ELISABETH MANN BORGESE–Berichte

Baltic Sea Long-term Observation Programme

Cruise No. EMB323

4 August – 16 August 2023,

Rostock – Sassnitz – Rostock (Germany)

HELCOM/long-term

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2023

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1 Summary

1.1 Summary in English

The cruise of r/v Elisabeth Mann Borgese No. 323 was done in the frame of the HELCOM monitoring and the IOW long-term observation of the Baltic Sea from August 4th to 16th 2023. During the first two days, a moderate to fresh breeze well allowed to fulfil the station work in the western Baltic Sea. On 6th August a storm low over the southern Baltic Sea deepened that led to wind of about 7 bft that subsequently increased with locally near hurricane force gusts. We entered the port of Sassnitz on 6th August for a scientific crew exchange, but stayed there until the storm calmed down. On 9th August we continued the station work at the Oder buoy, and subsequently finalized the station work in the Arkona Sea. Then the measurements along the Thalweg were continued from the Bornholm Basin to the eastern and western Gotland Sea at fair weather conditions. We investigated the hydrographic, hydrochemical and biological state of the Baltic Sea on transect of 1400 nm with 87 stations. Thereby, we also took samples for UV Filter and an eDAN sample archive. The water temperature was on average about 19 °C before and 16 °C after the storm. Similarly, the air temperature dropped from 17.3 ± 1 °C in the first 3 days to autumn-like temperatures of 16.3 ± 2 °C afterwards. In the deep Gotland Sea, the euxinic conditions intensified. In the Słupsk furrow, between the Bornholm Basin and the eastern Gotland Basin, the bottom water oxygen concentrations of about 1.5 mL/L were measured. Moreover, a plume of slightly oxygenated water reached far into the eastern Gotland Basin along the 100 ± 10 m depth horizon. The weak oxygenated water layer enabled nitrate concentrations of up to 6.6 µmol/L in an otherwise nitrate depleted environment.

1.2 Zusammenfassung

Die Reise des F/S Elisabeth Mann Borgese Nr. 323 wurde im Rahmen des HELCOM Monitorings und der IOW Langzeit Überwachung der Ostsee vom 4. bis 16. August 2023 durchgeführt. Während der ersten beiden Tage ermöglichte eine schwache bis mäßige Briese das Stationsprogramm in der westlichen Ostsee abzuarbeiten. Am 6. August verstärkte sich ein Sturmtief über der südlichen Ostsee, das zu Wind mit 7 bft führte der dann weiter zunahm und orkanartige Böen aufwies. Wir liefen den Hafen von Sassnitz für einen Wissenschaftlerwechsel an und blieben, bis sich der Sturm gelegt hatte. Am 9. August konnten wir die Stationsarbeiten an der Station Oderboje fortsetzen und anschließend auch die Stationsarbeiten in der Arkonasee beenden. Dann wurden die Messungen entlang des Talwegs von dem Bornholmbecken zur östlichen und westlichen Gotlandsee bei guten Wetterbedingungen fortgesetzt. Wir untersuchten den hydrographischen, hydrochemischen und biologischen Zustand der Ostsee auf 87 Stationen entlang eines Schnitts von 1400 sm. Dabei wurden auch Proben zur Untersuchung von UV Filtern und für ein eDNA Probenarchiv genommen. Die Wassertemperatur lag vor dem Sturm im Mittel bei 19 °C und danach bei 16 °C. Ähnlich fiel auch die Lufttemperatur von 17.3 ± 1 °C in den ersten 3 Tagen auf 16.3 ± 2 °C danach. In der tiefen Gotlandsee hatten sich die euxinischen Bedingungen verstärkt. In der Słupsker Rinne, zwischen dem Bornholm- und dem östlichen Gotlandbecken, wurde im Bodenwasser etwa 1.5 mL/L Sauerstoff gemessen. Weiterhin hatte sich ein mäßig sauerstoffhaltiger Wasserkörper weit in das östliche Gotlandbecken auf einem Tiefenhorizont von 100 ± 10 m ausgebreitet. Diese schwach sauerstoffhaltige Wasserschicht ermöglichte Nitratkonzentrationen von bis zu 6.6 µmol/L in einem sonst nitratfreien Bereich.

2 Participants

2.1 Principal Investigators

Name	Institution
Kuss, Joachim, Dr. (Marine Chemistry)	IOW
Mohrholz, Volker, Dr. (Hydrography)	IOW
Dutz, Jörg, Dr. (Zooplankton)	IOW
Kremp, Anke, Dr. (Phytoplankton)	IOW

2.2 Cruise Participants

Name	Discipline	Institution
Kuss, Joachim, Dr.	Marine Chemistry, Chief Scientist	IOW
Markfort, Greta	Phys. Oceanography, CTD	IOW
Köhn, Josef	Phys. Oceanography, CTD	IOW
Sadkowiak, Birgit	Marine Chemistry, Nutrients	IOW
Dierken, Madleen	Marine Chemistry, Oxygen	IOW
Renner, Lara	Marine Chemistry, Nutrients support	IOW
Fechtel, Christin	Biol. Oceanogr., Plankt. and Microbiol.	IOW
Sakpal, Harshada	Ökologische Chemie	JKI
Heins, Anneke, Dr.	Microbiology	MPI-MM

2.3 Participating Institutions

IOW	Leibniz Institute for Baltic Sea Research Warnemünde
JKI	Julius-Kühn-Institut
MPI-MM	Max Planck Institute for Marine Microbiology

3 Research Programme

3.1 Description of the Work Area

The working area for IOW's contribution to the HELCOM monitoring comprised German territorial waters with the German Exclusive Economic Zone and bordering sea areas. Therefore, basic hydrographic data, major nutrients, phyto- and zooplankton parameters were determined. Moreover, the Leibniz Institute for Baltic Sea Research Warnemünde (IOW) extends the investigated sites by its long-term observation programme of the Baltic Sea. This contributes with additional stations in the Belt Sea, the Arkona Sea, and the Bornholm Sea, as well as with station work in the eastern and western Gotland Sea. Sampling in the frame of the project for "Identification of UV Filter enrichment areas in the Baltic Sea" and a DAM (Deutsche Allianz Meeresforschung) initiative to establish an archive of eDNA samples was added to the cruise's work programme. Therefore, additional CTD-rosette casts were done to provide water samples for the projects. However, a major focus is always on the Thalweg transect, which reflects the main path of inflowing North Sea water via the Belt Sea, Arkona Sea, Bornholm Sea, along the Słupsk channel to the eastern Gotland Basin and further to the northern and western Gotland Sea, bringing

episodically haline oxygen rich water to the central basins. An overview of the location of CTD stations is shown in Fig. 3.1. In addition, the list of stations is given in Chapter 6.

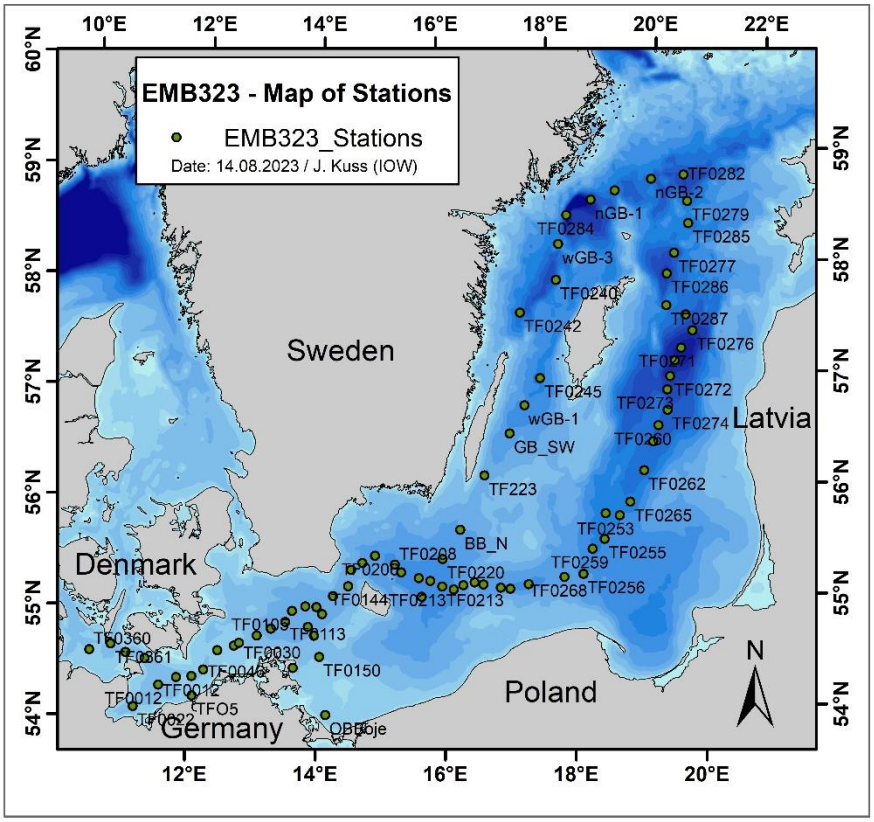

Fig. 3.1 Map of stations (green dots) of the cruise EMB323 from 4th August – 16th August 2023; for clarity, a couple of station names are not shown; for the details of the sampled stations the reader is referred to the list of stations in Chapter 6.

3.2 Aims of the Cruise

The cruise EMB323 was carried out as a joined cruise of the environmental monitoring programme of the Federal Maritime and Hydrographic Agency (BSH) and the Baltic Sea long-term observation programme of the IOW. It was the fourth cruise in 2023 as one of five expeditions performed annually. The acquired data are used for the regular national and international assessments of the state of the Baltic Sea, and provide the scientific basis for measures to be taken for the protection of the Baltic Sea ecosystem. The hydrographic and hydrochemical conditions as well as the development of phyto- and zooplankton populations are investigated. Microbial habitats, acidification and greenhouse gases were additionally studied in the frames of the long-term observation of the Baltic Sea and by projects. A special focus of the long-term observation is always the occurrence or absence of inflow events that both have major consequences for the state of the Baltic Sea hydrochemistry and the ecosystem. The oxygen entrained by the Major Baltic Inflows that occurred between 2014 and 2016 vanished and euxinic conditions intensified in deep waters. Baroclinic inflows of warm water of summer 2018 caused a record high bottom water temperature in the Gotland Deep in 2019 but did not improve the oxygen situation significantly. But again in August 2023 indication of a small inflow was observed in the largely oxygenated Słupsk Furrow and some oxygenated waters penetrated far into the eastern Gotland Basin at the 100 m depth level.

3.3 Agenda of the Cruise

The work on the stations usually started with a CTD cast and already programmed sampling on standard depth levels and manually released samplings in near-bottom and surface waters. Then other CTD casts were carried out to meet the additional water sample requirements on the respective stations. Net sampling and depth of visibility determinations by means of a Secci disk were done on selected stations. The project UV Filter to investigate their enrichment areas, transport processes and long-term sinks in water and sediment required many additional water samples mainly in the western Baltic Sea. Moreover, surface water was sampled in German territorial and EEZ waters for a DAM initiative that plans to establish an eDNA sample archive and investigates the metabolic pathways of bacteria by a metagenomic and metaproteomic approach. For details see list of stations in Chapter 6.
Measures are taken to conduct responsible marine research to protect species, habitats, threatened and declining features. Our sampling in the Baltic Sea does not cause any noticeable changes in the ecosystem. No intentional sampling of any threatened features of the marine ecosystem takes place. The amount of sampled biota is small and the sampling strategy is designed to answer a number of questions on the same samples. Our working program will not affect any other research conducted concurrently in the same region. No toxic or harmful substances is released into the environment. All chemical waste is collected on-board and brought back to the home laboratory for disposal.

CTD and Sampling
The CTD-system "SBE 911plus" (Seabird-Electronics, USA) was used to measure the variables: Pressure, Temperature (2x SBE 3), Conductivity (2x SBE 4), Oxygen concentration (2x SBE 43), Chlorophyll-a fluorescence (683 nm), Turbidity, Photosynthetic active radiation in water (PAR), and above the sea (SPAR). The Rosette water sampler was equipped with 13 Free Flow bottles of 5 L volume each. The CTD sensors were checked during the cruise by comparison measurements. In detail, for temperature a high precision thermometer SBE RT35 was used. Salinity samples were taken for measurement after the cruise by means of a salinometer. Slope and offset of the oxygen sensors SBE 43 are determined by daily comparison with Winkler titration.

Nutrients
Nitrate, nitrite, phosphate, and silicate were analyzed using standard colorimetric methods by means of an autoanalyser (FlowSys, Alliance-Instruments, Ainring, Germany) and ammonium was determined manually as indophenole blue (Grasshoff *et al.*, 1999) from unfiltered water on-board. Total and total dissolved nitrogen and phosphorous samples as well as particulate and dissolved organic matter samples were prepared and stored deep frozen for digestion and analysis in the IOW nutrients and natural organic matter labs, respectively.

Oxygen and hydrogen sulphide
Oxygen was analyzed by Winkler titration and hydrogen sulphide was determined by spectrophotometry after its conversion to methylene blue (Grasshoff *et al.*, 1999). To continue the oxygen profiles in anoxic waters and for comparison, H_2S concentration was converted to negative oxygen values according to its reduction capacity: $H_2S + 2\ O_2 \rightarrow H_2SO_4$. During CTD casts the

SBE 43 sensors (duplicate installation) recorded oxygen values that are validated by daily Winkler titration from 3 water sampling bottles released according to a specific time-regime, each by triplicate analysis.

Plankton sampling
Plankton sampling was performed by means of a rosette sampler (combined with CTD) as well as with a small phytoplankton net and the zooplankton nets WP2 and Apstein. Samples were taken in a tight follow up of depths levels in order to get representative data from the water column. The traditional method to estimate water transparency/primary production by means of a Secci disk is also applied here. (Responsible scientists: Dr. Anke Kremp, Dr. Jörg Dutz).

Long-term observation of the microbial habitat of the redoxcline
Insights into the redoxcline microbial food web is obtained by well resolved sampling in the range of the redoxcline at Gotland Deep and Landsort Deep stations on each monitoring cruise. Therefore, in the redoxcline as well as 6 depths above and below, respectively, in depth intervals of 2 m, samples were taken by CTD/water sampling bottles and prepared for microbiological analysis (FISH and DNA) and determination of pigments. (Responsible scientist: Prof. Dr. Klaus Jürgens)

Long-term investigations of CH_4, N_2O, CO_2 and the marine carbonate system
Sampling for simultaneous CH_4 and N_2O observation is carried out on 4 stations (TF0113, TF0213, TF0271, TF0286) in the frame of an accompanying project for long term data collection. All samples were taken in septum-sealed 250 mL water bottles and fixed with 200 µL saturated $HgCl_2$-solution to prevent microbiological activity and stored dark. On the same stations and depths also samples were taken for the analyses of carbon dioxide, total inorganic carbon, total alkalinity and pH for their long-term observation. These samples were fixed by the same method and were also stored dark. In case of hydrogen sulphide presence, these samples were fixed with 500 µL saturated $HgCl_2$-solution. (Responsible scientist: Prof. Dr. Gregor Rehder).

Establishment of an eDNA-archive and Metaproteogenomic analyses (DAM project)
For a bio-archive of microorganisms and metazoans in the North and the Baltic Sea, biomass is collected by filtering seawater either through a 0.2 µm or a 0.45 µm filter to obtain respectively bacterial and metazoan DNA (CREATE project). All samples are frozen directly and stored at -20 °C and are available for further processing like DNA extraction and sequencing.

For metaproteogenomic analyses, surface water samples of 60 L were taken by a CTD-Rosette system. Subsequently, the water was filtered through 10 µm, 3 µm and 0.2 µm filters, respectively. Filters were stored at -80 °C. Macro- and microalgae were found on the 10 µm and 3 µm filters and bacteria were harvested on the 0.2 µm filter for metagenomic and metaproteomic analyses and furthermore for the determination of bacterial metabolic activity. (Responsible scientists: Prof. Dr. Matthias Labrenz, IOW, Dr. Alexandra Dürwald, Uni-Greifswald, Dr. Anneke Heins, MPI-Bremen).

Identification of UV Filter enrichment areas in the Baltic Sea - Investigation of transport processes and long-term sinks in water and sediment

The primary objective of this study is to contribute to a better understanding of UV Filter distribution and fate in the marine environment. This project aims to help identify enrichment areas where UV Filters were significantly contaminating, as well as, which transport processes contribute to the introduction of UV Filters into the open Baltic Sea.

Aim for EMB323 monitoring cruise: The sampling strategy focuses on the identification of enrichment areas for homogeneous or heterogeneous distribution of UV Filters across the coastal areas, bays and the open Baltic Sea, and on the transport processes for the occurrence of UV Filters in the Baltic Sea. Given the importance of seasonal variations in concentrations of UV Filters in the Baltic Sea, and the considerable high prominence of UV Filters in the summer, this cruise will aid in providing crucial information. (Responsible Scientists: Harshada Sakpal and Dr. Kathrin Fisch, JKI Berlin, Dr. Marion Kanwischer and Prof. Detlef Schulz-Bull, IOW)

Just a Surface water Monitoring Box (JSMB)

The JSMB system (Krüger and Ruickoldt, 2021) is used for continuous measurements in a pumped sea surface water flow of temperature salinity conductivity, calculated sound velocity, real sound velocity, Chl_a, turbidity and optional many more parameters. The measurement ranges, the accuracy or alternatively the sensitivity of the measurements are as follows: conductivity with a range of 0 to 70 mS/cm, and an accuracy of 0.003 mS/cm, temperature (-3 to 35 °C, 0.002 °C), salinity (2 to 42, 0.005), sound velocity (1375 to 1625 m/s, 0.025 m/s), turbidity (0 to 25 NTU, 0.013 NTU sensitivity), and chlorophyll_a (0 to 50 µg/L, 0.025 µg/L sensitivity). The system was used during transect for recording of these parameters in surface water that was pumped from below the ship's hull. Preliminary data of temperature, salinity, chlorophyll_a and turbidity are shown in Figure 5.2 (Responsible scientists: Robert Mars, Johann Ruickoldt).

4 Narrative of the Cruise

This paragraph is aimed to give an impression of the work on board during the campaign. It is a day by day report that includes the forecasted weather and sea condition as predicted by the Deutscher Wetterdienst (DWD, 2023) for the respective days.

Friday, 04 August 2023: For the Western Baltic Sea, the weather forecast for the first day of the cruise was westerly winds of about 4 bft, first with shower squalls at a sea of 1 meter wave height. It was a day with changing weather at low temperatures of 16-18 °C for August, partly sunny but with isolated showers and gusty winds. We reached the first station TFO5 at 9:10 o'clock. It usually serves as a test of instruments and procedures. The visibility depth was determined by the traditional method by using a Secci disk. The value is also used to optimize the filtration volume for organic matter analysis. Moreover, a CTD cast with water sampling for oxygen determinations, the inorganic nutrients nitrate, nitrite, phosphate, silicate, ammonium, total as well as total dissolved nitrogen and phosphorus, and for natural organic matter analyses was done. As well the sampling for the UV Filter analysis began just at this near-coastal site. The mandatory security exercise was completed, already on the way to next station TF0012. On TF0012, again all nutrient parameters, oxygen, organic matter and biological sampling for

phytoplankton determination were sampled by CTD-rosette for analysis. Also the first net catches were carried out with the small net and the larger WP2 by the small crane. An additional CTD provided 60 L water for the DAM project. The measurements were partly done on-board, other samples were filtrated and stored deep frozen or otherwise conserved for analyses in the IOW laboratories. Then TF0022 in the Lübeck Bight was completed by a CTD cast with a bottom water oxygen measurement and sampling for UV Filter analysis, then TF0010 and TF0014 in the Fehmarn Belt followed late in the evening.

Saturday, 05 August 2023: The forecast reads, wind from west to southwest 3 to 4 bft, for a time light and variable winds, backing east to northeast, later locally misty at a sea of 0.5 meter wave height. At midnight we started on TF0360 already in the Kiel Bight with a CTD cast, water sampling and net hauls. On TF0361 early in the morning, after the standard CTD cast the intercomparison measurements for oxygen, salinity, temperature, and pressure were done to secure the correctness and stability of the sensors, or in case, to adjust the sensor reading after the cruise. The next stations were TF0017, TF0041, the TF0046 with the extended chemical parameter set, Secci depth determination and net hauls. The Darss Sill stations TF0002, TF0001 and TF0030 were carried out in sunny weather with calm winds and 18-20 °C. Again the whole set of water sampling bottles were closed in surface water on station TF0030 to get a 60 L sample for the DAM project. The TF0115 and TF0114 in the afternoon each required a CTD cast only, then we reached the main station of the Arkona Sea TF0113 with 2 CTD casts, Secci depth and net hauls. CTD casts on the TF0105 and TF0104 followed later in the evening.

Sunday, 06 August 2023: The weather was expected to become bad with northerly winds of about 4 bft that were expected to increase to about 6 bft, later to about 5-8 bft at variable directions with near hurricane force gusts. At times heavy rain and thundery gusts were forecasted at a sea of increasing wave height to above 3 meter. The day began calm with a grey and misty morning and a flat sea at low wind speed and 17 °C. We fulfilled the TF0109 after midnight. Then TF0145 and TF0103 followed with CTD casts, and on the latter, a second intercomparison measurement for the sensor readings was done. The stations ABBOJE, TF0112 and TF0150 were completed in the morning. Then we headed straight to the harbour of Sassnitz for personnel exchange and to occupy a save place for the forecasted weather.

Monday, 07 August 2023: The weather forecast didn't promise any improvements, wind from northwest about 7, increasing a little, shifting west, locally near hurricane force gusts, at times misty, sea 2 meter. Still in the harbour, daily work on the ship turned more and more from lab work and cruise planning to home office work of data analysis and report writing.

Tuesday, 08 August 2023: The weather forecast was still bad with wind from west to southwest of 7 to 8 bft, decreasing 6, near hurricane force shower squalls, locally thunderstorms, at a sea of 3 meter wave height. Some improvements were expected for Wednesday that give hope to be able to continue the station programme on the next day.

Wednesday, 09 August 2023: The forecast read, wind from southwest to west of 6 bft, decreasing to 4-5 bft with shower squalls and isolated thunderstorms at a sea of 1.5 meter wave height. So this gave a good start for the coming day. The weather improved in terms of wind speed and was expected to get adequate to continue the station work. At 11:00 o'clock in the morning we left Sassnitz harbour after 3 days of weathering. At a cloudy sky and an air temperature of 12 °C we headed south in direction of the Odra buoy station. Since OBBoje is located close to the Odra Lagoon, a half day was basically occupied by the land-protected transit. The station was

completed by a CTD cast for Oxygen determination in the sensor depth of the buoy and sampling for UV Filter analysis. We left the station at 15:00 o'clock at a cloud covered sky with a light rain and 15 °C air temperature. We then fulfilled four repetition stations in the central Arkona Sea for a comparison with the time before the storm. We recorded a CTD profile and a surface and bottom water oxygen determination on each station. Thereby, from TF0112, to TF0105 we moved against the waves of a still rough sea of 1.5 m wave height. Later in the evening the white caps on the waves disappeared and the sea calmed down. Then TF0104 followed and TF0109 was scheduled after midnight.

Thursday, 10 August 2023: The forecast of the day was wind from west to southwest of about 5 bft, decreasing slowly to 3-4 bft with local shower squalls, at a sea 1.5 meter wave height. The morning was again cold with 12 °C in mid-summer but the wind was of force 4, comfortable compared to the days before. After completion of TF0109, we continued with the Thalweg transect by a CTD-cast on station TF0144 with an additional intercomparison measurements for oxygen, salinity, temperature, and pressure. Then we reached the Bornholmsgatt and fulfilled the TF0142 and subsequently the TF0140. Then several stations with a CTD cast on each followed, TF0206, TF0208, and on TF0200. On the latter, a complete profile of inorganic nutrients and a bottom as well as a surface water oxygen determination was done. Then the stations TF0211, TF0214 and TF0212 were completed by respective CTD casts. In the afternoon we reached the Bornholm Deep station TF0213 which was intensely studied with 2 CTD casts and 8 zooplankton net hauls with the large net, and 3 with the smaller Apstein net and a few plankton catches with the small net. Once, the falling weight to release the closure mechanism of the WP2 got stuck, but this was fixed by the boatman. A crack in the net could be quickly repaired with the net repair kit by the responsible technician. Overall, four hours of station time were needed. The stations TF0221, TF0225 followed afterwards with CTD casts and bottom water oxygen/hydrogen sulphide determinations.

Friday, 11 August 2023: The weather forecast of the south-eastern Baltic Sea for the day read, wind from southwest of about 4 bft, abating, locally misty, at a sea of first 1 meter wave height. We had a cloudy sky with sunny passages in the morning. Even the air temperature of 16 °C was a bit higher, indicating that the summer was back in the Baltic. TF0224 was right around midnight, then early in the morning TF0227, TF0229 and TF0222 with sampling for inorganic nutrients including ammonium, and oxygen/hydrogen sulphide determinations in deep and bottom waters followed, and TF0266 was completed afterwards. On TF0268 and TF0256 we carried out CTD casts without water sampling. The next station TF0259 at 11:00 o'clock was then done by sampling for inorganic nutrient determinations including ammonium and a bottom water oxygen/hydrogen sulphide profile. Then the Thalweg was continued by CTD casts on TF0255, TF0252, TF0253, TF0265, TF0262 and TF0261. Late in the evening, on TF0260 the sampling programme of TF0259 was repeated.

Saturday, 12 August 2023: In the central Baltic Sea southerly winds of 3 to 4 bft were expected to increase a little with some fog patches later in the day, at a sea of 1 meter wave height. In the night and early in the morning, the stations TF0274, TF0273, TF0272 and TF0275 were completed by a respective CTD cast. The important international station Gotland Deep (BY15, TF0271) was scheduled after breakfast with 6 CTD casts for hydrographic, chemical, and biological parameters. Also samples were taken for analyses of greenhouse gases and the carbonate system of seawater. The sampling is carried out in four CTDs of different depths intervals. By double and triple water

sampler releases in all respective depths it is secured that each parameter is sampled at the same time and enough water is available. A blue sky with some clouds and calm winds of 3 bft at 15.4 °C air temperature provided nice general conditions during the morning hours. Finally, a CTD for biological surface water measurements and UV-Filter samples as well as one CTD cast dedicated to the microbiology of the redoxcline were done. Parallel three net hauls with the small net were carried out. Further activities around noon and during the afternoon were done on stations TF0276, TF0270, and further North on TF0276, as well as on TF0287 by one CTD cast on each stations just with CTD sensor measurements. The next main station was reached at 18:30 o'clock. The Fårö Deep station (TF0286) required two CTD casts accounting for the whole bunch of chemical parameters and was the last station for sampling of trace gases carbon dioxide, methane and dinitrogen oxide. The final stations of the day were TF0277 and TF0285 with a respective CTD cast.

Sunday, 13 August 2023: The weather forecasted for the day was wind from southeast of about 4 bft, shifting southwest to west while decreasing to 3 bft. For the northern part, light and later variable winds were expected, locally with shower squalls at a sea of 1 meter wave height. Early morning the stations TF0279, TF0282 and nGB-2 were completed, each by a CTD cast at a cloud covered sky, 16.6 °C air temperature and an elevated wind speed of up to 6-7 bft right before breakfast. The TF0283 and nGB-1 followed before we reached the deepest site of the Baltic Sea in the afternoon - Landsort Deep station TF0284 with a depth of 459 m. All nutrient parameters oxygen/hydrogen sulphide, dissolved and particulate organic matter were sampled for on-board analyses or were stored deep frozen for analyses in the IOW laboratories. Because of many investigated depth layers, sampling was distributed on three CTD casts for the deeper, the medium and the upper water column, respectively, similarly as for the Gotland Deep. A fourth one was solely dedicated to the redoxcline and the range above and below in 2 m depth steps. Therefore, all 13 water sampling bottles were used. Also the Secci depth was determined. Then we continued the route further south to wGB-3. The wind calmed down after lunch. In the late afternoon at a bright blue sky we did the CTD cast on wGB-3. Later in the evening TF0240 and right before midnight TF0242 followed.

Monday, 14 August 2023: The weather forecast for the Central Baltic was wind from southwest of 3 bft, shifting southeast, in some areas for a time light and variable winds, first coastal fog patches, at a sea of 0.5 meter wave height. At 4:30 o'clock we started the station TF0245 Karlsö Deep and completed the station after half an hour at a partly cloudy sky at mild 16.4 °C air temperature and light wind. The next stations were wGB-1, GB-SW and TF223 with a CTD cast in less than 20 min on each. Later in the morning, we entered cold waters of about 10 °C that caused a humid cold air with mist near the Island of Oland. The sky was covered by clouds in the afternoon. Then we left the Gotland Sea and moved to BB_N and TF0220 in the Bornholm Sea, finishing the regular station work. For dinner a joint barbeque of the crew and the scientific party was carried out in the sunny, but a bit cold evening. Later in the evening the first biological repetition station TF0213 was fulfilled by first a CTD cast with water sampling for nutrient and chlorophyll analyses and afterwards 6 net hauls with WP2 and 3 with the small Apstein net for plankton investigation.

Tuesday, 15 August 2023: After the long transect of 90 nm overnight, we were back in the Arkona Sea and the weather was forecasted to be good with wind from south of 3 to 4 bft that were expected to shift west to northwest, however with thundery gusts at a sea of 0.5 meter wave height.

The day started with blue sky and few clouds only, at 18 °C. However, the wind partly increased to 6 bft. About 8:45 o'clock a man over board procedure was done because a life belt was observed on the ships track. The background of the lost rescue item is unknown. After breakfast the repetition stations TF0113 and TF0030 in the Arkona Sea at flat sea with fog and light rain. Behind Darss Sill in the Cadet furrow TF0046 and subsequently in the Mecklenburg Bight the final station TF0012 was fulfilled until the evening. Later an emergency call reached us that a diver got lost and r/v Elisabeth Mann Borgese was asked to support the search. We went closer to the area near Heiligendamm but finally the diver was found and the emergency status was cancelled.

Wednesday, 16 August 2023: Early in the morning, another emergency call reached us that required help in a case of fire on a ferry ship in the Lübeck Bight. Despite the immediate reaction and a maximum ship speed, we didn't reach the location before the emergency was cancelled. Finally, we continued our transfer to Rostock harbour and docked at the pier of Rostock-Marienehe at about 8:15 o'clock in the morning, a quarter of an hour later than scheduled. After the customs clearance, all the lab equipment either packed in a small container or in pallet cages was heaved from board by the ship's large crane and loaded on the institute's lorry. As well, the fixed and frozen samples and the valuable data were taken from board and taken to the institute.

5 Preliminary Results

The results presented in the following sections are preliminary and many samples taken are to be analysed and interpreted during the next weeks and months. The aim of this section is to give a first impression of the actual state of the western and central Baltic Sea in August 2023. An advanced data analysis will follow when the validated data set is available.

5.1 Meteorological Conditions

In the beginning of the cruise (4^{th}-6^{th} August) the weather situation was characterized by a trough over northern and central Europe that was flanked by higher air pressure over the eastern North Atlantic and western Russia (Deutscher Wetterdienst, 2023). Individual disturbances moved along a frontal zone that established from north-western France across northern France and southern Central Europe. In a westerly cyclonic setting from 7^{th} to 9^{th} August, individual disturbances with embedded highs or wedges of high pressure moved in a normal frontal zone from the sea area west of Ireland across Great Britain, the North Sea and the Baltic Sea to Eastern Europe. From 11^{th} to 13^{th} a south-westerly anticyclonic weather situation formed between an area of high pressure over southern Europe and western Russia and a depression over the central North Atlantic and the Arctic Ocean. A frontal zone extended from the southwest to the northeast, from a sea area west of Ireland to the Baltic region. From 14^{th} to 16^{th} a trough over Western Europe with low pressure on the ground and at higher altitude extended from the Norwegian Sea along the western European coast to the Iberian Peninsula, flanked by high pressure over the mid North Atlantic and Western Russia.

During the first two days, the weather was characterized by a moderate to fresh breeze that well allowed to fulfil the station work in the western Baltic Sea. On 6^{th} August a storm low over the southern Baltic Sea of 988 hPa deepened and moved along the Swedish coast. Later another core of 982 hPa developed over the Oslofjord that led to wind from northwest of about 7 bft that subsequently increased with locally near hurricane force gusts (Deutscher Wetterdienst (DWD),

2023). On Wednesday 9th August after three days in Sassnitz harbour, we continued the station work at the land protected Oder buoy, then four repetition stations for a comparison to prior storm hydrography, and then the Thalweg followed. The next days we had fair weather with cloudy times and partly blue sky and weak to moderate winds. Air temperature was relatively low for August, mostly about 16 °C but temporary well above 20 °C. The development of the on-board measured wind speed, the air temperature and the surface water temperature (upper panel) as well as the wind direction and humidity (lower panel) during the cruise are shown in Fig. 5.1.

Closely related to the weather conditions are the surface water parameters. Continuous recording of chlorophyll and turbidity (Fig. 5.2, upper panel) as well as of temperature and salinity on pumped seawater from below the ship during transect is shown (Fig. 5.2, lower panel) with the depth profile for orientation. The three days of storm changed many parameters from prior to after the storm significantly. Water temperature was about 19 °C before and 16 °C afterwards, thereby also the low temperature of 10-11 °C in the western Gotland Sea near Oland contributed to the autumn-like situation. As well the air temperature dropped from 17.3 ± 1 °C in the first 3 days changed to 16.3 ± 2 °C

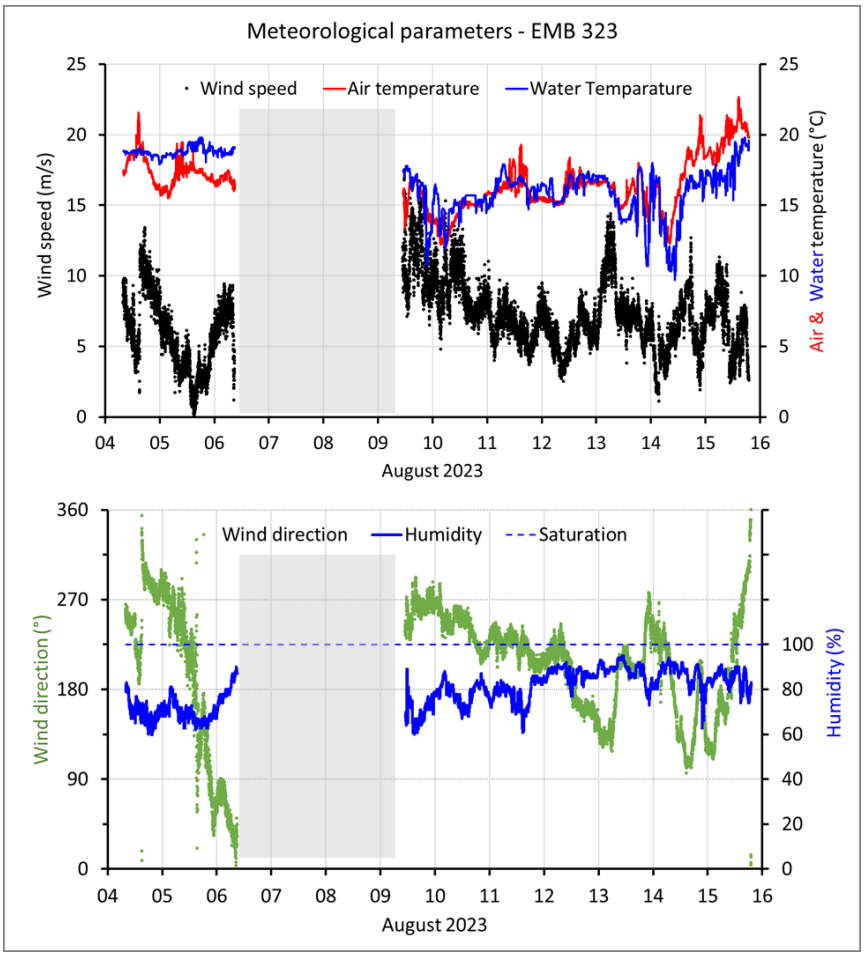

Fig. 5.1 Surface water temperature (JSMB-thermosalinograph), air temperature, and wind speed (upper panel) as well as humidity and wind direction (lower panel) measured on-board by the automatic weather station of the DWD; the time period of the stay in Sassnitz is shaded grey.

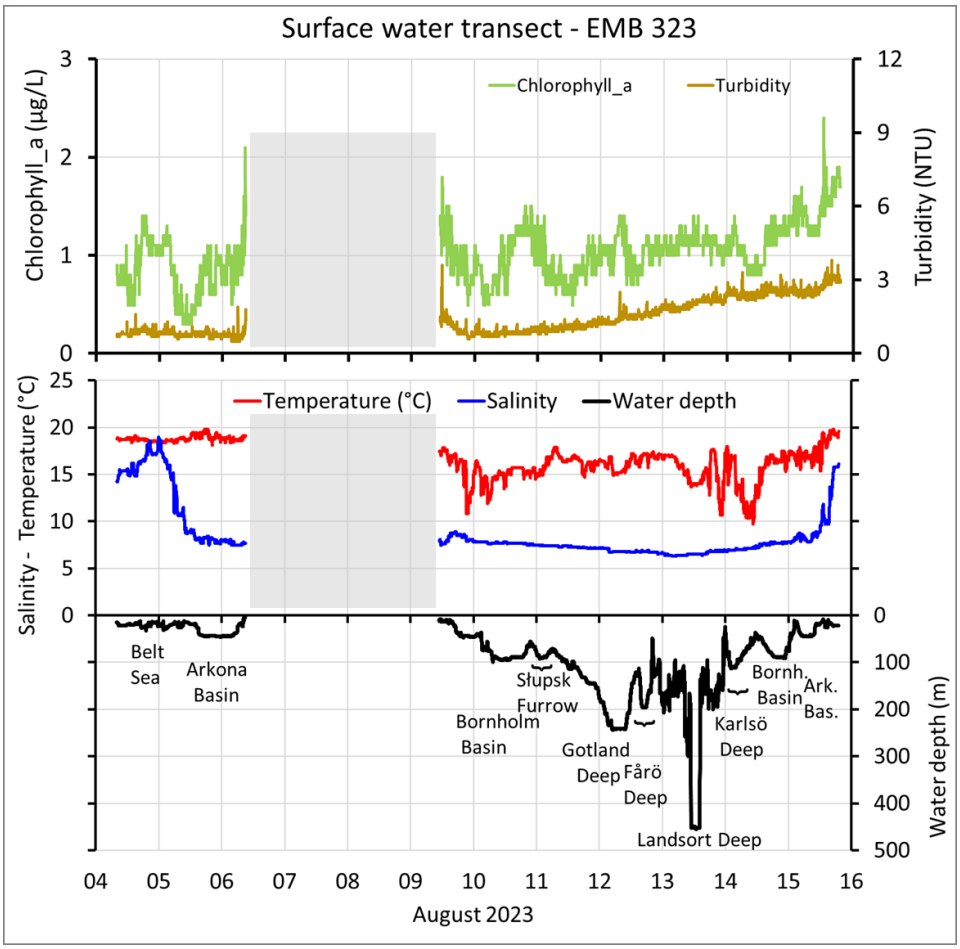

Fig. 5.2 Recording of chlorophyll and turbidity data (upper panel, drift corrected), compared to temperature and salinity in surface waters with the corresponding water depth and sea area during the cruise EMB323 of r/v *Elisabeth Mann Borgese* from August 4th to August 16th; the time period of the stay in Sassnitz is shaded grey.

5.2 Baltic Thalweg Transect

For an overview of the hydrographic and the hydrochemical state of the Baltic Proper during the cruise EMB323, data of the CTD casts along the Thalweg from the Kiel Bight to the eastern, via the northern to the western Gotland Sea were combined to contour plots of salinity, temperature and oxygen for August 2023 (Fig. 5.3, with a small map of the selected stations in the lowest panel).

The average mixed layer temperature of about 18.8 °C in the western Baltic Sea prior to the storm, and 16.5°C in the Baltic Proper after the storm with locally lower temperatures of 14 °C down to 10 °C in the transition area between the Bornholm Sea and the western Gotland Sea. This region is frequently affected by coastal upwelling off the Swedish coast, bringing up cold intermediate water. As well the thickness of mixed layer varied strongly between 5 down to about 40 m depth in the southern Eastern Gotland Sea that is clearly visible by the red shading in Fig. 5.3 (upper panel). In other regions, the thermocline is partly steep and reaches temperature below 5 °C already in the range between 25 and 30 m depth. The layer of cold winter water (blue ribbon) shows a thickness of about 50 m in the Gotland Basin, but is less pronounced and thinner in the

transition between the Bornholm Sea and the southern Gotland Sea. The deep water in the central basins is warmer at a temperature of 6-8 °C.

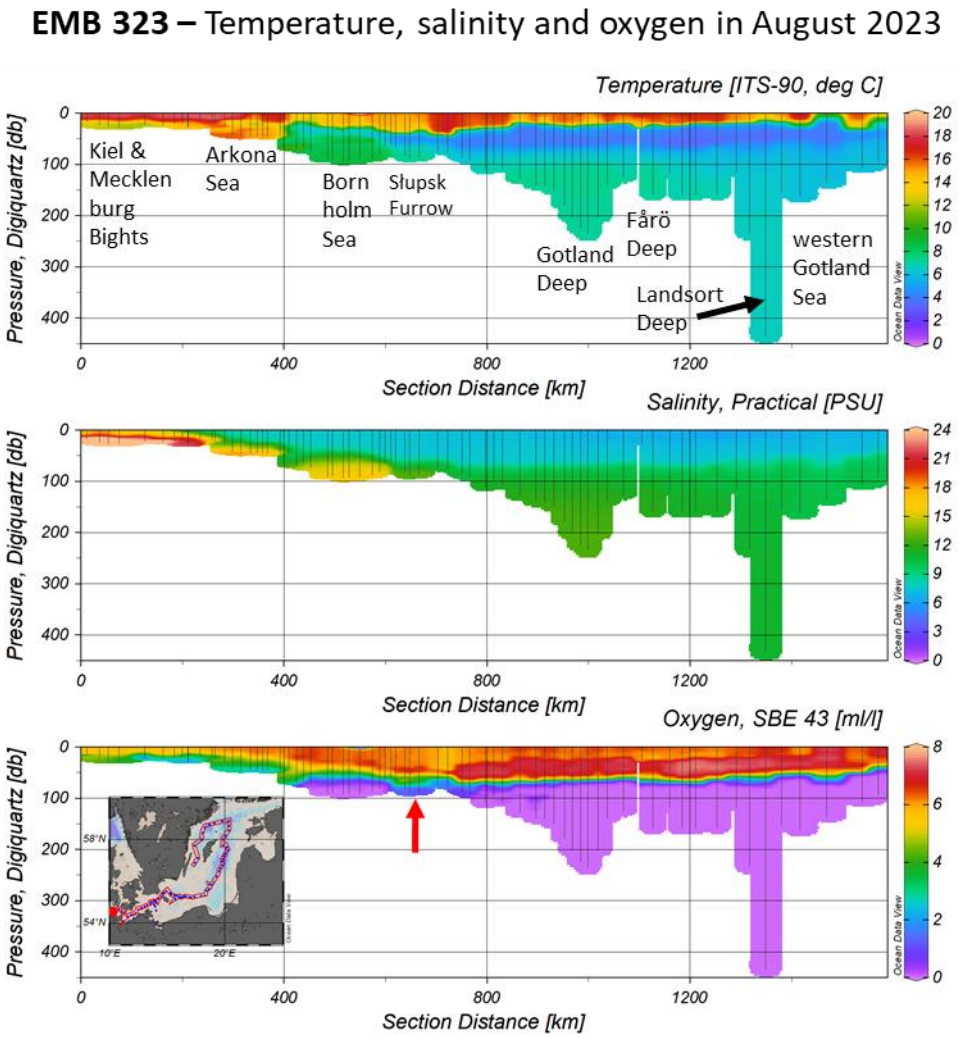

Fig. 5.3 Temperature, salinity and oxygen (without H_2S) along the Thalweg of the Baltic Sea from the Kiel Bight via the eastern and northern to the western Gotland Sea (4 Aug – 14 Aug 2023). The elevated oxygen concentration in the bottom water of Słupsk Furrow is indicated by a red arrow. The figure is based on the preliminary data of the CTD casts (vertical grey lines) by using ODV 5 (Schlitzer, 2018).

The low salinity of 6-8 in upper waters extends down to 70 m in the central basins (light blue, Fig. 5.3, middle panel) that is primarily influenced by freshwater supply from the large drainage area of the Baltic sea. The strong halocline below marks the winter mixing depths and is a permanent feature in the central basins. A high salinity of partly around 22 (red) was measured in in bottom waters of the Kiel Bight and Mecklenburg Bight in August 2023. In Baltic Sea deep waters at greater depths than 120 m, the salinity ranged between 11 and 13.

The oxygen concentration distribution in upper waters was about 6-8 mL/L (reddish, Fig. 5.3, middle panel). It is mainly determined by its lower solubility at still elevated surface water temperature in August 2023 in contact with the atmosphere. In the halocline the supply of oxygen decreased and oxygen consumption processes dominated. Striking was again the oxygen situation

in the Słupsk furrow, between the Bornholm Basin and the eastern Gotland Basin, where bottom water showed oxygen concentration of about 1.5 mL/L (marked by a red arrow, Figure 5.3, lower panel). Moreover, a plume of slightly oxygenated water ~ 0.5 mL/L reached far into the eastern Gotland Basin along the 100 ± 10 m depth horizon (slightly darker shading), in the area from station TF0252 to TF0260. Further North and West, oxygen was depleted to an undetectable concentration below 90 m in the eastern and below 70 m in the western Gotland Basin, respectively.

5.3 Development of Baltic Sea Water Masses – Comparison to Previous Cruises

5.3.1 Surface Water Temperature

The surface water temperature during the cruise EMB323 along the transect was already shown (Fig. 5.2). Here we compare the values determined at selected Baltic Sea monitoring stations to the temperatures of the last summers from 2018 to 2022 and to the long-term mean values 1971-1990 measured during the respective July/August cruises in the 1970ies and 1980ies (Table 5.1). Surface water temperatures in August 2023 show exceptional low. This is mainly caused by the cold and windy second half of July 2023 and intensified during the strong wind period 6.-8. August that led to deeper mixing and upwelling of colder waters. The temperatures were partly even below the long-term averages, as for the Bornholm Deep surface water (15.8 °C/17.6 °C), Gotland Deep (14.9 °C/17.1 °C) and Landsort Deep (13.6 °C/18.2 °C). For the other stations the temperature was closer to the long-term averages compared to measurements during the last summers. So surface water temperatures clearly depended on the respective weather situation at the respective sites during the couple of weeks before monitoring campaign and the unprecedented stormy days during the beginning of the campaign. A potential warming trend over decades is thus not supported by surface water measurements in August 2023.

Table 5.1 Surface water temperature (°C) of Baltic Sea areas of this cruise (Aug 23) compared to the last five years and to a former long-term average (rightmost column).

Temperature (°C)	Aug 18	Aug 19	Jul 20	Jul 21	Aug 22	**Aug 23**	1971-1990
Mecklenb. Bight (TF0012)	22.5	18.9	17.1	19.7	20.6	**18.7 ***	17.7
Arkona Basin (TF0113)	21.7	19.9	16.0	20.0	18.6	**18.0 ***	17.0
Bornholm Deep (TF0213)	22.0	18.9	16.0	20.9	18.5	**15.8 ***	17.6
Gotland Deep (TF0271)	23.0	17.8	19.1	21.8	19.8	**14.9**	17.1
Fårö Deep (TF0286)	23.1	16.9	16.9	21.4	19.9	**16.8**	17.0
Landsort Deep (TF0284)	23.1	18.5	16.1	20.8	18.7	**13.6**	18.2
Karlsö Deep (TF0245)	24.5	18.6	16.3	21.6	19.5	**16.3**	16.9

* Averages of measurements prior and after the storm.

5.3.2 Deep Water Salinity and Temperature

The salinity of the bottom water layer measured in August 2023 is shown in comparison to data from the cruises in August 2018 to July 2022 (Table 5.2). It is documented that the salinity was still decreasing since August 2018 in the Gotland Deep and Fårö Deep, whereas in the Landsort

and Karlsö Deeps, the salinity had slightly increased since last summer. However, an overall decreasing trend since 2018 with some variability is also documented for the deeps of the western Gotland Basin. The salinity of the Gotland Deep bottom water decreased significantly from August 2019 to August 2023 by 0.51. Thereby, the change in salinity seemed to have slowed down a bit. Lower salinity close to the bottom improves the chance of inflowing water to reach the bottom water layer. But with regard to the already strong oxygen deficit, the salinity of 12.77 appears still high in August 2023 in comparison to pre-inflow time in August 2014 when the salinity was 12.25 (Kuss, 2019).

Table 5.2 Bottom water salinity of Baltic Sea deeps of this cruise (Aug 23) compared to the last 5 years.

Salinity	Aug 18	Aug 19	Jul 20	Jul 21	Aug 22	**Aug 23**
Gotland Deep	13.27	13.28	13.13	13.00	12.87	**12.77**
Fårö Deep	12.75	12.63	12.55	12.42	12.13	**12.07**
Landsort Deep	11.46	11.38	11.53	11.23	10.92 *	**11.02**
Karlsö Deep	10.70	10.45	10.59	10.52	10.26	**10.33**

* Value measured on 284a in 359 m depth

The temperatures of the bottom water of the Bornholm Deep were about 0.7 °C higher than in August 2022 that is above the relative high value of August 2019. Gotland Deep bottom water showed 7.22 °C in August 2023, almost the same summer value since July 2020. Also the temperature in the Fårö Deep bottom water appeared relatively stable 7.24±0.05 °C. Landsort and Karlsö Deeps bottom waters were 0.17 °C warmer and 0.04 °C colder, respectively, compared to last summer (Table 5.3). The data of bottom water temperatures of August 2023 confirm the finding that temperatures in recent years are clearly above the long-term averages of 1971-1990. In August 2023 the differences ranged between 1.6 (Gotland Deep) and 2.6 °C (Bornholm Deep), with an average of about 2 °C higher temperatures in bottom waters compared to 1971-1990.

Table 5.3 Bottom water temperature (°C) of Baltic Sea deeps of this cruise (Aug 23) compared to the last 5 years and to a former long-term average.

Temperature (°C)	Aug 18	Aug 19	Jul 20	Jul 21	Aug 22	**Aug 23**	1971-1990
Bornholm Deep	6.97	8.54	8.31	8.42	8.08	**8.74 ****	6.12
Gotland Deep	6.9	7.37	7.22	7.21	7.22	**7.22**	5.62
Fårö Deep	6.76	7.19	7.30	7.23	7.20	**7.27**	5.20
Landsort Deep	6.28	6.50	6.89	6.66	6.55 *	**6.72**	4.76
Karlsö Deep	5.83	5.68	5.97	6.17	6.05	**6.09**	4.18

* Value measured on 284a in 359 m depth; ** Averages of measurements prior and after the storm.

5.3.3 Oxygen

The oxygen concentration in the bottom water of the eastern Gotland Basin worsened since August 2018, despite intermediate slight improvements. The western basin only showed a relatively weak hydrogen sulphide increase, subjected to a strong interannual variability of the negative oxygen

equivalents with a standard deviation ±0.7 mL/L at Landsort Deep and ±0.5 mL/L at the Karlsö Deep site. The respective concentration equivalents were for the Gotland Deep of -9.4 mL/L in August 2023, the Fårö Deep of -5.4 mL/L, the Landsort Deep of -2.1 mL/L, and the Karlsö Deep to -2.8 mL/L. This reflects a striking oxygen deficits for the Gotland Deep, reaching almost -10.0 mL/L oxygen. However, these unprecedented high values are under scrutiny and require confirmation.

Table 5.4 Bottom water oxygen concentration (mL/L) of Baltic Sea deeps during this cruise (Aug-23) compared to the summer values of the last five years.

Oxygen (mL/L)	Aug 18	Aug 19	Jul 20	Jul 21	Aug 22	**Aug 23**
Gotland Deep	-4.29	-6.15	-7.88	-7.17	-9.72	**-9.42**
Fårö Deep	-3.52	-4.68	-4.17	-4.91	-5.55	**-5.37**
Landsort Deep	-0.82	-2.08	-1.74	-1.60	-2.87*	**-2.06**
Karlsö Deep	-3.10	-2.93	-3.48	-2.43	-3.80	**-2.79**

* Value measured on 284a in 359 m depth; d.l.: O_2 detection limit

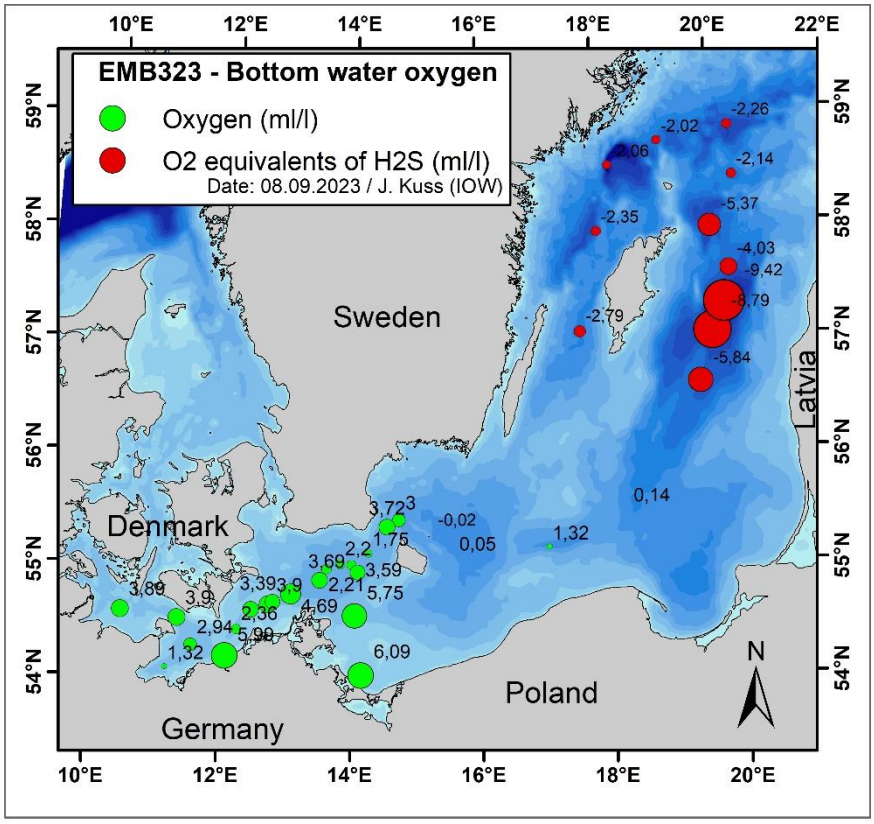

Fig. 5.4 Oxygen (green in mL/L) and hydrogen sulphide concentrations (as negative oxygen equivalents, red) in bottom waters of selected Baltic Sea stations.

The oxygen concentration in bottom waters of the western Baltic Sea (Kiel Bight to the Arkona Basin with Odra Bight) was on average 3.6 mL/L (n=21) for the selected station (Fig. 5.4 map). However, two stations showed bottom water oxygen concentrations below 2 mL/L, Lübeck Bight 1.32 mL/L and in the north-eastern Arkona Sea 1.75 mL/L oxygen. The situation was really good for an August month that was mostly investigated prior to the strong wind period that happened

after August 6th. The reason is likely coupled to the relative cold and windy second half of July 2023 that partly weakened the summer thermocline and enabled oxygen transport to deeper water.

In August 2023, the deep parts of the Bornholm Basin were characterized by anoxic or weak oxic conditions with close to 0.0 mL/L oxygen. Further east on station TF0222 in the Slupsk Furrow an oxygenated situation was found with 1.32 mL/L oxygen in bottom water. The weak oxygen supply in the southern part of the eastern Gotland Basin was already shown in Fig. 5.3. On station TF0259 this was confirmed by Winkler titration as a weak oxygen signal of 0.14 mL/L in bottom waters (Fig. 5.4). However, the deep Gotland Sea showed a strong oxygen deficit, as mentioned before, especially in the eastern basin hydrogen sulphide accumulated up to a negative oxygen equivalent of almost -10 mL/L. However, these unprecedented high values are under scrutiny and require confirmation. Whereas the sampled stations in the western basin were between -2.0 to -2.8 mL/L (Fig. 5.4).

In this context, it was interesting to also investigate the turbidity zones in intermediate and deeper waters in comparison to low oxygen waters, as it was observed that turbidity often marks the mixing or diffusion zones between sulphidic and oxygenated waters (Fig. 5.5, lower panel).

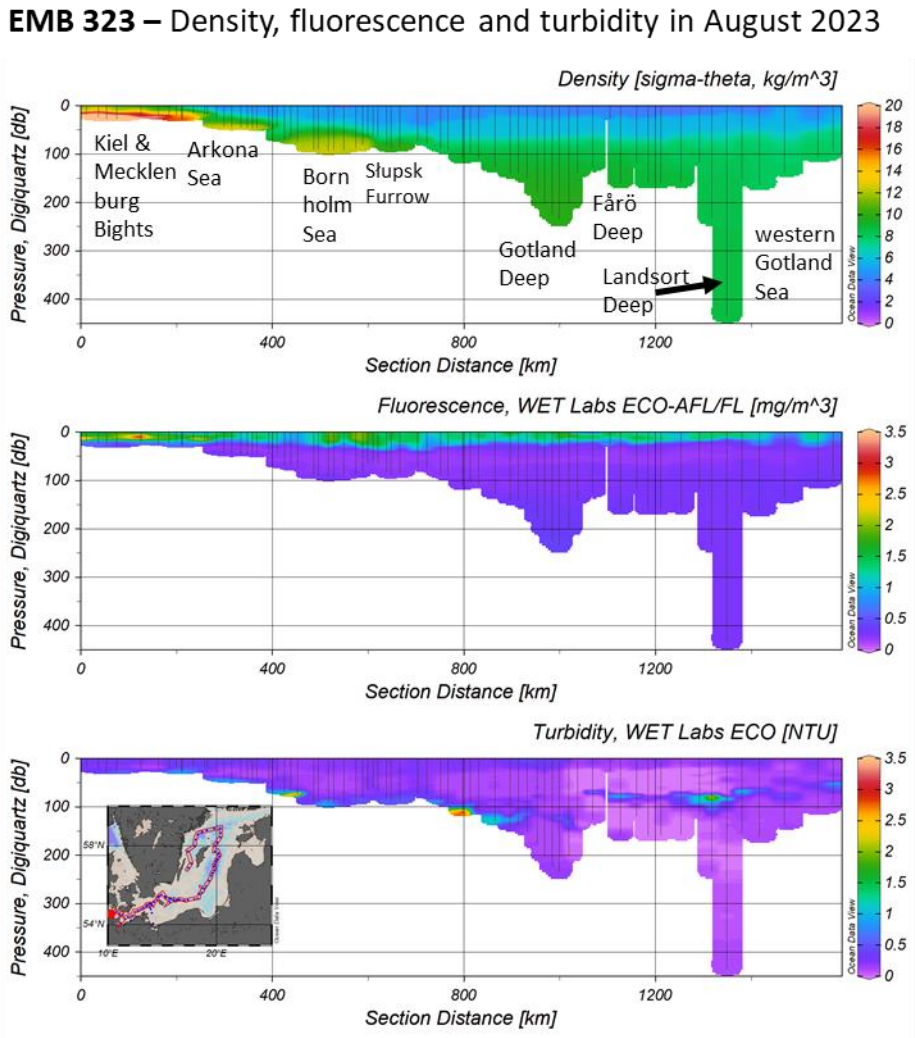

Fig. 5.5 Sensor measurements of density, fluorescence and turbidity along the Thalweg transect (see Fig. 5.3). The figure is based on the preliminary data of the CTD casts (vertical grey lines) by using ODV 5 (Schlitzer, 2018).

Partly this is caused by precipitation of fine particles of elemental sulphur (Kamyshny *et al.*, 2013) and likely manganese(IV) and iron(III) oxyhydroxides and phosphates play a role too (Dellwig *et al.*, 2010). The density distribution (Fig. 5.5, upper panel) is basically determined by salinity (Fig. 5.3, middle panel), but also the warm mixed layer can be distinguished by its lower density. Interestingly, along the permanent halocline, the turbidity maxima can be seen that likely indicate former supply of oxygenated water in the range of the halocline in the northern and western Gotland Sea (Fig. 5.5, lower panel). But also in deeper waters of the eastern Gotland Basin in a depth range of 120-130 m, indication of former inflows of oxygenated waters can be assumed. The chlorophyll_a fluorescence in upper waters is well visible but reflects relative low values for a mid-summer situation in August 2023, except some elevated concentrations in the Lübeck Bight and the Bornholm Sea in Fig. 5.5 (middle panel). The strong winds before and during the cruise might have spread the microalgae and cyanobacteria over a deeper mixed layer

5.3.4 Nutrients

In August 2023 the inorganic nitrogen was depleted in the upper 10 meters of the water column except in the eastern Gotland Sea, where nitrate was measured on average with 0.4 µmol/L. Phosphate was available at an average concentration of 0.04 µmol/L, 0.02 µmol/L in the Arkona Sea surface water and at an average of 0.19 µmol/L in the upper 10 m of the Bornholm Sea. Both elevated concentrations might be linked to the stormy beginning of August that caused deeper mixing and local upwelling, right before these measurements were done. However, in the deep central basins, nitrate was depleted in deep waters below about 80 m in accordance with the depletion of oxygen. An exception was indeed the Slupsk furrow in the area of station TF0222 and the southern part of the eastern Gotland Basin (TF0259, TF0260), where oxygen was determined until a depth of 100 m and nitrate was measured at elevated concentration, partly up to a concentration of about 7 µmol/L. As well the oxygen imprint on station TF0259 enabled a nitrate concentration of 6.6 µmol/L in 80 m and still 1.9 µmol/L in 88 m depth. But even at higher latitude on TF0260 4.3 µmol/L nitrate was determined at 100 m depth at an oxygen concentration of ~0.5 mL/L (sensor measurement).

The weak oxygen supply does not significantly improve the ongoing stagnation phase in deep waters of the Gotland Sea since 2017 characterized by the accumulation of hydrogen sulphide and phosphate in deep waters and the depletion of nitrate (Table 5.5). Anoxic condition lead to a total consumption of nitrate as remaining nitrate is used for oxidation, and remineralisation of organic nitrogen does not go beyond ammonium, and thus remineralization does not deliver nitrate anymore. So nitrate was not detectable in August 2023 in the bottom waters of the Gotland, Fårö, Landsort, and Karlsö Deeps like in previous years. Thereby, the phosphate concentration showed some variability with an increasing tendency in the Gotland Deep and Fårö Deep bottom waters and relative stable concentrations of about 4 µmol/L in the Landsort and the Karlsö Deeps in recent years. Whereas, the Bornholm Sea is subjected to frequent episodic inflows of oxygenated waters that also replaced the bottom water and changed nutrient concentrations strongly. So nitrate concentrations varied during the summer cruises of recent years between the detection limit and up to 7.2 µmol/L (July 2020). The observation was similar for the phosphate concentration that scattered from 2.6 to 11.7 µmol/L in bottom waters. In August 2023 nitrate was not detectable and

phosphate showed a moderate concentration of 4.5 µmol/L in the bottom water of the Bornholm Deep, indicating the changing oxic/anoxic conditions (Table 5.5).

Table 5.5 Bottom water Nitrate (upper part) and phosphate (lower part) concentrations (µM) of Baltic Sea deeps of this cruise (Aug-19) compared to the last 5 years.

Nitrate (µM)	Aug 18	Aug 19	Jul 20	Jul 21	**Aug 22**	**Aug 23**
Bornholm Deep	< d.l.	2.3	7.2	< d.l.	**0.4**	**< d.l.**
Gotland Deep	< d.l.	< d.l.	< d.l.	< d.l.	**< d.l.**	**< d.l.**
Fårö Deep	< d.l.	< d.l.	< d.l.	< d.l.	**< d.l.**	**< d.l.**
Landsort Deep	< d.l.	< d.l.	< d.l.	< d.l.	**< d.l.**	**< d.l.**
Karlsö Deep	< d.l.	< d.l.	< d.l.	0.1	**< d.l.**	**< d.l.**

Phosphate (µM)	Aug 18	Aug 19	Jul 20	Jul 21	Aug 22	**Aug 23**
Bornholm Deep	8.3	7.0	2.6	11.7	7.3	**4.5**
Gotland Deep	5.3	4.7	5.6	6.3	6.5	**6.8**
Fårö Deep	4.4	4.6	4.4	5.3	5.1	**5.5**
Landsort Deep	3.0	3.4	3.3	4.0	4.1	**3.9**
Karlsö Deep	3.8	3.8	3.8	4.0	4.2	**4.2**

6 Station List EMB323

6.1 Overall Station List

Station No.		**Date**	**Gear**	**Time**	**Latitude**	**Longitude**	**Water Depth**	**Remarks/ Recovery**
r/v *Elisabeth Mann Borgese*	**IOW**	**2023**		**[UTC]**	**[°N]**	**[°E]**	**[m]**	Max sampl. depth
EMB323_1-1	TFO5	04 Aug	CTD	7:22	54.2317	12.0751	9	CLmax: 10m
EMB323_2-1	TF0012	04 Aug	CTD	10:09	54.3151	11.5502	21	CLmax: 22m
EMB323_2-2	TF0012	04 Aug	PLA	10:11	54.3151	11.5502	21	
EMB323_2-3	TF0012	04 Aug	SD	10:06	54.3151	11.5499	21	
EMB323_2-4	TF0012	04 Aug	WP2	10:24	54.3151	11.5501	21	CLmax: 19m
EMB323_2-5	TF0012	04 Aug	WP2	10:32	54.3152	11.5502	21	CLmax: 10m
EMB323_2-6	TF0012	04 Aug	WP2	10:38	54.3151	11.5501	21	CLmax: 19m
EMB323_2-7	TF0012	04 Aug	CTD	11:03	54.3151	11.5499	21	CLmax: 22m
EMB323_2-8	TF0012	04 Aug	CTD	11:30	54.3151	11.5499	21	CLmax: 5m
EMB323_3-1	TF0022	04 Aug	CTD	13:55	54.1094	11.1750	20	CLmax: 20 m
EMB323_3-2	TF0022	04 Aug	CTD	14:14	54.1093	11.1749	20	CLmax: 20 m
EMB323_4-1	TF0010	04 Aug	CTD	17:47	54.5517	11.3199	25	CLmax: 26m
EMB323_5-1	TF0014	04 Aug	CTD	19:29	54.5948	11.0153	25	CLmax: 25m
EMB323_6-1	TF0360	04 Aug	CTD	22:15	54.5999	10.4500	15	CLmax: 15m
EMB323_6-2	TF0360	04 Aug	PLA	22:18	54.5999	10.4502	15	
EMB323_6-3	TF0360	04 Aug	WP2	22:34	54.5998	10.4497	15	CLmax: 15m
EMB323_7-1	TF0361	05 Aug	CTD	0:24	54.6646	10.7779	21	CLmax: 21m
EMB323_8-1	TF0017	05 Aug	CTD	5:20	54.3915	11.8230	19	CLmax: 20 m
EMB323_9-1	TF0041	05 Aug	CTD	6:35	54.4062	12.0600	16	CLmax: 16m
EMB323_10-1	TF0046	05 Aug	CTD	7:56	54.4696	12.2403	23	CLmax: 26m
EMB323_10-2	TF0046	05 Aug	SD	7:49	54.4694	12.2410	25	
EMB323_10-3	TF0046	05 Aug	PLA	8:00	54.4698	12.2403	25	
EMB323_10-4	TF0046	05 Aug	WP2	8:10	54.4700	12.2416	25	CLmax: 25m
EMB323_10-5	TF0046	05 Aug	CTD	8:26	54.4701	12.2411	25	CLmax: 26m

EMB323_11-1	TF0002	05 Aug	CTD	10:22	54.6498	12.4502	15	CLmax: 15m
EMB323_12-1	TF0001	05 Aug	CTD	11:48	54.6962	12.7075	18	CLmax: 18m
EMB323_13-1	TF0030	05 Aug	CTD	12:33	54.7235	12.7828	20	CLmax: 19m
EMB323_13-2	TF0030	05 Aug	PLA	12:38	54.7234	12.7832	20	
EMB323_13-3	TF0030	05 Aug	CTD	13:00	54.7234	12.7833	19	CLmax: 19m
EMB323_13-4	TF0030	05 Aug	CTD	13:18	54.7234	12.7834	20	CLmax: 5m
EMB323_14-1	TF0115	05 Aug	CTD	14:51	54.7954	13.0585	27	CLmax: 26 m
EMB323_15-1	TF0114	05 Aug	CTD	16:08	54.8600	13.2769	42	CLmax: 42 m
EMB323_16-1	TF0113	05 Aug	CTD	17:34	54.9251	13.4996	44	CLmax: 44 m
EMB323_16-2	TF0113	05 Aug	PLA	17:38	54.9250	13.5000	44	
EMB323_16-3	TF0113	05 Aug	SD	17:39	54.9250	13.5000	44	
EMB323_16-4	TF0113	05 Aug	WP2	17:54	54.9251	13.5000	44	CLmax: 44m
EMB323_16-5	TF0113	05 Aug	WP2	18:08	54.9250	13.5005	44	CLmax: 44m
EMB323_16-6	TF0113	05 Aug	CTD	18:29	54.9252	13.5006	44	CLmax: 44m
EMB323_16-7	TF0113	05 Aug	WP2	18:39	54.9255	13.5011	45	CLmax: 44m
EMB323_17-1	TF0105	05 Aug	CTD	19:52	55.0249	13.6072	44	CLmax: 43m
EMB323_18-1	TF0104	05 Aug	CTD	21:02	55.0684	13.8138	44	CLmax: 43m
EMB323_19-1	TF0109	05 Aug	CTD	22:31	55.0002	14.0816	45	CLmax: 45m
EMB323_19-2	TF0109	05 Aug	PLA	22:35	55.0007	14.0810	45	
EMB323_19-3	TF0109	05 Aug	WP2	22:43	55.0008	14.0823	45	CLmax: 45m
EMB323_19-4	TF0109	05 Aug	CTD	23:02	55.0001	14.0835	45	CLmax: 24m
EMB323_20-1	TF0145	06 Aug	CTD	0:37	55.1662	14.2492	44	CLmax: 43m
EMB323_21-1	TF0103	06 Aug	CTD	2:18	55.0637	13.9884	44	CLmax: 44 m
EMB323_22-1	ABBOJE	06 Aug	CTD	4:10	54.8799	13.8587	43	CLmax: 43 m
EMB323_23-1	TF0112	06 Aug	CTD	5:11	54.8034	13.9580	38	CLmax: 37 m
EMB323_23-2	TF0112	06 Aug	CTD	5:32	54.8034	13.9582	38	CLmax: 5 m
EMB323_24-1	TF0150	06 Aug	CTD	6:53	54.6118	14.0429	19	CLmax: 19m
EMB323_25-1	OBBoje	09 Aug	CTD	12:45	54.0766	14.1604	12	CLmax: 12m
EMB323_26-1	TF0112	09 Aug	CTD	17:53	54.8030	13.9594	37	CLmax: 37m
EMB323_27-1	TF0105	09 Aug	CTD	20:21	55.0250	13.6075	44	CLmax: 43m
EMB323_28-1	TF0104	09 Aug	CTD	21:34	55.0684	13.8148	44	CLmax: 43m
EMB323_29-1	TF0109	09 Aug	CTD	23:09	54.9998	14.0855	45	CLmax: 45m
EMB323_30-1	TF0144	10 Aug	CTD	1:54	55.2569	14.4907	42	CLmax: 41 m
EMB323_31-1	TF0142	10 Aug	CTD	3:32	55.3873	14.5714	70	CLmax: 68 m
EMB323_32-1	TF0140	10 Aug	CTD	4:43	55.4663	14.7169	68	CLmax: 66 m
EMB323_33-1	TF0206	10 Aug	CTD	6:04	55.5322	14.9145	75	CLmax: 73m
EMB323_34-1	TF0208	10 Aug	CTD	7:45	55.4533	15.2346	91	CLmax: 89m
EMB323_35-1	TF0200	10 Aug	CTD	8:48	55.3830	15.3336	90	CLmax: 88m
EMB323_36-1	TF0211	10 Aug	CTD	10:23	55.3298	15.6154	94	CLmax: 92m
EMB323_37-1	TF0214	10 Aug	CTD	12:04	55.1594	15.6610	93	CLmax: 90m
EMB323_38-1	TF0212	10 Aug	CTD	13:36	55.3020	15.7970	94	CLmax: 92m
EMB323_39-1	TF0213	10 Aug	CTD	14:48	55.2503	15.9837	89	CLmax: 86 m
EMB323_39-2	TF0213	10 Aug	PLA	14:49	55.2503	15.9836	89	
EMB323_39-3	TF0213	10 Aug	SD	14:50	55.2503	15.9836	89	
EMB323_39-4	TF0213	10 Aug	WP2	15:09	55.2502	15.9834	89	CLmax: 88 m
EMB323_39-5	TF0213	10 Aug	WP2	15:21	55.2501	15.9831	88	CLmax: 88m
EMB323_39-6	TF0213	10 Aug	WP2	15:34	55.2501	15.9833	89	CLmax: 88 m
EMB323_39-7	TF0213	10 Aug	WP2	16:11	55.2500	15.9836	89	CLmax: 22 m
EMB323_39-8	TF0213	10 Aug	WP2	16:19	55.2500	15.9830	89	CLmax: 88 m
EMB323_39-9	TF0213	10 Aug	WP2	16:56	55.2502	15.9836	89	CLmax: 88 m
EMB323_39-10	TF0213	10 Aug	CTD	17:18	55.2503	15.9834	89	CLmax: 25 m
EMB323_39-11	TF0213	10 Aug	APNET	17:34	55.2502	15.9834	89	CLmax: 89 m
EMB323_39-12	TF0213	10 Aug	APNET	17:56	55.2499	15.9828	89	CLmax: 89m
EMB323_39-13	TF0213	10 Aug	APNET	18:23	55.2501	15.9829	89	CLmax: 89m
EMB323_40-1	TF0221	10 Aug	CTD	19:41	55.2214	16.1674	81	CLmax: 79m
EMB323_41-1	TF0225	10 Aug	CTD	20:59	55.2586	16.3211	64	CLmax: 63m
EMB323_42-1	TF0224	10 Aug	CTD	22:07	55.2833	16.4998	60	CLmax: 59m
EMB323_43-1	TF0227	10 Aug	CTD	23:11	55.2615	16.6393	67	CLmax: 65m

EMB323_44-1	TF0229	11 Aug	CTD	0:39	55.2282	16.9143	84	CLmax: 82m
EMB323_45-1	TF0222	11 Aug	CTD	1:40	55.2166	17.0662	90	CLmax: 87m
EMB323_46-1	TF0266	11 Aug	CTD	3:12	55.2520	17.3602	88	CLmax: 86 m
EMB323_47-1	TF0268	11 Aug	CTD	5:43	55.3078	17.9305	73	CLmax: 72 m
EMB323_48-1	TF0256	11 Aug	CTD	7:12	55.3262	18.2360	75	CLmax: 75m
EMB323_49-1	TF0259	11 Aug	CTD	9:09	55.5496	18.4008	89	CLmax: 86m
EMB323_49-2	TF0259	11 Aug	PLA	9:09	55.5496	18.4009	89	
EMB323_50-1	TF0255	11 Aug	CTD	10:38	55.6328	18.6008	95	CLmax: 91m
EMB323_51-1	TF0252	11 Aug	CTD	12:37	55.8659	18.6416	114	CLmax: 110m
EMB323_52-1	TF0253	11 Aug	CTD	13:57	55.8397	18.8664	101	CLmax: 98 m
EMB323_53-1	TF0265	11 Aug	CTD	15:22	55.9587	19.0474	111	CLmax: 107m
EMB323_54-1	TF0262	11 Aug	CTD	17:45	56.2343	19.3010	132	CLmax: 128 m
EMB323_55-1	TF0261	11 Aug	CTD	19:59	56.4921	19.4819	144	CLmax: 139m
EMB323_56-1	TF0260	11 Aug	CTD	21:28	56.6333	19.5838	145	CLmax: 140m
EMB323_57-1	TF0274	11 Aug	CTD	23:08	56.7675	19.7526	154	CLmax: 150m
EMB323_58-1	TF0273	12 Aug	CTD	0:56	56.9528	19.7713	184	CLmax: 178m
EMB323_59-1	TF0272	12 Aug	CTD	2:33	57.0715	19.8302	209	CLmax: 203 m
EMB323_60-1	TF0275	12 Aug	CTD	4:05	57.2100	19.9300	231	CLmax: 224 m
EMB323_61-1	TF0271	12 Aug	CTD	5:50	57.3198	20.0510	241	CLmax: 234m
EMB323_61-2	TF0271	12 Aug	PLA	5:48	57.3197	20.0510	241	
EMB323_61-3	TF0271	12 Aug	SD	5:35	57.3194	20.0509	241	
EMB323_61-4	TF0271	12 Aug	CTD	6:42	57.3203	20.0500	241	CLmax: 152m
EMB323_61-5	TF0271	12 Aug	CTD	7:28	57.3198	20.0499	241	CLmax: 85m
EMB323_61-6	TF0271	12 Aug	CTD	8:10	57.3206	20.0503	241	CLmax: 30m
EMB323_61-7	TF0271	12 Aug	CTD	8:45	57.3198	20.0495	241	CLmax: 25m
EMB323_61-8	TF0271	12 Aug	CTD	9:31	57.3195	20.0498	241	CLmax: 95m
EMB323_62-1	TF0276	12 Aug	CTD	11:11	57.4695	20.2604	209	CLmax: 202m
EMB323_63-1	TF0270	12 Aug	CTD	12:43	57.6162	20.1675	144	CLmax: 139m
EMB323_64-1	TF0287	12 Aug	CTD	14:30	57.7148	19.8537	130	CLmax: 126 m
EMB323_65-1	TF0286	12 Aug	CTD	16:50	58.0000	19.9010	196	CLmax: 190 m
EMB323_65-2	TF0286	12 Aug	SD	17:02	58.0001	19.9006	196	
EMB323_65-3	TF0286	12 Aug	CTD	17:39	58.0003	19.9000	196	CLmax: 25 m
EMB323_66-1	TF0277	12 Aug	CTD	19:21	58.1833	20.0513	163	CLmax: 158m
EMB323_67-1	TF0285	12 Aug	CTD	21:41	58.4412	20.3343	122	CLmax: 118m
EMB323_68-1	TF0279	12 Aug	CTD	23:31	58.6414	20.3453	165	CLmax: 159m
EMB323_69-1	TF0282	13 Aug	CTD	1:38	58.8829	20.3164	166	CLmax: 158 m
EMB323_70-1	nGB-2	13 Aug	CTD	4:06	58.8658	19.7441	162	CLmax: 157 m
EMB323_71-1	TF0283	13 Aug	CTD	6:51	58.7834	19.1001	121	CLmax: 118m
EMB323_72-1	nGB-1	13 Aug	CTD	9:04	58.7128	18.6695	243	CLmax: 234m
EMB323_73-1	TF0284	13 Aug	CTD	11:38	58.5828	18.2346	453	CLmax: 436m
EMB323_73-2	TF0284	13 Aug	SD	11:14	58.5826	18.2354	450	
EMB323_73-3	TF0284	13 Aug	CTD	12:39	58.5831	18.2339	453	CLmax: 132m
EMB323_73-4	TF0284	13 Aug	CTD	13:13	58.5823	18.2329	453	CLmax: 18m
EMB323_73-5	TF0284	13 Aug	CTD	13:55	58.5835	18.2336	453	CLmax: 105 m
EMB323_74-1	wGB-3	13 Aug	CTD	16:11	58.3258	18.0683	157	CLmax: 154 m
EMB323_75-1	TF0240	13 Aug	CTD	18:53	58.0000	18.0003	167	CLmax: 162m
EMB323_76-1	TF0242	13 Aug	CTD	22:24	57.7157	17.3646	141	CLmax: 137m
EMB323_77-1	TF0245	14 Aug	CTD	2:52	57.1164	17.6665	111	CLmax: 106 m
EMB323_78-1	wGB-1	14 Aug	CTD	5:12	56.8772	17.3898	96	CLmax: 92 m
EMB323_79-1	GB_SW	14 Aug	CTD	7:26	56.6248	17.1304	78	CLmax: 75m
EMB323_80-1	TF223	14 Aug	CTD	10:46	56.2490	16.7008	56	CLmax: 54m
EMB323_81-1	BB_N	14 Aug	CTD	14:53	55.7619	16.2904	61	CLmax: 59 m
EMB323_82-1	TF0220	14 Aug	CTD	17:19	55.5002	16.0003	79	CLmax: 77 m
EMB323_83-1	TF0213	14 Aug	CTD	19:27	55.2501	15.9837	89	CLmax: 87m
EMB323_83-2	TF0213	14 Aug	PLA	19:28	55.2500	15.9836	89	
EMB323_83-3	TF0213	14 Aug	WP2	19:51	55.2503	15.9835	89	CLmax: 88m
EMB323_83-4	TF0213	14 Aug	WP2	20:01	55.2498	15.9840	89	CLmax: 88m
EMB323_83-5	TF0213	14 Aug	WP2	20:11	55.2500	15.9836	89	CLmax: 88m

EMB323_83-6	TF0213	14 Aug	APNET	20:25	55.2498	15.9837	89	CLmax: 89m
EMB323_83-7	TF0213	14 Aug	APNET	20:47	55.2495	15.9845	89	CLmax: 89m
EMB323_83-8	TF0213	14 Aug	APNET	21:06	55.2495	15.9839	89	CLmax: 89m
EMB323_84-1	TF0113	15 Aug	CTD	7:51	54.9248	13.5015	44	CLmax: 44m
EMB323_84-2	TF0113	15 Aug	PLA, SD	7:54	54.9245	13.5013	44	
EMB323_84-3	TF0113	15 Aug	WP2	8:06	54.9238	13.4997	44	CLmax: 44m
EMB323_85-1	TF0030	15 Aug	CTD	11:30	54.7234	12.7827	20	CLmax: 20m
EMB323_85-2	TF0030	15 Aug	PLA	11:32	54.7234	12.7827	20	
EMB323_86-1	TF0046	15 Aug	CTD	14:27	54.4697	12.2412	25	CLmax: 25 m
EMB323_86-2	TF0046	15 Aug	PLA	14:31	54.4696	12.2410	25	
EMB323_87-1	TF0012	15 Aug	CTD	17:51	54.3146	11.5503	22	CLmax: 22m
EMB323_87-2	TF0012	15 Aug	PLA, SD	17:57	54.3149	11.5500	22	
EMB323_87-3	TF0012	15 Aug	WP2	18:18	54.3153	11.5494	22	CLmax: 22m

CLmax: Maximum rope/cable length
PLA: Small plankton net for manual catches
WP2: Plankton net with closing mechanism and removable net bucket
APNET: Apstein net with cone
CTD: CTD rosette system with Fluorimeter, Oxygen Sensor, Water Sampler, and Camera
SD: Secci disk to determine the depth of visibility

7 Data and Sample Storage and Availability

All data gathered are saved on a data repository in the IOW immediately after the cruise. The processed and validated data will be stored in the ODIN data base (https://odin2.io-warnemuende.de) in due time after the cruise. According to the IOW data policy and to facilitate the international exchange of data, all metadata will be made available under the international ISO 19115 standards for georeferenced metadata.

The access to the data itself will be restricted for three years after data acquisition to protect the research process, including scientific analysis and publication. After that period the data becomes openly available to any person or organization who requests them, under the international Creative Commons (CC) data license of type CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/). For further details, refer to the IOW data policy document.

Table 7.1 Overview of data availability

Type	Database	Available	Free Access	Contact
Hydrographic data	ODIN	01.10.2023	01.10.2026	volker.mohrholz@io-warnemuende.de
Nutrient data	ODIN	01.02.2024	01.02.2027	joachim.kuss@io-warnemuende.de
Zooplankton data	ODIN	01.08.2024	01.08.2027	joerg.dutz@io-warnemuende.de
Phytoplankton data	ODIN	01.08.2024	01.08.2027	anke.kremp@io-warnemuende.de

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