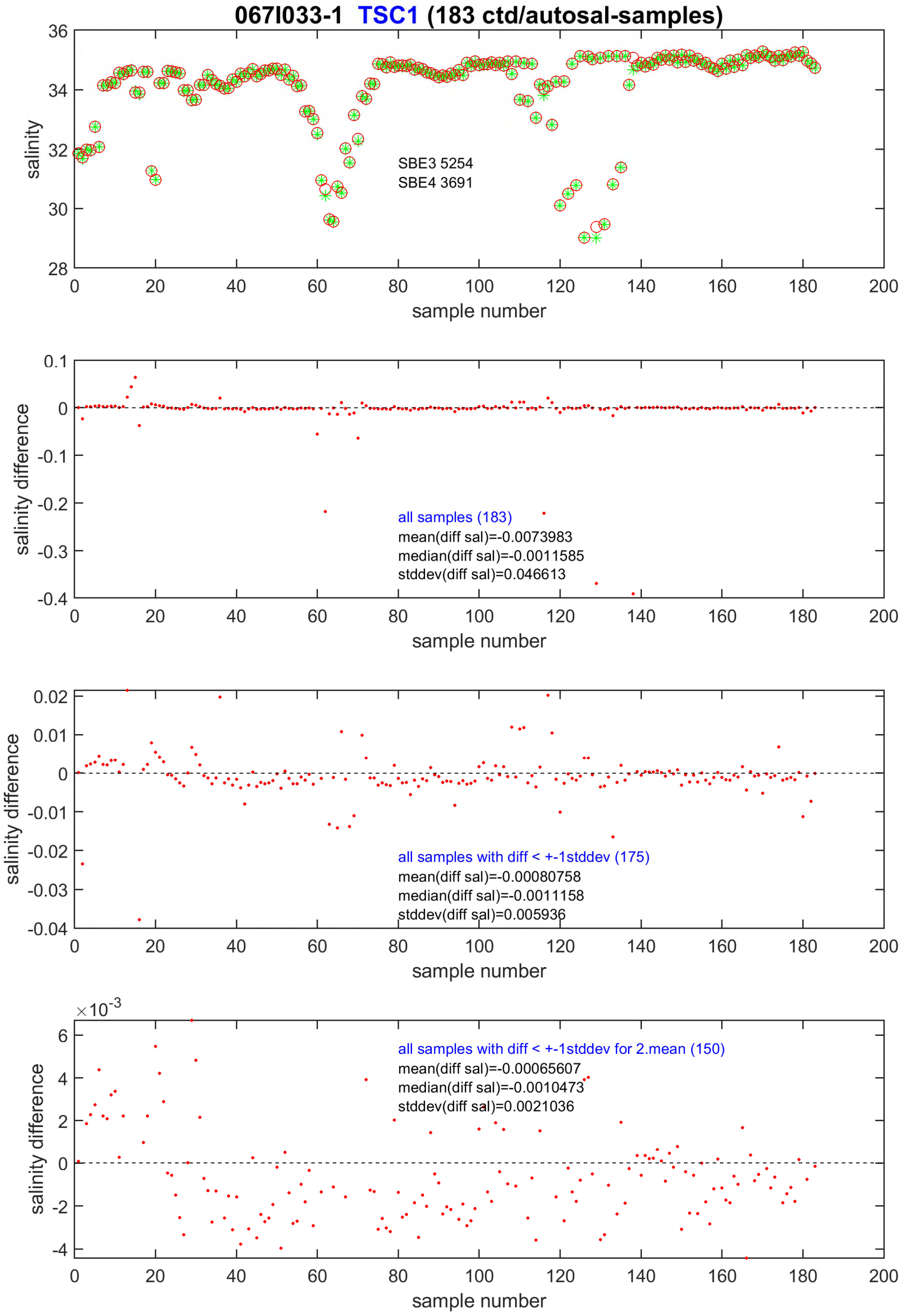

Figure 5.5. *Differences between bottle salinity samples measured with an AUTOSAL salinometer and CTD-derived salinity samples at the time of closing the Niskin bottles, here CTD sensor pack TSC1.*

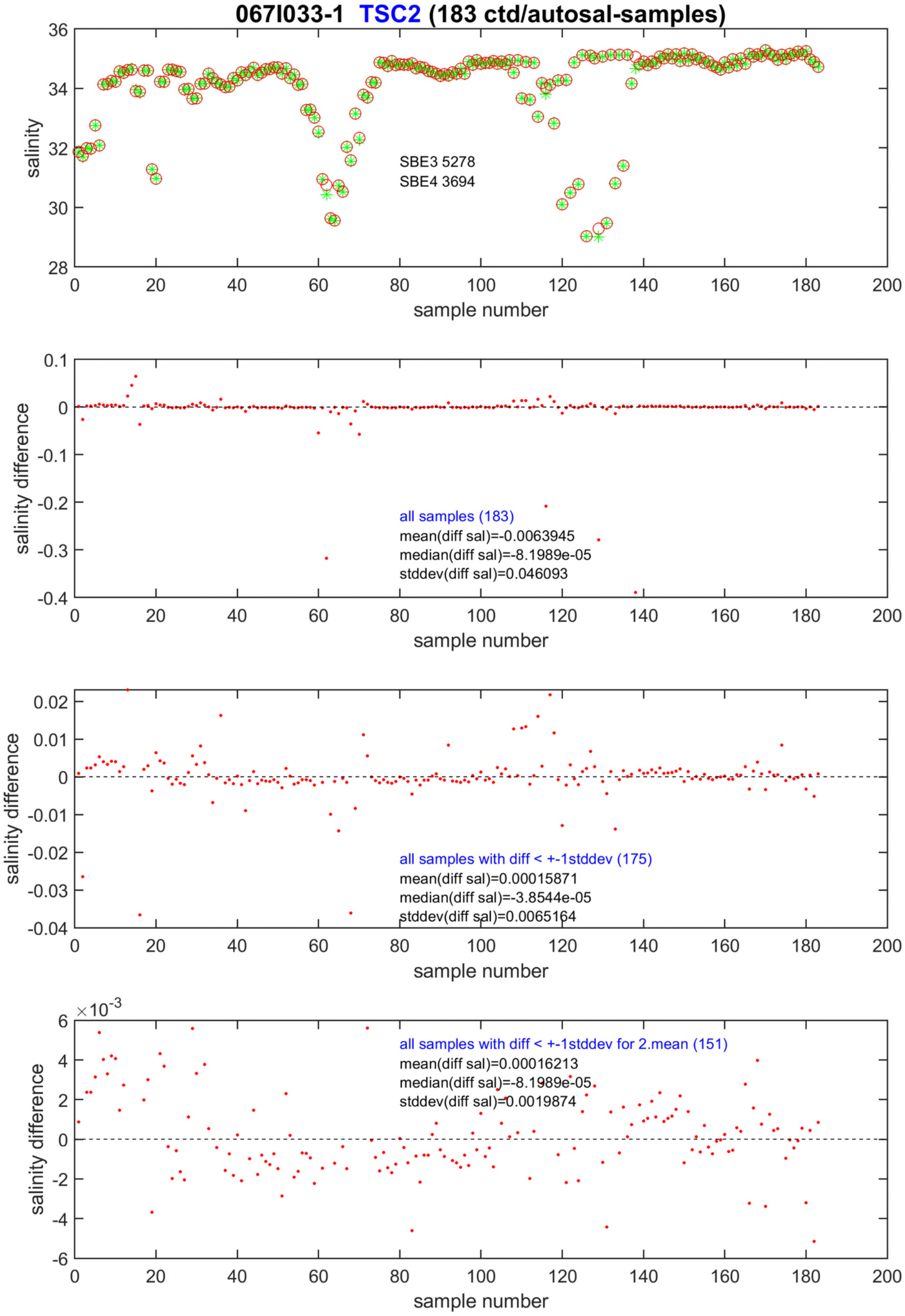

Figure 5.6. *Differences between bottle salinity samples measured with an AUTOSAL salinometer and CTD-derived salinity samples at the time of closing the Niskin bottles. Data as in Figure 5.5, but here shown for CTD sensor pack TSC2.*

5.7 Secchi Disc, Chlorophyll-a & Phytoplankton Sampling

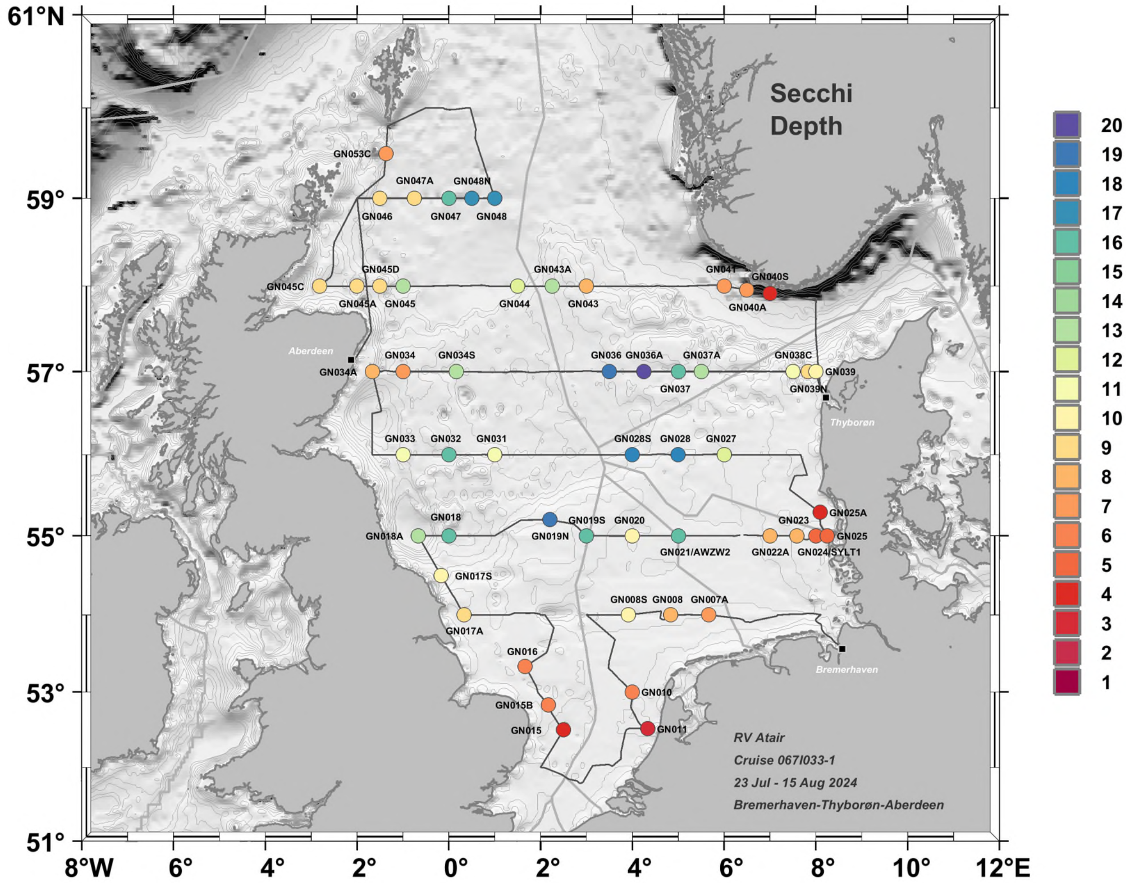

Figure 5.7. *Secchi depths observed during cruise 067I033-1, summer 2024.*

<u>Secchi Depth</u>

The Secchi depth is a measure for the transparency or clarity of the oceanic water column. Values typically range from < 1 m near estuaries to > 12 m in the open North Sea. Secchi depth measurements follow instructions described in *BSH (2007)*. The Secchi depth was measured using a Secchi disc, a white-painted metal plate with an additional weight, both connected to a rope. The rope in turn was connected to a mobile winch installed on the port side of the vessel. At daylight stations, the Secchi disc was lowered into the surface layer of the ocean until it was no longer visible. Coloured tapes at 0.5 m intervals along the rope mark every 0.5 m, 1 m, and 5 m. The mark on the rope closest to the sea surface represents the Secchi depth, i.e. the depth of transparency at that location. The accuracy of the Secchi depth observation is +/- 0.5 m. Figure 5.7 highlights the station locations and corresponding Secchi depths observed under daylight conditions during cruise *067I033-1*.

Chlorophyll-a Sampling and Filtration

To determine the chlorophyll-a content in the surface waters of the North Sea, water samples were taken during cruise *067I033-1* from the Niskin bottles closed at a depth of 5 m and filled into 3 L PE bottles. After sampling, the water sample was filtered using a low-pressure filtration system. Filtration was done through a glass fibre filter (ø = 47 mm and pore size 0.4µm) on a glass filter plate. For this purpose, the PE bottle was shaken at first to allow for homogensosation of the water sample. Then, a measured volume was filled into a filtration tulip, which was connected to a suction bottle. The volume to be measured was determined by the previously recorded Secchi depth, see Table 5.5. The exact sampling depth, the Secchi depth, the filtered volume and the room temperature were recorded. After filtration, the glass fibre filter with the sample residue was removed from the filtration tulip, folded twice and transferred to a PE centrifuge tube with a screw cap. This tube was wrapped in aluminium foil to avoid exposure to light. The sample was labelled by assigning a unique sample identification number similar to *Bedford* numbers, which was applied directly to the tube and the aluminium foil. The sample was then frozen and stored at -80°C to allow for later analysis in the home laboratory. One duplicate sample was analysed per day. On-board filtration was performed as described in *BSH (2022)*.

Figure 5.8 shows the location of stations with water sampling for subsequent chlorophyll-a determination. Corresponding water sampling was carried out on daylight stations with Secchi depth measurement. If there was a delay between collecting the water from the Niskin bottle and the filtration, the water sample was stored in the dark and cooled in the refridgerator.

Spectrophotometric analysis was carried out in the home laboratory after the cruise to determine the total chlorophyll-a content in seawater. The method follows *Jeffrey and Humphrey (1975),* and the phaeopigment content was determined according to *Lorenzen (1967)* and *Aminot & Rey (2001).* The interlaboratory performance study (QUASIMEME, R2024.2) for the parameter chlorophyll-a in seawater during the measuring period in the BSH laboratory was successfully. The resulting z-scores are 0.2 / 1.3. The mean range for the duplicates (12 samples) taken on cruise *067I033-1* was less than 0.05 µg/L CHLA.

Secchi Depth [m]	Required Volume [ml] for Filtration
0-2	up to 500, only for coastal stations
2-5	up to 1000
5-10	up to 1500
10-15	up to 3000

Table 5.5. *Secchi depth and corresponding sample volume required for the filtration of chlorophyll-a samples.*

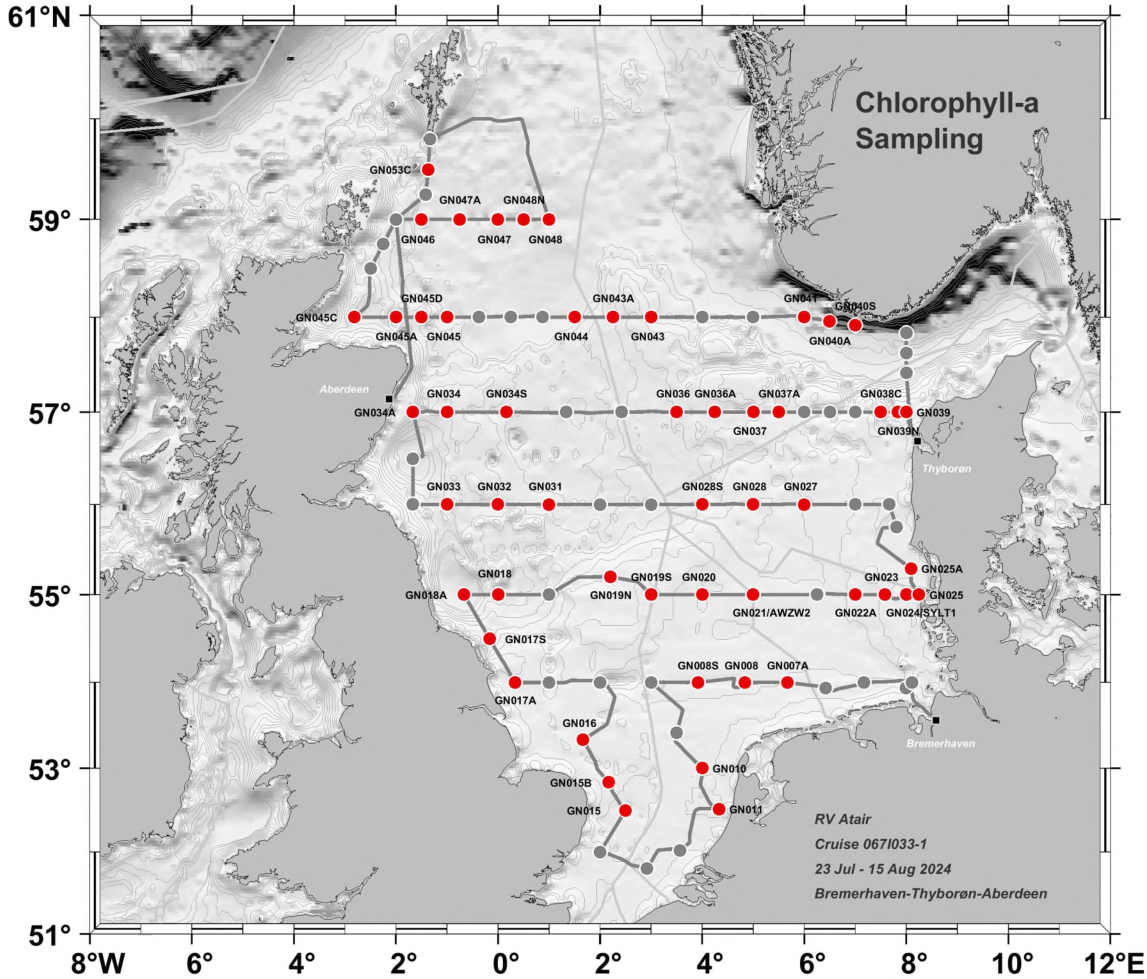

Figure 5.8. *Distribution of stations carried out during cruise 067I033-1 with water sampling and subsequent filtration for chlorophyll-a determination (red dots).*

The chlorophyll-a concentrations measured in the laboratory serve 1) as a rough measure of phytoplankton biomass and 2) are used for comparison with the chlorophyll-a concentrations determined by remote sensing for ground truthing.

<u>Phytoplankton Sampling</u>

Understanding the distribution and behaviour of plankton is key to deciphering the complex dynamics of marine ecosystems. The assimilation of satellite data bridges the gap between observation and theory. The *EnsAD* project aims to improve real-time forecasting capabilities for potentially problematic phytoplankton groups by integrating hyperspectral remote sensing data from the *EnMAP* and *PACE* satellites into biogeochemical models for the North Sea and Baltic Sea. In order to adapt the algorithms, the composition of the phytoplankton must be known during the satellites' flyover. For this purpose, the phytoplankton was collected and its taxonomic composition determined in the home laboratory for ground truthing.

During cruise *067I033-1*, water samples were taken at daylight stations with the purpose to determine the phytoplankton content in the surface layer of the North Sea, see Figure 5.9. The stations selected were consistent with those for Secchi depth observations and water sampling for chlorophyll-a analysis. For phytoplankton, 1 L of seawater was taken from the Niskin bottles closed at 5 m and placed in a glass bottle after rinsing the bottle three times with seawater. 200 mL of this sample was transferred to a smaller glass bottle using a graduated cylinder. Using a pipette, 2 mL of acidic Lugol's solution was added to the water sample in order to fix and preserve the phytoplankton samples during the field work. The glass jar was then sealed using a flexible parafilm and stored in the dark

In total, phytoplankton samples from 14 stations (GN007A, GN008S, GN018A, GN019S, GN021, GN022A, GN023, GN024, GN025, GN027, GN037, GN043, GN044, GN045) were evaluated as part of the EnsAD project to validate satellite data from hyperspectral sensors. Samples were selected based on the availability of useful remote sensing information at the time of the sampling.

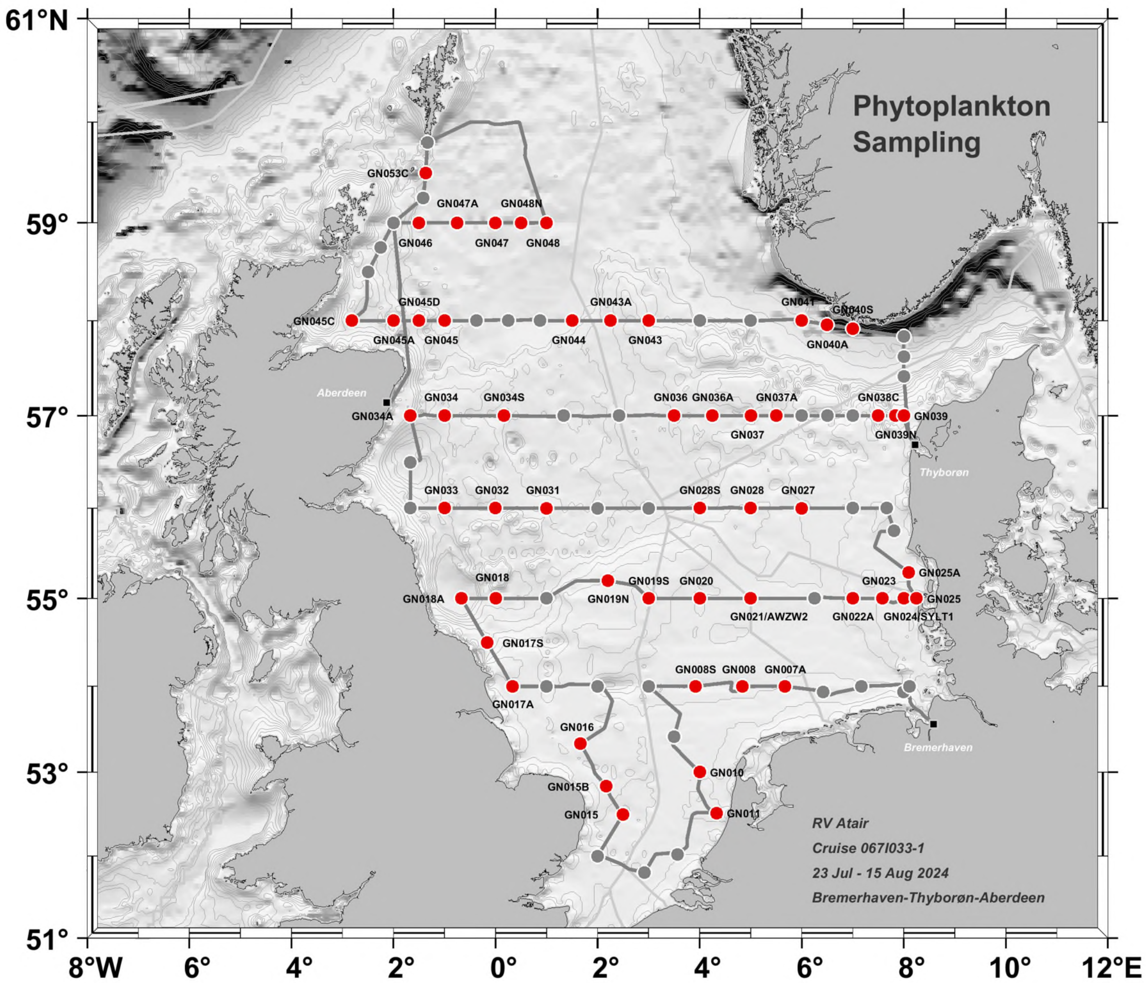

Figure 5.9. *Distribution of stations carried out during cruise 067I033-1 with phytoplankton sampling (red dots).*

5.8 Water Sampling with respect to Dissolved Inorganic Carbon & Alkalinity

Samples for total alkalinity (A_T) and total inorganic carbon (C_T) were taken at 2 to 8 depth levels per profile. The samples were collected from the Niskin bottles using silicone tubing. For A_T and C_T, unfiltered water samples were collected in 300 mL BOD bottles (avoiding gas exchange), stabilized with 300 µL of saturated mercury chloride solution ($HgCl_2$), and stored under dark conditions until further analysis in the home laboratory (Helmholtz-Zentrum Hereon) located in Geesthacht. In total, 501 samples for A_T and C_T analysis were taken.

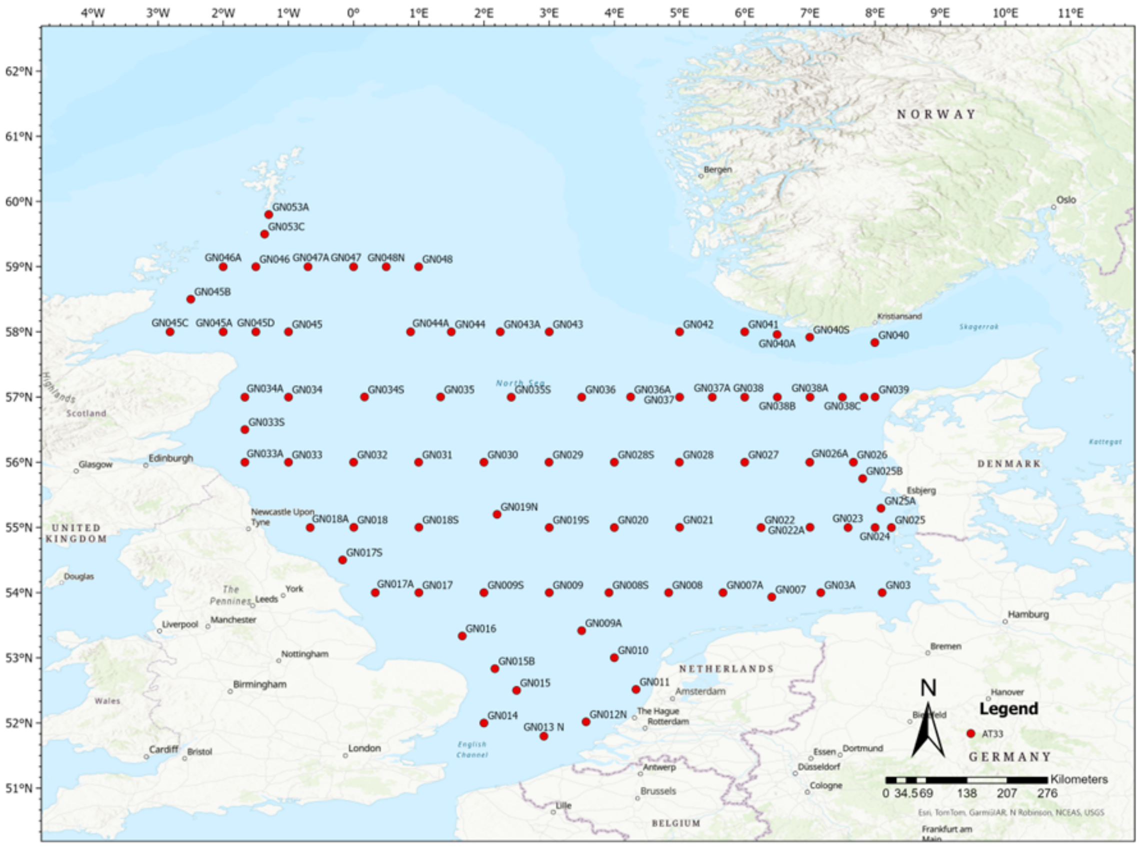

__Figure 5.10.__ Distribution of stations carried out during cruise 067I033-1 with alkalinity and dissolved inorganic carbon sampling (red dots).

5.9 Water sampling with respect to Trace Metal, Mercury, Nutrient & Lead Analysis

Samples for dissolved trace metal analysis were taken at 105 stations at 10 m water depths using one of the two available trace-metal clean Go-Flo sampling bottles. Water samples were collected in acid-cleaned 50 mL DigiTubes and stored cold until filtration. The samples were filtered onboard through 0.45 µm PTFE acid-cleaned DigiFilters. Filtration was carried out in a

Captair Flow (Erlab) clean bench with a HEPA air filtration unit. The samples were preserved by adding 500 µL of concentrated souble subboiled HNO_3 and stored under dark and cool conditions (4 °C / refrigerated) until analysis in the laboratory (Helmholtz-Zentrum Hereon) located in Geesthacht.

Samples for dissolved mercury species (inorganic mercury (iHg) and methylmercury (MeHg)), as well as nutrients were taken at 70 stations at the surface and bottom from Niskin bottles. Water samples were collected in acid-cleaned 2 L HDPE bottles using silicone tubing and stored cold until filtration. The samples were pressure-filtered through 0.45 µm acid-cleaned polycarbonate filters into acid-cleaned 1 L glass bottles (*Bravo et al.,* 2018). Filtration was carried out in a Captair Flow (Erlab) clean bench with a HEPA air filtration unit. The samples were preserved by adding double subboiled HCl (0.4 % *v;v*) and stored under dark and cool conditions (4 °C / refrigerated) until analysis in the laboratory (Helmholtz-Zentrum Hereon) located in Geesthacht.

Water samples for nutrient analysis (NO_x, PO_4 and SiO_4) were pressure filtered through 0.45 µm acid-cleaned polycarbonate filters and stored frozen (-20 °C) until analysis in the laboratory (Helmholtz-Zentrum Hereon) located in Geesthacht. In total, 168 samples for nutrient analysis were taken.

Samples for lead (Pb) isotope ratio analysis were taken at five stations (#003/GN003A, #004/GN007, #028/GN021/AWZW2, #029/GN022 and #041/GN029) at 10 m water depths in duplicate, using one of the two trace metal clean Go-Flo water samplers. Water samples were collected in acid-cleaned 2 L HDPE bottles, which were conditioned onboard by rinsing three times with sampled seawater. Samples were stored dark and frozen (-18°C) until further preparation in the laboratory (Helmholtz-Zentrum Hereon) located in Geesthacht.

5.10 Water sampling with respect to Microplastics

Microplastics were sampled from approximately 6 m below the surface using the vessel's metal-free clean seawater system along 11 different transects (see Table 5.6). The sampling workflow was based on using the *Geesthacht Inert MP Fractionator* (GIMP). Two filter cartridges with 300 µm mesh size and 10 µm mesh size were used. Around 1–3 m³ of ocean water were filtered per sample. The particulate matter was resuspended using ultrasonication and subsequently transferred onto polytetrafluoroethylene (PTFE) membrane filters (5 µm pore size) by vacuum filtration. The filters were transferred into 250 mL amber glass bottles and submerged in a mixture of approximately 50 mL MQW, 1 mL hydrochloric acid (HCl; 35 % *w*:*w*), and 2 mL sodium dodecyl sulfate (SDS) solution until further analysis in the laboratory (Helmholtz-Zentrum Hereon) located in Geesthacht.

	Start of Transect			End of Transect			
Sample#	Station	Date/Time [UTC]	Filtrated Volume [m^3]	Station	Date/Time [UTC]	Filtrated Volume [m^3]	Volume Difference [m^3]
1	GN007A	24 Jul 2024 06:32	162.6299	GN008	24 Jul 2024 10:47	165.2272	2.5973
2	GN010	25 Jul 2024 07:51	165.2649	GN011	25 Jul 2024 12:05	167.3957	2.1308
3	GN012	25 Jul 2024 19:29	167.5437	GN013N	25 Jul 2024 23:09	170.0551	2.5114
4	GN014	26 Jul 2024 04:04	170.0737	GN015	26 Jul 2024 08:04	171.1430	1.0693
5	GN015B	26 Jul 2024 12:17	171.2607	GN016	26 Jul 2024 16:23	173.4428	2.1821
6	GN017A	27 Jul 2024 07:25	173.4430	GN017S	27 Jul 2024 11:54	177.9087	4.4657
7	GN020	28 Jul 2024 15:19	177.9091	GN021 / AWZWZ	28 Jul 2024 19:21	181.4257	3.5166
8	NA	NA	NA	NA	NA	NA	NA
9	GN043A	10 Aug 2024 14:30	184.1943	GN044	10 Aug 2024 17:35	186.9202	2.7259
10	GN045C	11 Aug 2024 14:57	186.9241	GN045B	11 Aug 2024 19:13	188.6679	1.7438
11	GN048	13 Aug 2024 06:02	188.6841	GN048N	13 Aug 2024 09:15	191.9713	3.2872

Table 5.6. *Information related to transects between stations used for microplastics analysis.*

5.11 Water sampling with respect to Tritium

During cruise *067I033-1*, water samples for tritium (^{3}H) analysis to be carried out at the mass spectrometry laboratory *helis* of the University of Bremen were collected at a total of 74 stations (see Figure 5.11). The water samples were taken from Niskin bottles (typically closed at 5 dbar and at the bottom) and stored in 500 mL plastic bottles with watertight lids. After the cruise, all samples were shipped home for later laboratory analysis. First, the water samples were degassed using a high-vacuum gas extraction system and subsequently stored in flame-sealed glass containers to accumulate ^3He from tritium decay, using the so-called *helium ingrowth* method. During storage over several months, some of the ^3H decays to ^3He via β-decay. After sufficient ^3He production, the water samples are connected to a fully automated ultra-high vacuum system and reopened. Water vapour is then used to transfer the ^3He to a cryo-system kept at 14 K to separate ^3He from any other possible gases. A high-resolution rare gas mass spectrometer (MAP 215-50) is then used to analyse the ^3He. The system is regularly calibrated using atmospheric air standards (the precision for tritium is 3% or 0.02 TU, where TU stands for tritium units). Measurements of blanks and linearity are also performed. Further details of the method can be found in *Sültenfuß et al.* (2009).

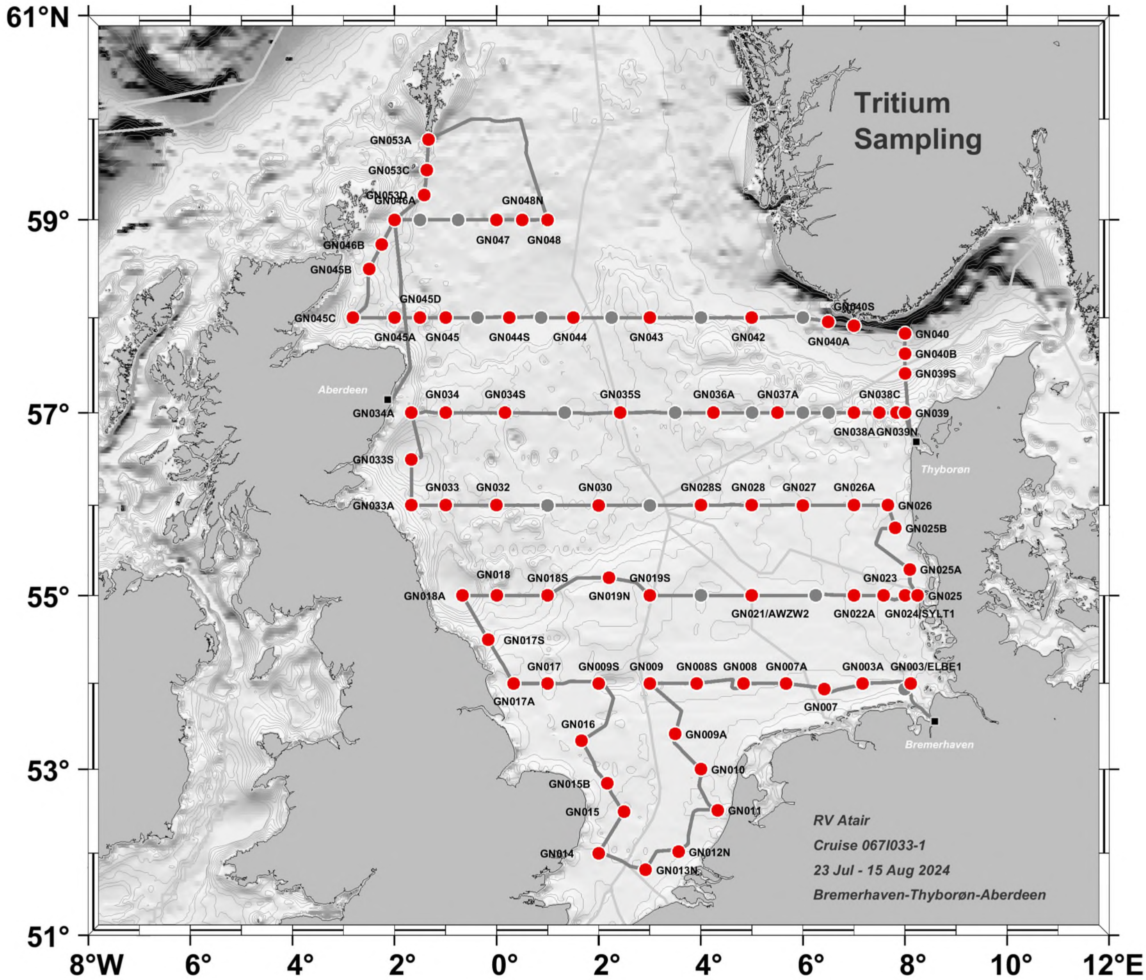

Figure 5.11. *Distribution of stations carried out during cruise 067I033-1 with tritium sampling (red dots).*

6. Oceanographic Conditions in Summer 2024

The BSH produces and provides a comprehensive weekly analysis of sea surface temperatures (see https://www.bsh.de/EN/DATA/Climate-and-Sea/Sea_temperatures/Sea_surface_temperatures/sea_surface_temperatures_node.html). This approach combines all measurements collected from time series stations and ships with satellite data and uses statistical methods and spatial interpolation to generate a comprehensive data set. This contains estimates for the weekly mean values of sea surface temperature as a raster data set with a spatial resolution (pixel size) of 20 km x 20 km.

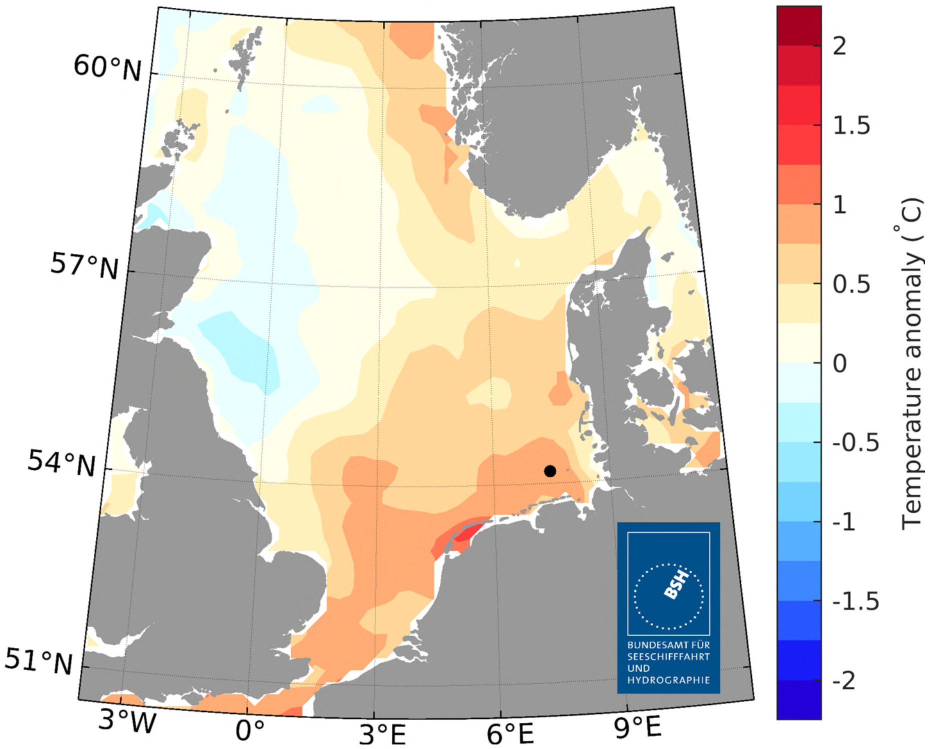

Figure 6.1. *Spatial distribution of sea surface temperature (SST) anomalies for the summer of 2024 (June, July and August). Anomalies are shown relative to a climatological mean SST field comprising the summers of the years 1997-2021, i.e. 25 years. Source: BSH.*

Information from this blended analysis SST analysis for the summer months of 2024 (June, July and August) reveals a region of pronounced warming in the southern North Sea, basically in the English Channel and along the West and East Frisian coasts. A further warming pattern stretches off western Norway along the Norwegian Trench (Figure 6.1). In these regions the SST was about 0.5°C to 1.0°C warmer than the 1997-2021 climatological summer mean. The coolest region with SST anomalies of about -0.5°C was observed off eastern UK, with a cool center located at about 56°N/1°30'W.

A respective ranking map (Figure 6.2) demonstrates that the southern English Channel and the waters of the West and East Frisian Coasts Sea succumbed to one of the three warmest summer conditions observed between 1997 and 2024. Conditions in the western half of the North Sea and in the Skagerrak and Kattegat regions were mostly normal.

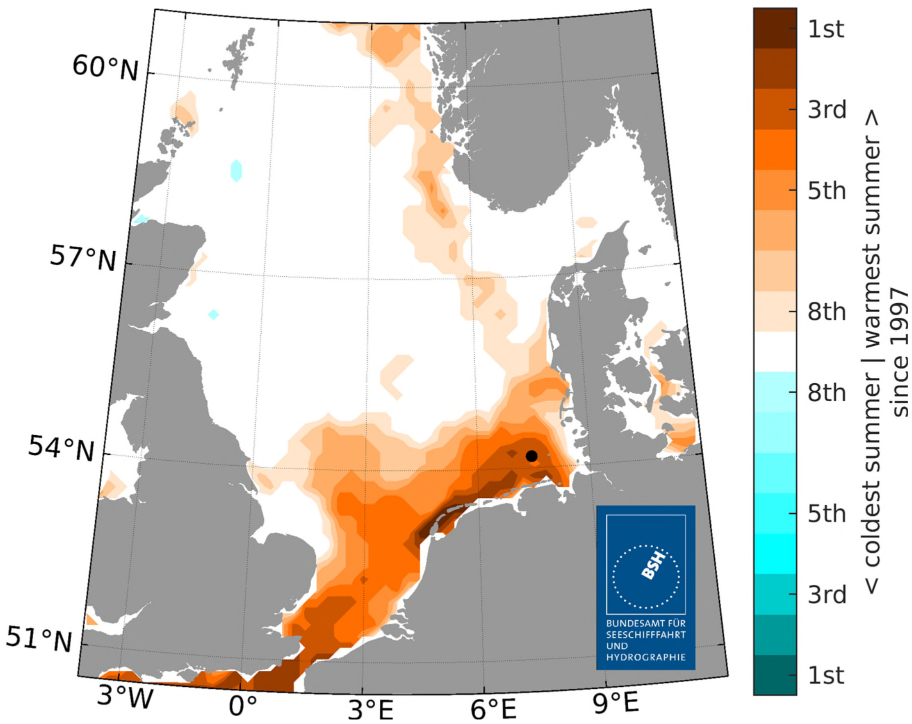

Figure 6.2. *Spatial distribution of the sea surface temperature (SST) ranking for summer 2024 (June, July and August), regionally indicating the nth coldest/warmest summer SST since 1997. Source: BSH.*

Figures 6.3 and 6.4 highlight the potential temperature obtained from CTD measurements during cruise *067I033-1* near the suface (5 dbar) and near the bottom. The respective temperatures are also compared to a long-term mean field comprised of CTD data from the summer months of the years 2000 to 2020 (*NSSS* surveys 2000 to 2020, except year 2019). Based on the ship observations, temperatures warmer than 18°C stretched along the entire continental coast, from the English Channel, along the Belgian, Dutch, German, Danish coasts towards Norway (Figure 6.3, left). A band-like pattern with cooler temperatures of < 15°C was present along the eastern British coasts from the Shetland Islands to about 56°N. Also, and even more pronounced as in the previous year, the region east of the mouth of the Humber Estuary off the British coast showed a cool patch with temperatures < 15°C. The 17°C-isotherm showed a rather meridional orientation along 4°E between 53°N and 58°N dividing the North Sea into a warmer half in the east and cooler half in the west. Temperature deviations from the long-term mean (Figure 6.3, right) reveal warmer conditions mostly across the central part of the North Sea and along the German and Danish coasts up to southern Norway. The pattern of temperature deviation seen in the CTD data at 5 dbar does not really match the one seen in the SST anomaly distribution (Figure 6.1), which may be due to the different data and reference periods. The CTD data showed stronger cooling at different locations than the SST data, namely in the regions off the western Danish coast and along the British coast. The southern and southwestern parts of the North Sea were regionally cooler by -1 °C compared to the average CTD-based temperature field. Also, the northwestern part of the area of investigation pointed to a cooling stretching in a band-like pattern from the Shetland Islands to 57°N.

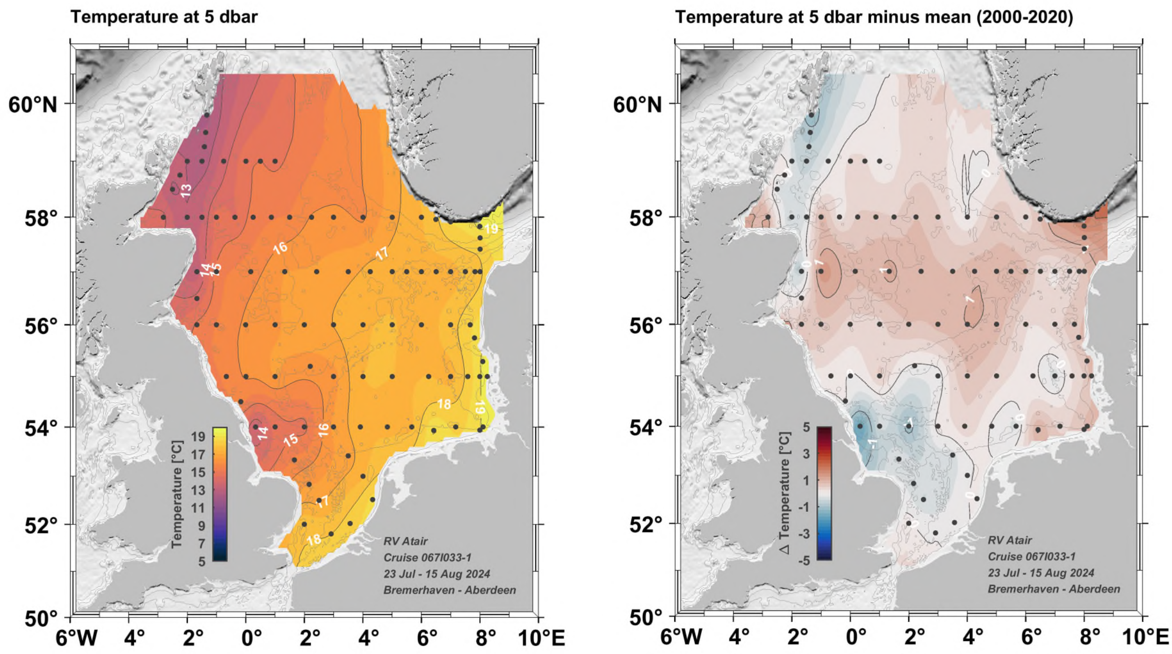

Figure 6.3. *CTD-derived spatial distribution for the potential temperature near the surface in summer 2024 (left) and respective temperature deviations (right) from a long-term summer mean, 20 years, comprising NSSS cruises of the years 2000-2020 (except 2019).*

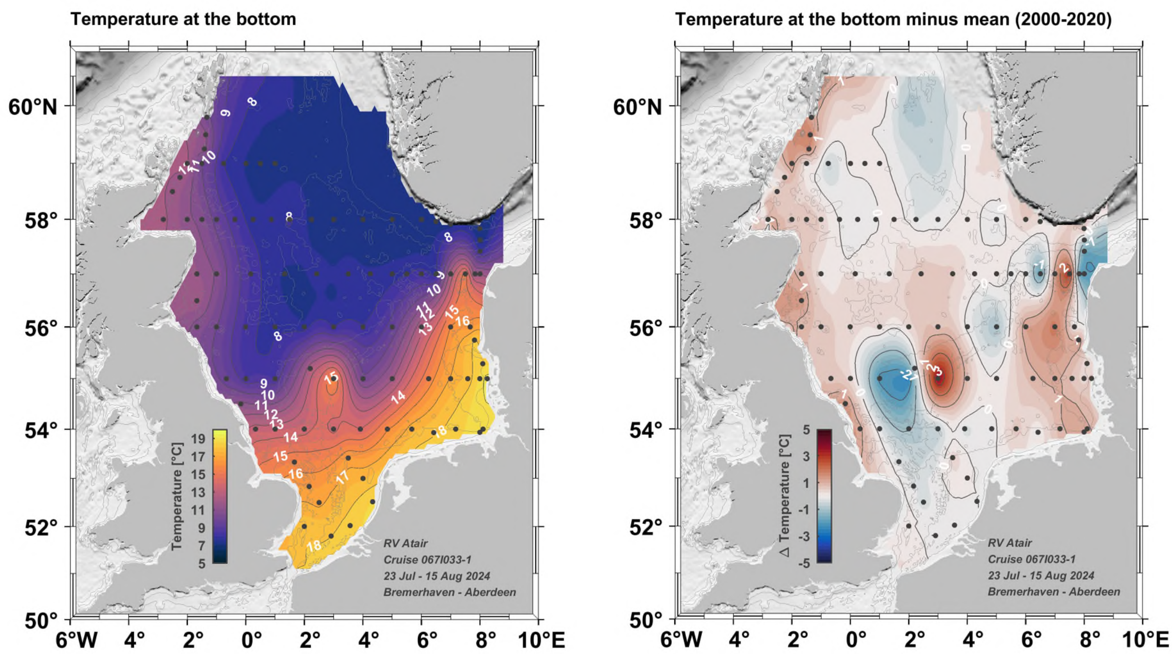

Figure 6.4. *CTD-derived spatial distribution for the potential temperature near the bottom in summer 2024 (left) and respective temperature deviations (right) from a long-term summer mean, 20 years, comprising NSSS cruises of the years 2000-2020 (except 2019).*

Bottom temperatures (Figure 6.4, left) are generally warmer south of 55°N, on the Dogger Bank and off the continental coasts compared to the central to northern North Sea due to shallower water depths. Bottom temperatures >18°C stretch along the Belgian, Dutch and German coast up to Denmark. The coldest bottom temperatures are located in the Norwegian Trench (< 7.5°C) and in larger bottom areas of the northeastern North Sea (near and north of ~58°N) Data from the northeastern North Sea along 59°N and 60°N is however not available. Bottom temperatures > 10°C stretch band-like along the eastern British coast from the Shetland Islands to 56°N. Deviations from the long-term mean show a rather patchy pattern, with the western and eastern rims of the North Sea and its central part being warmer at the bottom than the long-term mean distribution at the bottom.

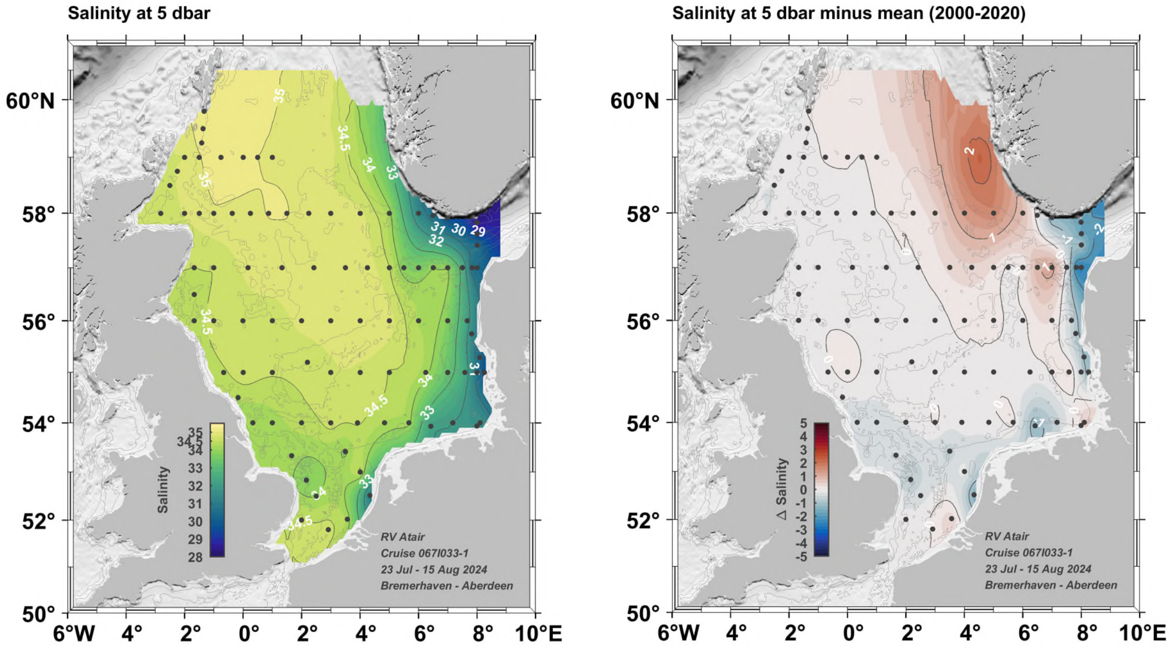

Figure 6.5. *CTD-derived spatial distribution for the salinity near the surface in summer 2024 (left) and respective salinity deviations (right) from a long-term summer mean, 20 years, comprising NSSS cruises of the years 2000-2020 (except 2019).*

In summer 2024, there was only one obvious path with near-surface salinities > 35 that was located southeast of Shetland. Due to missing data along 60°N (no station data at all) and 59°N (station data only west of 2°E) the eastward extension of this saline patch remains unclear in this year (Figure 6.5, left). As in previous years, the isohaline 34.5 formed a horseshoe pattern from about 57°N off the British coast to 54°N south of the Dogger Bank to 56°N, 6°E and at least 58°N,5°E. Near-surface water inside this horse-shoe encompassed the high-salinity patch mentioned earlier but mostly showed spatially quasi-homogeneous salinities around 34.7-34.8. Coastal salinities off the eastern British coast fell well below 34.5 in a band-like pattern between ~57°N and the entrance of the English Channel near 52°N. Coastal salinities on the continental side of the North Sea reveal a local minimum north of the Rhine delta (S < 31) and off the North Frisian German and Danish coasts (S < 32 and S< 31, respectively). The Norwegian Trench shows the fresh Baltic outflow with a local minimum with S < 30 directly south of Norway and fresh salinities < 32 close to the Norwegian coast until 58°N. Data from the trench region further north does not exist for this cruise.

The deviation from the long-term mean (Figure 6.5, right) points to the North Sea being fresher than average near the surface throughout major parts of the region of interest. The freshest signals appear along the German and Danish coasts up to southern Norway and in the southern North Sea south of Dogger Bank. The obivious maximum of the salinity deviation off western Norway near 59°N is not supported by observations.

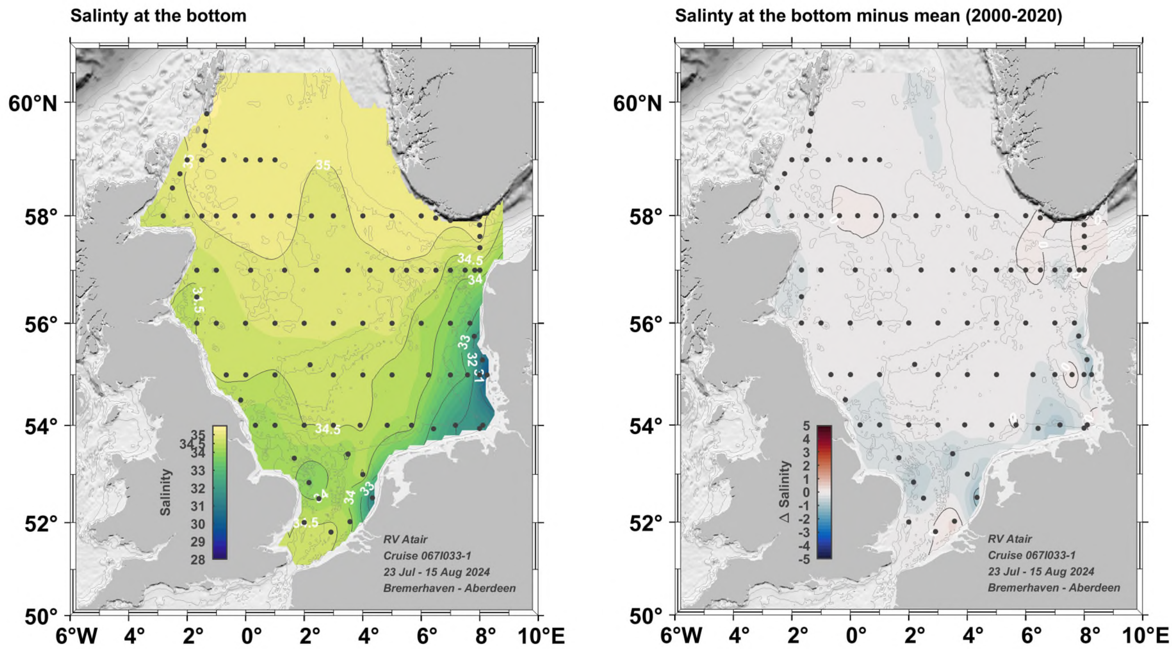

Figure 6.6. *CTD-derived spatial distribution for the salinity near the sea bottom in summer 2024 (left) and respective salinity deviations (right) from a long-term summer mean, 20 years, comprising NSSS cruises of the years 2000-2020 (except 2019).*

In summer 2024, the salinity distribution near the bottom compared quite well with that of 2022. Salinity > 35 filled most bottom regions of the North Sea from south of the Shetlands towards the southeast at about 58°N. Data from 60°N and the eastern part of the 59°N section is not available. Salinity as high as 34.5 spreading from the north was observed until 54°N south of the Dogger Bank. A local maximum with S = 34.63 at about 52°N/3°E may be indicative of more saline water entering the North Sea from the south via the English Channel. A similar pattern was noted in 2022 at 52°N/2°E, but was absent in 2023. Due to missing data in the English Channel south of 52°N in all three years, this signal cannot be further explored.

Fresh salinities with values well below S = 32 stretched along the western German and Danish coasts clearly pointing to the impact of runoff coming from the continental rivers like Elbe and Weser. Also, the salinity deviation from the long-term mean revealed a freshening in the German Bight off the East Frisian islands and in a pattern stretching along 53°N towards the UK. Salinity conditions in remaining parts of the North Sea were, however, rather normal.

Figures 6.7 and 6.8 present temperature and salinity along coast-to-coast sections following the latitudes 59°N, 58°N, 57°N, 56°N, 55°N and 54°N. Due to the varying water depths from the deep northern North Sea to the shallow southern North Sea, the lower part of the water column is typically colder in the north. The water column is typically more homogeneous in the south and becomes increasingly stratified in temperature towards the north. The input of Atlantic Water across the northern boundaries of the North Sea and its subsequent propagation within the North Sea is obvious through salinities exceeding 35 and in summer 2024 reaches as far south as 58°N.

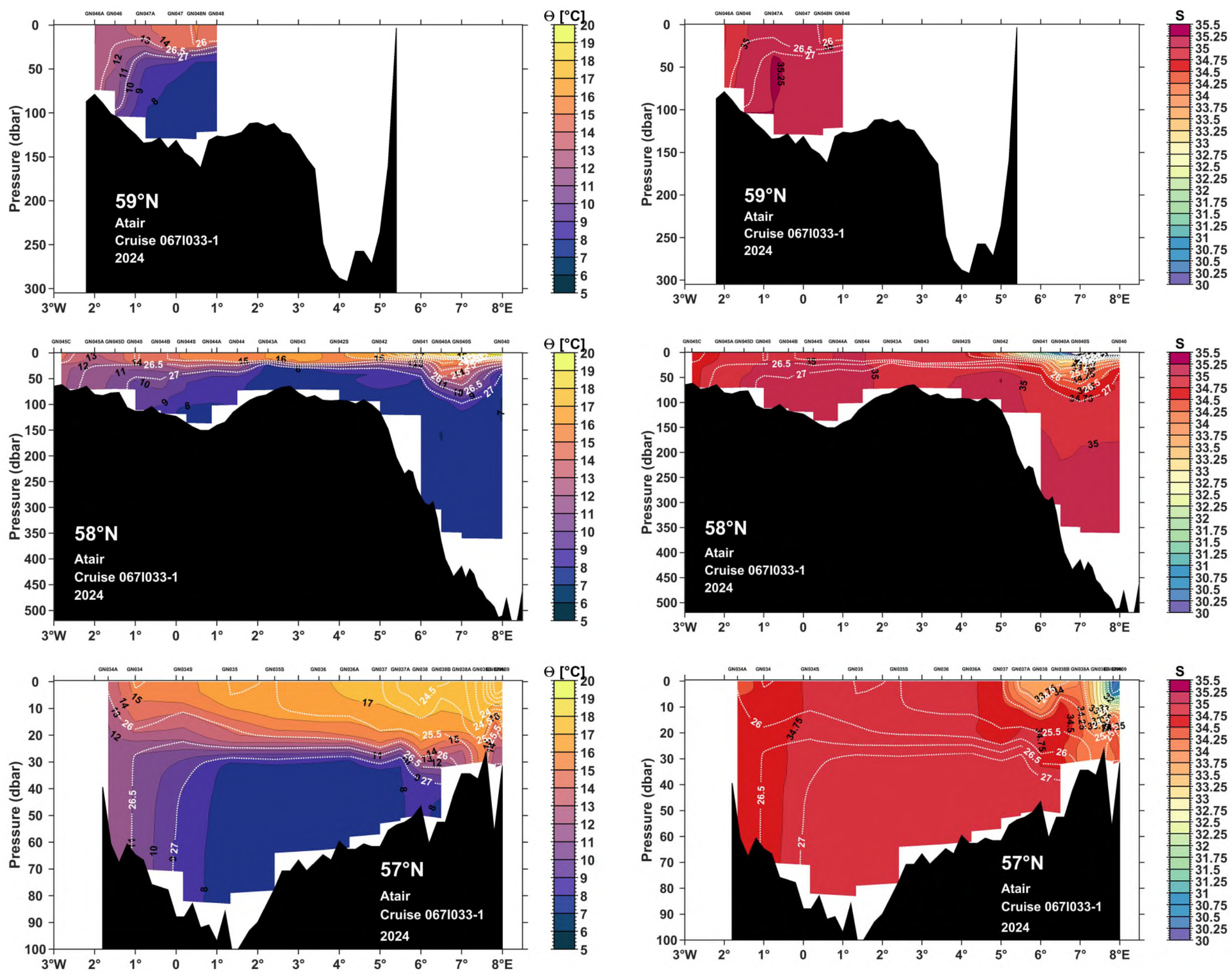

Figure 6.7. *Potential temperature [°C] (left) and salinity (right) along 59°N, 58°N and 57°N (from top to bottom) as observed during cruise 067I033-1, summer 2024. Superimposed white contours highlight selected σ_θ-isopycnals. CTD measurements along 60°N were not possible due to unfavourable weather conditions. For the same reason, data along 59°N exists only for its western part.*

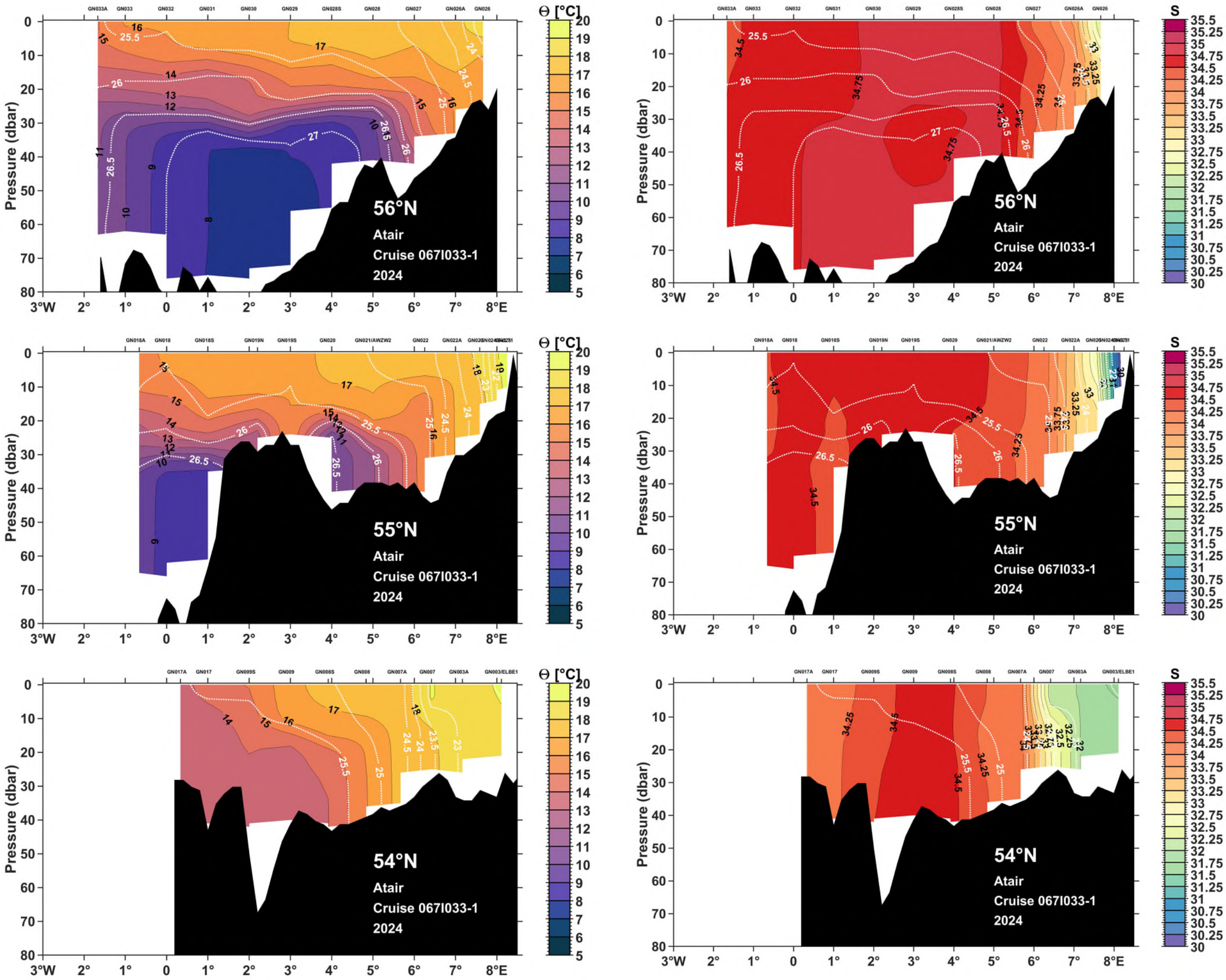

Figure 6.8. *Potential temperature [°C] (left) and salinity (right) along 56°N, 55°N and 54°N (from top to bottom) as observed during cruise 067I033-1, summer 2024. Superimposed white contours highlight selected σ_θ-isopycnals.*

7. Underway Measurements

A variety of routine underway measurements were carried out during cruise *067I033-1*. The acquired data of interest included navigational information and near-surface hydrography (temperature, conductivity, and thus salinity), which was measured by the vessel's thermosalinograph (TSG). Other data included near-surface fluorescence and turbidity, both obtained from a dual-wavelength *ECO* sensor attached to the TSG system. Meteorological parameters and water temperature were also recorded by the weather station, operated by the *German Weather Service* (DWD) under the identifier *CVTKCAL*. Navigational and meteorological data was recorded from the beginning of the cruise onwards. Recording of additional underway data was interrupted during the port stay in Thyborøn, Denmark, and resumed afterwards. Data was logged in time intervals of 1 or 10 sec by the vessel's DSHIP system with time intervals depending on measurement intervals of the respective devices. All underway data relevant to this cruise were exported from the DSHIP database daily. Water depths were measured by a single-beam echo-sounder along the cruise track and at hydrographic stations. Depths provided by the vessel's echo-sounding device result in water depths when the vessels's draft of 5 m is added. Any further processing or quality control of water depth data was not carried out.

Filtering of surface water to determine the size and abundance of microplastics was conducted on various transects (see Section 5.10). A Vessel-Mounted Acoustic Doppler Current Profiler (VMADCP) provided information on the speed and direction of the oceanic current field. Additionally, eight lightweight surface drifters were deployed in different regions of the North Sea. These were exposed to tides and the oceanic current field, which revealed major spreading pathways.

7.1 Ship's Meteorological Station

The autonomous weather station installed aboard *RV ATAIR* and operated by the DWD automatically records every second all meteorological standard parameters like wind speed and direction, air temperature and air pressure, relative humidity, surface water temperature, global radiation and others. While corresponding data is sent directly to the Global Telecommunication System (GTS), it is also fed into the DSHIP database. Figure 7.1 provides an overview on the meteorological conditions encountered during cruise *067I033-1*. Raw data was taken from the DSHIP database and smoothed by applying a moving median filter. The radiometer delivering global radiation data was not properly working during many days of the cruise due to unknown reasons, see Figure 7.1.

The average air temperature throughout the cruise was 16.7°C, but temperatures ranged from 12.8°C to 28.2°C while at sea. Maximum water temperatures exceeded 21.8°C right at the start of the cruise, minum water temperatures were 11.5°C, the average was 16.9°C. Average air pressure was 1012.6 hPa, and pressures ranged from 996.2 hPa to 1026.3 hPa. Notable periods of absolute wind speeds exceeding 7 Bf were observed on 9/10 August, on 12 August, on 13/14 August, and 14/15 August 2024. The average wind speed throughout the cruise was 7.45 m/s, which corresponds to a wind strength of 4 Bf. The maximum wind speed was 22.65

m/s, corresponding to 9 Bf. All statistical values refer to the smoothed data with outliers removed. Figure 7.2 displays the spatial distribution of absolute wind speeds and directions (15 min average values) along the cruise track. The high wind speeds (~ 9 Bf) caused by a pronounced storm system encountered near the Orkney and Shetland Islands near the end of the cruise finally resulted in the cancellation of the remaining station program.

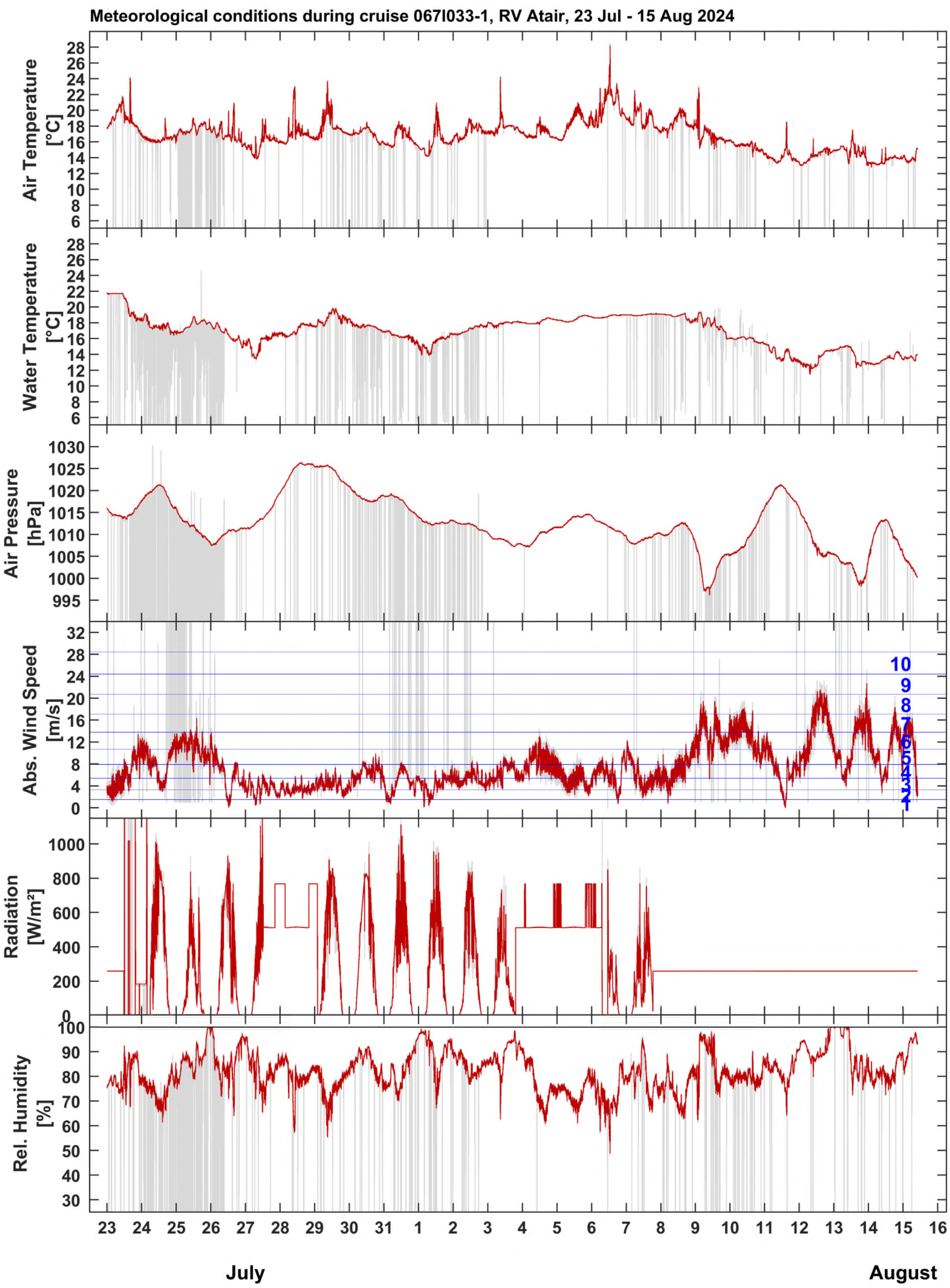

Figure 7.1. *Meteorological conditions observed during 23 July and 15 August, 2024, cruise 067I033-1. From top to bottom: Air temperature, near-surface water temperature, air pressure, absolute wind speed, global radiation and relative humidity. Blue horizontal lines and labels on the right side of the wind plot indicate absolute wind speeds reported on the Beaufort scale. Grey: original data including missing values and outliers, red: smoothed data by applying a moving median filter. Data taken from the DSHIP database.*

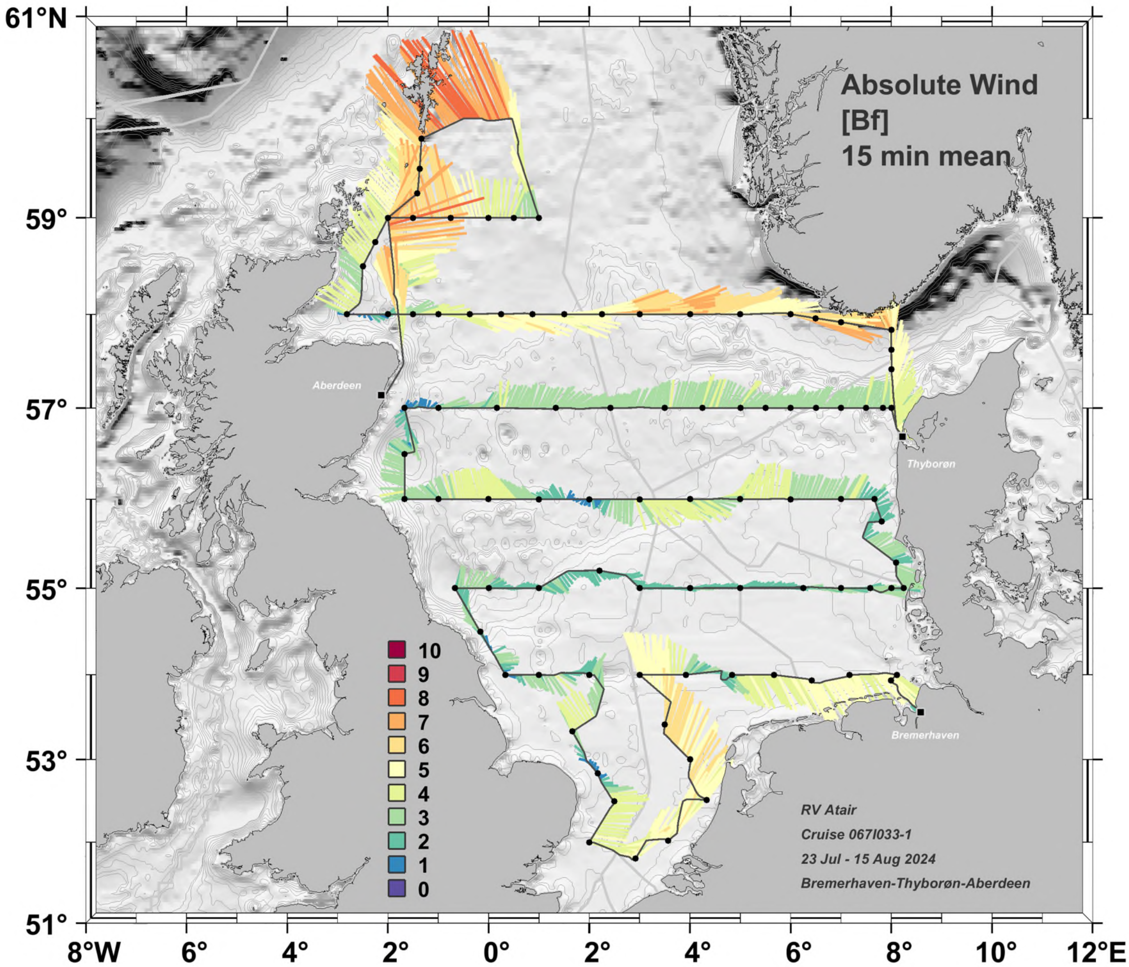

Figure 7.2. *Spatial distribution of the absolute wind strength and direction during cruise 067I033-1. Wind information is reported on the Beaufort scale (see colour bar) and averaged over 15 min intervals. The stick orientation denotes the wind direction. Data taken from the DSHIP database.*

7.2 Thermosalinograph & Fluororescence/Turbidity

The thermosalinograph (TSG) system aboard *RV ATAIR* is operated as a throughflow system with the pure seawater inlet installed in the vessel's hull at a depth of 4 m. It consists of a *SBE21 Seacat thermosalinograph* device delivering near-surface conductivity and internal temperature measurements. These are matched with an additional external temperature sensor of type *SBE38*, which is located near the water inlet. Next to the TSG system, a dual-wavelength sensor of type *WET Labs Environmental Characterization Optics* (ECO) is installed delivering near-surface underway measurements of fluorescence and turbidity through optical measurements at fixed wavelengths. Table 7.1 provides an overview of the sensor specifications. Data are recorded at time steps of 10 sec.

To check the quality performance of the TSG system, water samples were taken twice a day directly from the TSG system and analysed using an *AUTOSAL* salinometer. Standard operating procedures (SOPs) for assessing the data quality of the near-surface temperature and conductivity/salinity measurements from the TSG system installed aboard *RV ATAIR* are currently being developed at a national level in collaboration with the *German Marine Research Alliance* (DAM). Once the SOPs have been implemented, and the data quality control has been finalised and documented, the resulting data will be made publicly available via submission to the PANGAEA database (https://www.pangaea.de). Regarding the dual-wavelength ECO sensor data for fluorescence and turbidity, there are not yet any defined SOPs, and any data quality check is presently not carried out regarding near-surface mesurements for fluorescence and turbidity.

Sensor Device	Sensor Type	Serial Number	Calibration Date
SBE21	thermosalinograph, conductivity and internal temperature	3245	05 Dec 2023
SBE38	external temperature	1113	05 Dec 2023
WetLabs ECO FLNTURT	fluorescence and turbidity	FLNTURT-5883	---

Table 7.1. *Sensor specification of the thermosalinograph/fluormeter system operated during cruise 067I033-1.*

Figure 7.3 shows the temporal evolution of the properties derived from the TSG/ECO-sensors. The uncorrected TSG-derived temperature at a depth of 4 m ranged from 11.7°C to 19.8°C and was on average 16.3°C. Uncorrected TSG-derived salinity ranged from 26.81 to 35.22 and was on average 34.03. Fluorescence ranged from 010. µg/L to 10.36 µg/L and was on average 0.72 µg/L. Turbidity ranged from 0.17 NTU to 4.28 NTU and was on average 0.41 NTU. All statistical values refer to the smoothed data with outliers removed. Figures 7.4 to 7.7 show the spatial distribution of the near-surface temperature, salinity, fluorescence and turbidity, respectively.

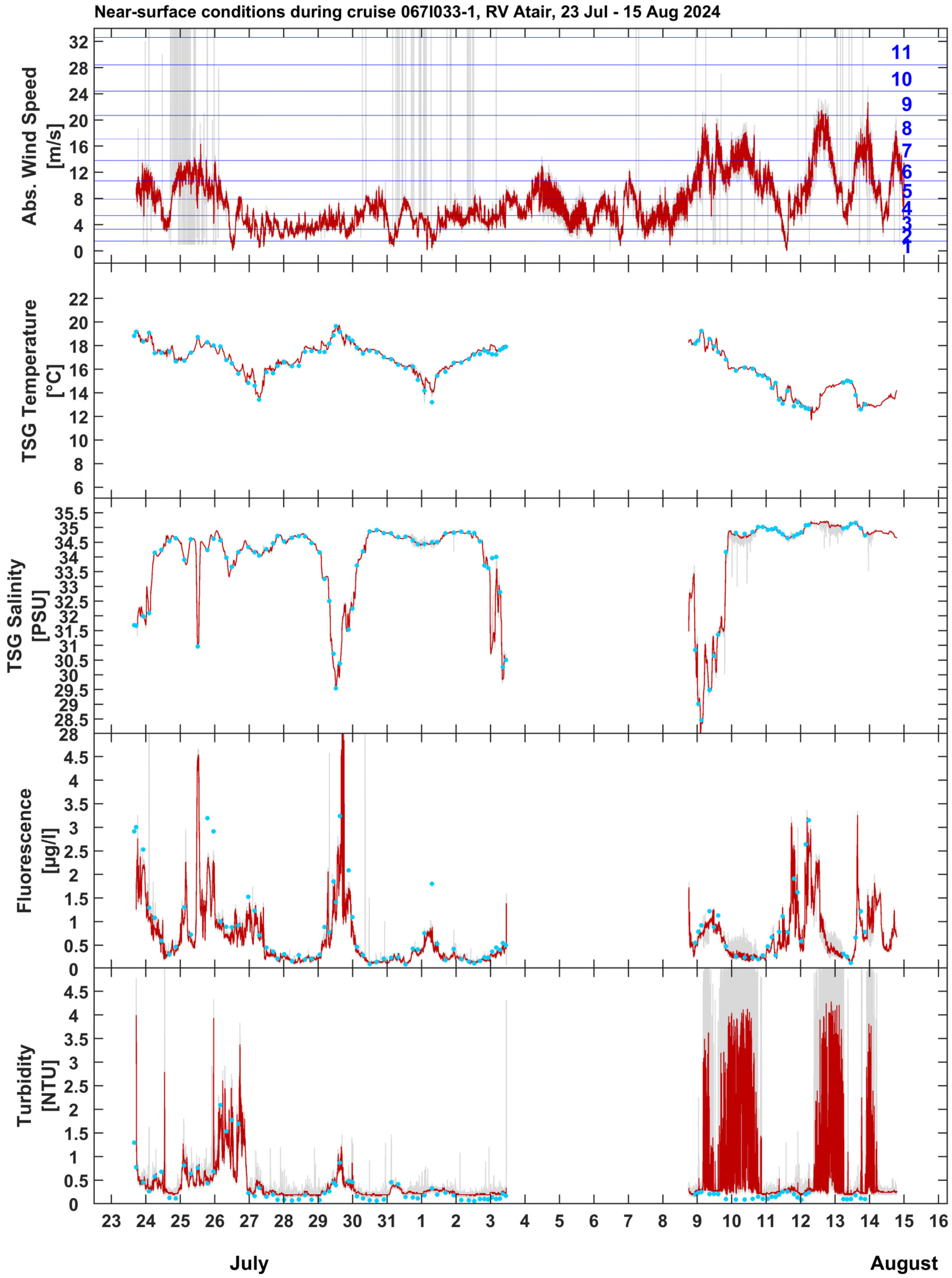

Figure 7.3. *Temporal evolution of absolute wind speed, TSG-derived near-surface (4 m) temperature, TSG-derived near-surface salinity, fluorometer-derived near-surface fluorescence, and fluorometer-derived near-surface turbidity (from top to bottom) recorded during cruise 067I033-1 (all values not corrected). Grey: original data including outliers, red: smoothed data by applying a moving median filter. Lightblue dots: CTD-derived values from a 4 dbar level. CTD and underway data was not availabe between late 03 Aug and late 08 Aug 2024.*

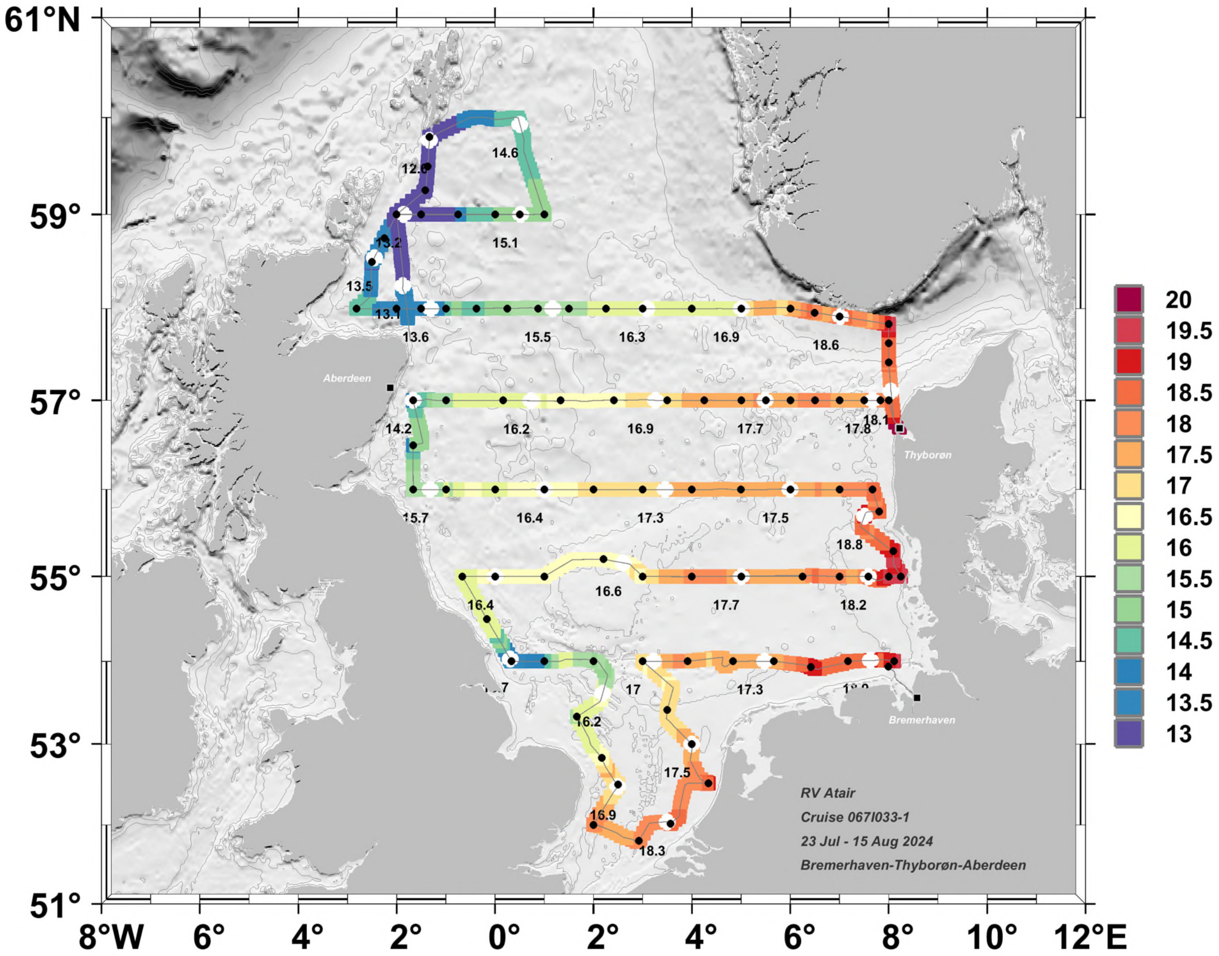

Figure 7.4. *Spatial distribution of the uncorrected near-suface temperature during cruise 067I033-1 obtained from the TSG system and displayed as 30 min averages. Colours denote temperatures in the range 13°-20°C, individual values are highlighted every 12 hours and marked by a white dot.*

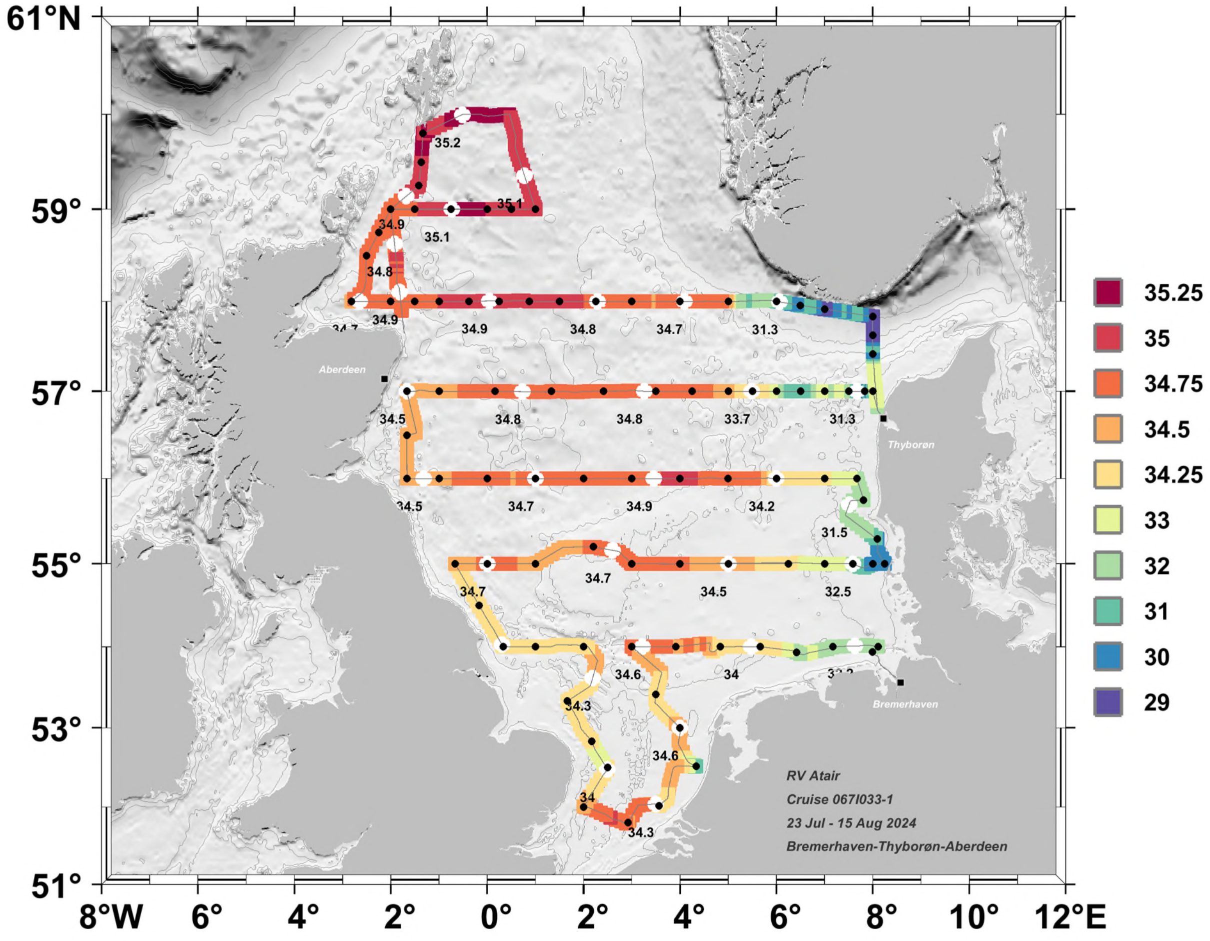

Figure 7.5. Spatial distribution of the uncorrected near-suface salinity during cruise 067I033-1 obtained from the TSG system and displayed as 30 min averages. Colours denote salinities in the range 29-35.25, individual values are highlighted every 12 hours and marked by a white dot.

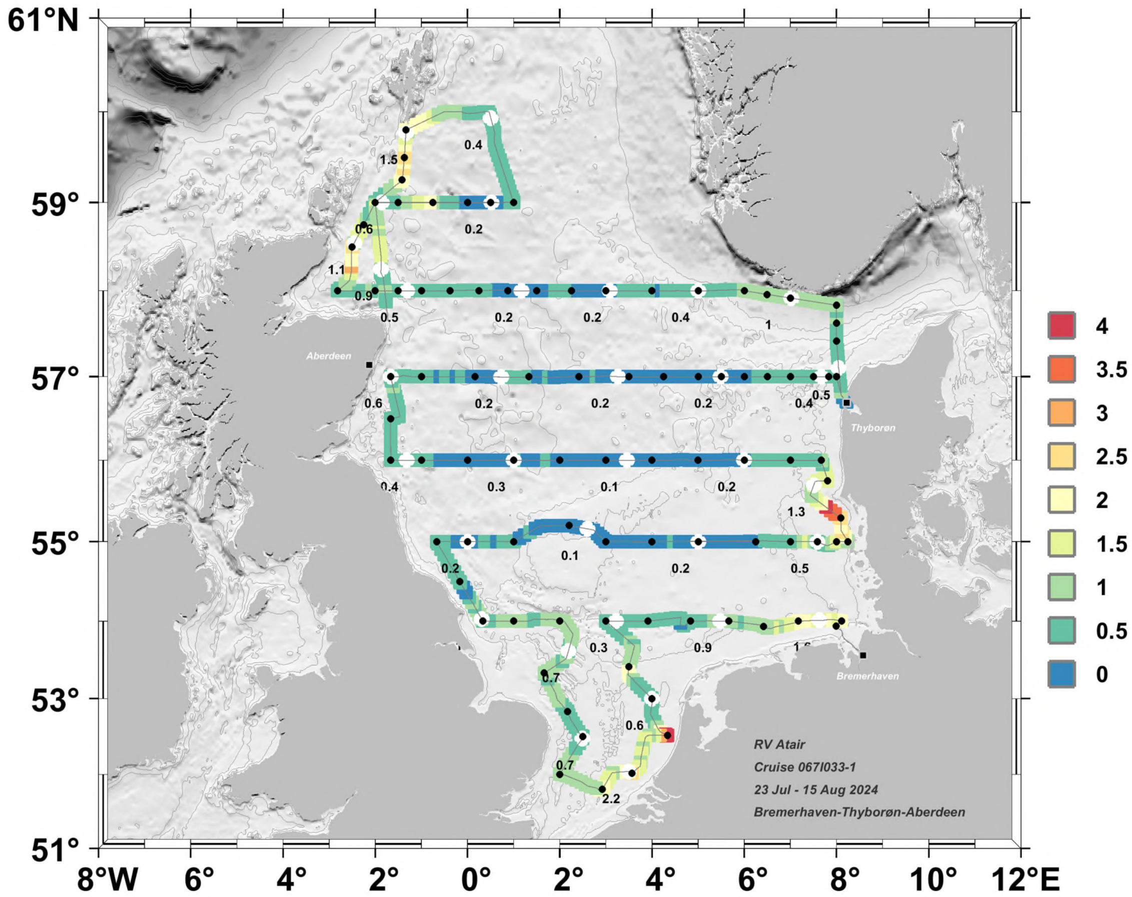

Figure 7.6. *Spatial distribution of the uncorrected near-suface fluorescence [µg/L] during cruise 067I033-1 obtained from the flow-through ECO sensor and displayed as 30 min averages. Colours denote fluorescence values in the range 0-4 µg/L, individual values are highlighted every 12 hours and marked by a white dot.*

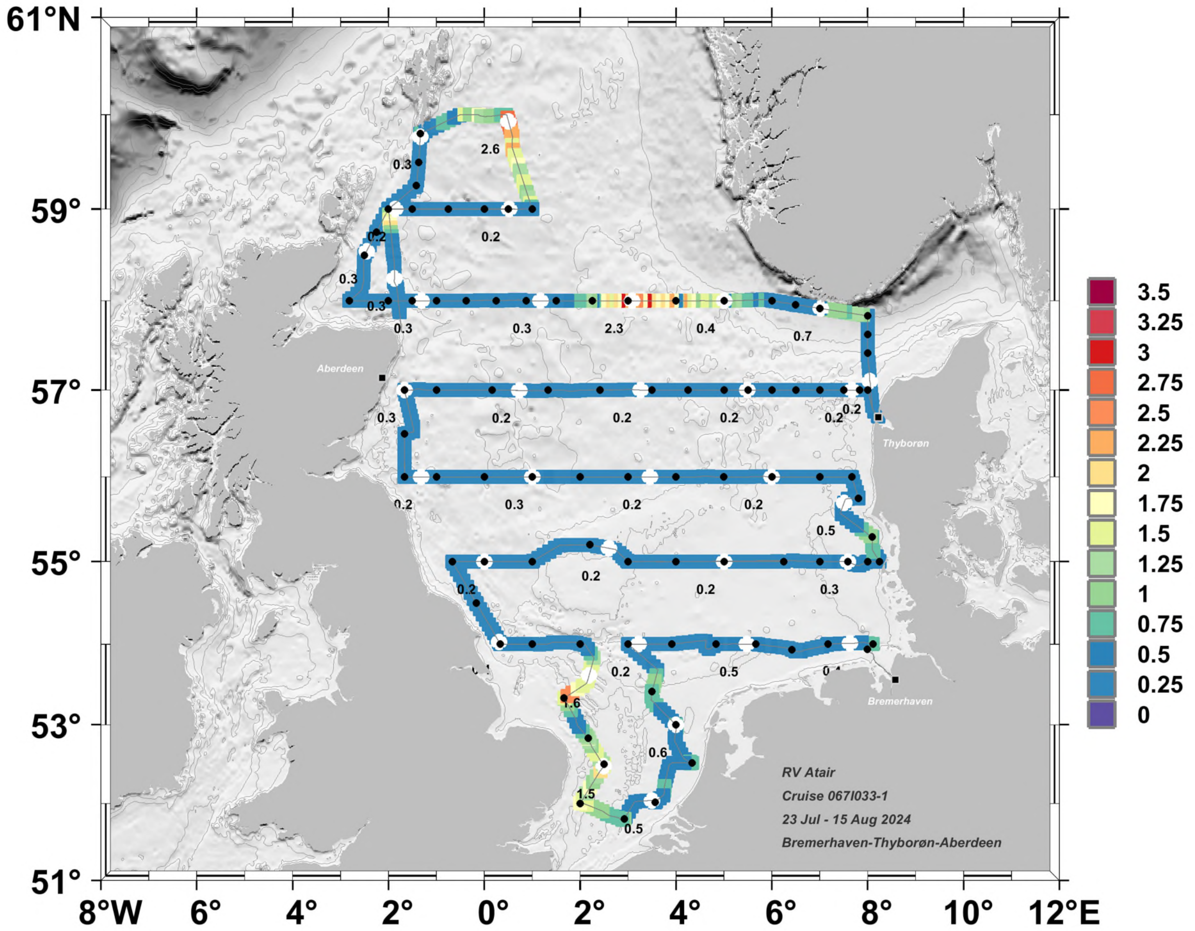

Figure 7.7. Spatial distribution of the uncorrected near-suface turbidity [NTU] during cruise 067I033-1 obtained from the flow-through ECO sensor and displayed as 30 min averages. Colours denote turbidity in the range 0- 3.5 NTU, individual values are highlighted every 12 hours.

7.3 Perfomance of the Vessel-Mounted Acoustic Doppler Current Profiler

A vessel-mounted Acoustic Doppler Current Profiler (VMADCP) was used for continuous recording of single-ping velocity data in the water column. The instrument is of type *Teledyne RD Instruments* (TRDI) *Ocean Surveyor* (OS), operating at 150 kHz, with a flat phased-array transducer mounted in the ship’s hull. As the VMADCP does not have any further built-in sensors, additional data on heading and tilt was obtained from the ship's *Hydrins* system. Data recording was carried out using the TRDI *VmDas* software, version 1.50.19. The characteristic parameters of the device installed on *RV ATAIR* are listed in Table 7.2.

OS 150 kHz	
Blanking Distance [m]	6
Maximum Range [m]	400
Transducer Depth [m]	5
Transducer Angle [°]	-1.6°

Table. 7.2. *Specification of the vessel-mounted Acoustic Doppler Current Profiler (VMADCP) in use during cruise 067I033-1.*

During the cruise, the VMADCP was operated in narrow-band mode to provide maximum data quality. Bin sizes were kept constant to sustain consistency throughout the cruise, while the bottom search threshold was kept constant at 100 m for the southern part of the cruise up to Thyborøn and at 400 m for the northern part. The detailed parameter settings are listed in Table 7.3. The obtained raw data were processed using the *CODAS*-toolbox, version "codas_focal_20.04", from the *School of Ocean and Earth Science and Technology* (SOEST) at the University of Hawaii, USA. Further information about the toolbox can be found on the CODAS website: https://currents.soest.hawaii.edu/docs/adcp_doc/. The settings and procedures follow the recommendations presented by *Firing and Hummon (2010)*.

In addition to single-ping data, the *TRDI VmDas* software calculated short-term averaged data (STA, 30s averages) and long-term averaged data (LTA, 5 min averages). Single-ping editing was not performed during the cruise due to the lack of sufficient calibration data. The processing resulted in data sets of zonal and meridional current velocities, distributed over latitude, longitude, time and depth along the ship's track. The processed data were stored in several output files in the native *MATLAB* format (*.mat) as well as *netcdf*. Erroneous signals from echoes at the seabed were removed from the data. Overview plots were stored alongside the data.

Data recording began at the CTD station #002/GN003/ELBE1 on 23 July 2024 at 17:05 UTC. Recording was temporarily stopped and resumed after transects along latitudes were finished in order to run the data pre-processing. Recording was stopped on 3 August 2024 at 10:57 UTC while the vessel was anchored and prior to entering Thyborøn Harbour on 4 August 2024. After leaving Thyborøn and crossing the 3 nm-limit, VMADCP data recording resumed on 8 August 2024 at 18:00 UTC. Again, recording was temporarily stopped and resumed after transects along the northern latitudes were finished in order to run the data pre-processing. The VMADCP recording was stopped on 14 August 2024 at 19:29 UTC when entering the British 12 nm-zone at the end of the cruise when heading for the port of Aberdeen, UK.

Whenever the VMADCP was restarted, a new file was created, and the file counter was automatically increased. The operation of the VMADCP was documented manually throughout the cruise in a log file. Setup files were stored alongside the data whenever the configuration was changed.

#	Start Date, Time (UTC)	Stop Date, Time (UTC)	Mode of Operation	Bin Size [m]	Number of Bins	Bottom Search [m]
1	23 Jul 2024 17:05	27 Jul 2024 15:46	narrowband	4	45	100
2	27 Jul 2024 15:47	29 Jul 2024 23:00	narrowband	4	45	100
3	29 Jul 2024 23:01	01 Aug 2024 01:35	narrowband	4	45	100
4	01 Aug 2024 18:19	03 Aug 2024 10:57	narrowband	4	45	100
5	08 Aug 2024 18:00	11 Aug 2024 15:01	narrowband	4	120	400
6	11 Aug 2024 15:02	12 Aug 2024 14:15	narrowband	4	120	400
7	12 Aug 2024 14:16	13 Aug 2024 06:39	narrowband	4	120	400
8	13 Aug 2024 06:40	13 Aug 2024 21:54	narrowband	4	120	400
9	13 Aug 2024 21:54	14 Aug 2024 19:29	narrowband	4	120	400

Table. 7.3. *VMADCP settings for different periods of cruise 067I033-1.*

The VMADCP worked properly during the entire cruise, and the data is of good quality. Some exceptions have to be made due to the temporary malfunctioning of the ship's navigational system, which led to a wrong input of position and heading data between the CTD stations #021/GN017S and #022/GN018A on 27 July 2024. These data were removed from the LTA dataset during processing and must be exckuded from any further additional post-cruise quality control and post-processing (single ping data and STA data).

Further exceptions must be made due to severe weather conditions between 12 and 13 August 2024 (track between 60°N and 59°N), which resulted in disturbed data due to a large abundance of air bubbles beneath the ship. On 14 August, short-time tests of other sounding devices of the vessel were performed resulting in disturbed VMADCP data due to interference between the different systems. These errorneous data have to be removed from the dataset during post-processing.

The data of cruise *067I033-1* need further additional post-cruise quality control and post-processing steps to obtain a final dataset, e.g. detailed inspection and manual editing of suspicious measurements.

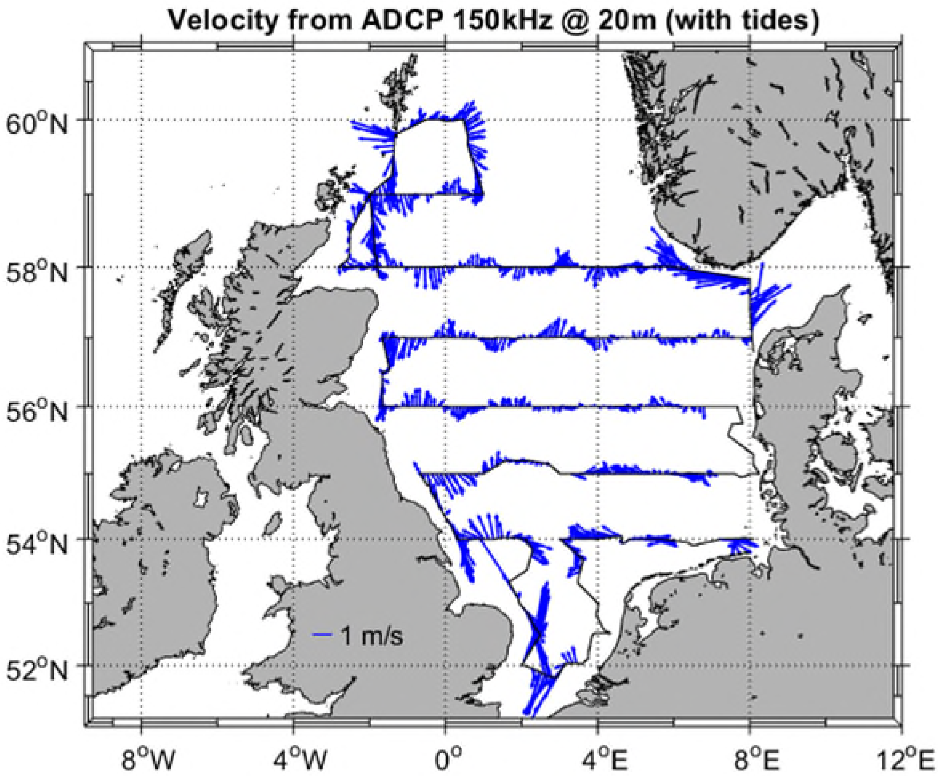

Figure 7.10. *The oceanic flow field at a depth of 20 m as observed with a VMADCP system during cruise 067I033-1, summer 2024. Shown data are pre-processed LTA-ADCP velocities with arrows indicating strength and direction of the flow. The tidal contribution to the flow field is still included.*

Figure 7.10 shows an example of the oceanic flow field at 20 m as observed during the entire cruise. The tidal contribution is still included.

7.4 Deployments of Surface Drifters

During cruise *067I033-1*, a total of eight cost-efficient surface drifters were deployed (see Figure 7.11) that aimed at revealing details of the surface circulation in three different subregions of the North Sea. These three subregions of interest are as follows:

- deployment of one drifter off the island of Borkum, Germany, to study the connectivity between the conservation areas Borkum Reef Ground and Sylt Outer Reef (Fig. 7.12)
- deployment of three drifters when crossing the Baltic outflow on the way from Thyborøn at the Danish west coast towards the southern Norwegian coast (Skagerrak) (Fig. 7.13)
- deployment of the final four drifters to the east of the Orkney Islands to capture the inflow of Atlantic Water into the North Sea (Fig. 7.14)

Deployments were made on behalf of the *Center for Marine Sensors* (ZfMarS), *Institute for Chemistry and Biology of the Marine Environment* (ICBM) at the *Carl von Ossietzky Universität* Oldenburg. ZfMarS designs and builds these drifters that are equipped with 12 conventional D-cell alkaline batteries powering a GPS tracking device of type *SPOT Trace*. The tracker transmits the surface position of the drifter at a temporal resolution of 5 min. Once deployed, the drifters follow the flow field at the sea surface. Details on the drifters and earlier results can be found in *Meyerjürgens et al. (2019)* and *Deyle et al. (2024)*.

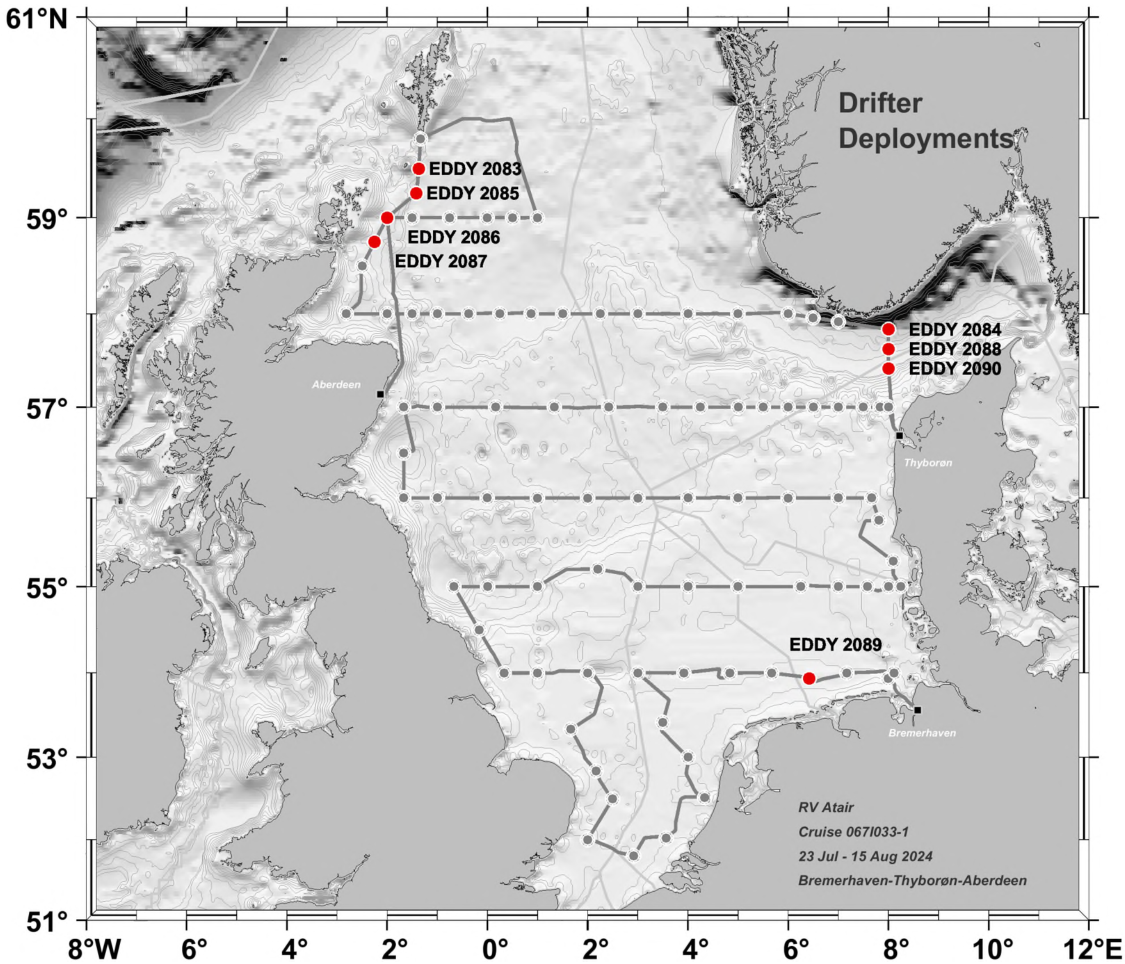

Figure 7.11. *Location of surface drifter deployments conducted during cruise 067I033-1.*

The drifters were provided in a disessambled state ahead of the cruise. Consequently, each drifter was reassembled before deployment. This involved connecting the GPS tracking device to its power supply, switching the tracking device on, sealing the drifter properly, and attaching buoyancy and fins to the main housing of the drifter. Afterwards, the drifter was ready for deployment, which happened typically at the end of a CTD station with the vessel starting to steam at low speed. Figure 7.11 shows drifter deployment location and corresponding trajectories. Table 7.4 summarises the individual deployment information for each drifter.

#	Drifter ID	Tracker ID	Date	Time [UTC]	Latitude	Longitude	Station
1.	EDDY 2083	049	12 Aug 2024	06:19	59°30.11'N	001°21.97'W	085/GN053C
2.	EDDY 2084	053	09 Aug 2024	03:47	57°50.02'N	007°59.92'E	065/GN040
3.	EDDY 2085	073	12 Aug 2024	03:52	59°15.07'N	001°24.80'W	084//GN053D
4.	EDDY 2086	070	12 Aug 2024	00:42	58°59.95'N	001°59.99'W	083/GN046A
5.	EDDY 2087	061	11 Aug 2024	22:12	58°44.94'N	003°14.97'W	082/GN046B
6.	EDDY 2088	058	09 Aug 2024	01:11	57°37.50'N	007°59.89'E	064/GN040B
7.	EDDY 2089	067	24 Jul 2024	02:51	53°56.13'N	006°24.95'E	004/GN007
8.	EDDY 2090	056	08 Aug 2024	23:01	57°24.92'N	008°00.05'E	063/GN039S

Table 7.4. *Information on surface drifters deployed during cruise 067I033-1.*

The drifters deployed during cruise *067I033-1* partly contribute to the CREATE project (*Concepts for Reducing the Effects of Anthropogenic pressures and uses on marine Ecosystems and on Biodiversity*), which is part of the scientific mission *sustainMare* within the German Alliance for Marine Research (DAM). Drifters deployed in the Norwegian Trench will support preparatory work for the *SkaMix* project, which aims to investigate water mass transformation and mixing in the vicinity of fronts and filaments in the Skagerrak. The deployments near the Orkney Islands further regionally extend the existing drifter data set, which has so far focused on the central North Sea and the German Bight.

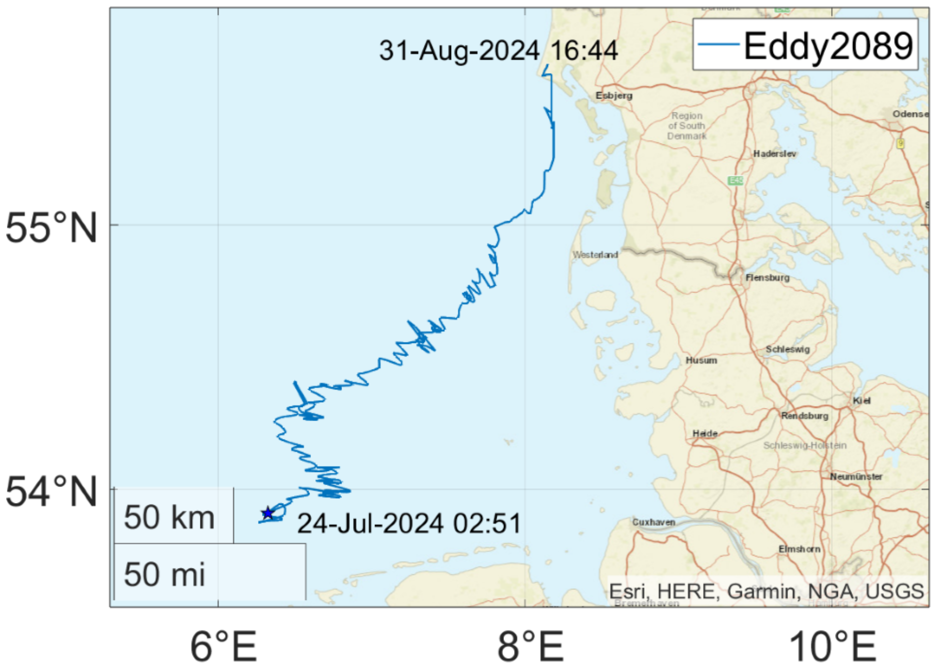

Figure 7.12. *Surface trajectory of drifter EDDY 2089 in the period 24 July to 31 August 2024. The drifter was deployed northwest of the island of Borkum.*

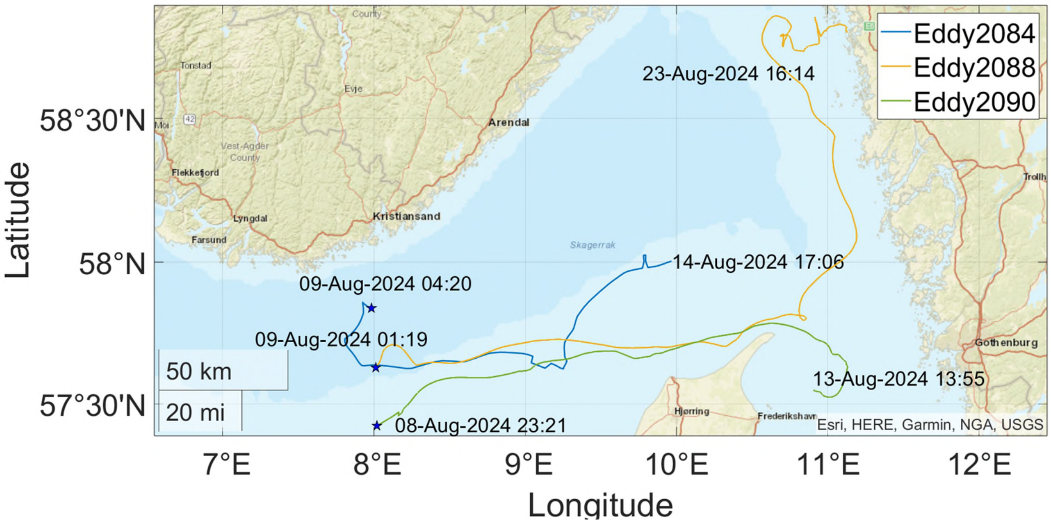

Figure 7.13. *Surface trajectory of drifters EDDY 2084, EDDY 2088 and EDDY 2090 in the period 08 August to 23 August 2024. All drifters were deployed along 8°E in the Skagerrak.*

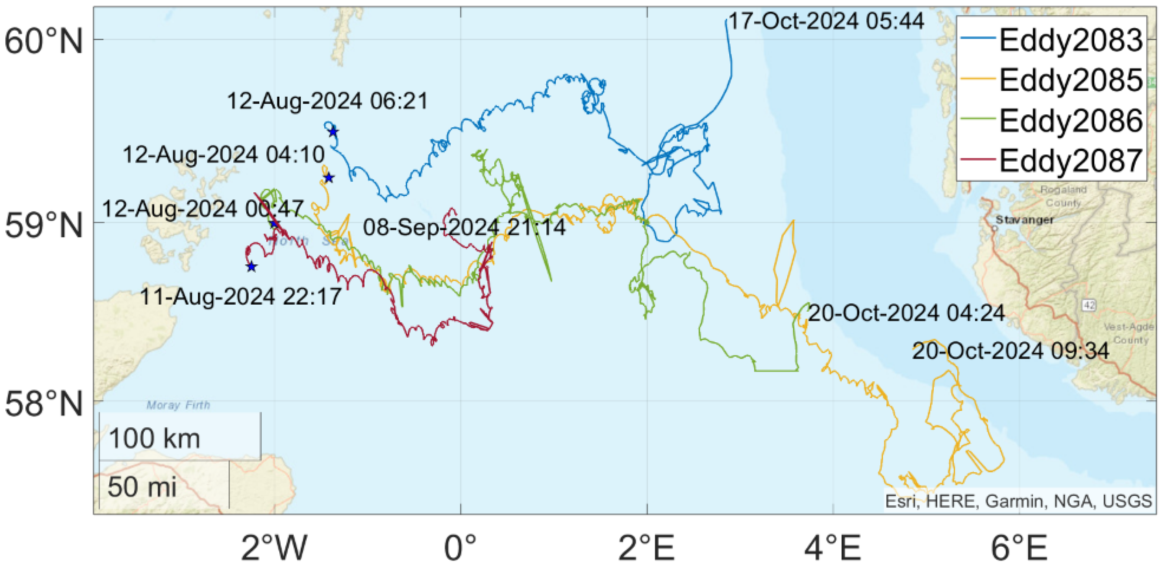

Figure 7.14. *Surface trajectory of drifters EDDY 2083, EDDY 2085, EDDY 2086 and EDDY 2087 in the period 11 August to 20 October 2024. All drifters were deployed to the east of the Orkney Islands.*

8. Data Availability & Sample Storage

Further data analysis and interpretation will be carried out together with national and international collaborators in the framework of e.g. BSH's contribution to the international *Working Group on Oceanic Hydrography* (WGOH), which is hosted by the *International Council for the Explorations of the Seas* (ICES). Data from this cruise will be used for respective assessment reports and reporting in the framework of the *Marine Strategy Framework Directive* (MSFD) of the European Union. The data also serve for validating numerical operational ocean and climate models, for the calibration of satellite-based ocean colour data, hyper-spectral satellite data and downstream products (e.g. Secchi depth, turbidity, fluorescence, chlorophyll-a). In particular, chlorophyll-a data contributes to the EOMAP effort (https://eomap.com), while phytoplankton sampling contributes to the EnSAD project, which is part of the *Environmental Mapping and Analysis Program* (EnMAP, https://www.enmap.org).

A cruise summary report (CSR) is available on the *SeaDataNet* portal, CSR reference number: 21038345; https://csr.seadatanet.org/report/21038345. See also: https://www2.bsh.de/aktdat/dod/fahrtergebnis/2024/20240052.htm

BSH data related to cruise *067I033-1* is genereally stored in various long-term storage databases (DOD database, DSHIP land system and others) of the German Oceanographic Data Service hosted at BSH (DOD, email: dod@bsh.de), DOD reference number: 20240052, https://www.bsh.de/EN/DATA/Climate-and-Sea/Oceanographic_Data_Center/oceanographic_data_center_node.html.

Near-realtime CTD data has been submitted and is available for download on the BSH data portal:

Temperature: https://gdi.bsh.de/en/feed/temperature-of-sea-water-2024.xml

Salinity: https://gdi.bsh.de/en/feed/salinity-of-sea-water-2024.xml

Dissolved oxygen: https://gdi.bsh.de/en/feed/dissolved-oxygen-in-sea-water-2024.xml

Fluorescence (chlorophyll): https://gdi.bsh.de/en/feed/chlorophyll-a-in-sea-water-2024.xml

Turbidity: https://gdi.bsh.de/en/feed/turbidity-in-sea-water-2024.xml

Finally processed CTD data has been submitted to DOD and is available on the MUDAB data portal (https://geoportal.bafg.de/MUDABAnwendung/), the mandatory data portal for German governmental agencies. Therein, data of cruise *067I033-1* contributes to the “Bund-Länder Monitoring-Programm” (BLMP/BLMP+). Respective data will be provided via MUDAB to the ICES data portal (https://www.ices.dk). Also, data regarding chlorophyll-a concentrations measured in the home laboratory, Secchi depths and oxygen are available via the MUDAB database and will be pushed forward to ICES. The following ICES divisions were sampled: IIIa, IVa, IVb, IVc and VIa. The respective ICES ecoregion is the Greater North Sea.

Data from water sampling regarding phytoplankton can be requested from BSH via contact person Dr. Karin Heyer, Karin.Heyer@bsh.de. This data will be available in the MUDAB data portal (see link above) in 2026.

VMADCP data is kept on long-time archives of the BSH's oceanography group as the establishment of an official data storage work flow is in the making through collaboration with the *German Marine Research Alliance* (DAM). Data can be obtained on request from: M22_obs@bsh.de

Drifter data is kept on long-time archives of the ICBM working group *Marine Sensorsystems* and will be made available on PANGAEA at a later stage. Contact person for drifter data is Dr. Thomas Badewien, thomas.badewien@uol.de.

Data related to the analysis of the participating group from the *Helmholtz Centre Hereon* will be made available after publication via the *Helmholtz Coastal Data Center* (HCDC) data portal, accessible at https://hcdc.hereon.de/datasearch. Contact person for trace metals, mercury, lead and microplastics is Dr. Daniel Pröfrock, daniel.proefrock@hereon.de. Contact person for dissolved inorganic carbon, alkalinity and nutrients is Prof. Dr. Helmuth Thomas, helmuth.thomas@hereon.de.

Tritium data is stored in long-term archives of the University of Bremen and will be submitted to permanent data repositories at a later stage. Contact person for tritium data is Dr. Jürgen Sültenfuß, suelten@uni-bremen.de.

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10. Acknowledgments

We would like to express our gratitude to the master of *RV ATAIR*, Ulrich Klüber, and his entire crew for their assistance and great support granted to us during cruise *067I033-1*. The very friendly working environment, the hospitality experienced on board the vessel, and the very professional and constructive cooperation between the scientific team and the ship's crew, often under unfavourable weather conditions, were all greatly appreciated. We would also like to thank our colleagues at our home laboratories for assistance in the preparation of the cruise and processing of the cruise-related data. We would particularly like to acknowledge the support of the BSH's shipping company *N3* and the respective sections *N32-Vessel Operation* and *N31-Technology and Equipment of Vessels*. We would also like to thank the various international authorities for granting us permission to conduct this survey in their national waters.

11. Station List

Station Number	Station Name	Date, Station Begin	Time [UTC], Station Begin	Latitude, Station Begin	Longitude, Station Begin	Water Depth [m], Station Begin	Date, Station End	Time [UTC], Station End	Latitude, Station End	Longitude, Station End	Water Depth [m], Station End	CTD	Water samples (Niskin, GoFlo)	Secchi Disc	Bottle Salinity	Bottle Density	Bottle Chlorophyll-a	Bottle Plankton	Bottle Tritium	Bottle Mercury (Hg)	Bottle Nutrients	Bottle DIC/Alkalinity	Bottle Trace Metals	Bottle Lead	Comment
001	Teststation	23-Jul-2024	15:53	53° 56.155' N	007° 59.606' E	15	23-Jul-2024	16:12	53° 56.155' N	007° 59.606' E	15	X													A001X001
002	GN003/ELBE1	23-Jul-2024	17:17	53° 56.155' N	007° 59.606' E	24	23-Jul-2024	17:42	54° 00.017' N	008° 06.525' E	24	X	X		X	X			X	X	X	X	X		A002X001
003	GN003A	23-Jul-2024	22:09	54° 00.187' N	008° 04.934' E	31	23-Jul-2024	22:35	53° 59.955' N	007° 10.084' E	31	X	X		X	X			X	X	X	X	X	X	A003X001
004	GN007	24-Jul-2024	02:19	53° 59.956' N	007° 10.086' E	27	24-Jul-2024	02:50	53° 56.134' N	006° 24.953' E	27	X	X		X				X	X	X	X	X	X	A004X001, EDDY 2089
005	GN007A	24-Jul-2024	06:10	53° 56.239' N	006° 24.802' E	37	24-Jul-2024	06:34	53° 59.996' N	005° 40.028' E	42	X	X	X	X		X	X	X	X	X	X	X		A005X001
006	GN008	24-Jul-2024	10:46	53° 59.995' N	005° 40.028' E	44	24-Jul-2024	11:21	53° 59.997' N	004° 49.981' E	43	X	X	X	X		X	X	X	X	X	X	X		A006X001
007	GN008S	24-Jul-2024	16:19	53° 59.989' N	003° 54.963' E	45	24-Jul-2024	16:53	53° 59.987' N	003° 54.974' E	46	X	X	X	X	X	X	X	X	X	X	X	X		A007X001
008	GN009	24-Jul-2024	20:51	54° 00.056' N	003° 54.659' E	43	24-Jul-2024	21:18	54° 00.020' N	003° 00.047' E	42	X	X		X				X	X	X	X	X		A008X001
009	GN009A	25-Jul-2024	02:49	54° 00.021' N	003° 00.047' E	27	25-Jul-2024	03:10	53° 24.961' N	003° 29.927' E	27	X	X		X				X	X	X	X	X		A009X001
010	GN010	25-Jul-2024	07:25	53° 24.962' N	003° 29.927' E	31	25-Jul-2024	07:51	53° 00.008' N	004° 00.014' E	31	X	X	X	X	X	X	X	X	X	X	X	X		A010X001
011	GN011	25-Jul-2024	12:04	53° 00.008' N	004° 00.015' E	20	25-Jul-2024	12:30	52° 30.941' N	004° 20.018' E	19	X	X	X	X		X	X	X	X	X	X	X		A011X001
012	GN012N	25-Jul-2024	18:59	52° 01.020' N	003° 33.985' E	29	25-Jul-2024	19:15	52° 01.018' N	003° 33.986' E	29	X	X		X				X	X	X	X	X		A012X001
013	GN013N	25-Jul-2024	23:05	52° 01.792' N	003° 31.227' E	28	25-Jul-2024	23:31	51° 47.964' N	002° 55.192' E	28	X	X		X	X			X	X	X	X	X		A013X001
014	GN014	26-Jul-2024	03:56	52° 00.019' N	002° 00.016' E	32	26-Jul-2024	04:19	52° 00.019' N	002° 00.015' E	31	X	X		X				X	X	X	X	X		A014X001
015	GN015	26-Jul-2024	08:03	52° 01.181' N	002° 01.174' E	49	26-Jul-2024	08:32	52° 30.001' N	002° 29.978' E	49	X	X	X	X		X	X	X	X	X	X	X		A015X001
016	GN015B	26-Jul-2024	11:47	52° 31.296' N	002° 27.766' E	42	26-Jul-2024	12:19	52° 49.964' N	002° 10.010' E	42	X	X	X	X	X	X	X	X	X	X	X	X		A016X001
017	GN016	26-Jul-2024	16:31	53° 20.052' N	001° 39.917' E	28	26-Jul-2024	16:52	53° 20.049' N	001° 39.924' E	28	X	X	X	X		X	X	X	X	X	X	X		A017X001
018	GN009S	26-Jul-2024	23:17	53° 59.993' N	002° 00.075' E	74	26-Jul-2024	23:49	53° 59.991' N	002° 00.071' E	74	X	X		X				X	X	X	X	X		A018X001
019	GN017	27-Jul-2024	03:48	54° 00.000' N	000° 59.985' E	44	27-Jul-2024	04:13	53° 59.992' N	000° 59.985' E	44	X	X		X				X	X	X	X	X		A019X001
020	GN017A	27-Jul-2024	06:56	54° 00.028' N	000° 58.058' E	55	27-Jul-2024	07:27	53° 59.994' N	000° 20.000' E	55	X	X	X	X		X	X	X	X	X	X	X		A020X001
021	GN017S	27-Jul-2024	11:55	54° 00.108' N	000° 19.908' E	62	27-Jul-2024	12:47	54° 30.034' N	000° 10.025' W	61	X	X	X	X	X	X	X	X	X	X	X	X		A021X001

Station Number	Station Name	Date, Station Begin	Time [UTC], Station Begin	Latitude, Station Begin	Longitude, Station Begin	Water Depth [m], Station Begin	Date, Station End	Time [UTC], Station End	Latitude, Station End	Longitude, Station End	Water Depth [m], Station End	CTD	Water samples (Niskin, GoFlo)	Secchi Disc	Bottle Salinity	Bottle Density	Bottle Chlorophyll-a	Bottle Plankton	Bottle Tritium	Bottle Mercury (Hg)	Bottle Nutrients	Bottle DIC/Alkalinity	Bottle Trace Metals	Bottle Lead	Comment
022	GN018A	27-Jul-2024	16:33	54° 59.970' N	000° 39.940' W	68	27-Jul-2024	17:03	54° 59.972' N	000° 39.938' W	68	X	X	X	X		X	X	X	X	X	X	X		A022X001
023	GN018	27-Jul-2024	19:39	54° 59.970' N	000° 39.759' W	77	27-Jul-2024	20:07	55° 00.038' N	000° 00.108' E	77	X	X	X	X		X	X	X	X	X	X	X		A023X001
024	GN018S	28-Jul-2024	00:15	54° 59.999' N	000° 05.898' E	63	28-Jul-2024	00:35	55° 00.034' N	001° 00.031' E	63	X	X		X				X			X	X		A024X001
025	GN019N	28-Jul-2024	05:43	55° 12.005' N	002° 12.067' E	35	28-Jul-2024	06:04	55° 12.005' N	002° 12.066' E	35	X	X	X	X		X	X	X	X	X	X	X		A025X001
026	GN019S	28-Jul-2024	10:33	55° 09.907' N	002° 32.372' E	25	28-Jul-2024	10:52	54° 59.987' N	003° 00.061' E	25	X	X	X	X		X	X	X			X	X		A026X001
027	GN020	28-Jul-2024	14:50	54° 59.987' N	004° 00.007' E	48	28-Jul-2024	15:18	54° 59.990' N	004° 00.006' E	53	X	X	X	X		X	X		X	X	X	X		A027X001
028	GN021/AWZW2	28-Jul-2024	19:24	55° 00.057' N	005° 00.060' E	41	28-Jul-2024	19:53	55° 00.055' N	005° 00.057' E	41	X	X	X	X		X	X	X			X	X	X	A028X001
029	GN022	29-Jul-2024	01:03	55° 00.055' N	005° 00.057' E	44	29-Jul-2024	01:26	54° 59.991' N	006° 15.034' E	45	X	X		X	X				X	X	X	X	X	A029X001
030	GN022A	29-Jul-2024	04:27	55° 00.016' N	007° 00.026' E	32	29-Jul-2024	04:57	55° 00.012' N	007° 00.021' E	33	X	X	X	X		X	X	X			X	X		A301X001
031	GN023	29-Jul-2024	07:37	55° 00.012' N	007° 00.022' E	25	29-Jul-2024	08:01	54° 59.999' N	007° 35.034' E	25	X	X	X	X		X	X	X	X	X	X	X		A031X001
032	GN024/SYLT1	29-Jul-2024	10:32	54° 59.882' N	007° 35.482' E	16	29-Jul-2024	11:01	54° 59.993' N	007° 59.979' E	16	X	X	X	X		X	X	X	X	X	X	X		A032X001
033	GN025	29-Jul-2024	12:14	54° 59.985' N	008° 15.019' E	13	29-Jul-2024	12:36	54° 59.986' N	008° 15.022' E	13	X	X	X	X		X	X	X	X	X	X	X		A033X001
034	GN025A	29-Jul-2024	15:11	55° 05.314' N	008° 09.140' E	16	29-Jul-2024	15:32	55° 17.512' N	008° 05.501' E	16	X	X	X	X		X	X	X	X	X	X	X		A034X001
035	GN025B	29-Jul-2024	21:15	55° 17.575' N	008° 05.308' E	20	29-Jul-2024	21:39	55° 45.018' N	007° 48.496' E	20	X	X		X				X			X	X		A035X001
036	GN026	29-Jul-2024	23:46	55° 45.018' N	007° 48.496' E	28	30-Jul-2024	00:07	56° 00.015' N	007° 39.995' E	28	X	X		X	X			X	X	X	X	X		A036X001
037	GN026A	30-Jul-2024	02:54	56° 00.031' N	007° 00.009' E	35	30-Jul-2024	03:17	56° 00.029' N	007° 00.006' E	35	X	X		X				X			X	X		A037X001
038	GN027	30-Jul-2024	07:18	56° 00.005' N	006° 59.043' E	48	30-Jul-2024	07:47	55° 59.998' N	005° 59.978' E	48	X	X	X	X		X	X	X			X	X		A038X001
039	GN028	30-Jul-2024	11:55	56° 00.009' N	005° 28.860' E	44	30-Jul-2024	12:20	56° 00.018' N	004° 59.996' E	44	X	X	X	X		X	X	X	X	X	X	X		A039X001
040	GN028S	30-Jul-2024	16:52	56° 00.006' N	004° 00.027' E	63	30-Jul-2024	17:24	56° 00.005' N	004° 00.003' E	63	X	X	X	X	X	X	X	X			X	X		A040X001
041	GN029	30-Jul-2024	21:46	55° 59.987' N	002° 59.991' E	75	30-Jul-2024	22:11	55° 59.985' N	002° 59.980' E	75	X	X		X					X	X	X	X	X	A041X001
042	GN030	31-Jul-2024	02:44	56° 00.003' N	002° 00.041' E	87	31-Jul-2024	03:08	56° 00.003' N	002° 00.041' E	87	X	X		X				X			X	X		A042X001
043	GN031	31-Jul-2024	07:42	55° 59.995' N	000° 59.911' E	78	31-Jul-2024	08:18	55° 59.996' N	000° 59.915' E	78	X	X	X	X		X	X		X	X	X	X		A043X001
044	GN032	31-Jul-2024	12:47	55° 59.995' N	000° 59.913' E	86	31-Jul-2024	13:18	56° 00.018' N	000° 00.022' W	86	X	X	X	X	X	X	X	X			X	X		A044X001
045	GN033	31-Jul-2024	17:52	56° 00.012' N	001° 00.021' W	64	31-Jul-2024	18:21	56° 00.006' N	001° 00.026' W	64	X	X	X	X		X	X	X	X	X	X	X		A045X001

Station Number	Station Name	Date, Station Begin	Time [UTC], Station Begin	Latitude, Station Begin	Longitude, Station Begin	Water Depth [m], Station Begin	Date, Station End	Time [UTC], Station End	Latitude, Station End	Longitude, Station End	Water Depth [m], Station End	CTD	Water samples (Niskin, GoFlo)	Secchi Disc	Bottle Salinity	Bottle Density	Bottle Chlorophyll-a	Bottle Plankton	Bottle Tritium	Bottle Mercury (Hg)	Bottle Nutrients	Bottle DIC/Alkalinity	Bottle Trace Metals	Bottle Lead	Comment
046	GN033A	31-Jul-2024	21:21	56° 00.001' N	001° 09.449' W	67	31-Jul-2024	21:52	56° 00.012' N	001° 40.015' W	67	X	X		X				X	X	X	X	X		A046X001
047	GN033S	01-Aug-2024	01:57	56° 30.022' N	001° 39.984' W	52	01-Aug-2024	02:20	56° 30.022' N	001° 39.992' W	51	X	X		X				X	X	X	X	X		A047X001
048	GN034A	01-Aug-2024	07:17	57° 00.012' N	001° 40.016' W	75	01-Aug-2024	07:48	57° 00.008' N	001° 40.014' W	75	X	X	X	X	X	X	X	X	X	X	X	X		A048X001
049	GN034	01-Aug-2024	10:56	56° 59.989' N	001° 37.457' W	73	01-Aug-2024	11:26	56° 59.976' N	000° 59.993' W	72	X	X	X	X		X	X	X			X	X		A049X001
050	GN034S	01-Aug-2024	16:42	57° 00.021' N	000° 09.964' E	85	01-Aug-2024	17:14	57° 00.017' N	000° 09.954' E	85	X	X	X	X		X	X	X	X	X	X	X		A050X001
051	GN035	01-Aug-2024	22:27	57° 00.023' N	001° 20.022' E	99	01-Aug-2024	22:50	57° 00.022' N	001° 20.030' E	100	X	X		X							X	X		A051X001
052	GN035S	02-Aug-2024	03:39	56° 59.987' N	002° 25.040' E	81	02-Aug-2024	04:03	56° 59.986' N	002° 25.032' E	81	X	X		X				X	X	X	X	X		A052X001
053	GN036	02-Aug-2024	08:53	57° 00.001' N	002° 26.875' E	65	02-Aug-2024	09:22	57° 00.003' N	003° 29.996' E	65	X	X	X	X		X	X				X	X		A053X001
054	GN036A	02-Aug-2024	12:44	57° 00.002' N	003° 29.996' E	65	02-Aug-2024	13:10	57° 00.021' N	004° 15.019' E	65	X	X	X	X		X	X	X	X	X	X	X		A054X001
055	GN037	02-Aug-2024	16:36	57° 00.021' N	004° 15.019' E	59	02-Aug-2024	17:06	57° 00.011' N	005° 00.123' E	60	X	X	X	X		X	X				X	X		A055X001
056	GN037A	02-Aug-2024	19:47	57° 00.000' N	005° 11.377' E	55	02-Aug-2024	20:10	57° 00.006' N	005° 30.057' E	55	X	X	X	X		X	X	X			X	X		A056X001
057	GN038	02-Aug-2024	22:27	57° 00.008' N	005° 30.062' E	53	02-Aug-2024	22:53	56° 59.979' N	005° 59.981' E	53	X	X		X					X	X	X	X		A057X001
058	GN038B	03-Aug-2024	01:13	57° 00.010' N	006° 29.993' E	60	03-Aug-2024	01:35	57° 00.009' N	006° 30.002' E	60	X	X		X							X	X		A058X001
059	GN038A	03-Aug-2024	03:55	57° 00.009' N	006° 30.002' E	33	03-Aug-2024	04:15	56° 59.977' N	007° 00.030' E	33	X	X		X				X			X	X		A059X001
060	GN038C	03-Aug-2024	06:32	56° 59.981' N	007° 00.504' E	32	03-Aug-2024	06:58	57° 00.012' N	007° 30.034' E	32	X	X	X	X		X	X	X	X	X	X	X		A060X001
061	GN039N	03-Aug-2024	08:33	57° 00.014' N	007° 30.033' E	41	03-Aug-2024	09:00	57° 00.012' N	007° 50.029' E	41	X	X	X	X		X	X	X	X	X	X	X		A061X001
062	GN039	03-Aug-2024	10:37	56° 59.998' N	007° 43.279' E	34	03-Aug-2024	10:55	57° 00.020' N	008° 00.038' E	34	X	X	X	X	X	X	X	X	X	X				A062X001
063	GN039S	08-Aug-2024	22:36	57° 24.969' N	008° 00.233' E	91	08-Aug-2024	23:01	57° 24.918' N	008° 00.046' E	91	X	X		X				X						A063X001, EDDY 2090
064	GN040B	09-Aug-2024	00:47	57° 37.534' N	008° 00.031' E	272	09-Aug-2024	01:12	57° 37.502' N	007° 59.985' E	272	X	X		X				X						A064X001, EDDY 2088
065	GN040	09-Aug-2024	02:53	57° 50.073' N	007° 59.909' E	524	09-Aug-2024	03:47	57° 50.011' N	007° 59.916' E	524	X	X		X				X	X	X	X	X		A065X001, EDDY 2084
066	GN040S	09-Aug-2024	08:26	57° 55.013' N	006° 59.958' E	363	09-Aug-2024	09:09	57° 55.010' N	006° 59.943' E	362	X	X	X	X		X	X	X	X	X	X	X		A066X001
067	GN040A	09-Aug-2024	11:36	57° 57.470' N	006° 29.912' E	354	09-Aug-2024	12:20	57° 57.473' N	006° 29.913' E	354	X	X	X	X	X	X	X	X	X	X	X	X		A067X001
068	GN041	09-Aug-2024	14:34	57° 59.986' N	006° 00.067' E	310	09-Aug-2024	15:22	57° 59.983' N	006° 00.067' E	310	X	X	X	X	X	X	X		X	X	X	X		A068X001
069	GN042	09-Aug-2024	19:51	58° 00.010' N	005° 00.027' E	127	09-Aug-2024	20:56	58° 00.003' N	005° 00.025' E	127	X	X		X				X	X	X	X	X		A069X001

Station Number	Station Name	Date, Station Begin	Time [UTC], Station Begin	Latitude, Station Begin	Longitude, Station Begin	Water Depth [m], Station Begin	Date, Station End	Time [UTC], Station End	Latitude, Station End	Longitude, Station End	Water Depth [m], Station End	CTD	Water samples (Niskin, GoFlo)	Secchi Disc	Bottle Salinity	Bottle Density	Bottle Chlorophyll-a	Bottle Plankton	Bottle Tritium	Bottle Mercury (Hg)	Bottle Nutrients	Bottle DIC/Alkalinity	Bottle Trace Metals	Bottle Lead	Comment
070	GN042S	10-Aug-2024	02:48	57° 59.994' N	004° 00.020' E	101	10-Aug-2024	03:15	57° 59.997' N	004° 00.016' E	100	X	X		X						X	X	X		A070X001
071	GN043	10-Aug-2024	08:54	58° 00.016' N	003° 00.015' E	76	10-Aug-2024	09:41	58° 00.009' N	003° 00.016' E	78	X	X	X	X	X	X	X	X	X	X	X	X		A071X001
072	GN043A	10-Aug-2024	14:31	58° 00.025' N	002° 14.994' E	78	10-Aug-2024	15:02	58° 00.022' N	002° 14.986' E	78	X	X	X	X		X	X			X	X	X		A072X001
073	GN044	10-Aug-2024	18:17	58° 00.000' N	001° 30.024' E	106	10-Aug-2024	18:51	57° 59.995' N	001° 30.016' E	106	X	X	X	X		X	X	X		X	X	X		A073X001
074	GN044A	10-Aug-2024	21:32	58° 00.012' N	000° 52.539' E	146	10-Aug-2024	22:14	58° 00.006' N	000° 52.515' E	146	X	X		X					X	X	X	X		A074X001
075	GN044S	11-Aug-2024	01:00	58° 00.008' N	000° 15.048' E	141	11-Aug-2024	01:20	58° 00.006' N	000° 15.039' E	141	X	X		X				X						A075X001
076	GN044B	11-Aug-2024	03:49	58° 00.003' N	000° 22.510' W	123	11-Aug-2024	04:04	58° 00.005' N	000° 22.514' W	123	X	X		X										A076X001
077	GN045	11-Aug-2024	06:30	57° 59.994' N	001° 00.000' W	114	11-Aug-2024	07:03	57° 59.995' N	001° 00.000' W	114	X	X	X	X		X	X	X	X	X	X	X		A077X001
078	GN045D	11-Aug-2024	09:00	58° 00.022' N	001° 29.985' W	72	11-Aug-2024	09:25	58° 00.015' N	001° 29.972' W	72	X	X	X	X		X	X	X		X	X	X		A078X001
079	GN045A	11-Aug-2024	11:24	57° 59.992' N	002° 00.031' W	85	11-Aug-2024	11:52	57° 59.989' N	002° 00.023' W	85	X	X	X	X	X	X	X	X		X	X	X		A079X001
080	GN045C	11-Aug-2024	14:56	58° 00.025' N	002° 49.033' W	73	11-Aug-2024	15:24	58° 00.024' N	002° 49.027' W	73	X	X	X	X		X	X	X	X	X	X	X		A080X001
081	GN045B	11-Aug-2024	19:26	58° 30.033' N	002° 29.957' W	72	11-Aug-2024	19:49	58° 30.034' N	002° 29.956' W	71	X	X		X				X	X	X	X	X		A081X001
082	GN046B	11-Aug-2024	21:52	58° 45.009' N	002° 14.990' W	79	11-Aug-2024	22:12	58° 44.940' N	002° 14.972' W	80	X	X		X				X						A082X001, EDDY 2087
083	GN046A	12-Aug-2024	00:19	59° 00.010' N	001° 59.970' W	79	12-Aug-2024	00:42	58° 59.945' N	001° 59.987' W	79	X	X		X	X									A083X001, EDDY 2086
084	GN053D	12-Aug-2024	03:30	59° 15.009' N	001° 25.006' W	103	12-Aug-2024	03:52	59° 15.068' N	001° 24.798' W	106	X	X		X				X						A084X001, EDDY 2085
085	GN053C	12-Aug-2024	05:40	59° 29.972' N	001° 21.996' W	103	12-Aug-2024	06:19	59° 30.109' N	001° 21.968' W	103	X	X	X	X		X	X	X	X	X	X	X		A085X001, EDDY 2083
086	GN053A	12-Aug-2024	09:50	59° 48.010' N	001° 20.029' W	87	12-Aug-2024	10:40	59° 48.003' N	001° 20.030' W	87	X	X		X	X			X	X	X	X	X		A086X002, 2nd cast
087	GN048	13-Aug-2024	05:47	58° 59.995' N	000° 59.941' E	125	13-Aug-2024	06:19	58° 59.999' N	000° 59.953' E	126	X	X	X	X	X	X	X	X		X	X	X		A087X001
088	GN048N	13-Aug-2024	08:19	58° 59.975' N	000° 30.002' E	149	13-Aug-2024	08:53	58° 59.976' N	000° 30.019' E	149	X	X	X	X		X	X	X	X	X	X	X		A088X001
089	GN047	13-Aug-2024	10:56	59° 00.005' N	000° 00.008' E	133	13-Aug-2024	11:27	59° 00.001' N	000° 00.002' E	133	X	X	X	X		X	X	X	X	X	X	X		A089X001
090	GN047A	13-Aug-2024	14:19	59° 00.009' N	000° 45.052' W	135	13-Aug-2024	14:53	59° 00.011' N	000° 45.054' W	136	X	X	X	X		X	X		X	X	X	X		A090X001
091	GN046	13-Aug-2024	17:54	59° 00.017' N	001° 29.985' W	107	13-Aug-2024	18:44	59° 00.017' N	001° 29.991' W	107	X	X	X	X		X	X							A091X001
092	GN046A	13-Aug-2024	20:53	59° 00.005' N	001° 59.975' W	78	13-Aug-2024	21:40	59° 00.006' N	001° 59.990' W	80	X	X		X				X	X	X	X	X		A092X001