ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

751
2021

Berichte
zur Polar- und Meeresforschung

Reports on Polar and Marine Research

The MOSES Sternfahrt Expeditions of the Research Vessels ALBIS, LITTORINA, LUDWIG PRANDTL, MYA II and UTHÖRN to the Elbe River, Elbe Estuary and German Bight in 2020

Edited by

Ingeborg Bussmann, Norbert Anselm, Holger Brix,
Philipp Fischer, Götz Flöser, Felix Geissler, Norbert Kamjunke

with contributions of the participants

HELMHOLTZ

Die Berichte zur Polar- und Meeresforschung werden vom Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung (AWI) in Bremerhaven, Deutschland, in Fortsetzung der vormaligen Berichte zur Polarforschung herausgegeben. Sie erscheinen in unregelmäßiger Abfolge.

Die Berichte zur Polar- und Meeresforschung enthalten Darstellungen und Ergebnisse der vom AWI selbst oder mit seiner Unterstützung durchgeführten Forschungsarbeiten in den Polargebieten und in den Meeren.

Die Publikationen umfassen Expeditionsberichte der vom AWI betriebenen Schiffe, Flugzeuge und Stationen, Forschungsergebnisse (inkl. Dissertationen) des Instituts und des Archivs für deutsche Polarforschung, sowie Abstracts und Proceedings von nationalen und internationalen Tagungen und Workshops des AWI.

Die Beiträge geben nicht notwendigerweise die Auffassung des AWI wider.

Herausgeber
Dr. Horst Bornemann

Redaktionelle Bearbeitung und Layout
Birgit Reimann

Alfred-Wegener-Institut
Helmholtz-Zentrum für Polar- und Meeresforschung
Am Handelshafen 12
27570 Bremerhaven
Germany

www.awi.de
www.awi.de/reports

The Reports on Polar and Marine Research are issued by the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI) in Bremerhaven, Germany, succeeding the former Reports on Polar Research. They are published at irregular intervals.

The Reports on Polar and Marine Research contain presentations and results of research activities in polar regions and in the seas either carried out by the AWI or with its support.

Publications comprise expedition reports of the ships, aircrafts, and stations operated by the AWI, research results (incl. dissertations) of the Institute and the Archiv für deutsche Polarforschung, as well as abstracts and proceedings of national and international conferences and workshops of the AWI.

The papers contained in the Reports do not necessarily reflect the opinion of the AWI.

Editor
Dr. Horst Bornemann

Editorial editing and layout
Birgit Reimann

Alfred-Wegener-Institut
Helmholtz-Zentrum für Polar- und Meeresforschung
Am Handelshafen 12
27570 Bremerhaven
Germany

www.awi.de
www.awi.de/en/reports

Titel: RV Ludwig Prandtl vom Heck der RV Uthörn aus gesehen (Foto: I. Bussmann, AWI)

Cover: RV Ludwig Prandtl as seen from the stern of RV Uthörn (Photo: I. Bussmann, AWI))

The MOSES Sternfahrt Expeditions of the Research Vessels ALBIS, LITTORINA, LUDWIG PRANDTL, MYA II and UTHÖRN to the Elbe River, Elbe Estuary and German Bight in 2020

Edited by
Ingeborg Bussmann, Norbert Anselm, Holger Brix, Philipp Fischer, Götz Flöser, Felix Geissler, Norbert Kamjunke

with contributions of the participants

Please cite or link this publication using the identifiers

https://hdl.handle.net/10013/epic.fdb9fdcd-cf0f-4193-8c7a-0417317e929b
https://doi.org/10.48433/BzPM_0751_2021

ISSN 1866-3192

The MOSES Sternfahrten 2020
with RV *Albis*, RV *Littorina*, RV *Ludwig Prandtl*, RV *Mya II*, RV *Uthörn*

Stern_4	11 – 12 May 2020
Sylt Transects	March – November 2020
Binnen Elbe	04 – 12 August 2020
Tide Elbe	25 – 26 August 2020
Stern_5	31 August – 3 Sept. 2020

From Dresden to the North Sea

Modular Observation Solutions for Earth Systems

Chief Scientists
Ingeborg Bussmann (AWI) – RV *Mya II* and RV *Uthörn*
Holger Brix (HZG) – RV *Ludwig Prandtl*
Felix Geissler (Geomar) – RV *Littorina*
Norbert Kamjunke (UFZ) – RV *Albis*

Coordinator
Ingeborg Bussmann

Contents

1. ZUSAMMENFASSUNG UND FAHRTVERLAUF

Aufbauend auf unseren Fahrten und Erfahrungen im Jahr 2019 wollten wir die Fahrten in 2020 fortsetzen und ausbauen (vgl. BzPM_0741_2020). In Absprache mit Kollegen von Modular Observation Solutions for Earth Systems (MOSES) und der Programm-orientierten Förderung (PoF) IV der Helmholtz-Gemeinschaft dienten die geplanten Fahrten im Jahr 2020 als gemeinsamer Testfall für die MOSES-Instrumentierung sowie der weiteren Etablierung der Kommunikation zwischen den Gruppen hinsichtlich der Vorbereitung gemeinsamer Kampagnen, der Planung der verfügbaren Ausrüstung, der Festlegung von Verantwortlichkeiten und der Bildung von zusammenarbeitenden Teams. Ein besonderes Augenmerk wurde auf die Interkalibrierung von Sensoren und Parametern gelegt.

Das Datenmanagement wird eine Herausforderung sein, da Daten von marinen Instituten/Sensoren mit terrestrischen Instituten/Sensoren kombiniert werden müssen. Alle Sensoren wurden im Vorfeld im MOSES-Datenmanagement-Tool (https://moses-dmp.gfz-potsdam.de/) registriert. Das Registrierungsverfahren wurde erheblich verbessert, nun sollte die Anwendbarkeit in der Praxis überprüft werden. Alle Sensoren und Daten sind nun im neuen MOSES data discovery portal (https://moses-data.gfz-potsdam.de) verlinkt.

Entscheidend für die südliche Nordsee (bzw. Deutsche Bucht) ist, welcher Wasserkörper mit welchen Bestandteilen in den Tide-Elbe-Bereich gelangt und wie er sich dort weiter verändert. So entstand die Idee, eine Gruppe von Parametern kontinuierlich von den Anfängen der Elbe bis in die Nordsee zu verfolgen. Was sind die wichtigsten Einflussfaktoren für die terrestrische und küstennahe Wasserqualität während Hoch- und Niedrigwasserperioden? Für ein besseres Verständnis der verschiedenen Abschnitte der Ereigniskette lieferten Untersuchungen im Elbe-Einzugsgebiet (beginnend an der tschechisch-deutschen Grenze), entlang des Mittellaufs, der Tide-Elbe und des Elbe-Ästuars (Deutsche Bucht).

Um dem Wasser der Elbe zu folgen, begann unsere Kampagne mit der *Albis* (UFZ), welche fließzeitkonform in 8 Tagen von Dresden bis zum Wehr von Geesthacht fuhr. Der nächste Abschnitt der Tide-Elbe, startete zeitlich versetzt am 25. und 26. August 2020, da das Wasser von Geesthacht bis zur Mündung in Cuxhaven ca. 2 Wochen benötigt. Die *Ludwig Prandtl* (HZG) startete bei Niedrigwasser in der Nähe von Cuxhaven, um den marinen Einfluss zu reduzieren, um dann gegen den Strom die Elbe aufwärts zu fahren. An den Abschnitt „Tide Elbe“ schloss sich die Fahrt in die Nordsee an, bei der die drei Küstenforschungsschiffen ein grosses Gebiet innerhalb der Deutschen Bucht abdeckten.

Die grundlegenden hydrographischen Parameter (Temperatur und Leitfähigkeit oder Salzgehalt) wurden mit FerryBoxen und Sonden auf den Schiffen gemessen, wobei einige Instrumente sogar von Schiff zu Schiff weitergegeben wurden. Auch die atmosphärischen und gelösten Treibhausgase (CH_4 und CO_2) wurden durchgehend gemessen. Um mehr über das Phytoplankton oder die Produktivität des Wassers zu erfahren, wurden auch Chlorophyll *a*, Trübung und Nährstoffe bestimmt. Der Kohlenstoffkreislauf wurde kontinuierlich mit den Parametern TA, DOC, POC und DIC (Gesamtalkalinität, gelöster und partikulärer organischer Kohlenstoff und gelöster anorganischer Kohlenstoff) beschrieben.

Als Verbesserung gegenüber den vorangegangenen Fahrten verlängerten wir die Dauer unserer Fahrten. So konnten wir für Sternfahrt_5 vier Tage lang mit drei Schiffen ein weites

Gebiet abdecken. Und das, obwohl die Corona-Restriktionen nur 4 Wissenschaftler an Bord zuließen und der Zugang zu den Schiffen teilweise eingeschränkt war.

Auch das Problem der Umstellung vom „on the way"-Modus auf die vertikale Beprobung wurde gelöst, da nun alle Schiffe mit d-ship ausgestattet sind, das genaue Zeitangaben zu den Stationen und Umstellungen liefert. Diese Informationen werden nun als Aktionen in den O2A-Datenbank übernommen, so dass die Daten leicht getrennt werden können.

In den folgenden Kapiteln und den Tabellen im Anhang erläutern wir den Aufbau der Fahrten und unsere Erfahrungen genauer. Alle unsere Daten sind nun in der Datenbank unter https://sensor.awi.de und https://www.ufz.de/record/dmp hinterlegt. Allerdings lassen sich so komplexe Aufbauten wie bei unseren kombinierten Elbe-2020-Fahrten nicht ohne weiteres in der Datenbank abbilden, so dass dieser Fahrtbericht auch helfen soll, die gewonnenen Daten mit ihren Metadaten entlang der Elbe und ihrer Mündung sowie in der südlichen Nordsee besser zu nutzen.

SUMMARY AND ITINERARY

Building on our cruises and experiences in 2019, we wanted to continue and expand the trips in 2020 (*cf*. BzPM_0741_2020). In discussion with colleagues from Modular Observation Solutions for Earth Systems (MOSES) and Program-oriented Funding (PoF) IV of the Helmholtz Association, the planned cruise in 2020 served as a joint test case for MOSES instrumentation, as well as the further establishment of the communication between the groups concerning preparation of common campaigns, planning of available equipment, determination of responsibilities and building collaborating teams to investigate processes across the compartments. A special focus was set on the intercalibration of sensors and parameters, by insisting on several inter-calibration times for most sensors, measuring at the same time and location.

The data management will be challenging as data from marine institutes / sensors will have to be combined with terrestrial institutes / sensors. All sensors were registered in MOSES data management tool (https://moses-dmp.gfz-potsdam.de/) beforehand. The registration procedure had been considerably improved, now the applicability in practice was to be checked. All sensors and data are now linked in the new MOSES data discovery portal (https://moses-data.gfz-potsdam.de).

The decisive factor for the southern North Sea (or German Bight) is which water body and with which constituents it arrives in the Tide-Elbe area and how it is further modified in this area. Thus, the idea arose to continuously trace a group of parameters from the beginnings of the Elbe to the North Sea. What are the main impact factors for terrestrial and coastal water quality during floods and low water periods? Data for a better understanding of the different branches of the relevant event chain were provided by investigations within the Elbe river catchment (starting at the Czech/German border), along the middle course, Tide-Elbe und Elbe estuary (German Bight). To follow the water from the Elbe our campaign started with the *Albis* (research vessel from the UFZ), travelling with the water velocity of the Elbe; from 4 to 12 August. As the water takes about 2 weeks to travel from Geesthacht to Cuxhaven at the river mouth, the next campaign started on 25 and 26 August 2020. The *Ludwig Prandtl* (HZG) started at ebb tide near Cuxhaven, thus reducing the marine influence and focusing on the Elbe water. The estuarine cruise was followed by the marine cruise, from 31 August to 3 September 2020 with three coastal research vessels, covering a broad area within the German Bight. Different thematic teams were covering the various processes across the considered compartments: terrestrial waters, coastal and marine zones.

The basic hydrographic parameters (temperature and conductivity or salinity) were measured by FerryBoxes and probes on the ships, with some instruments actually being passed from ship to ship. Similarly, atmospheric and dissolved greenhouse gases (CH_4 and CO_2) were measured throughout. To learn more about the phytoplankton or productivity of the water, chlorophyll *a*, turbidity and nutrients were also determined. The carbon cycle was continuously described with the parameters TA, DOC, POC and DIC (total alkalinity, dissolved and particulate organic carbon, and dissolved inorganic carbon).

As improvement from the previous cruises, we extended the duration of our cruises. Thus, for Sternfahrt_5 we could cover a wide area for four days with three ships, even though Corona restrictions allowed only 4 scientists on board and partly restricted access to the vessels.

Also, the problem of switching from “on the way” modus to vertical sampling has been solved as now all vessels have d-ship installed which provides exact timing of the stations and switches. This information is now incorporated into the O2A as actions, consequently the data can be easily separated.

In the following chapters and the tables in the annex, we explain in more detail the set-up of the cruises and our experiences. All of our data are now deposited in the database at https://sensor.awi.de and https://www.ufz.de/record/dmp. However, such complex set-up as in our combined Elbe-2020 cruises are not easily mirrored in the database, thus this cruise report should also help to use the obtained data and their meta data along the river Elbe and its estuary as well as in the southern North Sea.

2. STERNFAHRT_4 (11 – 12 MAY 2020)

Objectives

Aims of the cruise were:

To improve ship to ship communication and data / screen transfer. Burkard Baschek (HZG) offered a communication system used now for ocean eddies;

To get a clear separation line between Weser and Elbe water in the German Bight with the help of the back-tracking model. Both ships will criss-cross the expected separation line several times.

A communication system has been successfully used as part of the ocean eddies Cape Verde campaign. HZG has ordered another antenna system that should be available for the May cruise, i.e., we will have two ship systems and one land system to be installed in Heligoland. With these 2 antennas, there should be a ship-to-ship communication at a distance of 40 km. This set-up would be like an Intranet, able to send data and pictures / figures. The shore station allows access to the Internet, the ship antennas only ship to ship communication.

In spring 2020 severe restrictions due to the Corona Epidemy were in place. Therefore, we could only head for a limited scientific programme i.e., only 2 - 3 scientists on board and only a one-day cruise (Fig. 2.1). We decided to focus our efforts on an intelligent data transfer on each ship between the measuring instruments and one central computer on the ships bridge, reliable communication and shared screens between the two ships and independent internet access for near real time data transfer into the awi-sensor-net.

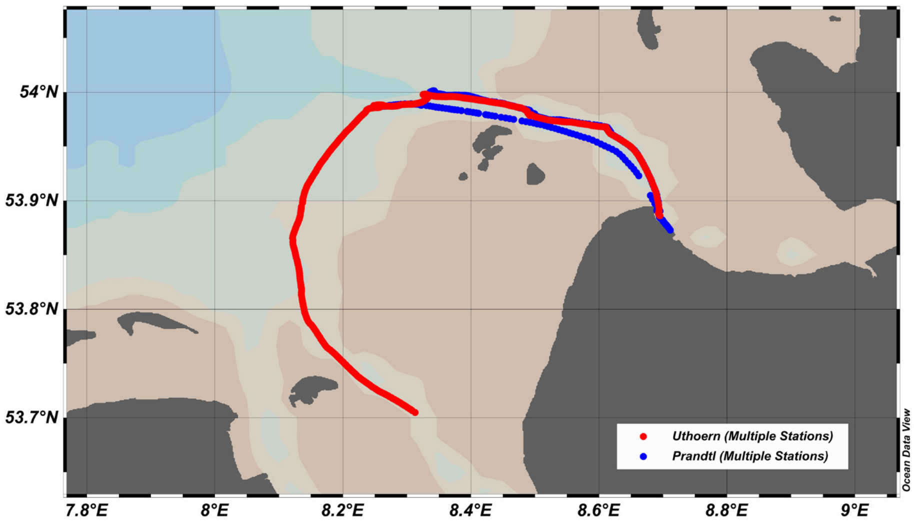


Fig. 2.1: Cruise track from Ludwig Prandtl and Uthörn on 12.05.2020

Work at sea with *Uthörn*

Norbert Anselm[1], Ingeborg Bussmann[1], Philipp Fischer[1]

[1]DE.AWI

Due to Corona restrictions we had to minimize the scientific crew on board to three persons. As no people were allowed to leave ships in Heligoland Harbour, we rescheduled the cruise for one-day only, leaving and ending the cruise in Cuxhaven / Bremerhaven.

On 11 May equipment was loaded in Bremerhaven, as well as the set-up of the Kongsberg-Antenna on the compass bridge. *Uthörn* left for Cuxhaven and arrived there at 17:00, when the other equipment was set up. On Tuesday morning at 06:45 UTC we left the lock Cuxhaven, when the crew realized that a cooling pump stopped working. We decided to go onto the cruise with only one engine.

To test the coverage of the antenna we planned for a parallel northward course, a deep vertical station for better comparison of the in-situ CTDs. Then the ships should turn west or east to reach a maximal distance. However, as the *Uthörn* was running with only one engine and strong westerly winds our actual speed was very slow. We reached our deep station around 12:20 UTC, and decided to return to Bremerhaven, which we reached around 18:30 UTC.

The water supply of the Pocket FerryBox was redirected via a pressure housing with a volume of approx. 10 L. A pressure of a minimum of 500 mbar in the system was kept to prevent degassing. The flow rate of the board water supply through this system was 13 L/min. The pocket FerryBox was running fine; however, the pH sensor was started delayed at 11:35 (UTC).

On 5 Stations along the way, surface water was sampled with a single Niskin bottle, after an in-situ CTD had been at 2 m water depths for approx. 2 min. This should allow a comparison with the ferrybox attached to the ship's water supply. At two stations a vertical profile with the CTD was taken, water samples were only from the surface. At 08:52 the MS *Helgoland"* passed us with a short distance.

Details on station list, the applied sensors and locations for data access be found in table Tab. A.3.3 and Tab. A.3.4.

Work at sea with *Ludwig Prandtl*

Holger Brix[2], Martina Gehrung[2]

[2]DE.HZG

Due to the Corona-related restrictions, *Ludwig Prandtl* could only be operated with two crew and two scientists. The cruise programme was adjusted accordingly: CTD operations were skipped and the programme condensed for a one-day cruise to and from Cuxhaven on Tuesday, May 12.

Ludwig Prandtl arrived in Cuxhaven on Monday, May 11 around 09:30 UTC for setup and installation. The Kongsberg antenna system had been installed (permanently) during maintenance time in the shipyard earlier. Also, a semi-permanent installation of the FerryBox system in a new, smaller container had been done then. The setup in Cuxhaven on the day before the cruise was therefore limited in scope and could be done in a short time.

On the cruise day, *Ludwig Prandtl* left the Alte Fischereihafen in Cuxhaven at 06:40 UTC and took the first water samples immediately in front of the FerryBox container Cuxhaven (station P0). This position was resampled upon return to Cuxhaven (P6, back in Alter Fischereihafen at 14:02 UTC). Beyond those two stations, a total of five stations were occupied in the immediate vicinity of *Uthörn*. During those stations water was sampled from the surface (at approx. 2 meters depth), for the last shared station (P5) also at (two) greater depths. The FerryBox underway system operated during the entire cruise. The pCO_2 sensor malfunctioned early on and was exchanged between stations P4 and P5. Beyond this problem the measurement programme enfolded as planned with stations roughly spaced every 3 PSU distance. The last shared station (P5) was taken in shallower waters than planned as the engine problem of *Uthörn* prohibited going further due to the very limited cruise speed.

This also affected the testing of the antenna signal reach. The original plan was to see up to which distance a ship-to-ship communication was viable by sailing in opposite directions. The results that could be gathered were encouraging though as the maximum distance without any signal transmission problems was 35 km and was only limited by *Ludwig Prandtl* entering Cuxhaven harbor (where the shading due to building structures ended reception). Communication with (and internet access through) the Heligoland antenna was available during the entire cruise, that is, all the way to Cuxhaven harbor.

Details on the station list, the sensors used and locations for data access can be found in Tab. A.3.1 and Tab. A.3.2.

Fig. 2.2: Ludwig Prandtl as seen from Uthörn by I. Bussmann

Communication and IT

HZG operates, as part of MOSES, a Kongsberg communication system used until now for the ocean eddies experiments. It included for this campaign two ship borne antennas and one land borne station (Fig. 2.3). One station has been installed permanently on Ludwig *Ludwig Prandtl*, one temporarily on the compass bridge of *Uthörn*. The land borne antena was installed on the Lighthouse of Heligoland, at a height of 82 m.a.s.l. Aboard of the AWI-operated vessel *Uthörn* additionally the standard node was used. Both network's capacities were pentested along the cruise.

Fig. 2.3: Installation of the communication antenna on the Lighthouse Heligoland and on the Uthörn. By M. Brand and I. Bussmann

Preliminary results of Sternfahrt_4

The new communication setup (compared to earlier cruises) allowed Teamviewer access between the ships for the entire cruise duration, as well as exchange of files. One logistical problem was that chat communication happened in multiple windows as multiple Teamviewer connections were open, which led to temporary confusion. It is advisable to have one dedicated computer on each ship for collecting all relevant information from the ship and for communication. There is no need to have direct access to, for example, the FerryBox computer of the other ship. Another minor problem was that a video chat could be established but the audio connection did not work.

The aimed procedure of having a collection computer was not successful aboard *Uthörn* due to networking issues on the client side. Nonetheless, the desired procedure (collection pc) is still the preferred one. For the upcoming cruises it is highly advised to set the measuring devices to a kind of auto-export (device dependent ingest). Additionally, it is highly recommended to have the whole system running (from the sensor setup to the ingest) prior to leaving the lock.

All of the participating devices were integrated in the O2A workflow. The meteorological measurements from *Uthörn* were ingested in near real-time (standard procedure 10-minute values, raw data can be obtained via https://dms.awi.de/) and the measurements of ‘ctd_awi_1413’ and ‘pfb_awi_741801’ were ingested within 24 h after Sternfahrt_4. All remaining data was ingested at a later time, however all data is available (and, if necessary, time corrected) via https://dashboard.awi.de/data-ingest/index.html.

3. SYLT TRANSECT CRUISES

Ingeborg Bussmann[1], Finn Mielck[1]

[1]DE.AWI

Objectives and work at sea

As a spatial extension of our main research area, we initiated monthly cruises with *Mya II* (if possible, every first Wednesday of the month). Starting from List (Sylt), these cruises headed towards about 7.5°E to the north-west (Fig. 3.1) while the inboard FerryBox continuously measured the basic hydrographic parameters (T, S, pH, O_2, chlorophyll, pCO_2, turbidity). We thus hope to assess the influence of the Elbe inflow to the northern German Bight. These trips took place on the following dates: 04.03.2020; 31.03.2020; 06.05.2020; 26.05.2020; 02.07.2020; 18.08.2020; 07.10.2020 and 11.11.2020. The data can be found at https://dashboard.awi.de/data-ingest/index.html# (vessel *Mya II*) and the respective dates.

Preliminary results of the transect cruises

In August we observed rather warm water along the whole transect (>20 °C) and cold water in February (5 - 6°, Fig. 3.2). A phytoplankton bloom was observed in May reaching towards 7.8°E and again in July but only reaching toward 8°E (Fig. 3.3). Other colleagues from Sylt joined these interesting cruises and they will be continued in 2021.

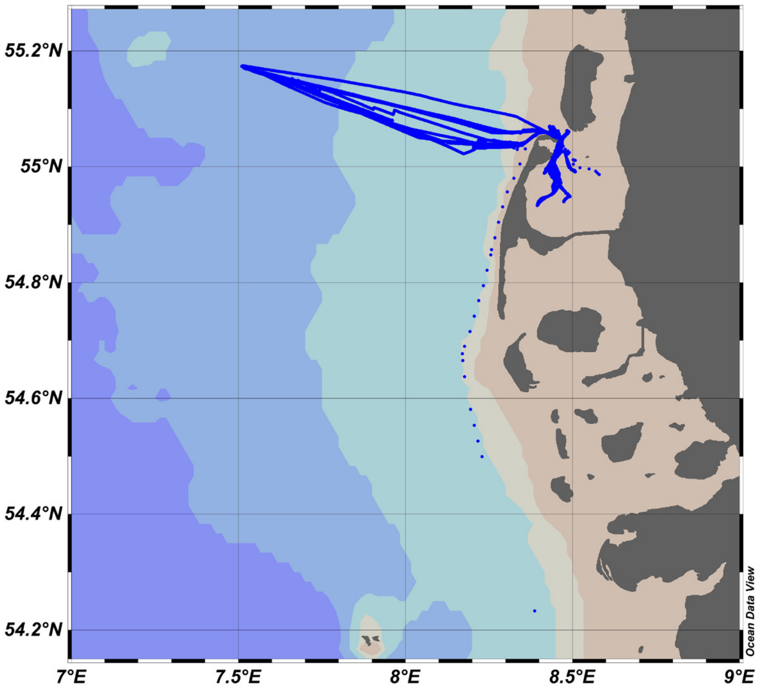


Fig. 3.1: Track of Mya II on the monthly western cruises

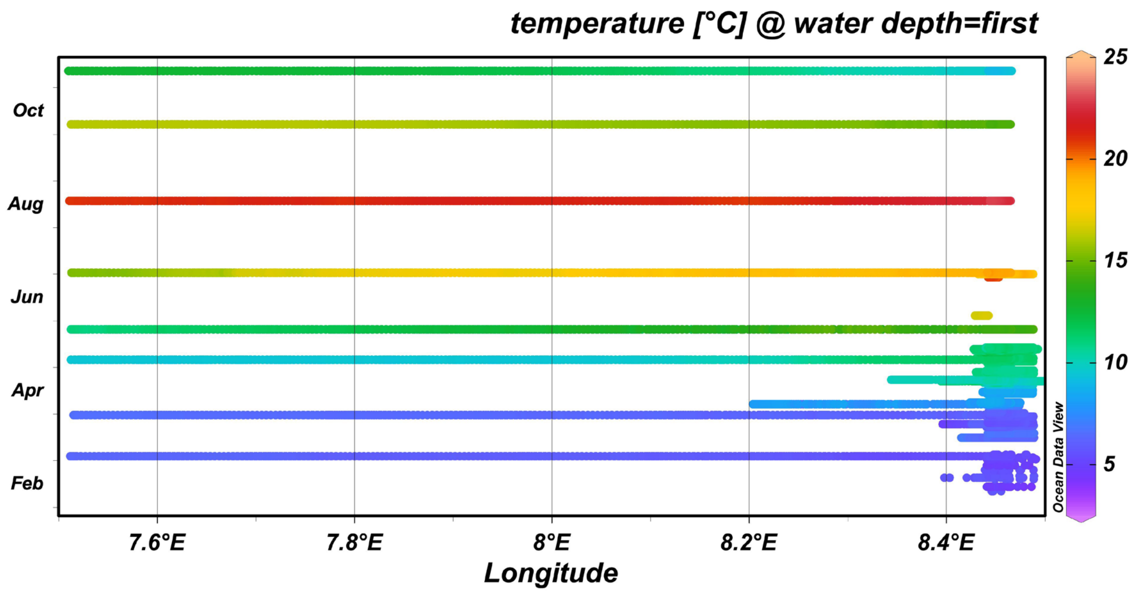


Fig. 3.2: Temperature profile in the surface waters during 2020

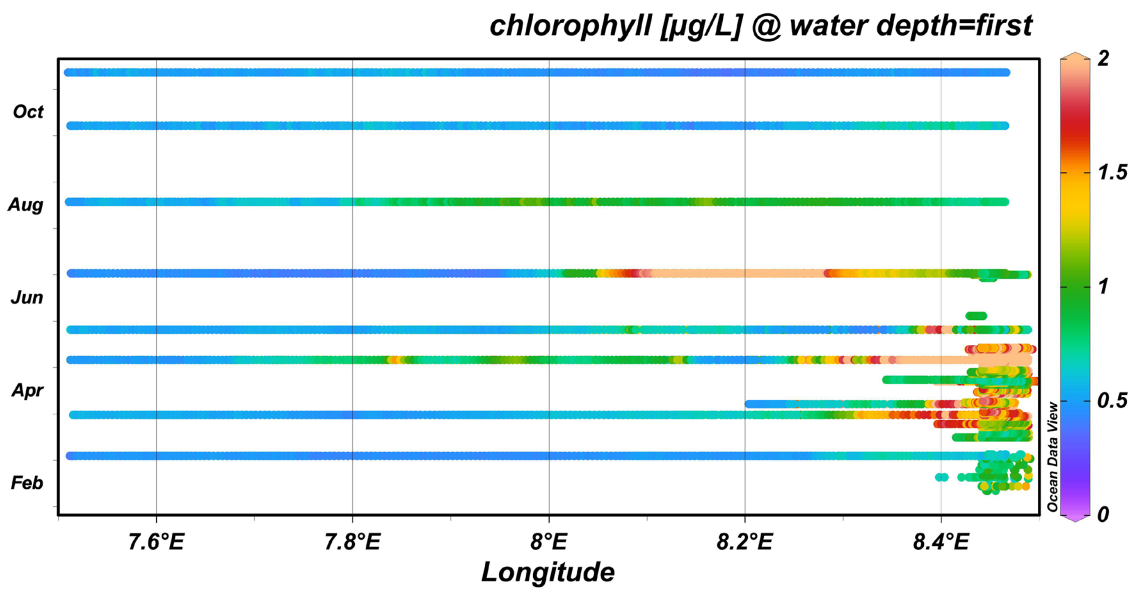


Fig. 3.3: Chlorophyll profile in the surface waters during 2020

4. BINNEN ELBE (4 – 12 AUGUST 2020)

Sven Bauth[1], Erik Evers[2] (not on board),
Heike Goretzka[1], Norbert Kamjunke[1], Ute Link[1]

[1]DE.UFZ
[2]DE.AWI

Objectives

The objective of the measurements in the freshwater part of the Elbe River was to test the hypothesis that hydrological extremes affect eutrophication, i.e., phytoplankton and nutrient dynamics, in rivers. In particular, drought conditions increase the travel time of water (time for algal growth) and underwater light intensity due to low water depth (enabling algal photosynthesis). As a consequence, we expect a longitudinal decrease of dissolved nutrients taken up by algae such as nitrate and phosphate. The growth of high algal biomass in the river might affect water quality in the estuary as the degradation of the algal bloom causes oxygen deficieny.

Work on the river

Sampling was performed using the research vessel *Albis* applying a Lagrangian approach, i.e., a sampling of nearly the same water body along the way downstream according to its travel time (Fig. 4.1 and 4.2). The cruise was performed between August 4 and August 12, 2020 under low discharge conditions: discharge at Magdeburg was 242 $m^3 s^{-1}$ which is around the mean low discharge (231 $m^3 s^{-1}$).

Water samples were taken at fixed stations which were investigated in previous years / cruises. These stations are located along the Elbe, mainly at bridges and at the outlet of tributaries. At these stations the left side, the middle and right side of the river were sampled. At each location the ship was anchored. Basic hydrographic parameters were measured using a YSI multiparameter probe at each station. Each evening water samples were picked up from colleagues and transported to the home laboratory (UFZ Magdeburg) for subsequent analyses.

Two ferries (in Westerhüsen and Werben) are crossing the Elbe several times per day. On these ferries two CTDs are installed and are measuring continuously the basic hydrographic parameters. The ferries and CTDs are in operation from April to October 2020.

At a pontoon in Teseperhude (near Geesthacht and the end of the cruise track) a CTD was installed measuring continuously during the cruise period. For comparison the *Albis* with its board-CTD measured simultaneously near this pontoon at the last cruise day (12 August 2020 at 15:50, see Tab. A.4.1).

In addition to the programme of the colleagues from Magdeburg, a PocketFerryBox and a LosGatos Analyzer were set up to continuously measure the basic hydrographic parameters and dissolved methane. PocketFerryBox and LosGatos Analyzer were pumping water from the “moon pool” of the *Albis*. Its volume was approx. 14.7 L with a flow rate of approx. 0.8 L/sec, thus the turnover time (V/f) was 19 sec. Due to Corona restrictions the student taking care of these instruments was not allowed on board and could only start and stop the instruments each day. Therefore, problems with the Ferrybox, i.e., the water pump was not running all the time, could not be detected.

In addition, a LICOR 7810 was installed on the upper deck to continuously measure atmospheric CO_2 and CH_4 concentrations.

Details on station list, the applied sensors and locations for data access can be found in Tab. A.4.1 and Tab. A.4.2.

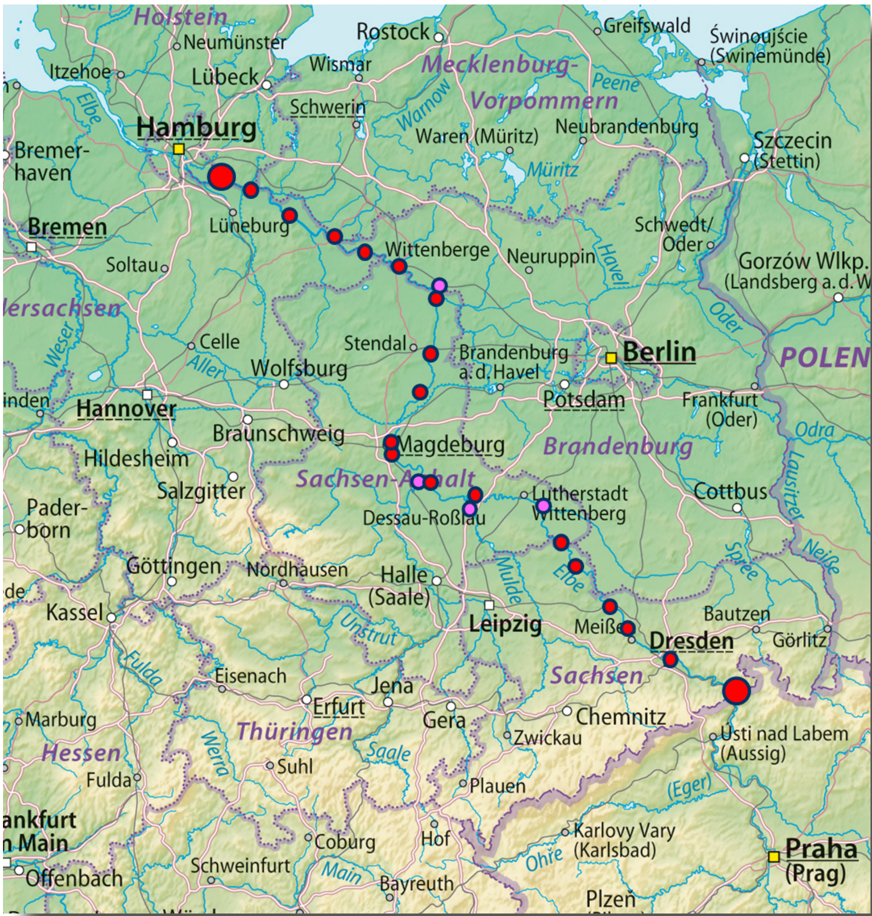


Fig. 4.1: Map of the Elbe sampling sites in Germany from Schmilka (Elbe km 4) towards Geesthacht (Elbe km 585)

Fig. 4.2: Albis on the Elbe in Magdeburg by N. Kamjunke

Preliminary results of Binnen Elbe

Water temperature increased along the river stretch from 21 °C near Schmilka to maximal temperatures of 27 °C at downstream sites. Chlorophyll-*a* concentration decreased slightly at the beginning, started to increase from km 200, and decreased at the end due to reduced flow velocity of the Elbe and subsequent sedimentation of phytoplankton. As a consequence of high photosynthesis, oxygen saturation and pH increased in the downstream part.

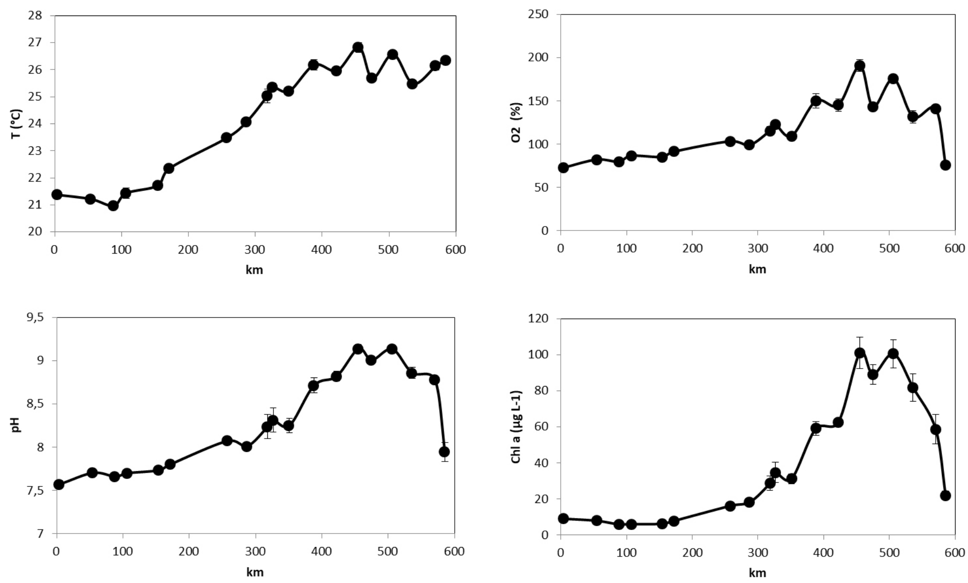


Fig. 4.3: Longitudinal probe measurements of water temperature, oxygen saturation, pH and chlorophyll a concentration. Measurements were not performed at identical times each day causing some diurnal fluctuations.

The comparison of probes at *Albis* and at the landing stage in Tesperhude showed a good agreement (Tab. 4.1).

Tab. 4.1: Comparison of probe measurements (EXO2) at Tesperhude (landing stage) with YSI probe at the Albis on 12.08.2020 15:50

	YSI *Albis*	**EXO2 landing stage**
T (°C)	26.56	26.67
O_2 (mg L-1)	7.27	7.56
O_2 (%)	90.3	95.3
Cond (µS cm-1)	1034	1039
pH	8.07	8.09
Turb (NTU)	3.85	4.46
Chl *a* (µg L-1)	20.72	20.53

Dissolved methane concentrations (Fig. 4.4) in the first third of the cruise ranged between 100 and 200 nM and increased towards Geesthacht to > 1,000 nM. Local hotspots of methane were detected near Dessau / Roßlau and in Magdeburg. Especially at Dessau a steep increase from <100 nM to >1,000 nM was observed. The tributary "Schwarze Elster" had methane concentrations twice as high as in the Elbe, the other tributaries "Saale" and "Havel" showed no difference or only slightly higher concentrations than in the Elbe (Erik Evers, Bachelor Thesis, University Braunschweig, 2020).

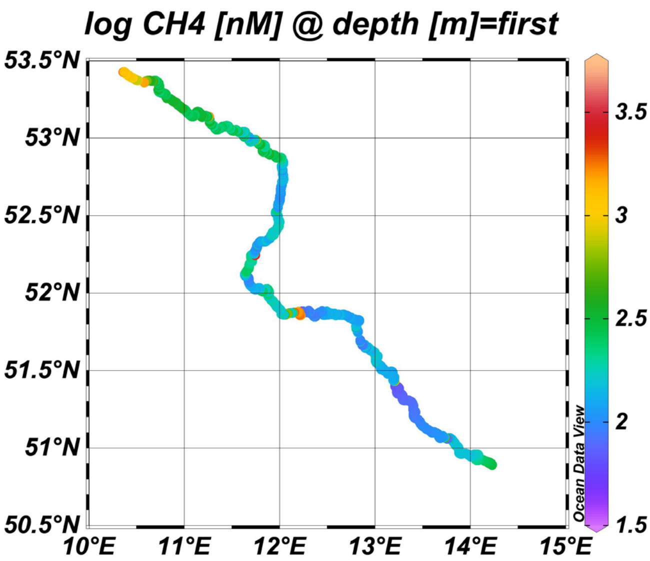


Fig. 4.4: Concentrations of dissolved methane along the Elbe, note the logarithmic scale

The LICOR-7810 Gas Analyzer is a high-precision, high-stability, laser-based gas analyzer that uses Optical Feedback—Cavity-Enhanced Absorption Spectroscopy (OF-CEAS) to measure gases in the air. It measures CH_4 with a precision of 0.6 ppb (1 sec averaging), CO_2 with 3.5 ppm precision, and H_20 with 45 ppm precision.

The device was installed on the ship deck using a tube of 2 m and a filter at the tube end. This tube length results in a time delay of 1s in the measurements and the measuring time was corrected according to the offset. The device measured the methane mole fraction in dry air (in ppb), the carbon dioxide mole fraction in dry air (ppm), and the water vapor concentration (ppm). All parameters were measured every second. The device does not have an integrated GPS Position system. Hence, the position data of the ship were merged with the GPS from the FerryBox using the UTC time. Also, outliers were selected and removed from the data. The $C0_2$ outlier range was defined to be 380 ppm <Outlier CO_2 <1,500 ppm and for CH_4, 1,700 ppb <Outlier CH_4 <15,000 ppb.

The measured data were loaded in the GIS system and are displayed in Fig. 4.5. Likewise, the temporal characteristic is shown in Fig. 4.6. It indicates some very pronounced CH_4 maximum between Rosslau und Aken (CH_4-1), a maximum during mooring at the Niegripper Verbindungskanal (CH_4-2), maximum near Wittenberge (CH_4-4) and maximum values between Lauenburg and Geesthacht (CH_4-4). Elevated CO_2 concentrations were found in an area between Rosslau and Aken (CO_2-1) and near Lauenburg (CO_2-1).

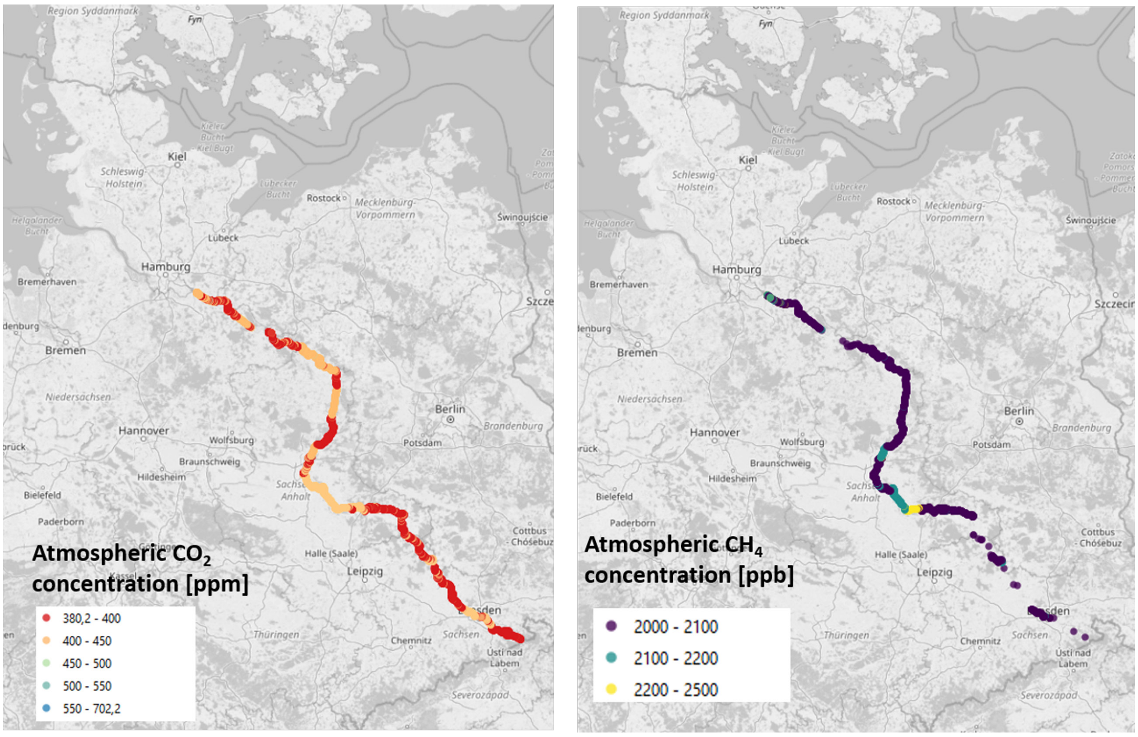


Fig. 4.5: Atmospheric gas concentrations along the Elbe track

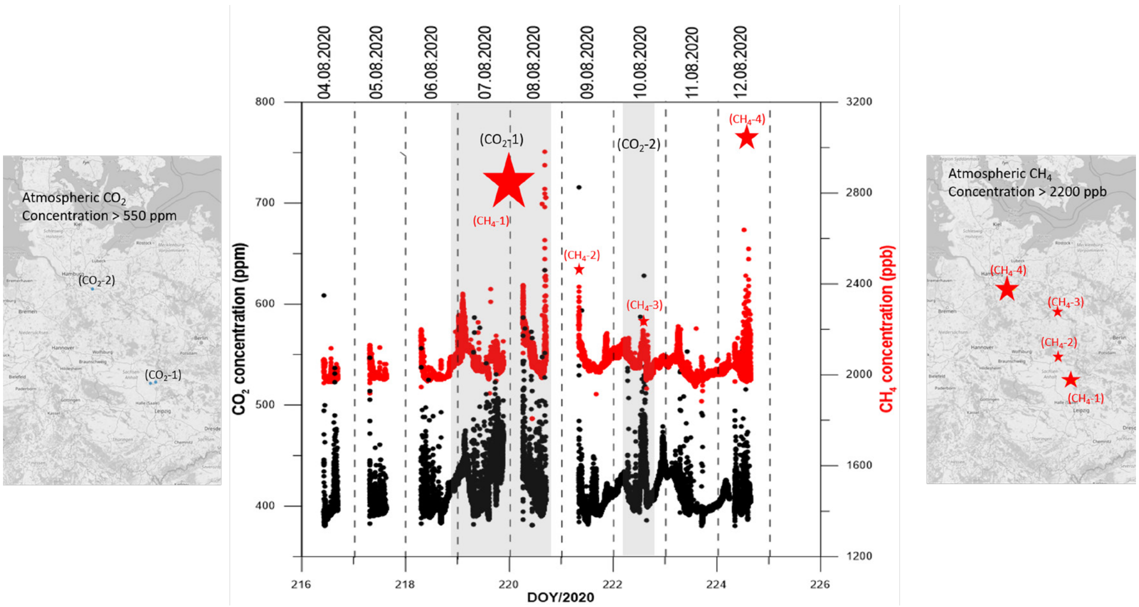


Fig. 4.6: Temporal variations of atmospheric gas concentrations along the Elbe track

5. TIDE ELBE (25 – 26 AUGUST 2020)

Objectives

Overall objective of the Tide Elbe cruise was to continue the measurements taken during the Binnen Elbe cruise and thus to close the gap between the freshwater measurements in the upper part of the Elbe river and the German Bight. The time frame for these measurements was determined by an average water transport time from Geesthacht to Cuxhaven, that depending on the prevailing conditions can be between one and six weeks due to the strong tidal influence. The cruise was designed to address two main topics:

- Gradient of measurement quantities between Geesthacht and Cuxhaven
- Determination of tidal influence

The chosen strategy for the gradient measurements was to sail against ebb tide, starting off Scharhörn, with a leg to Glückstadt on the first day, continuing to the weir in Geesthacht on the second day. In between the two legs a moored station over one complete tidal cycle would see to capture the dynamics of tidal flow in the measured quantities.

During the entire campaign the FerryBox on board *Ludwig Prandtl* would see for underway measurements, while water samples for nutrients, carbon cycle parameters, phyto- and zooplankton measurements, as well as pollutants were to be taken. As an additional benefit for the sampled quantities the same two-day cruise (without the tidal cycle measurements) were planned to be performed by the Bundesanstalt für Gewässerkunde.

Work at sea / on the river with *Ludwig Prandtl*

Holger Brix[2], Hannah Jebens[1], Louise Rewrie[2],
Hendrik Rust[2] – cruise legs;
Burkard Erbslöh[2], Götz Flöser[2], David Kaiser[2],
Anna Reese[2] - tidal cycle station

[1]DE.AWI,
[2]DE.HZG

As the Corona-related restrictions had been somewhat relaxed since the last (Stern_4) cruise, *Ludwig Prandtl* could this time be operated with two crew and four scientists. The cruise programme could therefore be conducted as planned.

Ludwig Prandtl arrived in Cuxhaven on Monday, August 24 around 18:30 UTC for final setup and installation, most work had been done before in Oortkaten. The setup in Cuxhaven on the day before the cruise was therefore limited in scope and could be done in short time.

On the first cruise day (August 25), Ludwig Prandtl left the Alte Fischereihafen in Cuxhaven at 04:59 UTC and took the first water samples off the island of Scharhörn. (Fig. 5.1). Two types of stations were performed: with stopping and sampling (stations numbers starting with "P"), and with taking samples from the FerryBox only (station numbers starting with "St"). The FerryBox (FB) showed a number of problems, such as a small leakage, malfunctioning of the GPS (solved by 07:50 UTC) and an issue with missing reagent for the pH measurements. At station P02 the FB had to be restarted due to CPU overload. Another issue arose with the atmospheric gas measurements, as due to a setup glitch the gas intake tube was inside the dry lab. This was fixed at 10:44 UTC. A total of seven “P” stations were occupied on the first day, plus thirteen “St” *stations*. The original plan of arriving in Glückstadt at approx. 11:00 UTC had to be revised due to the strong ebb flow (cruising speeds at time were only 6 km/h). Even with one cancelled station, arrival in Glückstadt was only at 13:05 UTC.

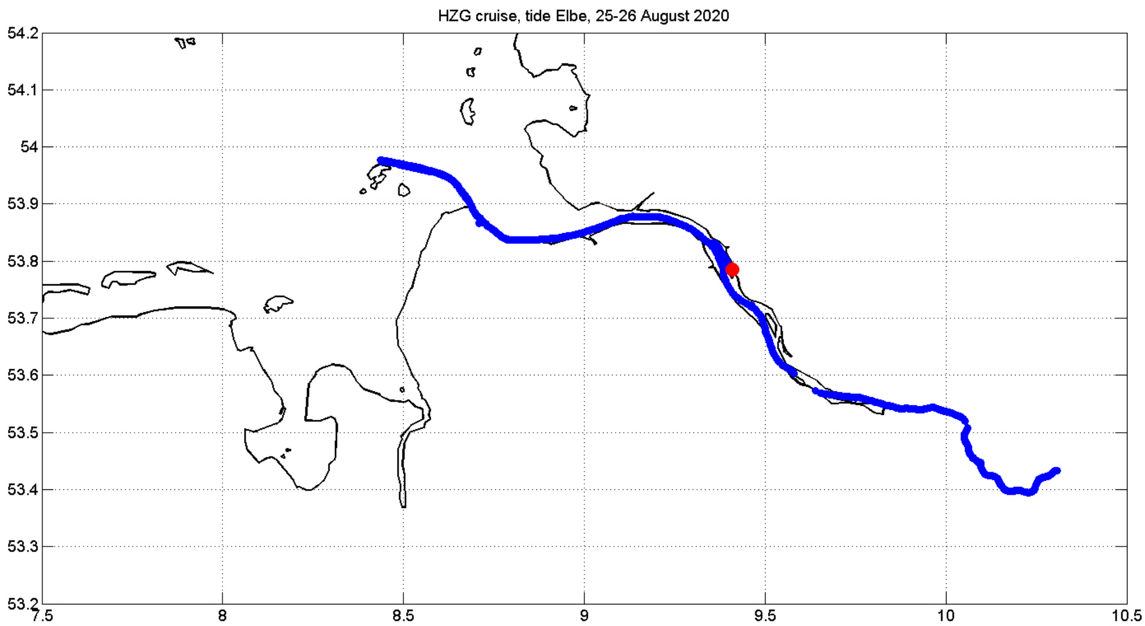


Fig. 5.1: Cruise track of the Tide Elbe campaign. The tidal cycle station near Glückstadt is depicted in red.

In Glückstadt, the crew changed for the first shift of the overnight station covering the complete tidal cycle. In addition, an NDR TV crew joined for some footage of our measurement activities. We left Glückstadt at 13:15 UTC and arrived at the overnight anchor station at 13:23 UTC. After the termination of the TV shooting at approx. 14:40 UTC, the film crew was brought back to Glückstadt via dinghy. At the anchor station (Fig. 5.2) measurements were taken every hour (total of thirteen stations). A change of crew happened between 18:00 and 20:00 UTC (again via dinghy). During the night shift the GoFlow device (for taking water samples for pollutant measurements) broke. As a work around water samples were hauled up from approx. 2 m depth without a lid. This technique was also used during day two of the cruise.

Ludwig Prandtl returned to Glückstadt harbour briefly after 05:00 UTC on August 26 (Fig. 5.2). Departure from Glückstadt was 06:33 UTC (again with the crew from the first day). Licor was restarted at 06:34 (crew had shut it off due to a noise issue during the night). The FerryBox crashed between station St18 and St19, therefore at St19 no water samples were taken from the FB. Arrival in Hamburg-Holthusenkai at 12:09 UTC, waiting for the water level to drop sufficiently to allow *Ludwig Prandtl* to pass under the Elb bridges. Departure 13:15 UTC, arrival Oortkaten 14:25 UTC, change of captain (different permit required upstream of Oortkaten), departure 14:28. The point closest to Geesthacht with the last station off Altengamme was reached at 16:04 UTC with return to Oortkaten (end of trip) at 17:17 UTC. A total of seven “P” and thirteen “St” stations were occupied.

Weather during the cruise was fine for departure in Cuxhaven and arrival in Geesthacht / Oortkaten. In between, the situation was determined by a passing storm with heavy wind and, in parts, heavy rain.

The filters of the degasser for online measuring of dissolved methane got clogged due to very turbid water. Therefore, no data are available for 26 August. Thus, we decided to take water samples along the cruise track. However, due to an error all water samples that were to be probed for methane were frozen over the following weekend and could therefore not be analyzed.

Details on the station list, the sensors used and locations for data access can be found in Tab. A.5.1 and Tab. A.5.2.

Fig. 5.2: Ludwig Prandtl at anchor station near Glückstadt (left) and approaching downtown Hamburg (right) by H. Brix

Preliminary results of "Tide Elbe"

Our measurements show a distinct increase in water temperature from the Elbe estuary (20°C) until the confluence of Norder- and Süder-Elbe in Hamburg (23°C) at approximately 10°E (Fig. 5.3). The effect of the overnight rains in Glückstadt (at 9.4°E) with an associated temperature drop can be clearly seen. It is also not surprising that the temperature readings from the Binnen Elbe campaign in Geesthacht (27°C) deviate from the Tide Elbe measurements (21°C) as almost two weeks had passed since these measurements.

With regard to salinity the along-Elbe part of the cruise clearly shows the expected decrease in salinity from the estuary (30 psu) and the strongly developed gradient leading to values under 3 psu in Glückstadt. The time-series of the tidal cycle measurements near Glückstadt depict the variation in salinity caused by the tidally driven change of water mass influence with a maximum influence of the saline North Sea water shortly after high tide (18:22 UTC).

Oxygen saturation (Fig. 5.4) and pH (not depicted) show their most distinctive features with minima for both in the Hamburg area (centered at about 10°E). Oxygen saturation there lies below 50 % and the pH drops to almost 7. This "Hamburg signal" is also reflected in the dissolved inorganic carbon (DIC) concentrations in Fig. 5.5. The relationship between DIC and salinity (Fig. 5.5) shows distinctly different behaviours for the low and high salinity portions of the cruise.

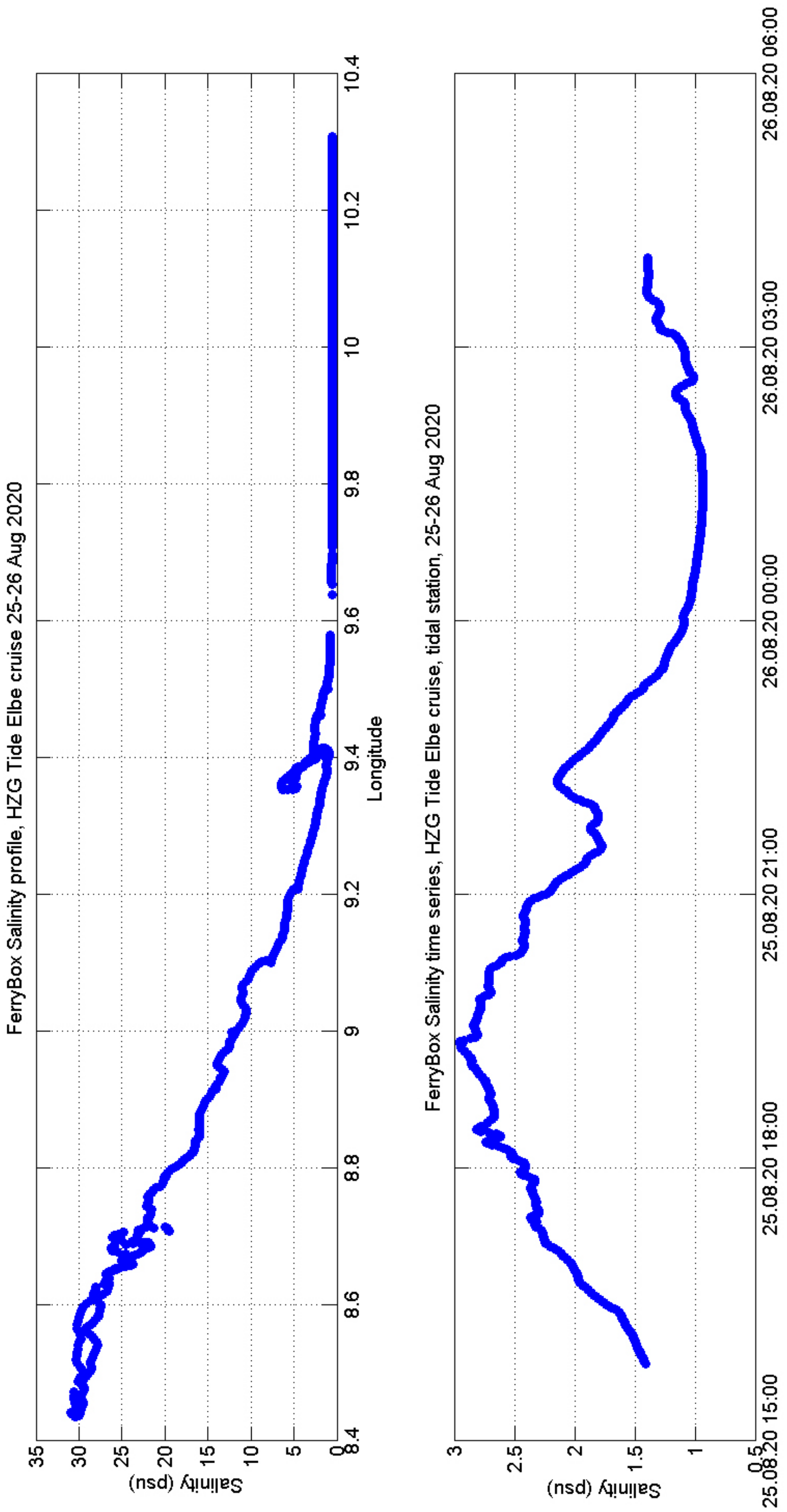


Fig.5.3: Salinity plotted against longitude (for the along-Elbe part of the cruise) and against time (for the tidal station near Glückstadt), respectively

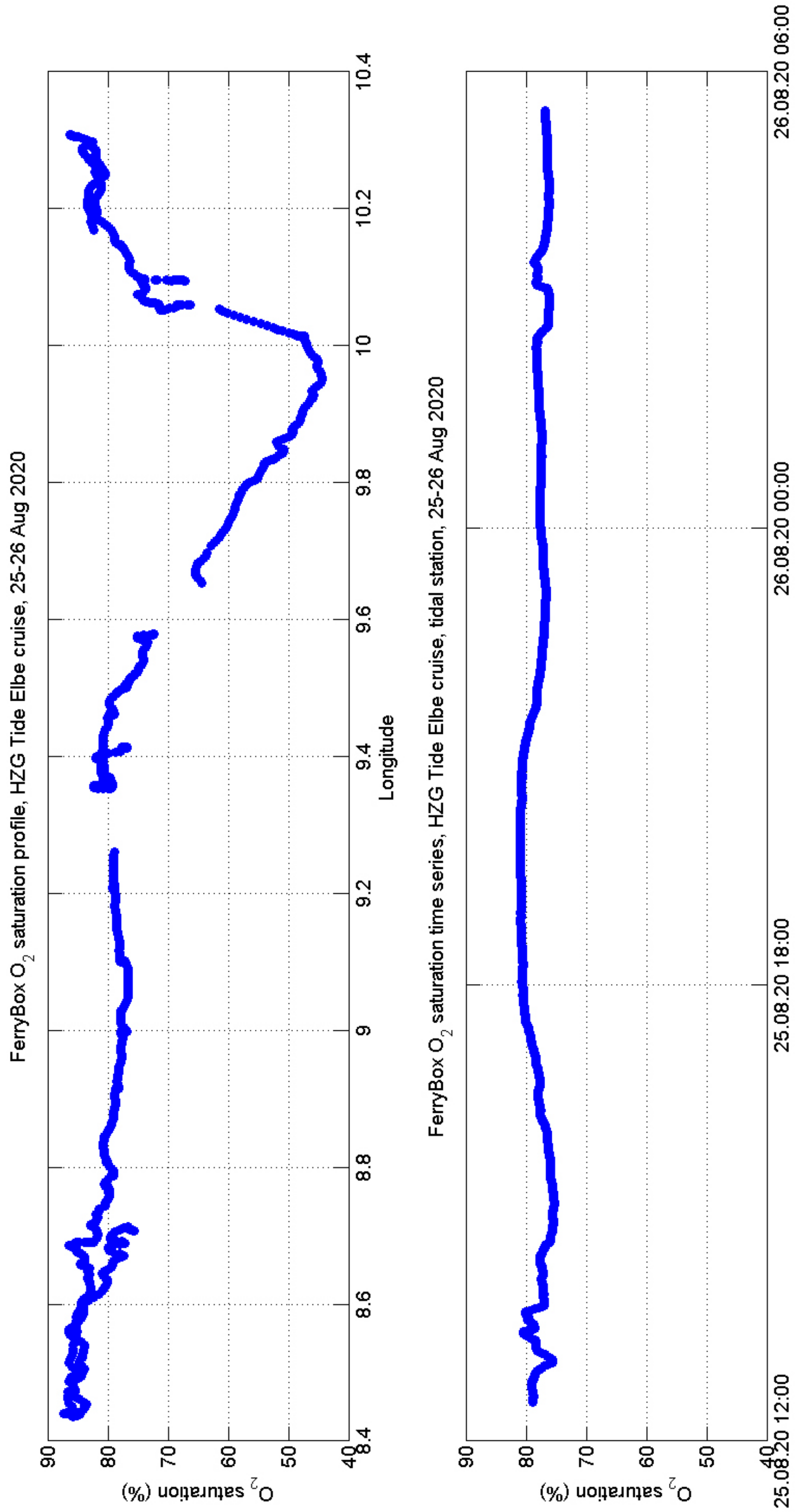


Fig. 5.4: Oxygen saturation plotted against longitude (for the along-Elbe part of the cruise) and against time (for the tidal station near Glückstadt), respectively

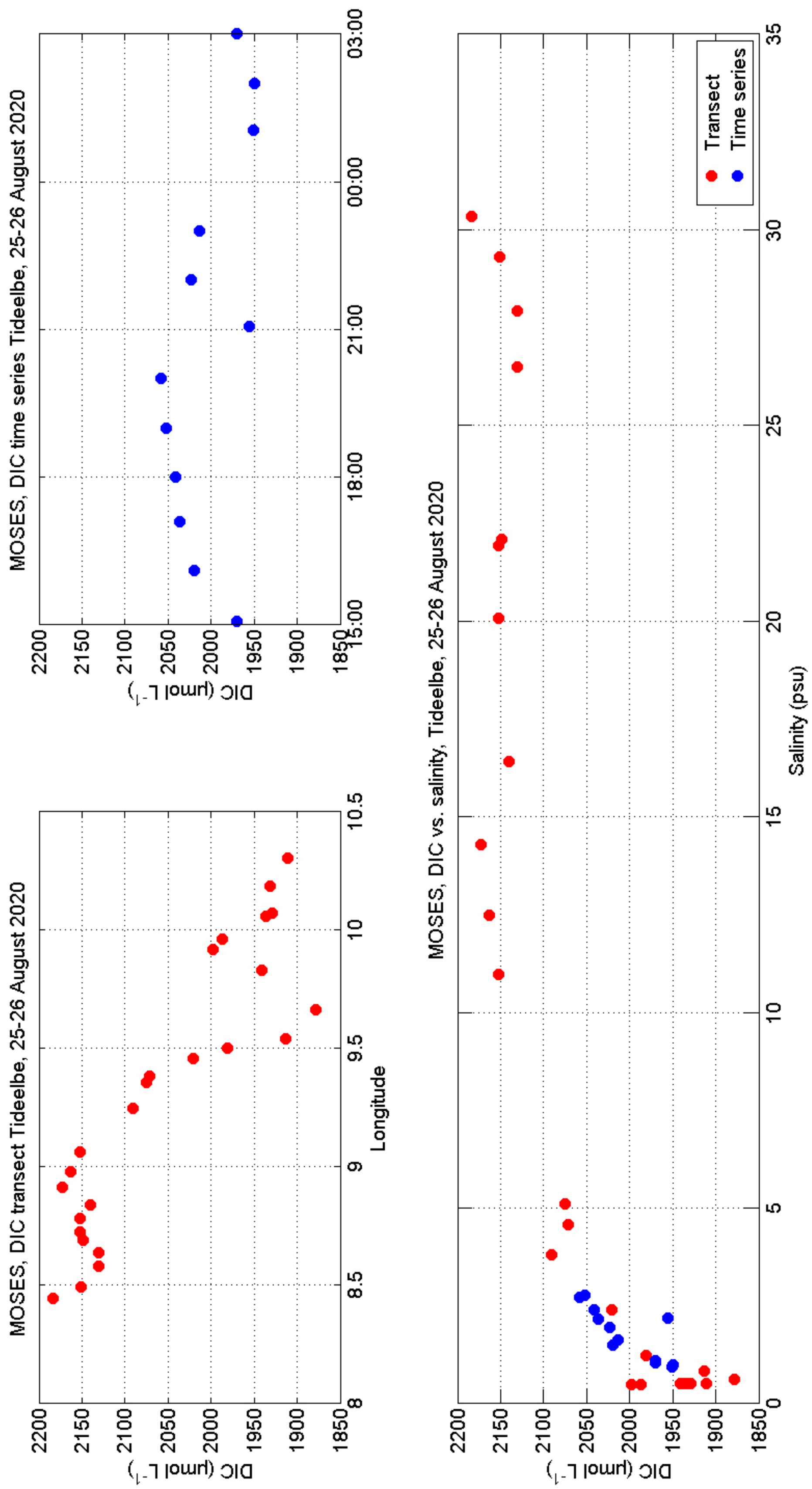


Fig. 5.5: Concentrations of dissolved inorganic carbon (DIC) for (top left) the cruise from the Elbe estuary to Geesthacht and (top right) for the occupation of the tidal cycle station near Glückstadt. The lower plot depicts DIC vs. salinity for both cruise parts.

6. STERNFAHRT_5 (31 AUGUST – 3 SEPTEMBER 2020)

Objectives

After following the same water mass during the preceding cruises, the North Sea portion of the campaign was aiming at detecting: the spatial extension of the riverine influence of Elbe and Weser and therefore aimed to cover a large area with three vessels (Fig. 6.1, Fig. 6.2) and four cruise days. The investigated area can be expanded making use of the northern transects of *Mya II* (see chapter 3). Using the spatial coverage of this cruise would also allow us to verify the spatial and temporal persistence of the dissolved and atmospheric methane (and CO_2) distributions observed in Sternfahrt 2 and 3. In addition, we wanted to establish a communication network between the ships, the lighthouse on Heligoland, a motor glider and the internet. The three vessels should then act as a sensor swarm. To characterize the depth distribution of our main parameters, we also tested profiling *in-situ* pumps. In contrast to the previous cruises, a stronger effort was made to investigate the different compounds of the carbon cycle by additional water sampling in the whole area.

Fig. 6.1: All three research vessels in the south port of Heligoland on 01.09.2020 by P. Fischer

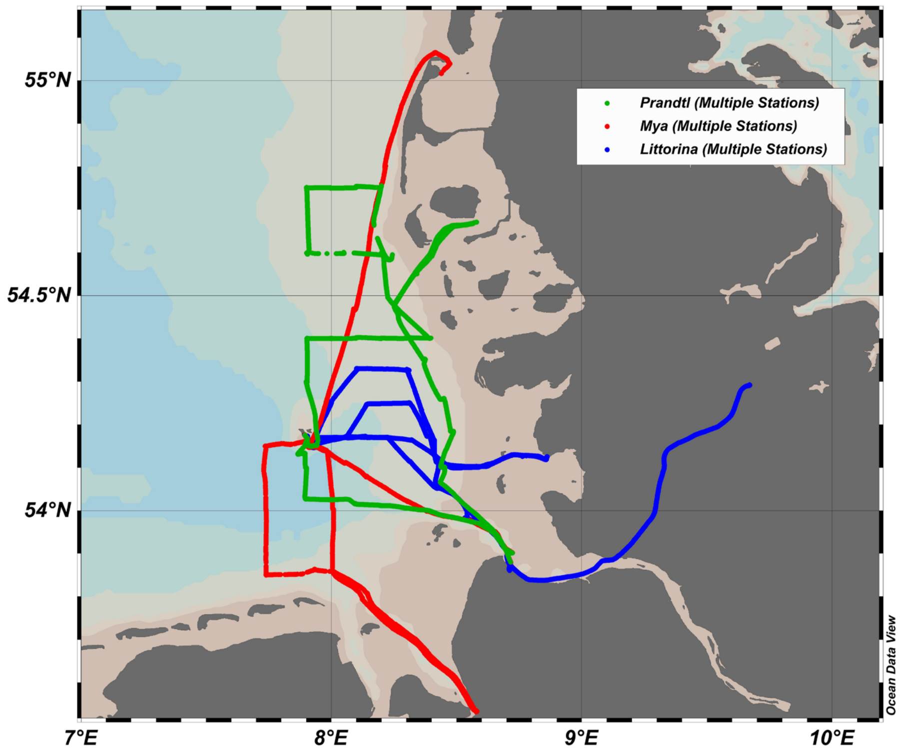


Fig. 6.2: Cruise track of Littorina (blue), Ludwig Prandtl (green) and Mya II (red) on Sternfahrt_5

Work at sea with *Littorina*

Mahmoud Altahan[3], Erik Evers[1],
Felix Geißler[3]

[1]DE.AWI
[3]DE.Geomar

The *Littorina* cruise L16-20 (Sternfahrt_5) was conducted as a joint suey of the German Bight with the research vessels *Mya II* (DE.AWI) and *Ludwig Prandtl* (HZG) (Fig. 6.3). Onboard *Littorina* oceanographic real-time data in the outflow region of the Elbe River between Cuxhaven, Heligoland and Büsum were collected. For this purpose, a suite of sensors (e.g. CTDs, Methane, Nitrate, pCO_2, pH) was placed in a 200 L tank on deck, which was continuously supplied with surface water (from 3 m depth) from the underway water supply of *Littorina* during transects. The flow rate was set to about 100 L/min allowing for fast exchange of the entire water volume inside the box. Although the fast water exchange, the turnover time of two minutes should be considered when processing the data. The analyzers “LosGatos” and “Picarro” were set up for continuous measurements of methane and CO_2 in the surface water and in the atmosphere, respectively. A lab based FerryBox system for measuring physical and chemical oceanographic parameters was supplied with surface water from the underway water supply during transects. Eight vertical CTD casts were performed each day, evenly distributed along the track. At those stations the water supply for LosGatos and the FerryBox was switched from underway to an *in-situ* pump, which was attached to the CTD rosette. The *in-situ* pump, supplied both devices with surface and deep water (max 18 m), for at least three minutes each. Additionally, discrete samples were taken from the onboard underway water supply in order to verify the sensor data. For collecting discrete samples an aquarium pump was submerged into the 200 L tank supplying the underway water via a ~ 3 m silicone hose into the laboratory, where samples were taken (Fig. 6.4).

Fig. 6.3: Littorina and Ludwig Prandtl as seen from Mya II, by I. Bussmann

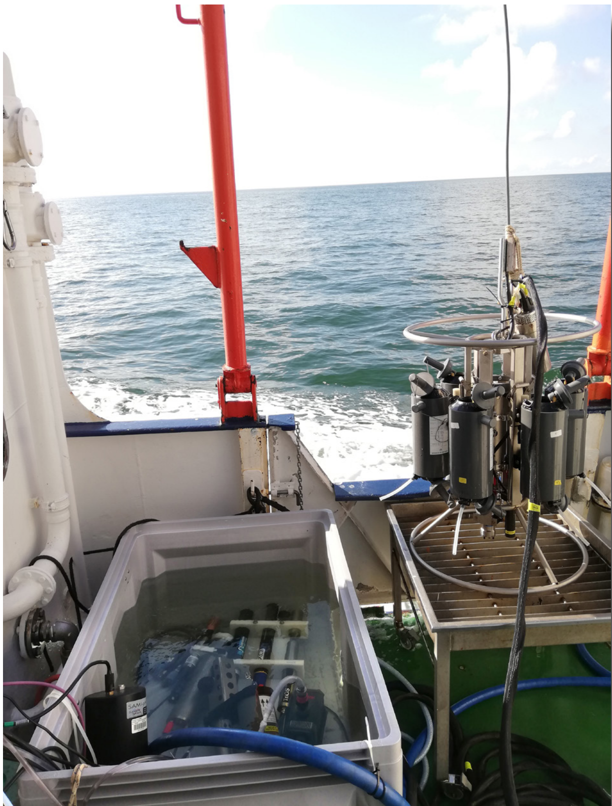


Fig. 6.4: Sensor setup deployed on Littorina

right: CTD rosette with in-situ pump for vertical profiles at station

bottom left: 200 L tank fed with water from the underway supply (blue hose), constant water level was adjusted with an outflow valve on the bottom back side, submerged biogeochemical sensors for underway measurements and aquarium pump for taking discrete samples.
By F. Geissler

Two scientists started from Kiel on August 30, 2020 at 05:00 h (UTC) heading to Cuxhaven via the Nord-Ostsee-Kanal. The transit was used to set up the instruments and the water basin for continuous real-time measurements of the surface water. After arrival in Cuxhaven at 13:30 h (UTC) the third scientific crew member from AWI joined the group and equipment from AWI, including the FerryBox, LosGatos and the *in-situ* pump, was lifted on board. Due to COVID-19 restrictions the installation of the FerryBox, Los Gatos system and *in-situ* pump had to be conducted via remote guidance from the pier as no others than the scientific crew and the ship's crew members were allowed to enter the vessel. Additionally, a Kongsberg MBR IT antenna was successfully installed on the compass bridge of *Littorina* in order to set up a network system which allows fast data transfer and communication between the participating vessels. This antenna was connected via Ethernet to a central computer placed in the laboratory. An internal network was configured in order to have full control of the Picarro and the FerryBox instruments from the central computer via remote desktop connections and to share a live screen via Team Viewer to the other two ships which were also members of the Kongsberg antenna network.

On August 31, 2020 the *Littorina* sailed from Cuxhaven to Heligoland. Despite rough sea conditions all eight CTD stations, including a joint station with *Mya II* and *Ludwig Prandtl* off Cuxhaven, were successfully conducted. The purpose of the joint station was the intercalibration of the onboard sensor systems of the participating research vessels. At calm sea conditions the *Littorina* sailed on September 01 and 02, 2020 from Heligoland to Büsum, and back to Heligoland, respectively (on different routes), including another joint station on the morning of September 01, 2020 off Heligoland with *Mya II* and *Ludwig Prandtl*. On September 03, 2020 the *Littorina* was heading towards Cuxhaven. At the last station off Cuxhaven the *Littorina* was waiting for the *Ludwig Prandtl* to conduct another joint intercalibration station. After arrival in Cuxhaven at 13:15 h (UTC) LosGatos and the IT antenna were packed for unloading and one scientist disembarked. The *Littorina* was then heading towards Rendsburg for an overnight stay and reached Kiel on the morning of September 04, 2020 at 09:00 h (UTC).

The water for the PocketFerryBox and LosGatos was sucked in from the "tower". The "tower" was continuously supplied with surface water from the ship's water supply. On stations, this board water supply was switched off and the "tower" was filled by the *in-situ* pump which was lowered manually to the desired depths. Water samples for methane analysis were taken from overflow of the tower filling a bucket.

Details on the station list, the sensors used and locations for data access can be found in Table A.6.2 and Table A.6.3.

Work at sea with *Ludwig Prandtl*

Holger Brix[2], Brieuc Crénan[2], Götz Flöser[2], Hannah Jebens[1]

[1]DE.AWI, [2]DE.HZG

This cruise was basically the continuation of the Tide Elbe cruise for *Ludwig Prandtl*. As for the other cruise, the Corona-related restrictions allowed for operations with two crew and four scientists. The cruise programme could therefore be conducted as planned.

Ludwig Prandtl arrived in Cuxhaven on Sunday, August 30 for final setup and installation, most work had been done before in Oortkaten. The antenna system could not be tested as they were not powered up on all installations.

On the first cruise day (Aug 31), the *Ludwig Prandtl* left Cuxhaven at 06:31 UTC with a first intercomparison station (P01) at “Tonne 32”. The *in-situ* pump did not work due to an issue with the power supply unit. At station P5 the winch malfunctioned (problem with the winding of the cable on the spool); therefore, CTD operations had to stop and the pump was deinstalled. At stations P4 and P5 issues with the driver program of the profiler. The big pH unit in the FerryBox did not work due to problems with the reagents. Before turning into Heligoland there was an approx. one hour stop at “Tiefes Loch” to repair the winch (successfully). Arrival in Heligoland was at 14:58 UTC. A total of 8 stations were covered on the first day.

On the second cruise day (Sep 01), we left Heligoland at 06:15 UTC, had another intercalibration station (P09) for 20 minutes. The issues with the pump had been fixed as we had received a different power supply unit from AWI. The pump throughflow was determined to be about 10.5 litres per minute. At station *P10* problems with switching the pump from the regular FB supply to the hose with the pump arose, which could be fixed before the next station. A total of nine stations (P09 - P17) were occupied. Arrival in Wyk auf Föhr at 16:20 UTC.

As Wyk harbour was not dredged properly and *Ludwig Prandtl* was lying in the mud during low tide the departure time for the next morning (Sep 02) had to be changed to very early hours and the measurement programme had to be adapted to a shorter cruise day: the Northbound leg was performed further east than planned and the Eastbound leg further to the south. Departure in Wyk was at 03:54 UTC. The FB system could not be started immediately after departure as there was too much mud in the system, which had to be flushed for several minutes. On station *P18* we lost the KBA bottle for the pollutant measurements. Fortunately, a replacement could be furnished from spare parts (thanks, Detlev!). Close to P20 the FB system crashed and had to be restarted at P20 with the pump system (afterward switch to underway system). Around P21 the FB GPS was malfunctioning – could be restored. On the return to Wyk station *P18* was repeated (P18a) to take the sample for the lost KBA bottle. A total of eight stations was occupied (P18 - P25). Arrival in Wyk at 15:30 UTC.

Day four (Sep 03) saw us leaving Wyk at 04:24 UTC. The atmospheric measurements that were supposed to run overnight were unplugged by the crew for noise reasons. A drifter was released at 11:30 UTC. Eight stations were occupied with the last one (P32) being a rendezvous and intercalibration station with Litorina. At this very station a problem arose with *Ludwig Prandtl*’s side steering stand and capability, so that the captain decided not to go into Cuxhaven as planned but continued back to Oortkaten. We reached Hamburg-Holthusenkai at 18:35 UTC, where we managed to unload the samples that urgently needed to go to Geesthacht, while the rest of the equipment was picked up the next day in Oortkaten.

Weather on the cruise was fair to sunny, with the exception of day four when a low-pressure system brought some winds and rain.

Water samples were taken from the FerryBox outlet. After sampling for surface water, the water supply for the FerryBox was switched to vertical sampling with the in-situ pump. The *in-situ* pump with attached hose, a CTD and a Niskin water sampler were lowered by wire to the maximal depth. The waterflow of the *in-situ* pump was 10.5 L/min. Afterwards the water supply was switched back to the standard water supply of the FerryBox.

The LICOR-7810 Gas Analyzer was set up as described in Chapter 4. The measured data were loaded in the GIS system and are displayed in. Likewise, the temporal characteristic is shown (Fig. 6.5). It indicates a very pronounced maximum near the island of Amrum.

Details on the station list, the sensors used and locations for data access can be found in Table A.6.5 and Table A.6.6.

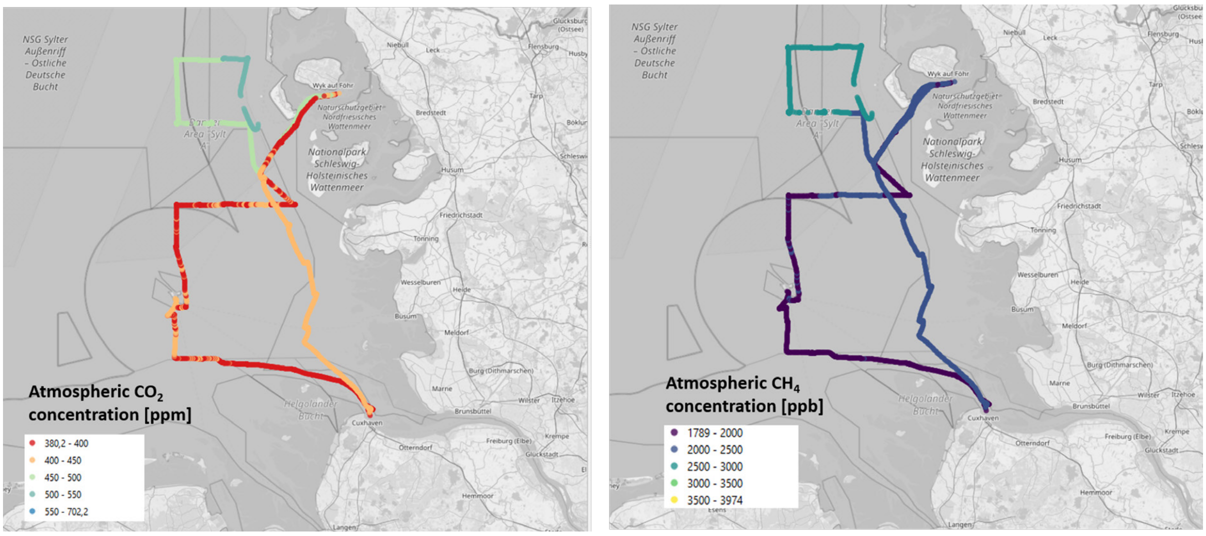


Fig. 6.5: Atmospheric gas concentrations

Work at sea with *Mya II*

Norbert Anselm[1], Ingeborg Bussmann[1], Philipp Fischer[1], Madlen Friedrich[1], Lena Blum[1]

[1]DE.AWI

On Saturday 29 August the scientists could start to set up their instruments on board of *Mya II*. The set up of the communication antenna required some rewiring from the top deck to the bridge. The installation of the pressurized MOSES pump system for intermittent vertical profiling sampling among the routine underway sampling with the ship FerryBox system was not easy and required some bypass tubing of the ships FerryBox water circuit. But with the active support of the crew everything was arranged to their and the scientists satisfaction (Fig.6.6). The communication antenna and atmospheric methane suction hose were located on the *Mya II*'s top deck, approximately 4.5 m above the water surface.

On 31 August the *Mya II* left Cuxhaven (Fig. 6.7) with the other research vessels for a first intercalibration station at “Tonne 32”. There, the vertical profiling pump was lowered to 1 m water depth and ran for 3 minutes to rinse the system. The pump was then slowly lowered to the maximum hose length (25 m) or to about 1 m above ground whatever came first (Fig. 6.8). There, the system remained for 3 minutes. A pressure sensor attached to the vertical profiling pump to record the exact depths. For calibration of the depth measurements, an air pressure sensor was mounted on board, which continuously recorded the air pressure. After the vertical profiling pump was back on board, water samples were taken on the port side with a Niskin bottle. Altogether, eight stations were sampled evenly distributed along the cruise track from Cuxhaven to Heligoland where we arrived at approx. 14:00 UTC.

On the second cruise day (Sep 01), we left Heligoland at 06:15 UTC and had met with the other ships for another intercalibration station at the 50 m station off Heligoland. The *Mya II* then headed for Bremerhaven with another eight stations on the way. The lock at Handelshafen was entered around 19:00 hours and the ship stayed at the port near AWI overnight.

On the third cruise day (Sep 02) we headed back to Heligoland but on a more westerly way (Fig. 6.2). With fair and calm weather, the East Frisian islands were clearly visible.

On the fourth cruise day (Sep 03), two scientists stayed on Heligoland and returned to Cuxhaven in the afternoon by the passenger ferry. With one scientist and a student helper on board, the *Mya II* set off for Sylt to cover the northern part of our research area. On this last day, the wind increased together with rain showers. The *Mya II* reached the home port at Sylt around 14:00 UTC and started unloading. However, there were problems with the rental car, thus the scientist could only leave at 16:00 UTC to catch the ferry to Rømø. After an overnight stay in Neumünster we arrived in Bremerhaven the following day.

Details on the station list, the sensors used and locations for data access can be found in Table A.6.7, Table A.6.8 and Table A.6.9.

Fig. 6.6: Setting up the laboratory on Mya II by M. Friedrich

Fig. 6.7: Mya II leaving the lock in Cuxhaven by M. Friedrich

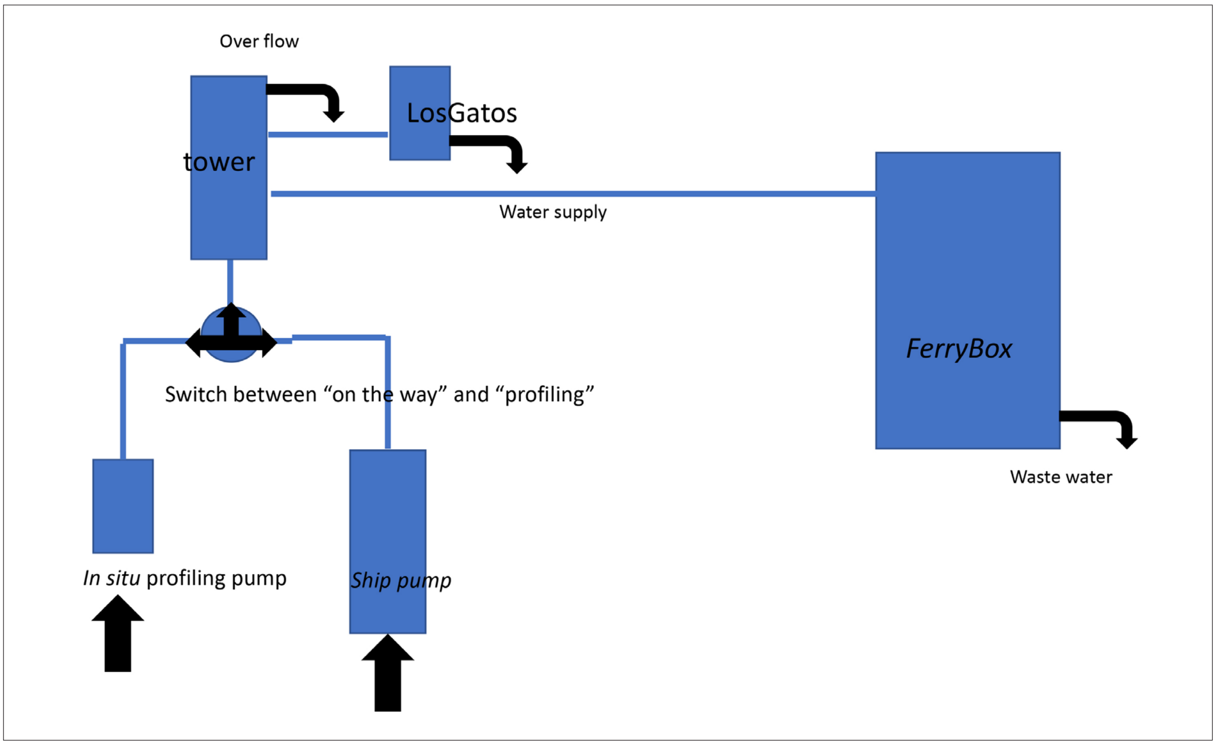


Fig. 6.8: Water supply on Mya II for Ferrybox and LosGatos for underway and vertical profiles during Stern_5

Aerial surveys with a motor glider

In addition to the ship-based investigations we attempted to include an aerial survey with the motor glider "Stemme S10VTX D-KNFH" from the Fachhochschule Aachen, operated by Henning Burmester from HZG. The motor glider was equipped with infrared and thermal imaging cameras. The concept was to try to use the data gathered in the air and see if an online transmission of images through our communication system was viable. The operation of the motor glider was planned for the first two days of the campaign. Beyond strong limitations regarding the allowed flight paths due to extensive official no-fly zones in our area of operation, the issues that hampered ship-to-ship communication did also not allow to get in contact with the motor glider. The data gathered on the glider transects will be analyzed after the campaign.

Communication, IT and Data Management

Besides each vessel's standard communication systems, a marine broadcasting radio system (MBR) was installed to make a local area network (LAN) available between the three vessels. The MBR consisted of one antenna per ship and a land-based antenna (lighthouse at Heligoland) connected to an LTE-modem serving as a gateway.

Aboard *Mya II* the vessel's network was facilitated to access and transfer data. A central storage and service PC (Raspberry Pi v4) was used as network share (smb/cifs). Each device aboard had its own supervised folder to save raw data to the service PC. Frequently these data were processed and ingested to the "observation to archive" (O2A) process chain (if applicable). Some devices could not be facilitated in that manner. The picarro_awi_cfads2156 (https://hdl.handle.net/10013/sensor.435a9f82-ab9a-47c2-94e5-f197c6126170) was: i) not attached to the network, and ii) the time shift between sensor and inlet of the hose was not estimated. The losgatos_awi_1303 (https://hdl.handle.net/10013/sensor.9fd3386a-6c1a-4775-bcbb-cc5d50e27494) also had the issue regarding time shift and additional the IT section had no virtual access to the device. The several data loggers owned by UFZ and operated by AWI needed to be read-out manually. After on-the-fly correction the measuring data could be placed in the respective folder. The FerryBox fb_741202 (https://hdl.handle.net/10013/sensor.1cde5be5-4783-4252-87d2-cf29cd1f7b80) was ingested to O2A in near-real time as far as network was available. The temporal aggregation was minute values. During the cruise the logging interval was set to maximum values per sensor, thus every ten minutes raw data ranging from approximately 8 Hz to 0.5 Hz are available for that device.

The MBR system in principle was functional. Nonetheless, several drawbacks in comparison to the MOSES Sternfahrt_4 occurred:

At no time the goal to have a ship-to-ship communication (chat > voice > video) was successful. Recurring network problems – either on board or at the land-based station – led to no direct data exchange. Furthermore, the approach to grant access to Oliver Listing's FB2ODV-Script (live plot per FerryBox) failed due to various reasons: i) password-less shared-folders are technically prohibited at HZG ii) most time of the second day there were extended network issues iii) caused by the technical limitations and the modified workflow *Mya II* FerryBox data was not obtained from LAN, but from ingested data in O2A.

It turned out that the MBR system in its current configuration is a peer-to-peer network, but not a meshed-network. Hence, 'visibility' and availability of data is not necessarily guaranteed in most parts of the German Bight between the vessels.

Nonetheless, the fundamental procedures and workflows remain unaltered. A permanent working group formed in order to agree on technical procedures and to specify workflows for the operational phase of MOSES.

Preliminary results of Stern_5

We wanted to detect the spatial extension of the riverine influence of Elbe and Weser and therefore aimed to cover a large area with three vessels and four cruise days. The investigated area will be connected to the northern transects of *Mya II* (see chapter 3).

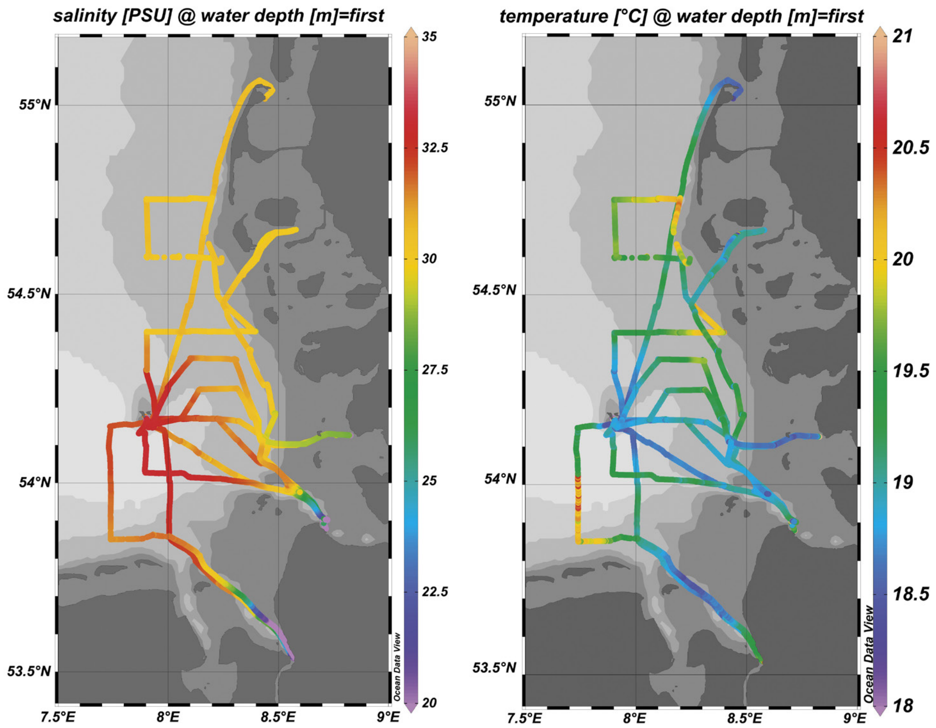


Fig. 6.9: Temperature and salinity of surface water in the study area

With three research vessels measuring for 4 days we covered a wide coastal area, from 7.7°E to 8.7°E and from 53.4°N to 55.1°N. Figure 6.9 shows the surface distribution of temperature and salinity. The areas with higher salinity were detected around Heligoland and towards the west, while the areas of reduced salinity (around 30) extended more towards the North. This indicates that the river plumes from Elbe and Weser mainly flow along the west coast of Schleswig-Holstein. The temperature distribution was rather uniform, however with unexpected warm water north of the Frisian islands and east from Amrum.

In addition, we tested also profiling *in-situ* pumps to observe the depth distribution of our main parameters. At the beginning of the cruise we had some issues with the power supply for the pumps. The pumps worked successfully on *Littorina* and *Mya II*. On *Ludwig Prandtl* the water flow between *in-situ* pump and FerryBox did not work on the first day due to issues with the pump's power supply unit. After replacing the unit with one from AWI Heligoland on the evening of the first day, the pump worked reliably for the rest of the cruise. On *Littorina* and *Ludwig Prandtl* an additional CTD measured in parallel to the instruments attached to the *in-situ* pumps.

In Figure 6.10 an example of the application of the *in-situ* pumps on *Littorina* and *Mya II* is given. The *in-situ* pump was lowered to approx 1 m water depth and stayed there for 5 minutes, then the pump was lowered to the maximal tube length of approx. 20 m depth, stayed there for another 5 minutes and recovered. The timing was the same on *Mya II* and *Littorina*. The water temperature of the FerryBox *Mya II* remained stable during the whole procedure. The water temperature of the FerryBox *Littorina* showed a clear shift of 0.2°C when switching the water supply from "on the way" to "*in-situ* pump". The temperature sensor of the water level logger seemed to have a long hysteresis; at the end of the surface phase it showed a temperature of 18.50 °C versus 18.47 °C at the end of the bottom phase.

Unfortunately, the water column was well mixed at all stations and no stratification or difference between surface and bottoms water could be observed (Fig. 6.11). Also, the profiles of dissolved methane showed no depth profiles.

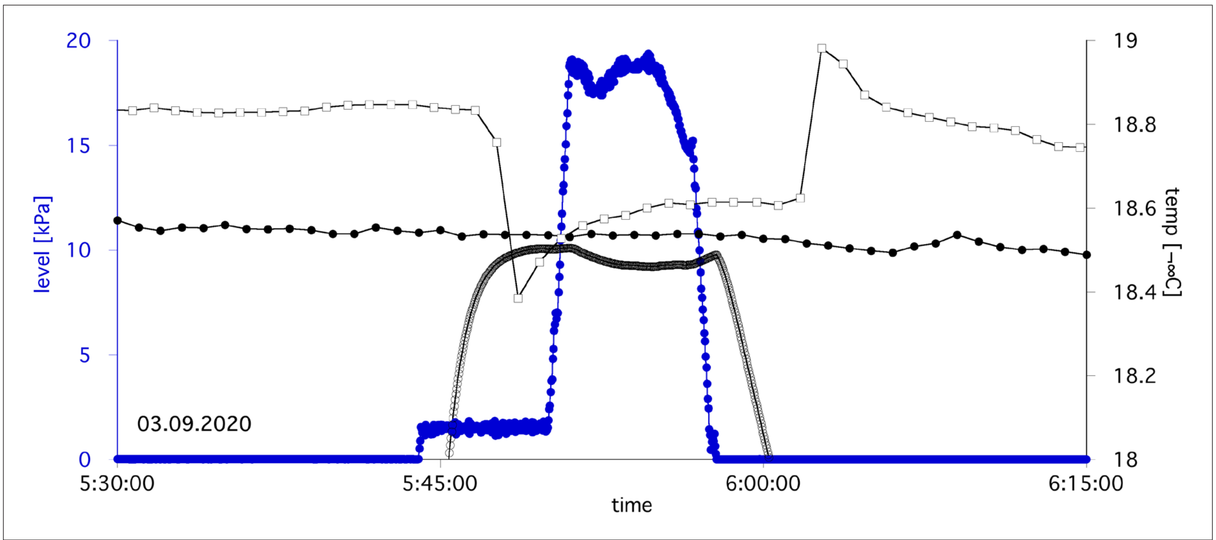
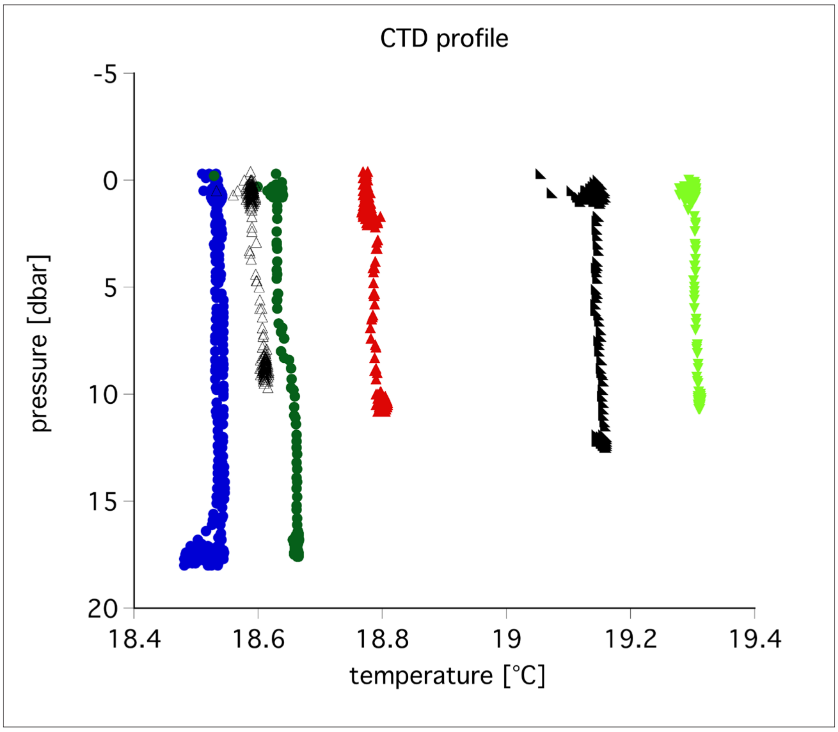


Fig. 6.10: Water temperature as measured with FerryBoxes connected to the in-situ pump during intercal station 3, in blue the water level and the open circles indicate the water temperature as measured with logger attached to the in-situ pump of Mya II. The closed circles indicate the water temperature measured with the FerryBox on Mya II and the open squares on Littorina.



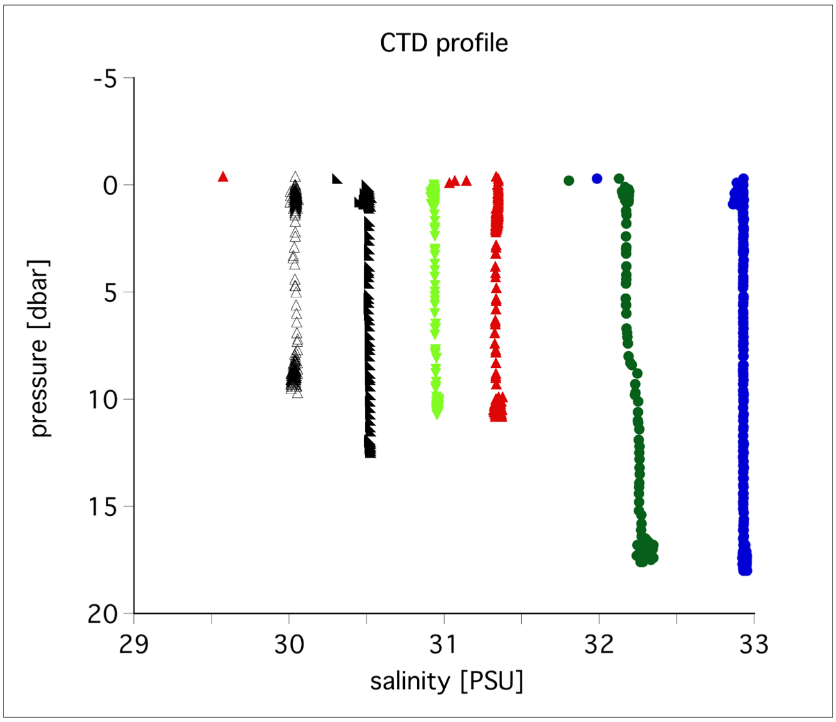


Fig. 6.11: Depth profiles of temperature and salinity measured with a CTD at the stations L-4-1 up to L-4-6

With the whole set of cruises in August 2020 we were able to measure (among other parameters) dissolved methane along the Elbe, its estuary towards Heligoland with the same method and instrument (Figure 6.12 with a logarithmic scale). With this wide spatial range also dissolved methane revealed a concentration range of three orders of magnitude. Highest values with thousands of nmol/L were observed near the weir of Geesthacht, hundreds of nmol's were observed along the Elbe and tens of nmols in the marine area.

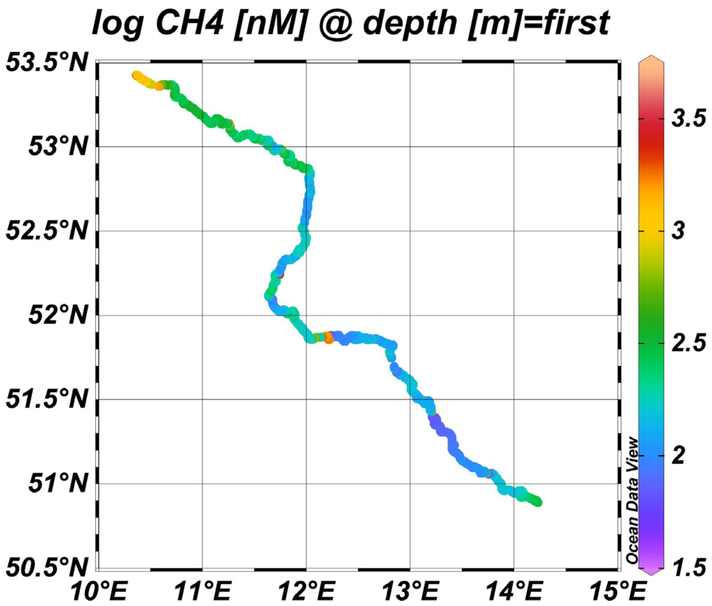


Fig. 6.12: Concentrations of dissolved methane in surface waters from Dresden to Heligoland, note the logarithmic scale.

Water samples to support information on the carbon cycle were taken in the whole area. Samples for nutrients, pigments and carbon compounds (DOC, POC, TA, DIC, see Table A.6.2, Table A.6.5 and Table A.6.7) had been taken from all partners. Work is in progress and data will be published in pangea as soon as possible.

7. DATA MANAGEMENT FOR ALL CRUISES

We have made a strong effort to make the obtained data from all cruises available as soon as possible so that all cruise participants can work with the same (level 0) raw data.

To achieve this, all available data have been uploaded to the AWI O2A Near-Realtime Database from where scientists can download the data via a web-interface (https://dashboard.awi.de/data-xxl/) or directly by an API using R, Matlab or Python (see https://github.com/o2a-data/o2a-data-dws) or any other higher scripting language. On Stern_5 most of the data were transferred directly from the *Mya II* to the AWI O2A Database.

For all legs the 2020 cruises, missions and actions were created in the data base. Thus, when looking for all parameters of Stern_5, the mission "MOSES Sternfahrt_5 mission" can be selected and all ships with all sensors are on display. This data set can be further narrowed down to search for I) scientific actions, II) specific parameters or parameter groups, or III) certain devices.

1. Further actions (beside 'MOSES Sternfahrt_5 mission') can be derived from the respective entries in sensor.awi.de, such as "MOSES Sternfahrt_5 Intercal 1 Mya".

2. Specific parameters can be filtered by applying wild cards, for example vessel:prandtl*:temperature* is giving all temperature data obtained with this ship during the expedition. Alternatively, the search can be narrowed by using the facet 'Parameter' on the left by ticking 'temperature'.

3. Certain devices' data can be obtained by following the traditional URN schema, such as 'vessel:mya_ii:fb_741202:optode'.

Combinations of all parameters from different ships during one cruise are referenced by a unique timestamp and can be downloaded accordingly. More details can be found in the appendix with the corresponding tables. In addition, all cruises with the respective sensors are included in the Moses Data Discovery Portal (https://moses-data.gfz-potsdam.de/onestop/#/), as well as links for the data download. This tool was predominantly filled via device entries in https://sensor.awi.de.

Data in the AWI O2A Near-Realtime Database are considered level 0 data, even though basic quality and plausibility checks are conducted by O2A autoQC routine (https://spaces.awi.de/x/22WjEw) when the data is ingested and thresholds or indices regarding the certain parameter are available in https://sensor.awi.de. Nonetheless further ARGO plausibility checks and manual intervention may be applied to the data by the responsible data scientists.

Therefore, level 0 data in the AWI O2A NRT Database are actually processed (April – May 2021) and quality checked using enhanced quality check procedures including a manual visual data control procedure by the responsible data scientists. These quality-controlled data for all cruises, ships and sensors including the respective water sample data will be published in World Data Center PANGAEA Data Publisher for Earth & Environmental Science (https://www.pangaea.de/) in 2021.

8. RESUME AND OUTLOOK

The year 2020 has been a challenging year with respect to ship-based science. Due to the severe and among institutes significantly varying restrictions and quarantine requirements prior to entering a research vessel, coordinating three vessels for a joint and highly interactive cruise with sensors from different institutes on different ships was quite complex. Additionally, due to the Corona restrictions, the number of scientists and technicians on the participating ships was reduced so that parts of the programme had to be cut. Nevertheless, we were able to successfully carry out several campaigns and cruises.

Despite the above restrictions, we were able to equipping all three ships with state-of-the-art sensors for atmospheric and dissolved methane and pCO_2 sensors, fully equipped FerryBox systems, the new MOSES vertical profiling systems for taking depth-distributed samples on regular fixed positions as well as with the new Kongsberg long distance communication system which was installed on all ships as well as on the island Heligoland and a motor glider. The logistic success of this programme however was not only made possible by the participating scientists and technicians but to a large part also because the ship crews of the three coastal research vessels *Mya II*, *Littorina* and *Ludwig Prandtl* (as well as *Uthörn* in the spring cruise 2020) were highly motivated to support science far beyond their normal duty.

Besides the ship cruise itself, MOSES as relevant CCA (Cross cutting activity) in the new PoF IV Helmholtz Research Programme aims at fostering the collaboration among the participating Helmholtz Institutes within the Earth & Environment sector. The MOSES cruises "Hydrological Extremes" in 2020 scientifically covered the area from the Elbe headwater at the Czech-German border down to the North Sea and addressed also parts of the Weser estuary. Therefore, collaborations among terrestrial, limnological and marine scientists were indispensable for the project. The project therefore initiated close collaborations among colleagues from the required disciplines and institutes spanning and joining expertise on inland waters (UFZ), tidal areas (HZG), coastal regions (AWI, Geomar & HZG) as well as from various agencies in the estuarine area (e.g. BfG and BSH).

The transects of the three ships covered a large part of the southern North Sea and for the first time provided a draft synoptic quantitative 3D map of the methane and CO_2 distribution and concentration in the target area. The scientific output of this expedition contributes to our so far restricted knowledge on the origin and dynamic of these climate relevant gases in the North Sea and significantly improved our knowledge on a proper joint assessment strategy for these climate relevant gases in larger coastal areas. Furthermore, the results of this cruise stimulated additional programmes for a better monitoring for these carbon derivatives in the North Sea. The transects of *Mya II* done during this cruise from List/Sylt heading north-west initiated an overall interest of the participating scientist on Sylt and Heligoland on the matter distribution and the hydrological dynamics on this transect and initiated monthly cruises from beginning 2020 and will be continued in 2021.

To continue and to provide a baseline for the atmospheric measurements of CH_4 and CO_2 a permanent set up is now established on the "Radarturm" on Heligoland until the end of 2021. In addition, permanent sensors for measuring the dissolved gases methane and CO_2 are set up and will be permanently exposed from February 2021 on in the underwater experimental area MarGate off Heligoland on a profiling lander system from 10 m water depth to the surface.

For joint data evaluation of the cruise, a corona-conform virtual workshop with up to 15 participants was held in November 2020 followed by a second workshop planned for February 2021. As first output, a Bachelor Thesis based on work on the *Albis* is already finished and submitted. Results pertaining to these cruises will be presented in two talks at the EGU-symposium in April 2021 and several scientific manuscripts are in discussion or already in preparation

Data exchange between ships and institutes is still complex. The 2020 approach was to establish internal data collection systems for all sensors based on adapted O2A network technology on each individual ship. The main goal was to compile all sensor data from one ship and to exchange these data among ships in a second step. While the first step worked out to a certain degree depending on the within institution support by the respective IT departments, the among ship communication partly failed. It finally turned out that the set up of the long-range communication system by Kongsberg is highly valuable for such approaches but also quite complex to set up. It was decided that the IT departments of the four institutes have to organize a separate workshop to discuss the problems and pitfalls and that the company Kongsberg should be invited as a consultant to train the IT colleagues how to set up the system properly. As already experienced after the last Sternfahrten, the data post processing and analysis across institutes is also still challenging. Even though substantial progress has been made to establish a joint database (O2A) from which all participants of the different institutes can simply merge and download all data with a common time stamp, the post processing of the data takes time. While sensor data coming from a sensor in a “ready to use” state is available quite fast, data, which has to be post processed, still needs too much time and effort to transform it into a state where it can be considered trustworthy. For this data, more automated “on the fly” processing steps are needed to ease the data delivery to the entire project in time. To summarize the experiences from the 2020 Sternfahrt from the IT side, it is recommended that not only scientists hold multiple pre-cruise meetings to prepare and organize such interinstitutional campaigns. The same is true also for the IT specialists which need more inter-institutional exchange prior to such campaigns.

While public outreach activities via social platforms were rather limited in the first MOSES campaign, in 2020 all participating institutes and ships were active on the @HelmholtzMoses twitter channel. Most of the cruise tweets were linked and distributed by the communication channels of the participating institutes.

Based on the positive and experiences from 2018 to 2020, all four institutes decided to continue with the “Sternfahrten” in 2021. While the cruises so far were still classified as “test campaigns” for equipment and procedures, the consortium decided to be ready to put the main focus on scientific questions in 2021. Despite the still existing challenges and open issues in sensor technology, sampling strategy and ship-to-ship communication, the consortium is convinced that the test campaigns undertaken so far have formed a stable platform for joint science. This is also demonstrated by the multiple manuscripts which are in preparation not only on technical issues but already with a strong focus on scientific hypotheses. This shows that MOSES “Hydrological Extremes” has passed the stage of testing equipment and procedures and that all scientists are eager to implement this CCA (Cross Cutting Activity) in the new Helmholtz PoF IV Programme on a scientific level. However, during the upcoming “Sternfahrten” in 2021 and 2022, also some technical issues still have to be solved such as the not yet stable ship-to-ship communication systems or the influence of different water supplies on the individual ships on the measurements of dissolved gases (oxygen, methane).

APPENDIX

A.1 PARTICIPATING INSTITUTIONS

A.2 CRUISE PARTICIPANTS

A.3 TABLES FOR STERNFAHRT_4

A.4 TABLES FOR BINNEN ELBE

A.5 TABLES FOR TIDE ELBE

A.6 TABLES FOR STERNFAHRT_5

A.1 PARTICIPATING INSTITUTIONS

Tab. A.1.1: Participating Institutions and their address

Institution	Address
DE.AWI	Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung Postfach 120161 27515 Bremerhaven Germany
DE.Geomar	Geomar Helmholtz-Zentrum für Ozeanforschung Kiel Wischhofstraße 1-3 24148 Kiel Germany
DE.HZG	Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung Max-Planck-Str. 1 21502 Geesthacht Germany
DE.UFZ	Helmholtz Centre for Environmental Research GmbH – UFZ Brückstr. 3a 39114 Magdeburg Germany
DE.UFZ	Helmholtz Centre for Environmental Research GmbH – UFZ Permoserstr. 15 04318 Leipzig Germany

A.2 CRUISE PARTICIPANTS

Tab. A.2.1: Cruise Participants of Sternfahrt_4

Ship	Name / Last name	Vorname / First name	Institut / Institute	Beruf / Profession
Ludwig Prandtl	Brix	Holger	DE.HZG	Scientist
Ludwig Prandtl	Gehrung	Martina	DE.HZG	Engineer
Ludwig Prandtl	Gerbatsch	Heiko	Reederei Laeisz	Captain
Ludwig Prandtl	Heinze	Detlef	Reederei Laeisz	Shipman
Uthörn	Anselm	Norbert	DE.AWI	IT
Uthörn	Bussmann	Ingeborg	DE.AWI	Scientist
Uthörn	Fischer	Philipp	DE.AWI	Scientist
Uthörn	Jardner	Dirk	Reederei Laeisz	Captain
Uthörn	Becker	David	Reederei Laeisz	Nautical Officer
Uthörn	Mühle	Eric	Reederei Laeisz	Chief Technical Officer
Uthörn	Becker	Raymond	Reederei Laeisz	Shipman
Uthörn	Horst	Schröder	Reederei Laeisz	Ship mechanic

Tab. A.2.2: Cruise Participants of Binnen Elbe

Ship	Name / Last name	Vorname / First name	Institut / Institute	Beruf / Profession
Albis	Kamjunke	Norbert	DE.UFZ	Scientist
Albis	Bauth	Sven	DE.UFZ	Captain
Albis	Link	Ute	DE.UFZ	Technician
Albis	Goretzka	Heike	DE.UFZ	Technician
Albis	Evers	Erik	DE.AWI, Uni Braunschweig	Student, not on board

Tab. A.2.3: Cruise Participants of Tide Elbe

Ship	Name / Last name	Vorname / First name	Institut / Institute	Beruf / Profession
Ludwig Prandtl	Brix	Holger	DE.HZG	Scientist
Ludwig Prandtl	Erbslöh	Burkhard	DE.HZG	Engineer
Ludwig Prandtl	Flöser	Götz	DE.HZG	Scientist
Ludwig Prandtl	Jebens	Hannah	DE.AWI	Technician
Ludwig Prandtl	Kaiser	David	DE.HZG	Scientist

Ship	Name / Last name	Vorname / First name	Institut / Institute	Beruf / Profession
Ludwig Prandtl	Reese	Anna	DE.HZG	PhD Student
Ludwig Prandtl	Rewrie	Louise	DE.HZG	PhD Student
Ludwig Prandtl	Rust	Hendrik	DE.HZG	Engineer
Ludwig Prandtl	Bornhöft	Helmut	Reederei Laeisz	Captain
Ludwig Prandtl	Schacht	Marco	Reederei Laeisz	Captain
Ludwig Prandtl	Heinze	Detlef	Reederei Laeisz	Shipman

Tab. A.2.4: Cruise Participants of Sternfahrt_5

Ship	Name / Last name	Vorname / First name	Institut / Institute	Beruf / Profession
Littorina	Geißler	Felix	DE.Geomar	Scientist
Littorina	Altahan	Mahmoud	DE.Geomar	Doctoral student
Littorina	Evers	Erik	DE.AWI/Uni Braunschweig	Student
Littorina	Flindt	Danny	Briese Research	Captain
Littorina	Krause	Hinnerk	Briese Research	First Nautical Officer
Littorina	Witteck	Fred	Briese Research	Ship Machinist
Littorina	Tamm	Stefan	Kiel University	Ship Mechanic
Littorina	Rzhevsky	Volodymyr	Briese Research	Cook
Mya II	Anselm	Norbert	DE.AWI	IT
Mya II	Blum	Lena	DE.AWI	Student
Mya II	Bussmann	Ingeborg	DE.AWI	Scientist
Mya II	Fischer	Philipp	DE.AWI	Scientist
Mya II	Friedrich	Madlen	DE.AWI	Technician
Mya II	Hildebrandt	Valentin	Reederei Laeisz	Captain
Mya II	Schubert	Holger	Reederei Laeisz	Shipman
Ludwig Prandtl	Brix	Holger	DE.HZG	Scientist
Ludwig Prandtl	Crénan	Brieuc	DE.HZG	Engineer
Ludwig Prandtl	Flöser	Götz	DE.HZG	Scientist
Ludwig Prandtl	Jebens	Hannah	DE.AWI	Technician
Ludwig Prandtl	Gerbatsch	Heiko	Reederei Laeisz	Captain
Ludwig Prandtl	Heinze	Detlef	Reederei Laeisz	Shipman

A.3 TABLES FOR STERNFAHRT_4

Tab. A.3.1: Station list for *Ludwig Prandtl,* Stern_4 for water samples for total alkalinity (TA), nutrients (N), salinity (S), turbidity (T) and oxygen (O)

Water samples were either taken from the FerryBox outlet (FB) or from a Niskin water sampler (WS). Results will be published in the Pangaea data base (https://pangaea.de/) together with the corresponding cruise label.

Station ID	Date Time [UTC]	Latitude	Longitude	Water depth [m]	Remarks
00	12.05.2020 07:28	53.8878	8.6933	2	S, T from WS
01	12.05.2020 07:28	53.8878	8.6933	2	S, T from FB
02	12.05.2020 07:28	53.8878	8.6933	2	S, T from WS
03	12.05.2020 07:28	53.8878	8.6933	2	N from FB
04 / 05 / 06	12.05.2020 07:28	53.8878	8.6933	2	O from FB
07	12.05.2020 07:28	53.8878	8.6933	2	TA from FB
08	12.05.2020 08:23	53.9600	8.6200	2	S, T from FB
09	12.05.2020 08:26	53.9600	8.6200	2	S, T from WS
10	12.05.2020 08:26	53.9600	8.6200	2	N from FB
11 / 12 / 13	12.05.2020 08:27	53.9600	8.6200	2	O from FB
14	12.05.2020 08:25	53.9600	8.6200	2	TA from FB
15	12.05.2020 09:04	53.9800	8.5100	2	S, T from FB
16	12.05.2020 09:04	53.9800	8.5100	2	S, T from WS
17	12.05.2020 09:07	53.9800	8.5100	2	N from FB
18	12.05.2020 09:06	53.9800	8.5100	2	TA from FB
19	12.05.2020 10:40	54.0000	8.3400	2	S, T from FB
20	12.05.2020 10:41	54.0000	8.3400	2	S, T from WS

Station ID	Date Time [UTC]	Latitude	Longitude	Water depth [m]	Remarks
21	12.05.2020 10:42	54.0000	8.3400	2	N from FB
22 / 23 / 24	12.05.2020 10:43	54.0000	8.3400	2	O from FB
25	12.05.2020 10:41	54.0000	8.3400	2	TA from FB
26	12.05.2020 12:03	53.9900	8.2500	2	S, T from FB
27	12.05.2020 12:05	53.9900	8.2500	2	S, T from WS
28	12.05.2020 12:13	53.9900	8.2500	10	S, T from WS
29	12.05.2020 12:20	53.9900	8.2500	15	S, T from WS
30	12.05.2020 12:04	53.9900	8.2500	15	N from FB
31 / 32 / 33	12.05.2020 12:05	53.9900	8.2500	2	O from FB
34	12.05.2020 12:04	53.9900	8.2500	2	TA from FB
35	12.05.2020 13:14	53.9600	8.5700	2	TA from FB
36	12.05.2020 13:20	53.9500	8.6000	2	S, T from FB
37	12.05.2020 13:23	53.9200	8.6500	2	N from FB
38	12.05.2020 13:31	53.9500	8.6200	2	TA from FB
39	12.05.2020 13:36	53.9120	8.6700	2	S, T from FB
40	12.05.2020 13:38	53.9000	8.6800	2	N from FB
41	12.05.2020 13:45	53.8700	8.7000	2	N from FB
42	12.05.2020 13:46	53.8700	8.7000	2	S, T from FB
43	12.05.2020 13:47	53.8700	8.7000	2	TA from FB

Tab. A.3.2: Instruments on the *Ludwig Prandtl* on Stern_4

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://sensor.awi.de/ Mission: MOSES Sternfahrt_4 mission	Remarks
On the way		Position: latitude_0001, longitude_0001	G. Flöser	D-Ship *Prandtl*	vessel:prandtl_hzg:d_ship_prandtl_01:longitude_0001	No time offset
On the way		Position: latitude_0001, longitude_0001	G. Flöser	FerryBox	small_scale_facility:fb_hzg_orion:longitude_0001	No time offset
On the way	air	Weather: meteo_air_pressure_0001 Meteo_air_temperature_0001, meteo_radiation_0001, relative_humidity_0001, meteo_wind_east_0001, meteo_wind_direction_0001, meteo_wind_north_0001, meteo_wind_speed_0001,	G. Flöser	Weather Station GMX600	small_scale_facility:weather_station_hzg_1957ps001:meteo_air_pressure_0001	No time offset
On the way	water	Hydrography: cdom_cyclops_0001, oxygen_concentration_aanderaa_0001, oxygen_saturation_0001, ph_meinsberg_ega_0001, salinity_0001, temperature_citadel_0001	G. Flöser	FerryBox	small_scale_facility:fb_hzg_orion:salinity_0001	Time offset till 10:11 UTC = 19 sec, from 10:12 UTC = 15 sec

Tab. A.3.3: Station list for water samples taken on *RV Uthörn* on Stern_4

All surface samples at 2 m. Results will be published in the Pangea data base (https://pangaea.de/) together with the corresponding cruise label.

Station ID	DateTime (UTC) start	DateTime (UTC) end	Latitude	Longitude	Bottom depth (m)	Remarks
U1	12.05.2020 07:45	12.05.2020 07:48	53.8886	8.6934	7.5	samples for salinity, turbidity and oxygen (U1a-96, U1b-#, U1c-94), vertical *in-situ*CTD
U2	12.05.2020 08:23	12.05.2020 08:26	53.9648	8.6137		sample for salinity, turbidity, *in-situ*CTD at surface,end time not certain, either 8:45 protocol or 08:26 electronic protocol
U3	12.05.2020 09:07	12.05.2020 09:11	53.9785	8.4935		sample for salinity, turbidity, *in-situ*CTD at surface, at 25.5 PSU, end time not certain, either 9:11 protocol or 09:08 electronic protocol
U4	12.05.2020 10:41	12.05.2020 10:44	53.9977	8.3310		sample for salinity, turbidity, *in-situ*CTD at surface, at 28 PSU
U5	12.05.2020 12:02	12.05.2020 12:08	53.9882	8.2591	20.4	samples for salinity, turbidity and oxygen (U2a-87, U2b-#, U2c-305), vertical *in-situ*CTD
U6		12.05.2020 13:51	53.8693	8.1228		sample for salinity, turbidity from board water supply

Tab. A.3.4: Instruments on the *Uthörn* on Stern_ 4

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de Mission: MOSES Sternfahrt_4 mission	Remarks
On the way		Position: Longitude, latitude Weather: air_temperature, barometric_pressure, speed, true_wind_direction, true_wind_speed	N. Anselm	D-Ship	vessel:uthoern:weather:air_temperature	
On the way	water	Hydrography: Latitude_0001, longitude_0001, speed_0001, course_over_ground_0001, flow_main_0001, temperature_sbe45_0001, conductivity_sbe45_0001, salinity_sbe45_0001,temperature_phsensor_0001, oxygen_concentration_0001, oxygen_saturation_0001, temperature_0001, methane_dry_0001, carbon_dioxide_dry_0001, fit_flag_0001	P. Fischer	Pocket FerryBox	small_scale_facility:pfb_awi_751801:flow_main_0001	pH started at 11:35, no methane sensor attached, end at 15:41, started rinsing with freshwater

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de Mission: MOSES Sternfahrt_4 mission	Remarks
vertical	water	Hydrography: pressure_01 Temperature_406, chlorophyll_a_ awi_211t0078, turbidity_16157, salinity_17060902, oxygen_ saturation_224140948, oxygen_concentration_ mg_l_224140948, oxygen_concentration_ ml_l_224140948	P. Fischer	Sea and Sun CTD 1413	ctd:ctd_ awi_1413:salinity_17060902	mostly for 2 min at 2 m, only at U-1 and U-5 vertical profiles

A.4 TABLES FOR BINNEN ELBE

Tab. A.4.1: Station list

At each station the following parameters were determined: carbon, nutrients, ions, basic parameters, pigments, dissolved and particulate metals*

Station	Date Time [UTC]	Latitude	Longitude	Description	km
el00400l	04.08.2020 08:10	50.8890	14.2320	Schmilka links	4
el00400m	04.08.2020 08:33	50.8890	14.2320	Schmilka Mitte	4
el00400r	04.08.2020 08:48	50.8932	14.2277	Schmilka rechts	4
el05450l	04.08.2020 14:53	51.0541	13.7476	Elbe – Dresden Carolabrücke links	54.5
el05450m	04.08.2020 15:05	51.0547	13.7473	Elbe – Dresden Carolabrücke Mitte	54.5
el05450r	04.08.2020 15:17	51.0553	13.7471	Elbe – Dresden Carolabrücke rechts	54.5
el08800l	05.08.2020 09:50	51.2030	13.4110	Zehren links	88
el08800m	05.08.2020 10:03	51.2030	13.4110	Zehren Mitte	88
el08800r	05.08.2020 10:18	51.2030	13.4110	Zehren rechts	88
el10700l	05.08.2020 12:07	51.3104	13.2951	Elbe – Riesa Brücke links	107
el10700m	05.08.2020 12:17	51.3107	13.2954	Elbe – Riesa Brücke Mitte	107
el10700r	05.08.2020 12:34	51.3109	13.2957	Elbe – Riesa Brücke rechts	107
el15450l	06.08.2020 09:40	51.5579	13.0107	Elbe – Torgau Brücke links	154.5
el15450m	06.08.2020 09:55	51.5580	13.0111	Elbe – Torgau Brücke Mitte	154.5
el15450r	06.08.2020 10:05	51.5581	13.0115	Elbe – Torgau Brücke rechts	154.5
el17260l-MST	06.08.2020 12:58	51.6490	12.8945	Messstation Dommitzsch, links	172.6
el17260m	06.08.2020 13:07	51.6494	12.8951	Dommitzsch Mitte	172
el17260r	06.08.2020 13:15	51.6495	12.8955	Dommitzsch rechts	172
el19900münd	07.08.2020 07:30	51.8230	12.8390	Schwarze Elster Mündung	199
el25800l	07.08.2020 12:21	51.8600	12.2110	Roßlau links	258
el25800m	07.08.2020 12:31	51.8811	12.2342	Elbe Roßlau Mitte, km 258	258

Station	Date Time [UTC]	Latitude	Longitude	Description	km
el25800r	07.08.2020 12:41	51.8600	12.2110	Roßlau rechts; Autobrücke– Hochwasser-probenahme	258
el25900münd	08.08.2020 06:52	51.8737	12.2458	Mulde Mündung	259
el28700l	08.08.2020 09:20	51.9570	11.9130	Breitenhagen links	287
el28700m	08.08.2020 09:30	51.9570	11.9130	Breitenhagen Mitte	287
el28700r	08.08.2020 09:39	51.9302	11.9558	Breitenhagen rechts	287
el29070münd	08.08.2020 10:05	51.9770	11.8860	Saale Mündung	290.7
el31800l	08.08.2020 12:32	52.0669	11.6792	Elbe MD links, km 318, MD Westerhüsen	318
el31800m	08.08.2020 12:42	52.0672	11.6805	Magdeburg Mitte	318
el31800r	08.08.2020 12:53	52.0673	11.6816	Magdeburg rechts km 318	318
el32653l	08.08.2020 14:08	52.1291	11.6437	Magdeburg Neue Strombrücke links	326.53
el32653m	08.08.2020 14:30	52.1290	11.6442	Magdeburg Neue Strombrücke Mitte	326.53
el32653r	08.08.2020 14:32	52.1287	11.6446	Magdeburg Neue Strombrücke rechts	326.53
el35100l	09.08.2020 09:11	52.3340	11.8130	Rogätz links	351
el35100m	09.08.2020 09:21	52.3340	11.8130	Rogätz Mitte	351
el35100r	09.08.2020 09:32	52.3340	11.8130	Rogätz rechts	351
el38800l	09.08.2020 13:46	52.5398	11.9790	Elbe km 388,0 Tangermünde links	388
el38800m	09.08.2020 13:59	52.5397	11.9803	Tangermünde, Mitte km 388,0	388
el38800r	09.08.2020 14:13	52.5396	11.9815	Elbe km 388.0 Tangermünde rechts	388
el42225l	10.08.2020 12:10	52.8379	12.0393	Fähre Werben Elbe km 422,25 links	422.25
el42225m	10.08.2020 12:20	52.8376	12.0405	Fähre Werben Elbe km 422,25 Mitte	422.25
el42225r	10.08.2020 12:31	52.8374	12.0417	Fähre Werben Elbe km 422,25 rechts	422.25
el43800münd	10.08.2020 14:02	52.9081	11.8795	Havel Mündung	438
el45490l	10.08.2020 15:41	52.9863	11.7516	Wittenberge, links	454.9
el45490m	10.08.2020 15:49	52.9870	11.7519	Wittenberge, Mitte	454.9

Tab. A.4.1: Station list

Station	Date Time [UTC]	Latitude	Longitude	Description	km
el45490r	10.08.2020 15:58	52.9875	11.7523	Wittenberge, rechts	454.9
el47500l	11.08.2020 10:58	53.0472	11.5542	Schnackenburg links	475
el47500m	11.08.2020 11:10	53.0480	11.5560	Schnackenburg Mitte	475
el47500r	11.08.2020 11:20	53.0481	11.5572	Schnackenburg rechts	475
el50600l	11.08.2020 14:24	53.1335	11.2488	Dömitz, links	506
el50600m	11.08.2020 15:02	53.1342	11.2492	Elbe km 506, Dömitz, Mitte	506
el50600r	11.08.2020 15:36	53.1345	11.2508	Dömitz, rechts	506
el53600l	12.08.2020 11:13	53.2327	10.8978	Neu Darchau links	536
el53600m	12.08.2020 11:21	53.2335	10.8987	Neu Darchau Mitte	536
el53600r	12.08.2020 11:31	53.2340	10.8992	Neu Darchau rechts	536
el57040l	12.08.2020 14:35	53.3680	10.5477	Lauenburg links	570.4
el57040m	12.08.2020 14:44	53.3691	10.5482	Lauenburg Mitte	570.4
el57040r	12.08.2020 14:52	53.3701	10.5483	Lauenburg rechts	570.4
el58550l	12.08.2020 16:28	53.4245	10.3507	Geesthacht links	585.5
el58550m	12.08.2020 16:40	53.4261	10.3506	Geesthacht	585.5
el58550r	12.08.2020 16:52	53.4302	10.3507	Geesthacht rechts	585.5

*carbon: DIC, DOC, POC, TIC, TOC, nutrients: NH_4, NO_2, NO_3, PN, SRP, TP, Si, TSi, ions: K, Ca, Mg, Na, Cl, SO4, basic parameters: SPM, UV254, pigments with HPLC: Chl a, Chl b, phaeophytin a & b, dissolved and particulate metals: Al, As, Cd, Cr, Co, Cu, Fe, Hg, Mn, Ni, Pb, Sn, Zn,

Tab. A.4.2: Instruments on the *Albis* on the Binnen Elbe

On the way	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at	Remarks
at stations	water	Hydrography: water temperature, pH, turbidity, chlorophyll *a*, oxygen, conductivity	N. Kamjunke	YSI probe	https://www.ufz.de/record/dmp/logger/1493/de/	only surface water at 0.3 m depth
fixed station	water	Hydrography: water temperature, pH, turbidity, chlorophyll *a*, oxygen, conductivity, nitrate	N. Kamjunke	YSI sensor	https://www.ufz.de/record/dmp/logger/1245/de/	ferry at Westerhüsen (km 318)
fixed station	water	Hydrography: water temperature, pH, turbidity, chlorophyll *a*, oxygen, conductivity, nitrate	N. Kamjunke	YSI sensor	https://www.ufz.de/record/dmp/logger/1261/de/	ferry at Werben (km 422), crossing the Elbe several times each day
fixed station	water	Hydrography: water temperature, pH, turbidity, chlorophyll *a*, oxygen, conductivity	N. Kamjunke	EXO2	https://www.ufz.de/record/dmp/logger/1479/de/	continuous probe measurements at Tesperhude (km 579) landing stage)
on the way	water	Hydrography: salinity_citadel_0001, temperature_0001, temperature_citadel_0001, temperature_phsensor_0001, oxygen_concentration_0001, oxygen_saturation_0001, ph_0001, turbidity_0001, chlorophyll_0001, conductivity_citadel_0001	I. Bussmann	FerryBox**	https://dashboard.awi.de Mission: MOSES Binnenelbe 2020 vessel:albis:pfb_awi_751801:temperature_sbe45_0001	n O2A, see comments below** time offset -19 sec

Tab. A.4.2: Instruments on the Albis on the Binnen Elbe

On the way	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at	Remarks
on the way	water	Dissolved methane: Methane_dry_0001, carbon_dioxide_ dry_0001, fit_flag_0001 methane_nmolL_0001	I. Bussmann	LosGatos mit Degasser	https://dashboard.awi.de Mission: MOSES Binnenelbe 2020 laboratory:moses_stern_2:losgatos_awi_3599	time offset - 87 sec; only data with fitflag = 3; data were corrected for extraction efficiency based on water/gas flow from degasser; conversion to nmol/L with water samples from all dates => * 30.63
on the way	air	Atmospheric $CO_2/CH_4/H_2O$: Methane mole fraction in dry air, Carbon dioxide mole fraction in dry air, Water vapor concentration	U. Ködel / C. Schütze	LICOR CH4/CO2/H2O Trace Gas Analyzer	vessel:albis:ufz_licor_7810:ch4	Tube length 2 m, data corrected for a time offset of 1s, no GPS Position

**There have been problems with the PC of the FerryBox as it lost its timestamp. Time in the datafiles was corrected by comparing with start/end time of LosGatos: 29 July +527501 sec => 04 Aug; 6 Aug since 15:40 +56381 sec => 7 Aug; 7 Aug +107681 sec => 8 Aug

On 7 Aug, 8 Aug partly, 11 Aug, 12 Aug the water pump of the FerryBox was partly off (flow < 2 L/min), these data have to be discarded.

A.5 TABLES FOR TIDE ELBE

Tab. A.5.1: Station list for Tide Elbe for water sampling

Results will be published in the Pangaea data base (https://pangaea.de/) together with the corresponding cruise label.

Station ID	Sampling time	Latitude	Longitude	Samples
TC1	25.08.2020 14:55	53.7859	9.4021	TA, DIC, Chl-a, POC, DIC, nutrients
TC2	25.08.2020 16:06	53.7859	9.4021	TA, DIC, Chl-a, POC, DIC, nutrients
TC3	25.08.2020 17:08	53.7860	9.4023	TA, DIC, Chl-a, POC, DIC, nutrients
TC4	25.08.2020 18:00	53.7856	9.4035	TA, DIC, Chl-a, POC, DIC, nutrients
TC4	25.08.2020 18:55	53.7859	9.4029	TA, DIC, Chl-a, POC, DIC, nutrients
TC5	25.08.2020 20:00	53.7860	9.4030	TA, DIC, Chl-a, POC, DIC, nutrients
TC6	25.08.2020 21:04	53.7860	9.4030	TA, DIC, Chl-a, POC, DIC, nutrients
TC7	25.08.2020 22:01	53.7860	9.4029	TA, DIC, Chl-a, POC, DIC, nutrients
TC9	25.08.2020 23:00	53.7860	9.4030	TA, DIC, Chl-a, POC, DIC, nutrients
TC10	26.08.2020 00:02	53.7860	9.4029	TA, DIC, Chl-a, POC, DIC, nutrients
TC11	26.08.2020 01:03	53.7860	9.4031	TA, DIC, Chl-a, POC, DIC, nutrients
TC12	26.08.2020 02:00	53.7856	9.4031	TA, DIC, Chl-a, POC, DIC, nutrients
TC13	26.08.2020 03:00	53.7856	9.4031	TA, DIC, Chl-a, POC, DIC, nutrients

Tab. A.5.2: Instruments on the *Ludwig Prandtl* on Tide Elbe

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de Mission: MOSES Tide Elbe 2020	Remarks
On the way		Position: latitude_0001, longitude_0001	G. Flöser	FerryBox	vessel:prandtl_hzg:fb_hzg_orion	
On the way	air	Weather: meteo_air_pressure_0001 Meteo_air_temperature_0001, Meteo_radiation_0001: did not work, relative_humidity_0001, meteo_wind_east_0001, meteo_wind_direction_0001, meteo_wind_north_0001, meteo_wind_speed_0001	G. Flöser	Weather Station GMX600	vessel:prandtl_hzg:weather_station_hzg_1957ps001	
On the way	air	Atmospheric $CO_2/CH_4/H_2O$: Methane mole fraction in dry air, Carbon dioxide mole fraction in dry air, Water vapor concentration	U. Ködel / C. Schütze	LICOR CH4/CO2/H2O Trace Gas Analyzer	ufz_licor_7810	Tube length 2 m, data corrected for a time offset of 1s

A.6 TABLES FOR STERNFAHRT_5

Tab. A.6.1: Intercalibration table for Stern_5

Station ID	Date Time [UTC] start	Date Time [UTC] end	Latitude	Longitude	Bottom depth [m]	Remarks
Intercal 1	31.08.2020 06:56	31.08.2020 07:29	53.9048	8.7049	13	from *Mya II* distance M - L: 0.462 km distance M - P: 0.273 km distance P - L: 0.612 km
Intercal 1	31.08.2020 06:52	31.08.2020 07:28	53.9037	8.7117	9	from *Littorina* (no underway supply for FB, just *in-situ* pump; two vertical CTD casts)
Intercal 1	31.08.2020 06:55	31.08.2020 07:20	53.9028	8.7025	16.6	from *Ludwig Prandtl*
Intercal 2	01.09.2020 06:31	01.09.2020 06:51	54.1475	7.9086	50	from *Mya II* distance M - L: 0.130 km distance M - P: 0.635 km distance P - L: 0.600 km
Intercal 2	01.09.2020 06:32	01.09.2020 07:18	54.1482	7.9102	50	from *Littorina*
Intercal 2	01.09.2020 06:30	01.09.2020 06:56	54.1530	7.9060	17	from *Ludwig Prandtl*
Intercal 3	03.09.2020 05:22	03.09.2020 05:42	54.1513	7.9143	49	from *Mya II* distance M - L: 0.069 km
Intercal 3	03.09.2020 05:20	03.09.2020 06:05	54.1515	7.9133	48	from *Littorina*
Intercal 4	03.09.2020 12:08	03.09.2020 12:41	53.9052	8.7059	12	from *Littorina* distance L - P: 0.125 km
Intercal 4	03.09.2020 12:04	03.09.2020 12:45	53.9041	8.7063	14	from Ludwig Prandtl

Tab. A.6.2: Station list for *Littorina*, Stern_5

All water samples were collected from the ship's underway surface water supply (inlet at ca. 3 m depth). Stations marked in blue are intercalibration stations. Results will be published in the Pangaea data base (https://pangaea.de/) together with the corresponding cruise label.

Station ID [Sample ID]	Date Time [UTC]	Longitude	Latitude	Bottom depth [m]	Remarks
1_1 (L1)	31.08.2020 06:40	8.7117	53.9037	9	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
1_2 (L4)	31.08.2020 08:42	8.5355	53.9688	9	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
1_3 (L7)	31.08.2020 09:46	8.4239	54.0534	12	sal / tur, DIC/TA, DOC, nutrients
1_4 (L8)	31.08.2020 10:41	8.3146	54.1141	14	sal / tur, DIC/TA, DOC, nutrients
1_5 (L9)	31.08.2020 11:31	8.2239	54.1699	16	sal / tur, DIC/TA DOC, nutrients
1_6 (L11)	31.08.2020 12:07	8.1421	54.1701	19	sal / tur, DIC/TA, DOC, nutrients
1_7 (L13)	31.08.2020 12:47	8.0640	54.1692	24	sal / tur, DIC/TA, DOC, nutrients
1_8 (L15)	31.08.2020 13:31	7.9395	54.1699	21	sal / tur, DIC/TA, DOC, nutrients
2_1 (L17)	01.09.2020 06:32	7.9102	54.1482	50	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
2_2 (L19)	01.09.2020 07:46	8.0526	54.1703	26	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
2_3 (L21)	01.09.2020 08:17	8.1343	54.1705	19	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
2_4 (L23)	01.09.2020 08:47	8.2212	54.1701	17	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
2_5 (L25)	01.09.2020 09:22	8.3171	54.1640	15	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
2_6 (L27)	01.09.2020 10:13	8.4469	54.1126	9	sal / tur, DIC/TA, pigments, POC, DOC, nutrients

Station ID [Sample ID]	Date Time [UTC]	Longitude	Latitude	Bottom depth [m]	Remarks
2_7 (L28)	01.09.2020 11:04	8.6173	54.1060	10	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
2_8 (L30)	01.09.2020 11:59	8.7654	54.1273	12	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
3_1 (L32)	02.09.2020 04:17	8.7793	54.1278	10	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
3_2 (L33)	02.09.2020 05:08	8.6243	54.1035	12	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
3_3 (L34)	02.09.2020 06:20	8.4112	54.1644	9	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
3_4 (L36)	02.09.2020 07:01	8.3594	54.2335	11	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
3_5 (L39)	02.09.2020 07:52	8.3017	54.3283	12	sal / tur , Oxygen, DIC/TA, pigments, POC, DOC, nutrients
3_6 (L43)	02.09.2020 09:02	8.1014	54.3303	15	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
3_7 (L45)	02.09.2020 10:09	7.9980	54.2512	19	sal / tur, Oxygen, DIC/TA, pigments, POC, DOC, nutrients
3_8 (L48)	02.09.2020 10:56	7.9380	54.1705	20	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
4_1 (L51)	03.09.2020 05:20	7.9133	54.1515	48	sal / tur, Oxygen, DIC/TA, pigments, POC, DOC, nutrients
4_2 (L54)	03.09.2020 06:38	8.0598	54.1703	23	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
4_3 (L57)	03.09.2020 07:23	8.1412	54.2465	12	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
4_4 (L58)	03.09.2020 08:08	8.3038	54.2498	12	sal / tur, DIC/TA, pigments, POC, DOC, nutrients

Tab. A.6.2: Station list for Littorina, Stern_5

Station ID [Sample ID]	Date Time [UTC]	Longitude	Latitude	Bottom depth [m]	Remarks
4_5 (L61)	03.09.2020 08:52	8.3840	54.1728	12	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
4_6 (L62)	03.09.2020 09:28	8.4207	54.1125	10	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
4_7 (L63)	03.09.2020 10:41	8.5935	53.9762	11	sal / tur, DIC/TA, pigments, POC, DOC, nutrients
4_8 (L65)	03.09.2020 12:08	8.7059	53.9052	12	sal / tur, Oxygen, DIC/ TA, pigments, POC, DOC, nutrients

Tab. A.6.3: Station list for *in-situ* pump on *Littorina*, Stern_5

Maximal length of tube for *in-situ* pump is 20 m. Stations marked in blue are intercalibration stations.

Station ID	Date Time [UTC] surface, start - end	Date Time [UTC] bottom, start - end	Latitude surface / bottom	Longitude surface / bottom	Bottom depth [m] surface / bottom	Remarks
1_1	31.08.2020 07:03 31.08.2020 07:05	31.08.2020 07:07 31.08.2020 07:09	53.9040/ 53.9036	8.7114/ 8.7121	9	2 casts surface (1 m) bottom (7 m)
	31.08.2020 07:17 31.08.2020 07:21	31.08.2020 07:22 31.08.2020 07:25	53.9030/ 53.9025	8.7128/ 8.7162		
1_2	31.08.2020 08:44 31.08.2020 08:48	31.08.2020 08:49 31.08.2020 08:52	53.9828/ 53.9818	8.5360/ 8.5391	9	surface (1 m) bottom (7 m)
1_3	31.08.2020 09:46 31.08.2020 09:50	31.08.2020 09:53 31.08.2020 09:56	54.0533/ 54.0522	8.4237/ 8.4231	12	surface (1 m) bottom (10 m)
1_4	31.08.2020 10:41 31.08.2020 10:44	31.08.2020 10:45 31.08.2020 10:48	54.1142/ 54.1143	8.3144/ 8.3137	14	surface (1 m) bottom (12 m)
1_5	31.08.2020 11:31 31.08.2020 11:34	31.08.2020 11:35 31.08.2020 11:38	54.1700/ 54.1700	8.2239/ 8.2237	16	surface (1 m) bottom (14 m)
1_6	31.08.2020 12:15 31.08.2020 12:19	31.08.2020 12:20 31.08.2020 12:23	54.1720/ 54.1723	8.1379/ 8.1364	19	surface (1 m) bottom (17 m)
1_7	31.08.2020 12:49 31.08.2020 12:53	31.08.2020 12:54 31.08.2020 12:58	54.1693/ 54.1699	8.0636/ 8.0599	24	surface (1 m) bottom (17 m)
1_8	31.08.2020 13:31 31.08.2020 13:35	31.08.2020 13:36 31.08.2020 13:40	54.1700/ 54.1693	7.9392/ 7.9379	21	surface (1 m) bottom (18 m)

Tab. A.6.3: Station list for in-situ pump on Littorina, Stern_5

Station ID	Date Time [UTC] surface, start - end	Date Time [UTC] bottom, start - end	Latitude surface / bottom	Longitude surface / bottom	Bottom depth [m] surface / bottom	Remarks
2_1	01.09.2020 06:54 01.09.2020 06:59	01.09.2020 07:01 01.09.2020 07:07	54.1467/ 54.1463	7.9251/ 7.9289	50	surface (1 m) bottom (18 m)
2_2	01.09.2020 07:46 01.09.2020 07:49	01.09.2020 07:51 01.09.2020 07:54	54.1705/ 54.1711	8.0535/ 8.0557	26	surface (1 m) bottom (18 m)
2_3	01.09.2020 08:17 01.09.2020 08:20	01.09.2020 08:21 01.09.2020 08:25	54.1706/ 54.1707	8.1344/ 8.1367	19	surface (1 m) bottom (17 m)
2_4	01.09.2020 08:47 01.09.2020 08:51	01.09.2020 08:52 01.09.2020 08:55	54.1701/ 54.1698	8.2216/ 8.2239	17	surface (1 m) bottom (15 m)
2_5	01.09.2020 09:22 01.09.2020 09:25	01.09.2020 09:26 01.09.2020 09:29	54.1641/ 54.1642	8.3175/ 8.3192	15	surface (1 m) bottom (13 m)
2_6	01.09.2020 10:13 01.09.2020 10:17	01.09.2020 10:18 01.09.2020 10:21	54.1123/ 54.1119	8.4468/ 8.4471	9	surface (1 m) bottom (7 m)
2_7	01.09.2020 11:04 01.09.2020 11:07	01.09.2020 11:08 01.09.2020 11:11	54.1059/ 54.1058	8.6171/ 8.6166	10	surface (1 m) bottom (9 m)
2_8	01.09.2020 11:59 01.09.2020 12:02	01.09.2020 12:03 01.09.2020 12:06	54.1266/ 54.1262	8.7639/ 8.7631	12	surface (1 m) bottom (9 m)
3_1	02.09.2020 04:18 02.09.2020 04:21	02.09.2020 04:22 02.09.2020 04:25	54.1277/ 54.1278	8.7791/ 8.7773	10	surface (1 m) bottom (8 m)

Station ID	Date Time [UTC] surface, start - end	Date Time [UTC] bottom, start - end	Latitude surface / bottom	Longitude surface / bottom	Bottom depth [m] surface / bottom	Remarks
3_2	02.09.2020 05:08 02.09.2020 05:11	02.09.2020 05:13 02.09.2020 05:16	54.1034/ 54.1032	8.6242/ 8.6214	12	surface (1 m) bottom (10 m)
3_3	02.09.2020 06:21 02.09.2020 06:24	02.09.2020 06:25 02.09.2020 06:28	54.1644/ 54.1644	8.4111/ 8.4106	9	surface (1 m) bottom (9 m)
3_4	02.09.2020 07:02 02.09.2020 07:05	02.09.2020 07:06 02.09.2020 07:09	54.2334/ 54.2332	8.3591/ 8.3605	11	surface (1 m) bottom (10 m)
3_5	02.09.2020 07:53 02.09.2020 07:56	02.09.2020 07:57 02.09.2020 08:02	54.3280/ 54.3271	8.3024/ 8.3054	12	surface (1 m) bottom (11 m)
3_6	02.09.2020 09:03 02.09.2020 09:06	02.09.2020 09:08 02.09.2020 09:11	54.3303/ 54.3300	8.1019/ 8.1049	15	surface (1 m) bottom (14 m)
3_7	02.09.2020 10:10 02.09.2020 10:14	02.09.2020 10:15 02.09.2020 10:18	54.2513/ 54.2512	7.9982/ 7.9998	19	surface (1 m) bottom (18 m)
3_8	02.09.2020 10:57 02.09.2020 11:00	02.09.2020 11:02 02.09.2020 11:05	54.1704/ 54.1707	7.9380/ 7.9377	20	surface (1 m) bottom (18 m)
4_1	03.09.2020 05:46 03.09.2020 05:51	03.09.2020 05:53 03.09.2020 05:58	54.1515/ 54.1517	7.9134/ 7.9133	48	surface (1 m) bottom (18 m)
4_2	03.09.2020 06:39 03.09.2020 06:42	03.09.2020 06:43 03.09.2020 06:46	54.1704/ 54.1710	8.0599/ 8.0605	23	surface (1 m) bottom (17 m)

Tab. A.6.3: Station list for in-situ pump on Littorina, Stern_5

Station ID	Date Time [UTC] surface, start - end	Date Time [UTC] bottom, start - end	Latitude surface / bottom	Longitude surface / bottom	Bottom depth [m] surface / bottom	Remarks
4_3	03.09.2020 07:25 03.09.2020 07:29	03.09.2020 07:30 03.09.2020 07:33	54.2465/ 54.2471	8.1409/ 8.1435	12	surface (2 m) bottom (11 m)
4_4	03.09.2020 08:09 03.09.2020 08:11	03.09.2020 08:13 03.09.2020 08:16	54.2498/ 54.2503	8.3043/ 8.3087	12	surface (1 m) bottom (11 m)
4_5	03.09.2020 08:53 03.09.2020 08:56	03.09.2020 08:57 03.09.2020 08:59	54.1727/ 54.1734	8.3842/ 8.3884	12	surface (1 m) bottom (12 m)
4_6	03.09.2020 09:28 03.09.2020 09:31	03.09.2020 09:32 03.09.2020 09:35	54.1125/ 54.1127	8.4211/ 8.4262	10	surface (1 m) bottom (9 m)
4_7	03.09.2020 10:42 03.09.2020 10:45	03.09.2020 10:46 03.09.2020 10:49	53.9762/ 53.9756	8.5928/ 8.5982	11	surface (1 m) bottom (10 m)
4_8	03.09.2020 12:30 03.09.2020 12:34	03.09.2020 12:35 03.09.2020 12:40	53.9044/ 53.9030	8.7087/ 8.7145	12	surface (1 m) bottom (10 m)

Tab. A.6.4: Instruments on the *Littorina* on Stern_5

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi. de MOSES Sternfahrt 5 mission	Remarks
On the way		Position: ship_lat, ship_lon	F. Geißler	GPS Hemisphere Cresent R131RCVR	vessel:littorina:gps_ gmr_1228-160664-0011	
On the way	air	Atmospheric CH_4 and pCO_2: ch4dry, co2dry, lat, lon	J. Greinert	Picarro	vessel:littorina:crds_ cfbds2040	
On the way	water	Position: latitude_0001, longitude_0001, speed_0001 course_over_ground_0001	I. Bussmann	FerryBox pocket	vessel:littorina:pfb_awi_ 751801	
On the way & vertical with *in-situ* pump	water	Hydrography: flow_main_0001 Temperature_sbe45_0001, conductivity_sbe45_0001, salinity_ sbe45_0001, ph_0001 Temperature_ phsensor_0001, oxygen_ concentration_0001,[µmol/l], oxygen_saturation_0001, temperature_0001, turbidity_0001 chlorophyll_0001	I. Bussmann	FerryBox pocket	vessel:littorina:pfb_ awi_751801	

Tab. A.6.4: Instruments on the Littorina on Stern_5

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi. de MOSES Sternfahrt 5 mission	Remarks
On the way & vertical with *in-situ* pump	water	Dissolved methane: ambtemp, ch4, ch4dry, co2, co2dry, fitflag, gaspressure, gastemp, ch4_dissolved_ calculated	B. Cable	LosGatos	vessel:littorina:losgatos_ 3k43-3597	Time offset: -150 sec (GGA + Ferrybox), Correction with Degasser, Calibration from all days *26.92 - 0.98 with r^2 = 0.99 !
On the way	water	Oxygen: temperature_1039, salinity_1039, oxygen_1039, pressure_1039	E. Achterberg	SeapHOx	vessel:littorina:seaphox_ geomar_1039	
On the way	water	pCO2: carbon_dioxide_conc_ estimate_0001, carbon_dioxide_ pco2_corr_0001, carbon_dioxide_ xco2_corr_0001	E. Achterberg	ControsHydroC	vessel:littorina:co2_ geomar_0319001	no values for 31.08.
On the way	water	Nitrate: salinity, temperature, salinity	E. Achterberg	OPUS	vessel:littorina:opus_ geomar_71f9	
On the way	water	pH: ph_P0235, temperature_0001	F. Geißler	SAMI pH	vessel:littorina:sami_ph_ geomar_p0235	In progress, not yet in the database

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi. de MOSES Sternfahrt 5 mission	Remarks
On the way	water	Hydrography: conductivity_17F102065, depth_17h100268, , nlf_ conductivity_17f102065 odo_saturation_17h104627, odo_ concentration_17h104627, odo_local_17h104627, salinity_17f102065, specific_ conductivity_17f102065, total_ dissolved_solids_17f102065, tss_18E100560 temperature_17f102065, vertical_ position_17h100268	E. Achterberg	EXO1	vessel:littorina:exo1_ geomar_0001	
On the way	water	Dissolved methane: raw_ch4, corrected_ch4, pressure_sensor_temperature, pressure_millibar	E. Achterberg	ProOceanus Methane sensor	vessel:littorina:methane_ geomar_37-477-25	
Vertical	water	Hydrography: conductivity_0001, pressure_0001, salinity_0001,temperature_0001, oxygen_saturation_0001, oxygen_concentration_mll_0001, oxygen_concentration_0001, pH_0001, density_0001, sound_ velocity_0001	E. Achterberg	CTD rosette	vessel:littorina:ctd_ geomar_1070210	

Tab. A.6.4: Instruments on the Littorina on Stern_5

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi. de MOSES Sternfahrt 5 mission	Remarks
On the way	water	Hydrography: co2_4797-83, o2_4330-115, o2_4330-3316, o2_saturation_4330-115, o2_saturation_4330-3316, pco2_4797-83, temp_4330-115, temp_4330-3316, temp_4797-83	F. Geißler	Aanderaa SmartGuard and HUB	vessel:littorina:logger_gmr_smartguard_5100-410	

Tab. A.6.5: Station list for *Ludwig Prandtl* Stern_5 for water samples taken from the FerryBox outlet

Stations marked in blue are intercalibration stations. Results will be published in the Pangaea data base (https://pangaea.de/) together with the corresponding cruise label.

Station	Date Time [UTC]	Latitude	Longitude	Bottom depth [m]	Samples
1	31.08.2020 07:30	53.9023	8.7148	9.00	POC, DOC, multi element, TA, DIC, Chl, nutrients, Sal, Turb
2	31.08.2020 09:16	53.9981	8.3974	10.00	POC, DOC, multi element, TA, DIC, Chl, nutrients, Sal, Turb
3	31.08.2020 09:58	54.0058	8.2994	18.00	POC, DOC, TA, DIC, Chl, nutrients, Sal, Turb
4	31.08.2020 10:31	54.0117	8.1972	18.00	POC, DOC, TA, DIC, Chl, nutrients
5	31.08.2020 11:12	54.0155	8.0993	17.00	POC, DOC, TA, DIC, Chl, nutrients
6	31.08.2020 12:06	54.0000	8.0000	xxx	POC, DOC, TA, DIC, Chl, nutrients
7	31.08.2020 12:35	54.0000	7.9000	xxx	POC, DOC, multi element, TA, DIC, Chl, nutrients
8	31.08.2020 13:11	54.1000	7.9000	xxx	POC, DOC, multi element, TA, DIC, Chl, nutrients
9	01.09.2020 06:29	54.1515	7.9327	16.00	POC, DOC, TA, DIC, Chl, nutrients, Sal, Turb
10	01.09.2020 08:20	54.2996	7.9014	16.50	POC, DOC, multi element, TA, DIC, Chl, nutrients
11	01.09.2020 09:23	54.4005	7.9033	17.00	POC, DOC, multi element, TA, DIC, Chl, nutrients, Sal, Turb
12	01.09.2020 10:03	54.4005	8.0005	16.00	POC, DOC, TA, DIC, Chl, nutrients
13	01.09.2020 10:35	54.4014	8.0998	17.00	POC, DOC, multi element, TA, DIC, Chl, nutrients
14	01.09.2020 11:19	54.4003	8.1988	16.00	POC, DOC, TA, DIC, Chl, nutrients
15	01.09.2020 11:58	54.4011	8.2992	13.00	POC, DOC, TA, DIC, Chl, nutrients, Sal, Turb
16	01.09.2020 12:36	54.4007	8.3935	9.20	POC, DOC, multi element, TA, DIC, Chl, nutrients

Station	Date Time [UTC]	Latitude	Longitude	Bottom depth [m]	Samples
17	01.09.2020 14:07	54.5499	8.3361	10.20	POC, DOC, multi element, TA, DIC, Chl, nutrients, Sal, Turb
18	02.09.2020 04:28	54.6500	8.5000	17.00	POC, DOC, TA, DIC, Chl, nutrients, Sal, Turb
19	02.09.2020 06:42	54.6000	8.2000	8.00	POC, DOC, multi element, DO, TA, DIC, Chl, nutrients
20	02.09.2020 07:48	54.5983	8.0505	13.50	POC, DOC, TA, DIC, Chl, nutrients
21	02.09.2020 08:32	54.6000	7.9000	13.00	POC, DOC, multi element, TA, DIC, Chl, nutrients, Sal, Turb
22	02.09.2020 09:51	54.7500	7.9000	15.50	POC, DOC, multi element, DO, TA, DIC, Chl, nutrients, Sal, Turb
23	02.09.2020 10:29	54.7500	8.0000	13.50	POC, DOC, TA, DIC, Chl, nutrients
24	02.09.2020 11:06	54.7500	8.1000	15.90	POC, DOC, TA, DIC, Chl, nutrients, Sal, Turb
25	02.09.2020 11:44	54.7500	8.2000	11.40	POC, DOC, multi element, DO, TA, DIC, Chl, nutrients
18a	02.09.2020 14:35	54.6500	8.4500	20.00	multi element
26	03.09.2020 05:17	54.5900	8.4000	15.50	POC, DOC, DO, TA, DIC, Chl, nutrients, Sal, Turb
27	03.09.2020 05:55	54.5500	8.3700	14.00	POC, DOC, TA, DIC, Chl, nutrients
28	03.09.2020 06:48	54.4540	8.2670	7.70	POC, DOC, TA, DIC, Chl, nutrients
29	03.09.2020 07:46	54.3520	8.3700	7.00	POC, DOC, TA, DIC, Chl, nutrients, Sal, Turb
30	03.09.2020 08:39	54.2590	8.4430	9.00	POC, DOC, DO, TA, DIC, Chl, nutrients, Sal, Turb
31	03.09.2020 09:30	54.1800	8.4800	9.50	POC, DOC, TA, DIC, Chl, nutrients
32	03.09.2020 10:22	54.0963	8.4527	15.50	POC, DOC, TA, DIC, Chl, nutrients
33	03.09.2020 12:11	53.9030	8.7090	12.50	DO, TA, DIC, Chl, nutrients

Station	Date Time [UTC]	Latitude	Longitude	Bottom depth [m]	Samples
34	03.09.2020 13:40	53.8440	8.9345	underway	TA, DIC, Chl, nutrients, Sal, Turb
35	03.09.2020 14:04	53.8656	9.0586	underway	TA, DIC, Chl, nutrients, Sal, Turb
36	03.09.2020 14:46	53.8625	9.2795	underway	TA, DIC, Chl, nutrients, Sal, Turb
37	03.09.2020 15:17	53.7937	9.3765	underway	TA, DIC, Chl, nutrients, Sal, Turb

Tab. A.6.6: Instruments on the *Ludwig Prandtl* on Stern_5

On the way/ vertical	Water/ air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de MOSES Sternfahrt 5 mission	Remarks
On the way	water	Position: latitude_0001, longitude_0001	G. Flöser	FerryBox	vessel:prandtl_hzg:fb_hzg_orion	
On the way	air	Weather: meteo_air_pressure_0001 Meteo_air_temperature_0001, Meteo_radiation_0001: did not work, relative_humidity_0001, meteo_wind_east_0001, meteo_wind_direction_0001, meteo_wind_north_0001, meteo_wind_speed_0001	G. Flöser	Weather Station GMX600	vessel:prandtl_hzg:weather_station_hzg_1957ps001	
On the way	water	Hydrography: cdom_cyclops_0001 Chlorophyll_a_0001, oxygen_saturation_0001, ph_meinsberg_ega_0001, salinity_0001 Turbidity_0001, temperature_citadel_0001	G. Flöser	FerryBox	vessel:prandtl_hzg:fb_hzg_orion	The chlorophyll data are rather high and are now checked again

On the way/ vertical	Water/ air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de MOSES Sternfahrt 5 mission	Remarks
On the way/ vertical?	water	Dissolved methane methane_dry_0001, methane_in_air_0002, methane_in_water_0002 [ppm], methane_in_water_0004 [nmol/l], methane_nmolL_0001 [nmol/l], carbon_dioxide_dry_0001, carbon_dioxide_0002, fit_flag_0001	I. Bussmann	LosGatos greenhouse gas analyzer and Degasser	losgatos_awi_3599	A time offset of - 81 sec Only data where fitflag = 3 The ppm data was corrected for the efficiency of the degasser Conversion in nmol / L from all data of the trip => * gradient 22.72
vertical	water	Hydrography: pressure_01, temperature_01, conductivity_01,salinity_01, sigma_theta_01, light_transmission_01, turbidity_01, chlorophyll_a_01, oxygen_concentration_01,[mg/l], oxygen_saturation_01	G. Flöser	CTD	vessel:prandtl_hzg:ctd_hzg_313:salinity_01	

Tab. A.6.6: Instruments on the Ludwig Prandtl on Stern_5

On the way/ vertical	Water/ air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de MOSES Sternfahrt 5 mission	Remarks
On the way	air	Atmospheric $CO_2/CH_4/H_2O$: Methane mole fraction in dry air, Carbon dioxide mole fraction in dry air, Water vapor concentration	U. Ködel / C. Schütze	LICOR $CH_4/CO_2/H_2O$ Trace Gas Analyzer	vessel:prandtl_hzg:ufz_licor_7810:ring_down_time	Tube length 2 m, data corrected for a time offset of 1 s

Tab. A.6.7: Station list for water samples taken on *Mya II*, Stern_5

All water samples were taken from the Niskin bottle at 1 m water depth. The amount of filtered water for pigment and POC analysis was 500 mL. Stations marked in blue are intercalibration stations. Results will be published in the Pangaea data base (https://pangaea.de/) together with the corresponding cruise label.

Station ID	Date Time [UTC]	Latitude	Longitude	Bottom depth [m]	Remarks
M-1	31.08.2020 07:26	53.9020	8.7217	11	sal / tur, pigments, POC, DOC, nutrients, methane,
M-2	31.08.2020 08:22	53.9448	8.6637	8	sal / tur, pigments, POC, DOC, nutrients, methane, bei M1 oder M2 fehlt sal/ turb
M-3	31.08.2020 09:09	53.9755	8.5579	12	sal / tur, pigments, POC, DOC, nutrients, methane,
M-4	31.08.2020 10:06	53.9985	8.3816	12	sal / tur, pigments, POC, DOC, nutrients, methane,
M-5	31.08.2020 10:40	54.0211	8.3039	10	sal / tur, pigments, POC, DOC, nutrients, methane,
M-6	31.08.2020 11:39	54.0784	8.1389	20	sal / tur, pigments, POC, DOC, nutrients, methane,
M-7	31.08.2020 12:33	54.1105	8.0521	25	sal / tur, pigments, POC, DOC, nutrients, methane,
M-8	31.08.2020 13:06	54.1393	7.9731	41	sal / tur, pigments, POC, DOC, nutrients, methane,
M-9	01.09.2020 07:08	54.1481	7.9349	44	sal / tur, pigments, POC, DOC, nutrients, methane,
M-10	01.09.2020 08:32	54.0030	8.0085	31	sal / turb, pigments, POC, DOC, nutrients, methane,
M-11	01.09.2020 09:13	53.9179	8.0046	15	sal / turb, pigments, POC, DOC, nutrients, methane,
M-12	01.09.2020 09:45	53.8564	8.0057	19	sal / tur, pigments, POC, DOC, nutrients, methane,
M-13	01.09.2020 10:27	53.7940	8.1236	16	sal / turb, pigments, POC, DOC, nutrients, methane,
M-14	01.09.2020 11:11	53.7252	8.2476	15	sal / turb, pigments, POC, DOC, nutrients, methane,
M-15	01.09.2020 11:55	53.6686	8.3724	15	sal / turb, pigments, POC, DOC, nutrients, methane,
M-16	01.09.2020 12:42	53.6035	8.4966	12	sal / turb, pigments, POC, DOC, nutrients, methane,

Tab. A.6.7: Station list for water samples taken on Mya II, Stern_5

Station ID	Date Time [UTC]	Latitude	Longitude	Bottom depth [m]	Remarks
M-17	02.09.2020 07:39	53.6735	8.3802	11	sal / turb, pigments, POC, DOC, nutrients, methane, oxygen bottles 31, 32, 33
M-18	02.09.2020 08:41	53.7322	8.2603	11	sal / turb, pigments, POC, DOC, nutrients, methane,
M-19	02.09.2020 09:40	53.8046	8.1452	9	sal / turb, pigments, POC, DOC, nutrients, methane, oxygen bottles 29, 30, 34
M-20	02.09.2020 10:36	53.8579	8.0071	20	sal / turb, pigments, POC, DOC, nutrients, methane,
M-21	02.09.2020 11:05	53.8631	7.9348	21	sal / turb, pigments, POC only 200 ml filtered, DOC, nutrients, methane, oxygen bottles 26, 27, 28
M-22	02.09.2020 12:02	53.8502	7.7395	19	sal / turb, pigments, POC, DOC, nutrients, methane,
M-23	02.09.2020 13:09	54.0014	7.7391	37	sal / turb, pigments, POC, DOC, nutrients, methane, oxygen bottles 23, 24, 25
M-24	02.09.2020 14:14	54.1495	7.7359	34	sal / turb, pigments, POC, DOC, nutrients, methane,
M-25	03.09.2020 05:59	54.1526	7.9105	48	sal / turb, pigments, POC, DOC, nutrients, methane,
M-26	03.09.2020 06:35	54.2031	7.9543	14	sal / turb, NO pigments, POC, DOC, nutrients, methane,
M-27	03.09.2020 08:37	54.4670	8.0964	18	sal / turb, pigments, POC, DOC, nutrients, methane,
M-28	03.09.2020 09:43	54.5971	8.1472	13	sal / turb, pigments, POC, DOC, nutrients, methane,
M-29	03.09.2020 10:39	54.7057	8.1777	12	sal / turb, pigments, POC, DOC, nutrients, methane,
M-30	03.09.2020 11:31	54.7979	8.2142	12	sal / turb, pigments, POC, DOC, nutrients, methane,
M-31	03.09.2020 13:29	55.0647	8.4159	23	sal / turb, pigments, POC, DOC, nutrients, methane,
M-32	03.09.2020 14:01	55.0378	8.4714	11	sal / turb, pigments, POC, DOC, nutrients, methane,

Tab. A.6.8: Station list for *Mya II*, Stern_5 for *in-situ* pump

Maximal length of tube for *in-situ* pump is 20 m

Station ID	Date Time [UTC] surface, start - end	Date Time [UTC] bottom, start - end	Latitude surface / bottom	Longitude surface / bottom	Bottom depth [m] surface / bottom	Remarks
M-1	31.08.2020 07:14 31.08.2020 07:17	31.08.2020 07:18 31.08.2020 07:21	53.9048	8.7049	13	surface (1 m) bottom (13 m)
M-2	31.08.2020 08:13 31.08.2020 08:16	31.08.2020 08:17 31.08.2020 08:20	53.9494	8.6563	14	surface (1 m) bottom (13 m)
M-3	31.08.2020 09:00 31.08.2020 09:03	31.08.2020 09:04 31.08.2020 09:08	53.9770 / 53.9757	8.5526 / 8.5570	11 / 11	surface (1 m) bottom (10 m) Vorbeifahrt MS Helgoland um 09:02
M-4	31.08.2020 09:56 31.08.2020 09:59	31.08.2020 10:00 31.08.2020 10:04	54.0003 / 53.9988	8.3806 / 8.3817	12 / 13	surface (1 m) bottom (11 m)
M-5	31.08.2020 10:31 31.08.2020 10:34	31.08.2020 10:35 31.08.2020 10:38	54.0221 / 54.0211	8.3031 / 8.3041	10 / 11	surface (1 m) bottom (10 m)
M-6	31.08.2020 11:28 31.08.2020 11:31	31.08.2020 11:33 31.08.2020 11:36	54.0798 / 54.0786	8.1408 / 8.1389	20 / 20	surface (1 m) bottom (20 m)
M-7	31.08.2020 12:22 31.08.2020 12:24	31.08.2020 12:28 31.08.2020 12:32	54.1114 / 54.1105	8.0567 / 8.0530	24 / 25	surface (1 m) bottom (20 m)
M-8	31.08.2020 12:56 31.08.2020 12:59	31.08.2020 13:01 31.08.2020 13:05	54.1396 / 54.1394	7.9788 / 7.9738	40 / 41	surface (1 m) bottom (20 m)

Tab. A.6.8: Station list for Mya II, Stern_5 for in-situ pump

Station ID	Date Time [UTC] surface, start - end	Date Time [UTC] bottom, start - end	Latitude surface / bottom	Longitude surface / bottom	Bottom depth [m] surface / bottom	Remarks
M-9	01.09.2020 06:54 01.09.2020 06:59	01.09.2020 07:01 01.09.2020 07:08	54.1486 / 54.1481	7.9267 / 7.9345	49 / 44	surface (1 m) bottom (20 m)
M-10	01.09.2020 08:21 01.09.2020 08:25	01.09.2020 08:26 01.09.2020 08:29	54.0041 / 54.0031	8.0058 / 8.0083	31 / 31	surface (1 m) bottom (20 m)
M-11	01.09.2020 09:03 01.09.2020 09:07	01.09.2020 09:08 01.09.2020 09:11	53.9202 / 53.9182	8.0049 / 8.0047	13 / 14	surface (1 m) bottom (15 m)
M-12	01.09.2020 09:35 01.09.2020 09:38	01.09.2020 09:39 01.09.20 09:43	53.8589 / 53.8566	8.0051 / 8.0057	19 / 19	surface (1 m) bottom (20 m)
M-13	01.09.2020 10:17 01.09.2020 10:20	01.09.2020 10:22 01.09.2020 10:25	53.7969 / 53.7942	8.1241 / 8.1237	18 / 16	surface (1 m) bottom (20 m)
M-14	01.09.2020 11:02 01.09.2020 11:05	01.09.2020 11:06 01.09.2020 11:10	53.7273 / 53.7252	8.2436 / 8.2475	16 / 15	surface (1 m) bottom (15 m)
M-15	01.09.2020 11:46 01.09.2020 11:49	01.09.2020 11:50 01.09.2020 11:53	53.6706 / 53.6688	8.3717 / 8.3724	17 / 15	surface (1 m) bottom (15 m)
M-16	01.09.2020 12:34 01.09.2020 12:37	01.09.2020 12:38 01.09.2020 12:41	53.6034 / 53.6035	8.4972 / 8.4966	13 / 12	surface (1 m) bottom (15 m)
M-17	02.09.2020 07:30 02.09.2020 07:33	02.09.2020 07:35 02.09.2020 07:39	53.6736 / 53.6736	8.3803 / 8.3802	10 / 11	surface (1 m) bottom (10 m)

Station ID	Date Time [UTC] surface, start - end	Date Time [UTC] bottom, start - end	Latitude surface / bottom	Longitude surface / bottom	Bottom depth [m] surface / bottom	Remarks
M-18	02.09.2020 08:32 02.09.2020 08:36	02.09.2020 08:36 02.09.2020 08:40	53.7358 / 53.7324	8.2553 / 8.2600	10 / 11	surface (1 m) bottom (10 m)
M-19	02.09.2020 09:32 02.09.2020 09:35	02.09.2020 09:36 02.09.2020 09:39	53.8080 / 53.8048	8.1436 / 8.1451	9 / 9	surface (1 m) bottom (10 m)
M-20	02.09.2020 10:25 02.09.2020 10:29	02.09.2020 10:30 02.09.2020 10:34	53.8598 / 53.8581	8.0051 / 8.0069	20 / 20	surface (1 m) bottom (20 m)
M-21	02.09.2020 10:56 02.09.2020 10:59	02.09.2020 11:01 02.09.2020 11:04	53.8632 / 53.8631	7.9324 / 7.9348	21 / 21	surface (1 m) bottom (20 m)
M-22	02.09.2020 11:52 02.09.2020 11:55	02.09.2020 11:58 02.09.2020 12:01	53.8504 / 53.8502	7.7406 / 7.7395	22 / 22	surface (1 m) bottom (20 m)
M-23	02.09.2020 13:00 02.09.2020 13:03	02.09.2020 13:04 02.09.2020 13:07	54.0020 / 54.0014	7.7394 / 7.7391	37 / 37	surface (1 m) bottom (20 m)
M-24	02.09.2020 14:04 02.09.2020 14:08	02.09.2020 14:09 02.09.2020 14:13	54.1491 / 54.1495	7.7393 / 7.7358	34 / 34	surface (1 m) bottom (20 m)
M-25	03.09.2020 05:44 03.09.2020 05:49	03.09.2020 05:51 03.09.2020 05:56	54.1518 / 54.1523	7.9112 / 7.9106	49 / 49	surface (1 m) bottom (20 m)
M-26	03.09.2020 06:26 03.09.2020 06:29	03.09.2020 06:31 03.09.2020 06:34	54.2022 / 54.2031	7.9529 / 7.9543	15 /14	surface (1 m) bottom (15 m)

Tab. A.6.8: Station list for Mya II, Stern_5 for in-situ pump

Station ID	Date Time [UTC] surface, start - end	Date Time [UTC] bottom, start - end	Latitude surface / bottom	Longitude surface / bottom	Bottom depth [m] surface / bottom	Remarks
M-27	03.09.2020 08:23 03.09.2020 08:26	03.09.2020 08:28 03.09.2020 08:32	54.4679 / 54.4657	8.0895 / 8.0927	17 / 17	surface (1 m) bottom (20 m)
M-28	03.09.2020 09:31 03.09.2020 09:33	03.09.2020 09:36 03.09.2020 09:39	54.5992 / 54.5980	8.1460 / 8.1477	13 / 12	surface (1 m) bottom (15 m)
M-29	03.09.2020 10:30 03.09.2020 10:33	03.09.2020 10:34 03.09.2020 10:38	54.7085 / 54.7057	8.1784 / 8.1778	12 / 12	surface (1 m) bottom (15 m)
M-30	03.09.2020 11:20 03.09.2020 11:23	03.09.2020 11:24 03.09.2020 11:28	54.8015 / 54.7985	8.2157 / 8.2146	12 / 11	surface (1 m) bottom (10 m)
M-31	03.09.2020 13:17 03.09.2020 13:21	03.09.2020 13:22 03.09.2020 13:26	55.0632 / 55.0654	8.4111 / 8.4161	25 / 22	surface (1 m) bottom (20 m)
M-32	03.09.2020 13:49 03.09.2020 13:53	03.09.2020 13:54 03.09.2020 13:58	55.0411 / 55.0390	8.4697 / 8.4736	12 / 10	surface (1 m) bottom (15 m)

Tab. A.6.9: Instruments on the *Mya II* on Stern_5

On the way / vertical	**Water / air**	**Parameter(s)**	**Responsible person**	**Instrument name**	**Sensor ID** at https://dashboard.awi.de/?dashboard=10678	**Remarks** O2A: “MOSES Sternfahrt 5 mission”
On the way		Position: Longitude, latitude	N. Anselm	D-Ship	vessel:mya_ii:dgps	
On the way		Position: Longitude, latitude	N. Anselm	D-Ship	vessel:mya_ii:motion	
On the way		Weather station	N. Anselm	D-Ship		only as separate file
On the way	air	Atmospheric CH4 and pCO2: Carbon_dioxide_0001, carbon_dioxide_dry_0001, methane_0001 Methane_dry_0001, water_0001	I. Bussmann	Picarro	vessel:mya_ii:picarro_awi_cfads2156	
On the way & vertical with *in-situ* pump	water	Hydrography: chlorophyll_a, turbidity, pco2, xco2, o2_corr, oxygen, saturation, ph, conductivity, salinity, temperature (FSI), temperature (SBE38)	I. Bussmann	FerryBox	vessel:mya_ii:fb_741202	no values for turbidity on 03.09

Tab. A.6.9: Instruments on the Mya II on Stern_5

On the way / vertical	**Water / air**	**Parameter(s)**	**Responsible person**	**Instrument name**	**Sensor ID** at https://dashboard.awi.de/?dashboard=10678	**Remarks** O2A: "MOSES Sternfahrt 5 mission"
On the way & vertical with *in-situ* pump	water	Dissolved methane: Methane_in_water_0001, carbon_dioxide_water_0001, methane_dry_water_0001, carbon_dioxide_dry_water_0001 Fit_flag_water_0001, methane_in_water_0003,[nmol/l]	I. Bussmann	LosGatos greenhouse gas analyzer and Degasser	vessel:mya_ii:losgatos_awi_1303	Time offset: -171 sec (GGA + FerryBox), data every second, no correction with degasser, because defective Conversion to nmol/L: with bottles from tower of all days, *22.53 + 4.28
vertical	water	Hydrography: conductivity, level, temp	M. Friedrich	Levelogger	vessel:mya_ii:ufz_level_78743	only used on 31/8, no time offset
vertical	water	Hydrography: conductivity, level, temp	M. Friedrich	Levelogger	vessel:mya_ii:ufz_level_78969	no time offset

Die **Berichte zur Polar- und Meeresforschung** (ISSN 1866-3192) werden beginnend mit dem Band 569 (2008) als Open-Access-Publikation herausgegeben. Ein Verzeichnis aller Bände einschließlich der Druckausgaben (ISSN 1618-3193, Band 377-568, von 2000 bis 2008) sowie der früheren **Berichte zur Polarforschung** (ISSN 0176-5027, Band 1-376, von 1981 bis 2000) befindet sich im electronic Publication Information Center **(ePIC)** des Alfred-Wegener-Instituts, Helmholtz-Zentrum für Polar- und Meeresforschung (AWI); see https://epic.awi.de. Durch Auswahl "Reports on Polar- and Marine Research" (via "browse"/"type") wird eine Liste der Publikationen, sortiert nach Bandnummer, innerhalb der absteigenden chronologischen Reihenfolge der Jahrgänge mit Verweis auf das jeweilige pdf-Symbol zum Herunterladen angezeigt.

The **Reports on Polar and Marine Research** (ISSN 1866-3192) are available as open access publications since 2008. A table of all volumes including the printed issues (ISSN 1618-3193, Vol. 377-568, from 2000 until 2008), as well as the earlier **Reports on Polar Research** (ISSN 0176-5027, Vol. 1-376, from 1981 until 2000) is provided by the electronic Publication Information Center **(ePIC)** of the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI); see URL https://epic.awi.de. To generate a list of all Reports, use the URL http://epic.awi.de and select "browse"/ "type" to browse "Reports on Polar and Marine Research". A chronological list in declining order will be presented, and pdf-icons displayed for downloading.

Zuletzt erschienene Ausgaben:

Recently published issues:

751 (2021) The MOSES Sternfahrt Expeditions of the Research Vessels ALBIS, LITTORINA, LUDWIG PRANDTL, MYA II and UTHÖRN to the Elbe River, Elbe Estuary and German Bight in 2020, Edited by Ingeborg Bussmann, Norbert Anselm, Holger Brix, Philipp Fischer, Götz Flöser, Felix Geissler, Norbert Kamjunke

750 (2021) International Online Symposium: Focus Siberian Permafrost – Terrestrial Cryosphere and Climate Change, Editorial board: Pfeiffer EM, Vybornova O, Kutzbach L, Fedorova I, Knoblauch C, Tsibizov L & Beer C

749 (2021) Russian-German Cooperation: Expeditions to Siberia in 2019, edited by Matthias Fuchs, Dmitry Bolshiyanov, Mikhail Grigoriev, Anne Morgenstern, Luidmila Pestryakova, Leonid Tsibizov, and Antonia Dill

748 (2020) Das Alfred-Wegener-Institut in der Geschichte der Polarforschung: Einführung und Chronik, 2., erweiterte und überarbeitete Auflage, von Christian R. Salewski, Reinhard A. Krause, Elias Angele

747 (2020) Reconstruction of paleo sea ice and climate dynamics based on highly branched isoprenoids at the Western Antarctic Peninsula, by Maria-Elena Vorrath

746 (2020) Deutsche Südpolar-Expedition 1901-1903 Sport Kleidung und Ausrüstung für Schlittenreisen, herausgegeben von Cornelia Lüdecke, basierend auf einem Manuskript von Hans Gazert, Beiträgen von Expeditionsteilnehmern und anderen Zeitgenossen

745 (2020) Expeditions to Antarctica: ANT-Land 2019/20 Neumayer Station III, Kohnen Station, Flight Operations and Field Campaigns, edited by Tanja Fromm, Constance Oberdieck, Thomas Matz, Christine Wesche

744 (2020) The Expedition AF122/1 Setting up the MOSAiC Distributed Network in October 2019 with Research Vessel AKADEMIK FEDOROV, edited by Thomas Krumpen and Vladimir Sokolov

743 (2020) The Expedition to the Peel River in 2019: Fluvial Transport Across a Permafrost Landscape, edited by Frederieke Miesner, P. Paul Overduin, Kirsi Keskitalo, Niek J. Speetjens, Jorien Vonk, Sebastian Westermann

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

BREMERHAVEN

Am Handelshafen 12
27570 Bremerhaven
Telefon 0471 4831-0
Telefax 0471 4831-1149
www.awi.de

HELMHOLTZ