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Reports on Polar and Marine Research

The MOSES Sternfahrt Expeditions of the Research Vessels LITTORINA, LUDWIG PRANDTL, MYA II, UTHÖRN to the inner German Bight in 2019

Edited by

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with contributions of the participants

HELMHOLTZ

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Titel: Forschungsschiff Mya II bei der Anfahrt auf die Insel Helgoland (Foto: Dorit Kerschke, GFZ)

Cover: Research Vessel Mya II approaching the island of Helgoland (Photo: Dorit Kerschke, GFZ)

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MOSES Sternfahrten 2019
with
RV *Littorina*, RV *Ludwig Prandtl*, RV *Mya II*, RV *Uthörn*

Stern_1 15 - 18 April 2019
Stern_2 24 - 27 June 2019
Stern_3 09 - 12 Sept. 2019

Cuxhaven and Büsum to Helgoland and return

Modular Observation Solutions for Earth Systems

Chief Scientists

Ingeborg Bussmann (AWI) - RV *Uthörn* and RV *Mya II*
Holger Brix (HZG) - RV *Ludwig Prandtl*
Mario Esposito (GEOMAR) - RV *Littorina*

Coordinator
Ingeborg Bussmann

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1. SUMMARY AND ITINERARY

Recent global forecasts for the northern hemisphere predict an increase in the frequency and intensity of storm events with heavy rainfall and flooding of 10-20 % by the end of the century. Clearly discernible extremes in Central Europe are the summer floods in the Elbe catchment area in 2002 and 2013 as well as the extreme low water phases in 2018. Each of these extraordinary events caused damage running into billions and showed their enormous socio-economic as well as ecological effects.

The understanding of hydrological extremes and their role in water and material cycles requires a sound understanding of the interplay between conditions of origin such as weather conditions, precipitation and the topography of the affected areas as well as the influencing parameters along river and marine systems such as nutrient sources.

The Helmholtz program **M**odular **O**bservation **S**olutions for **E**arth **S**ystems (MOSES) with the event chain Hydrological Extremes aims to investigate the effects of such extreme high and low water events using the Elbe catchment area as an example and to assess the possible chemical, physical and ecological consequences of extreme events for the entire system from the river headwaters to the coastal zones.

With the help of specially adapted and partly newly developed mobile and modular sensor technology, situations that develop extreme characteristics in the water balance of the catchment area (heavy rainfall or extreme drought) can be monitored, recorded and evaluated taking the situation at hand into account. These measurement results can then be compared with the long-term measurements of existing permanent observatories, e.g. within the framework of **C**oastal **O**bserving **S**ystems for **N**orthern and **A**rctic **S**eas (COSYNA) in the Elbe estuary, autonomous observation systems of ferries from Büsum and Cuxhaven to Helgoland and the various existing governmental monitoring stations in the North Sea operated by the Bundesamt für Seeschifffahrt und Hydrographie (BSH) or other institutions.

Scientists from five research centers, *i.e.* Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven (AWI), GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel (GEOMAR), Helmholtz-Zentrum Potsdam - Deutsches GeoForschungsZentrum (GFZ), Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung (HZG), and Helmholtz-Zentrum für Umweltforschung, Leipzig (UFZ), sailed repeatedly from Cuxhaven and Büsum to Helgoland and return. They tested and operated the cross-ship application of networked sensors for the area-wide measurement of ecosystem quality in coastal waters. The research vessels also met with the ferries MS *Helgoland* and MS *Funny Girl* of the shipping company Cassen Eils on their way to Helgoland, as these vessels are also equipped with sensors which continuously recorded environmental measurement data which, in an emergency, complement the data of the research vessels.

In 2019, three cruises were carried out within the framework of MOSES as test campaigns with the research vessels *Littorina*, *Ludwig Prandtl*, *Mya II* and *Uthörn* in order to rehearse a simulated extreme case. For our cruises we applied the term „Sternfahrt“, as a cruise, which leads from different starting points (Cuxhaven and Büsum) to the same destination (Helgoland). The three ships of GEOMAR, AWI and the HZG are to be used in the future during high or low water events to collect samples and take real-time data during extreme events and to make them available, e.g. for modelling possible environmental scenarios and effects of the extreme events. The three test campaigns Sternfahrt 1, 2 and 3 were three exercises in the Elbe estuary which were intended to optimize the coordination and determine the course of the MOSES cruises. In the event of an imminent extreme flood event in the Elbe, the research team would have a relatively short lead time of about one week to prepare their ships with the measuring instruments, organize the response team and encounter the tidal wave when it arrives in the North Sea.

On Sternfahrt 1 with all three ships, the main focus was to coordinate the research vessels with the commercial ferries, operating in the same area. These ferries perform daily measurements of the basic water parameters with FerryBoxes on board. We had several meeting points with the ferries and aim now to compare the different data sets for a better incorporation into water mass modelling.

On Sternfahrt 2 with only two ships, the focus was on ship-to-ship communication and directing the cruise tracks of both ships towards observed plumes of water constituents.

On Sternfahrt 3 with all three ships again, the focus was to extend the ship-to-ship communication and to extend our study area in respect to better differentiate between water masses of the Weser and Elbe Estuary.

We established two intercalibration times each (during Stern_2 and Stern_3), when all ships stayed closely together with all instruments measuring. These periods turned out to be extremely helpful when comparing and relating the data between the ships and instruments.

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. However, such complex set up as in our „Sternfahrten“ is not easily mirrored in the database, thus this cruise report should also help to use the obtained data in the Elbe Estuary and Southern North Sea.

2. STERNFAHRT 1 (15 - 18 APRIL 2019)

2.1 Objectives

The main objective of this first „Sternfahrt“ was to compare data-sets obtained from the different research vessels with the ones obtained from the continuously recording FerryBox on the ferry MS *Helgoland* between Cuxhaven and Helgoland and the ferry MS *Funny Girl* between Büsum and Helgoland. This is necessary to evaluate, to which extend the data from these cruise ships are valuable in case of a real „extreme“ event. Therefore, we planned the cruise tracks of the research vessels to run in parallel the ferries, as often as possible.

Fig. 2.1: RV Mya II on Helgoland as seen from RV Ludwig Prandtl (right, by U. Ködel)

2.2 Work at sea with Ferries

The Ferries MS *Helgoland'* and MS *Funny Girl* both operated by Cassen Eils shipping company are equipped with FerryBoxes. These FerryBoxes run by the shipwater supply are measuring standard hydrographic parameters (temperature, salinity, chlorophyll and others). Twice a day the ferries are steaming from Cuxhaven to Helgoland and back, as well as from Büsum to Helgoland and back. The FerryBox at the MS *Helgoland* is operated by the AWI (Section Coastal ecology), the FerryBox at the MS *Funny Girl* is operated by the HZG, (Centre for Coastal Ecology). All data are stored in the near-realtime database of AWI https://dashboard.awi.de/data-xxl/overview.jsp under the sensor id's vessel:ms_hel and http://codm.hzg.de/codm/#.

Especially Stern_1 was conceived to enable comparison between the sensors on the research vessels and the ferries.

On 16. April the course of the research vessel *Mya II* was parallel to the MS *Helgoland* (Fig. 2.2), however with an offset of about 3 hours, we left at 6:00 UTC and the ferry at 9:30 UTC. As the ferries are much faster the two vessels only met shortly before Helgoland, around 11:00 UTC (54.176N; 7.894E, see Tab. A.3.1). The next day (17.4) we left Helgoland versus Cuxhaven in the morning, while the MS *Helgoland* first arrived from Cuxhaven in the morning and left Helgoland versus Cuxhaven at 15:00 UTC.

The research vessel *Ludwig Prandtl* left Cuxhaven on 16 April 2019, but was steaming in a northerly direction to meet with the vessels *Littorina* and *Funny Girl* at 8:34 (54.095N; 8.507E). Afterwards *Ludwig Prandtl* and *Funny Girl* were steaming towards Helgoland on a parallel course, while *Littorina* was 7 miles to the North. Next day (17 April) all ships took the same course back, from Helgoland towards Büsum (and further).

For all cruises back from Helgoland (17 April 2019) the research vessels left the island in the morning, while the ferries left the mainland around 09:30, and returned in the afternoon.

For the other cruises (Stern_2 and Stern_3) no specific meeting points between research vessels and ferries were assigned. But at least in the areas close to the ports of Cuxhaven and Helgoland overlapping cruise tracks should have occurred. Data have to be downloaded from the database with the corresponding time frames.

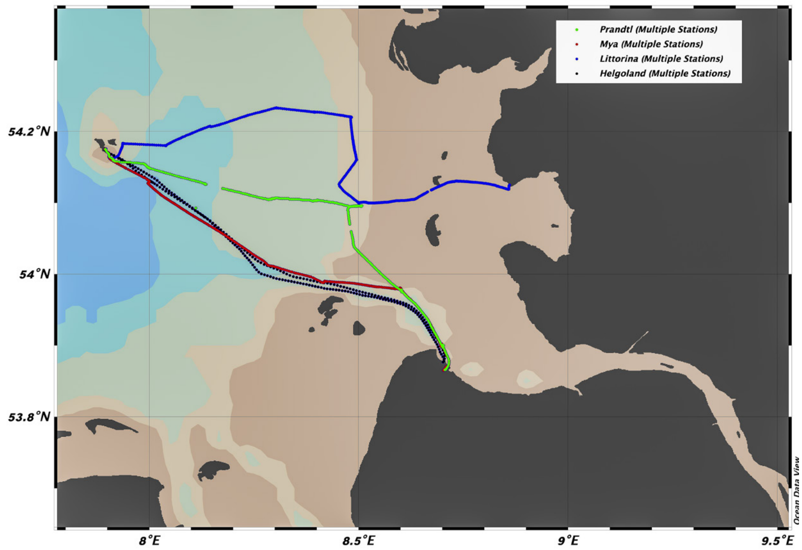

Fig. 2.2: Cruise track of the research vessels Littorina (blue), Mya II (red), Ludwig Prandtl (green) and the ferry Helgoland (black), for 16 April, Stern_1

Fig. 2.3: Meeting of RV Littorina (left), MS Funny Girl (right) as seen from the RV Ludwig Prandtl (by C. Schütze)

2.3 Work at sea with RV *Littorina*

Mario Esposito[1], Münevver Nehir[1], Peter Dietrich[2], Linda Jetter[3], Eric P. Achterberg[1]

[1]GEOMAR
[2]UFZ
[3]AWI

RV *Littorina* cruise L19-03 took place in the framework of the MOSES - Modular Observation Solutions for Earth Systems – project. Three participants (two from GEOMAR and one from AWI) sailed from Kiel in the morning of April 15, 2019 (06:00 h UTC). We started out of the Kiel fjord with very calm weather and into the Nord-Ostsee-Kanal until we reached Brunsbüttel. The time on the ship was used for setting up equipment and perform preliminary test measurements. Out of the channel we had to face the tide and we could reach Büsum only late in the evening (20:00 h). In Büsum, in the morning of the 16 April the fourth participant (from UFZ) joined the scientific party before we set sail at 06:00 h. A suite of sensors including CTDs (Seabird and Exo1) and nitrate sensors (Opus and Suna), were immersed into an aluminum box connected to the underway water supply. The flow rate was set to about 80 l per min allowing for fast exchange of the entire water volume inside the box. Additionally, a Ferrybox system integrated with LosGatos system allowed for continuous measurements of salinity, temperature, oxygen, pH, turbidity, chlorophyll and methane from the same underway water supply. A Picarro system for atmospheric pCO_2 and methane was also installed. The inlet was positioned on the bow at a height of about 4 m above sea level. The Picarro continuously recorded atmospheric data from Büsum to Helgoland and back to Kiel. Sensors measurements and underway water sampling started on departure from Büsum. Notwithstanding the rather tight time schedule and the strong tide, we reached the meeting point (53.10N, 8.50E) with the other ships (*Ludwig Prandtl* and MS *Funny Girl*) on time (08:30 h). At the meeting station the first vertical CTD cast was performed. A total of eight vertical profiles CTD casts were performed during the cruise with additional collection of water samples for carbonate chemistry, methane and nutrients analysis from the designated Niskin bottles (Tab. A.3.2).

The cruise ran smoothly (weather permitting) until arrival to Helgoland in the afternoon at 13:50 h. On the morning of April 17 at 06:00 h we sailed back to Büsum following the same cruise track as the previous day. All the sensors were continuously recording and similarly to the previous, hourly discrete water sampling from the underway water supply was performed. No vertical profiles CTD casts were however undertaken. We arrived in Büsum at 12:00 h. After one of the participants disembarked, we sailed to Brunsbüttel where we stopped overnight. On the morning of April 18, we entered the Nord-Ostsee-Kanal and reached our destination of Kiel at 12:00 h.

With a volume of approx. 160 Liter and a flow rate of 80 L/min, the turnover time (V/f) was 120 sec. There is no information on the length of the tubing and the position of the intake of water, therefore this offset was not considered. Thus, we subtracted the turnover time (120 sec) from all timestamps of instruments inside the box.

Details on station list, the applied sensors and locations for data access can be found in Tab. A.3.2 and Tab. A.3.3.

2.4 Work at sea with RV *Mya II*

Ingeborg Bussmann[1], Philipp Fischer[1], Madlen Friedrich[1], Hannes Fuchs[2], Dorit Kerschke[2], Robert Schima[3], Tobias Goblirsch[4]

[1]AWI
[2]GFZ
[3]UFZ
[4]Uni Rostock

On April 15 *Mya II* came from Sylt to Cuxhaven. On 16.4 at 06:00 UTC we started from the lock of Cuxhaven. Until about 07:00 UTC, we sailed in parallel to the *Ludwig Prandtl* and together took our first water sample at 07:01 - 07:10. Unfortunately it turned out that the bow thruster was not working anymore, so the stations were approached in a curve. Vertical water samples were taken with a Niskin bottle, together with a CTD over the A-frame. First the sample was taken over the ground and then the surface sample. For a later comparison of nutrient data, water was transferred to 0.5 L nalgene bottle, filtered and frozen. Three sample sets each were taken for AWI, GEOMAR and HZG, each with their respective filters and vials.

The methane concentration was recorded online via the on-board water system, as well as the hydrographic parameters with another CTD. Both devices were surrounded by overflowing water in a 10 L bucket. To calibrate the methane sensor, comparative samples were taken also from this bucket. With a volume of approx. 10 Liter and an estimated flow rate of 10 L/min, the turnover time (V/f) was 60 sec. There is no information on the length of the tubing and the position of the intake of water, therefore this offset was not considered. Thus, we subtracted the turnover time (60 sec) from all timestamps of instruments inside the bucket.

On the way the methane sensor was connected to a degassing device to determine the dissolved methane concentration in the water. However, in Helgoland port the atmospheric methane ratio was monitored at a height of 5.9 m above sea level. These data could then be compared with data obtained on *Littorina*.

In the further course the *Mya II* followed the transect of the *Helgoland* ferry. At 11:00 UTC, the *Mya II* and MS *Helgoland* both stopped, about 100 m away. Arrival in Helgoland was about 12:00 UTC. All three research vessels were lying next to each other in the harbor. The next day, we left Helgoland about 9:00, on the same way as before. No further stations were sampled.

Details on station list, the applied sensors and locations for data access be found in Tab. A.3.4 and Tab. A.3.5.

Fig. 2.4: Working on board of RV Mya II (by C. Schütze)

2.5 Work at sea with RV *Ludwig Prandtl*

Holger Brix[1], Hendrik Rust[1], Raimo Kopetzky[1], Viktoria Wichert[1], Claudia Schütze[2], Uta Ködel[2], Jan Hartmann[3]

[1]HZG
[2]UFZ
[3]AWI

RV *Ludwig Prandtl* arrived in Cuxhaven on Monday, 15 April for loading and installation. The *Ludwig Prandtl* left Cuxhaven on 16 April at 05:15 UTC with seven scientists and two crew members. From 05:35 through 05:57 we had a shared station with *Mya II* NW of Cuxhaven, then turning North to meet *Funny Girl* and *Littorina* at the Süderpiep. From there we set course to Helgoland. Arrival was at 12:45. On Wednesday, 17 April, we left Helgoland at 07:10, with the course back to Cuxhaven. The weather conditions on the return cruise were rather windy. Measurements were taken underway using a FerryBox, as well as oceanic CH_4/CO_2 with a LosGatos device and CO_2 air measurements with a LICOR 8100 (atmospheric measurements continued during the night between both cruise days). At stations, deep casts were taken with a side-mounted CTD with a three-bottle cylinder sampler. Water samples were taken at approximately 1 m depth, 1 to 1.5 m above ground and for some stations where a mixed layer structure was discernible at the relevant depth; some of the bottles misfired; therefore, only partial deep casts are available. Arrival in Cuxhaven was at 13:10.

Details on station list, the applied sensors and locations for data access can be found in Tab. A.3.6 and Tab. A.3.7.

Fig. 2.5: Setting up the LICOR-8100 on the RV Ludwig Prandtl (by D. Kerschke)

Preliminary results of Sternfahrt 1

One aspect of this cruise was to allow for a comparison of data between the different vessels and institutes. Therefore, water samples were taken along the cruises track and identical subsamples for nutrient analyses were performed by the laboratories of AWI, Geomar and HZG (for more details on the methods see also https://doi.pangaea.de/10.1594/PANGAEA.912011). Fig. 2.6 a first comparison for phosphate, silicate and nitrite concentrations of the water samples. Data were compared with a Wilcoxon Rank Sign Test for paired data.

For phosphate, the AWI-lab determined the same concentrations as the labs from HZG and GEOMAR, while phosphate concentrations differed between the labs from HZG and GEOMAR. For silicate, none of the data sets were statistically identical. For nitrate, HZG determined higher concentrations as compared to the analyses from GEOMAR and AWI.

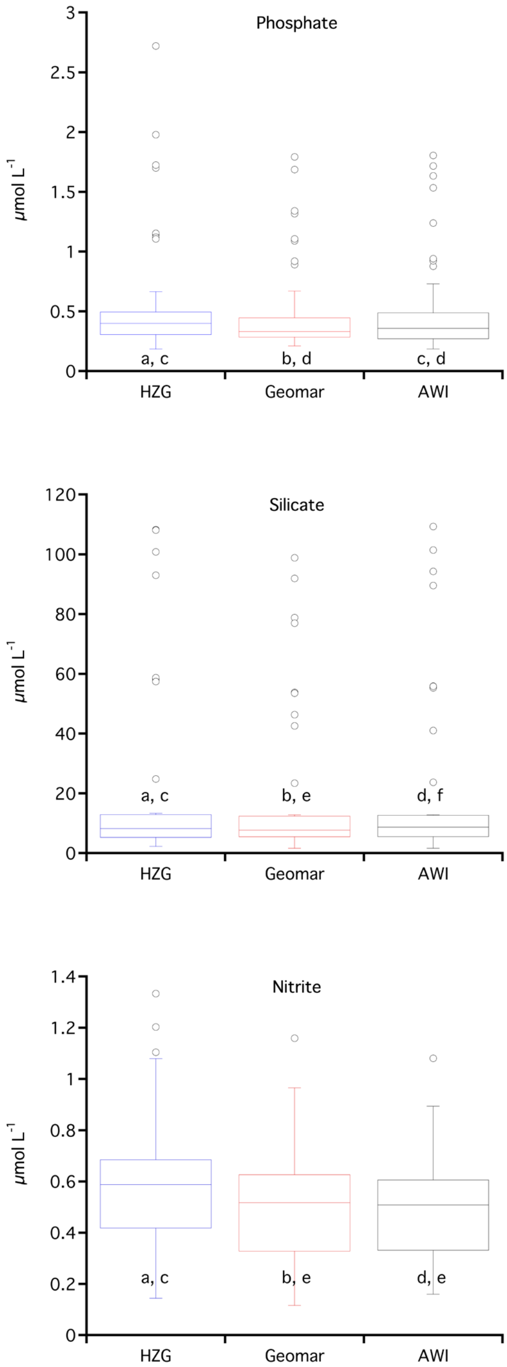

Fig. 2.6: Box plot for concentrations of phosphate, silicate and nitrite concentrations in water samples analyzed by the laboratories of HZG, GEOMAR and AWI. In these box plots the median value of the variable is displayed as a line. The top and bottom of the box mark the limits of ± 25% of the variable. The lines extending from the top and bottom of each box mark the minimum and maximum values. Outliers are displayed as individual points. Identical letters indicate no difference between the samples, different letters indicate significantly different values.

3. STERNFAHRT 2 (24 - 27 JUNE 2019)

3.1 Objectives

The aim of this trip was to test and optimize the coordination of the three Helmholtz centres with respect to joint ship campaigns in the North Sea. In the second „test“ cruise, a real scientific task was approached; to find and survey a methane plume, which earlier cruises had given an indication of. The specific goal was to verify the existence of such a methane plume and if verified, to locate and find areas with elevated concentrations of a substance in the water (here methane) and to verify its horizontal and vertical extent.

In June 2019 the two research vessels *Uthörn* and *Ludwig Prandtl* both started from Cuxhaven. Out of port, both ships stayed for about 1 hour and 50 m apart to calibrate / compare the instruments. This was repeated on the second day. At the end of each period a depth profile with CTD and water samples were taken. Both ships were equipped with devices for measurement on the way and for taking depth profiles with rosette water samplers and CTDs.

During cruise planning, the satellite images showed a large area of elevated chlorophyll in the coastal areas, but no smaller structures, hence we focused on methane in the water. During previous trips an area with increased methane concentration had been repeatedly observed southeast of Helgoland. We now wanted to investigate this area in more detail. In order to be able to drive a flexible course we placed the screens of the measuring instruments on the bridge / dry laboratory. Thus, a change of course could be arranged with the captains more quickly.

Fig. 3.1: Research vessels Uthörn and Prandtl in Cuxhaven (by H. Brix)

The origin of the water mass in which methane plume that was encountered during the first day of the cruise was determined on the morning of the second day by using the drift tool developed at HZG (https://coastmap.hzg.de/coastmap/modeldata/DriftApp/) based on a 2-D version of the PELLETS model, combined with output from the operational BSH model). These analyses informed our cruise planning for the second day.

For the intercalibration of all sensors, at the beginning of each day (25 and 26 June) both ships stayed close together, about 50 m, and all „on the way systems“ were running. At the end of this time a vertical profile with water samples and possibly CTD were taken, see Tab. A.4.1.

3.2 Work at sea with RV *Ludwig Prandtl*

Holger Brix[1], Marc Peters[1], Raimo Kopetzki[1], Tanja Pieplow[1], Tanja Brandt[2], Uta Ködel[2], Hannah Jebens[3]

[1]HZG
[2]UFZ
[3]AWI

RV *Ludwig Prandtl* arrived in Cuxhaven on Monday, 24 June for loading and installation. The *Ludwig Prandtl* left Cuxhaven on 25 June, at 07:15 (UTC) with seven scientists and two crew members. Off Cuxhaven, an intercalibration measurement with *Uthörn* was performed at 05:37 UTC. A total of four vertical stations were occupied on day one. The cruise track is shown in Fig. 3.2. Arrival in Helgoland was at 14:48. On day two, the *Ludwig Prandtl* left Helgoland before 07:00 UTC and another round of intercalibration measurements were performed between 07:05 and 07:25 hours. Due to weather conditions the *Ludwig Prandtl* took course toward Süderpiep and turned then south at about five SM west of Süderpiep to return to Cuxhaven at 13:58 UTC.

One general problem during the campaign was the quality of communication: the WiFi connection on *Ludwig Prandtl* was not stable which exacerbated the overall issues with 4G coverage in the German Bight. Without working connection, the initially working Teamviewer connections did not provide a lasting effect for the cruise.

The FerryBox sensors for fluorescence and turbidity were not working during the entire cruise. The ship pump stopped working early on the first day. This problem could be taken care of by using the fire pump instead. Issues with recording of CTD data due to computer failure could be repaired and data loss could be therefore avoided - for future cruises the number of peripherals working from one PC should be reduced and the number / frequency of backup copies should be increased.

To determine the dissolved methane concentration the degassing unit was sucking water from an overflowing bucket (10 L volume with a flow rate of approx. 2 l/min resulting in an offset of 300 sec). On the second day, the bucket was replaced by a waste water pipe. The methane measurements on the first day were hampered by too low flow rates in the pump which could be fixed by cleaning filters. Details on station list, the applied sensors and locations for data access can be found in Tab. A.4.2 and Tab. A.4.3.

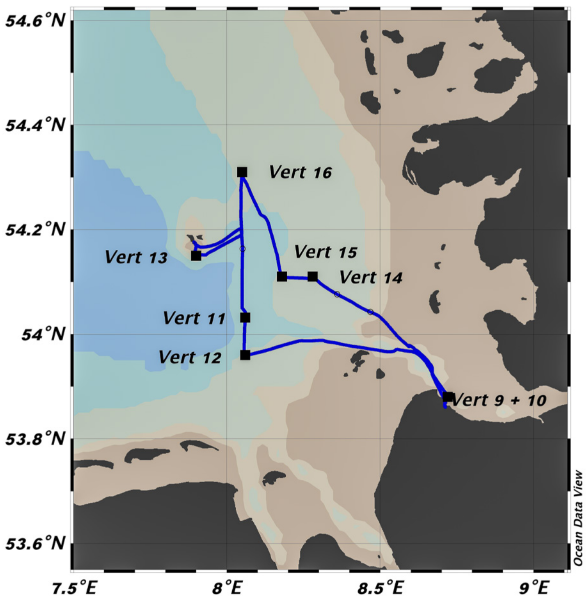

Fig. 3.2: Cruise track and stations of Ludwig Prandtl on Stern_2

Fig. 3.3: Screens of several instruments in the dry lab from the Ludwig Prandtl (by H. Brix)

3.3 Work at sea with RV *Uthörn*

Ingeborg Bussmann[1], Anna Lena Böger[1], Philipp Fischer[1], Madlen Friedrich[1], Uta Ködel[2]

[1]AWI
[2]UFZ

For Sternfahrt 2, the *Uthörn* left her home port Bremerhaven on 24 June to transfer to Cuxhaven, the starting point of the cruise. The cruise track is shown in Fig. 3.4. In the afternoon we set up our equipment and communication systems. We planned for on the way measurement of methane with two sensors, hydrochemistry in the water and CO_2 in the air. Depth profiles were taken for water samples with a rosette and mounted CTD. We also aimed for better communication between the laboratory and our partner-ship. Therefore, we applied the following set-up: in the laboratory all instruments were connected via VNC to a switch-board. This switch-board was connected to the bridge with a 20 m LAN cable, with 2 screens. In part, the mobile phone network and team-viewer were used to display *Ludwig Prandtl*'s measuring instruments. The (private) mobile phones were used for the short-term arrangement between the ships, and later on via ship's radio.

The first target was the area with the increased methane concentrations. The *Ludwig Prandtl* was parallel to *Uthörn* about 2 km south. As hoped, the methane levels in the target area increased, the 3rd station was made in the area of the highest values, the *Uthörn* continued its course further west, until background values could be seen on the screen again. The position of the elevated methane concentration was passed on to the *Ludwig Prandtl*, who then turned north to hit station 3. On the second day, we applied the model of Ulrich Callies (https://coastmap.hzg.de/coastmap/modeldata/DriftApp/) for backtracking water masses. Thus, we estimated that the water body with the increased methane values came from the Weser (Fig. 3.5). Therefore, the *Uthörn* followed and crossed this water body in a southerly direction. As we were already close to Bremerhaven during the verified course to follow the Weser waters and we decided to end our journey at the home port of the *Uthörn* (Bremerhaven) at short notice.

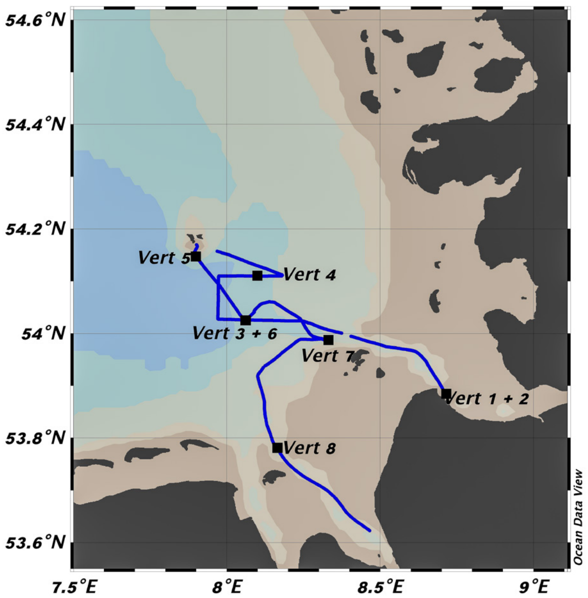

Fig.3.4: Cruise track of the RV Uthörn on 25 and 26 June

On board of the *Uthörn* we had two sensors to measure methane in the water. They were either sucking water from a big basin or were placed into this basin. For calibration, water samples were taken approx. every hour. These were analyzed in the home lab, for their methane concentration. From the same basin the pocket FerryBox was pumping water with a submerged pump to determine the standard hydrographic parameters. Reference samples for salinity and turbidity were also taken from this basin. These samples were analyzed by colleagues from the HZG. The basin with a volume of 65 L was rinsed with sea water from the ships pump with a flow rate of approx. 60 L/min, thus a turnover time of 65 sec can be calculated.

Details on station list, the applied sensors and locations for data access can be found in Tab. A.4.4 and Tab. A.4.5.

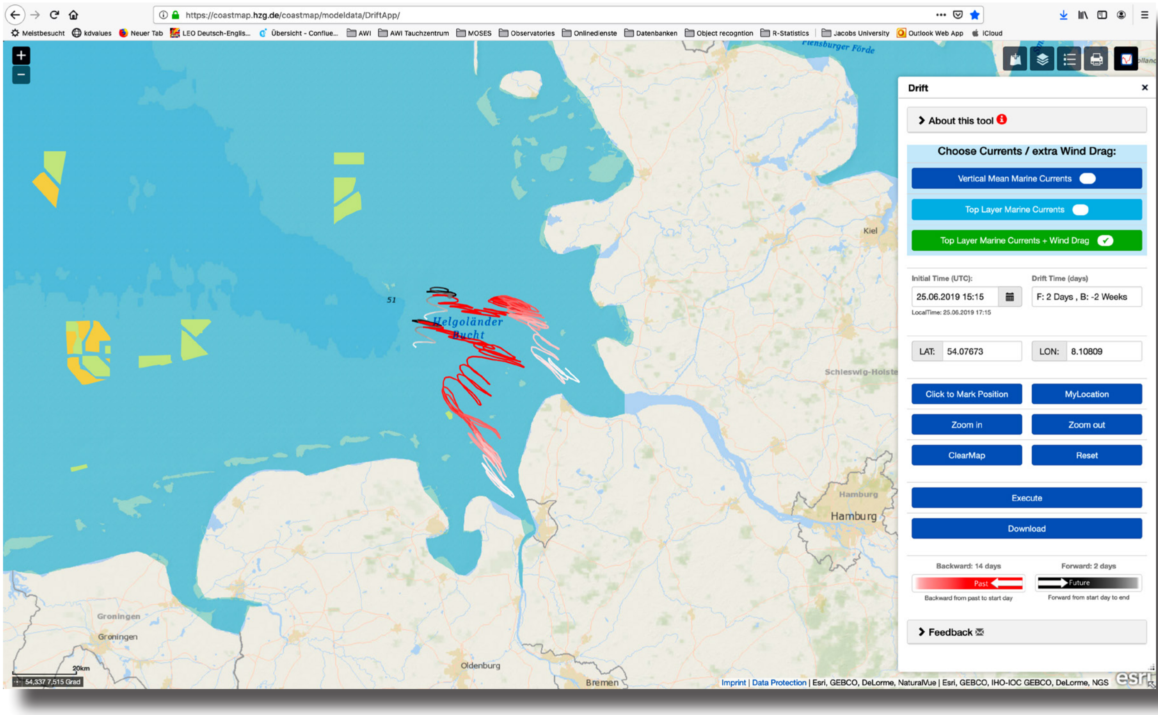

Fig. 3.5: Backward and forward trajectories for the water mass found with the highest methane concentrations

Fig.3.6: Screens of several instruments on the bridge of the Uthörn (by U. Ködel)

Preliminary results of Sternfahrt 2

We continuously measured dissolved methane in the surface waters of the study area, between the Elbe and Weser estuaries and the marine area around Helgoland. We observed increased methane concentrations in the estuaries of the rivers Elbe and Weser (Fig. 3.7). At a salinity of 25 PSU for both rivers, the Elbe estuary was colder with 19.3°C and 41 nmol/L methane versus 21.2°C and 43 nmol/L methane in the Weser estuary. By applying dilution models and water mass back tracking models, we want to further characterize the two river sources and also the marine endmember.

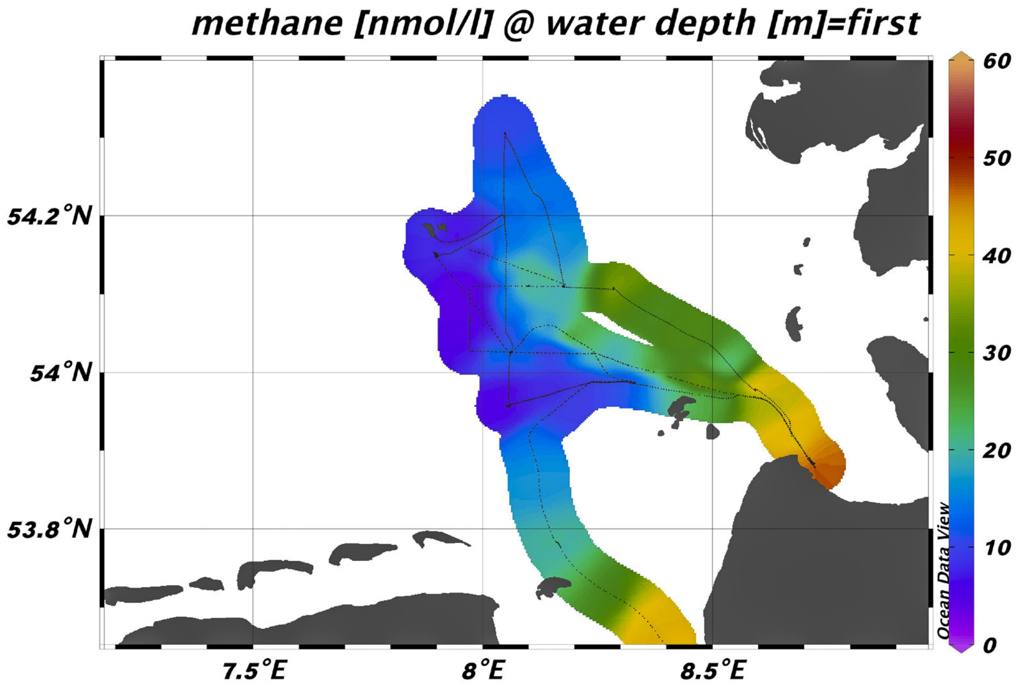

Fig. 3.7: Dissolved methane in the surface waters of Elbe and Weser Estuary on 25 and 26 June 2019

4. STERNFAHRT 3 (09 - 12 SEPTEMBER 2019)

4.1 Objectives

The aim of this trip was to revisit the methane „plume“southeast of Helgoland located during „Sternfahrt 2“, verify its horizontal and vertical extent and further investigate it using three ships. New investigations on this trip included the collection of vertical CH_4 samples as well as sediment samples.

All ships were equipped with FerryBoxes for underway measurements, methane throughflow degassers (Los Gatos) and CTDs for depth profiles including rosettes / sample collecting cylinders. *Uthörn* and *Ludwig Prandtl* also carried sediment samplers. With the support of colleagues from UFZ Magdeburg and FZ Jülich we were able to also measure methane in the air on board of all three ships.

All three ships (*Uthörn*, *Ludwig Prandtl* and *Littorina*) met in Cuxhaven on Monday, 09 September for loading and installation work. On Tuesday, 10 September all ships left port at 06:30 (UTC).

Out of port/lock at 07:04, all ships steamed to a shared position at approximately 53.98N, 8.57E (arrival ca. 08:30) for cross-calibration between the ships for about one hour (longer for *Uthörn* due to technical problems with pump for deep casts). Another cross calibration was performed on the second day off Helgoland. At the end of these periods, *Uthörn* and *Littorina* took a CTD cast (not possible on *Ludwig Prandtl* due to winch malfunction), *Uthörn* and *Ludwig Prandtl* switched water supply for the scientific equipment to a submersible pump to retrieve deep water samples (this option was not available on *Littorina*).

The cruise plan anticipated a shared west course towards a location south of Helgoland on the first day, with parallel northward courses through the assumed plume location. On the second day, W-E sections through the plume were planned. These courses could be followed only to a limited extent due to wind and swell/wave conditions (see Fig. 4.2). Nevertheless, an extended region of elevated methane surface concentrations was encountered, vertical profiles at a number of stations were performed and sediment samples taken.

The logistics of inter-ship communication continued to prove challenging as soon as GSM signals were lost.

For the intercalibration of all sensors, at the beginning of each day (10 and 11 September) all three ships stayed close together, about 50 m, and all on the way systems were running. At the end of this time a vertical profile with water samples and possibly CTD were taken (see Tab. A.5.1).

Fig. 4.1: Photo of all three ships in Cuxhaven: Ludwig Prandtl (foreground), Littorina (left) and Uthörn (right, by G. Flöser)

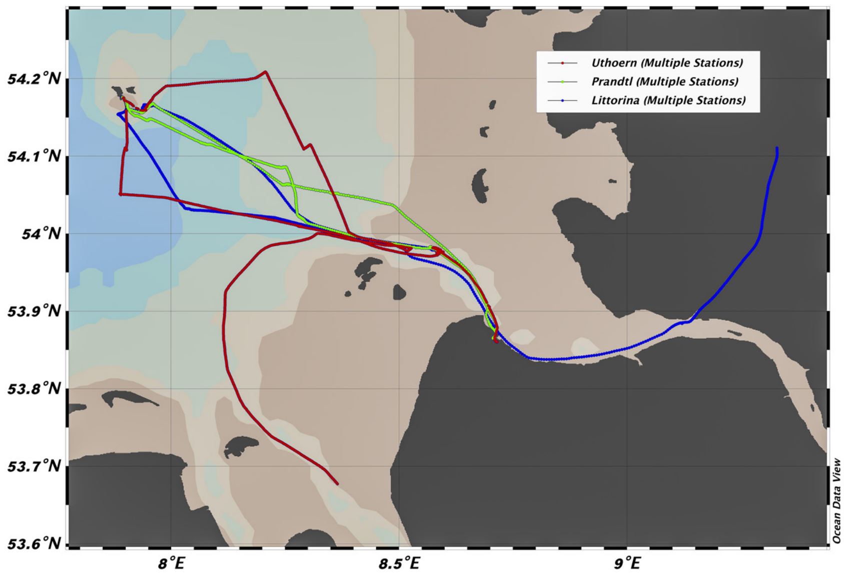

Fig. 4.2: Cruise track for all three ships on Sternfahrt 3, Littorina in blue, Ludwig Prandtl in green and Uthörn in red

4.2 Work at sea for RV *Littorina*

Mario Esposito[1], Münevver Nehir[1],
Sipan Isaa[2], Mahmoud Fatery
Abdalqader Altahan[1], Eric P. Achterberg[1]

[1]GEOMAR
[2]AWI

Littorina cruise L19-11 was the last of the 3 planned test campaigns in the Elbe estuary which took place within the framework of the Modular Observation Solutions for Earth Systems (MOSES) project. Three participants from GEOMAR sailed from Kiel on the morning of September 9, 2019 (06:00 h UTC) towards Cuxhaven. The ship entered the Nord-Ostsee-Kanal at 07:00 UTC and reached the port of Cuxhaven at 15:30 UTC. The first day was used to set up equipment (Tab. A.5.3) and perform preliminary measurements.

An internal wireless LAN was configured on the ship in order to transfer in real time the data collected from the several instruments to a central computer placed on the ship's bridge. Spacedesk Driver software was used to extend the various instrument desktops to the screen of the main computer.

In Cuxhaven in the morning of 10 September, the fourth participant (from AWI) joined the scientific crew party. We left the port of Cuxhaven at 07:00 UTC, the time when all the sensors started to log. The sensors were immersed into a 200 L tank placed on deck and connected to the underway water supply. Two pumps were used to feed both LosGatos and the Pocket FerryBox devices with the water from the same tank. The flow rate of the underway water supply was set to 100 L per minute to allow for fast replacement of the water inside the container. Although the fast water exchange, a delay of two minutes should be considered when processing the data. The Picarro system for atmospheric pCO_2 and methane was continuously recording atmospheric data from Kiel to Helgoland and back to Kiel. The inlet was positioned on the bow at a height of about 4 m above sea level.

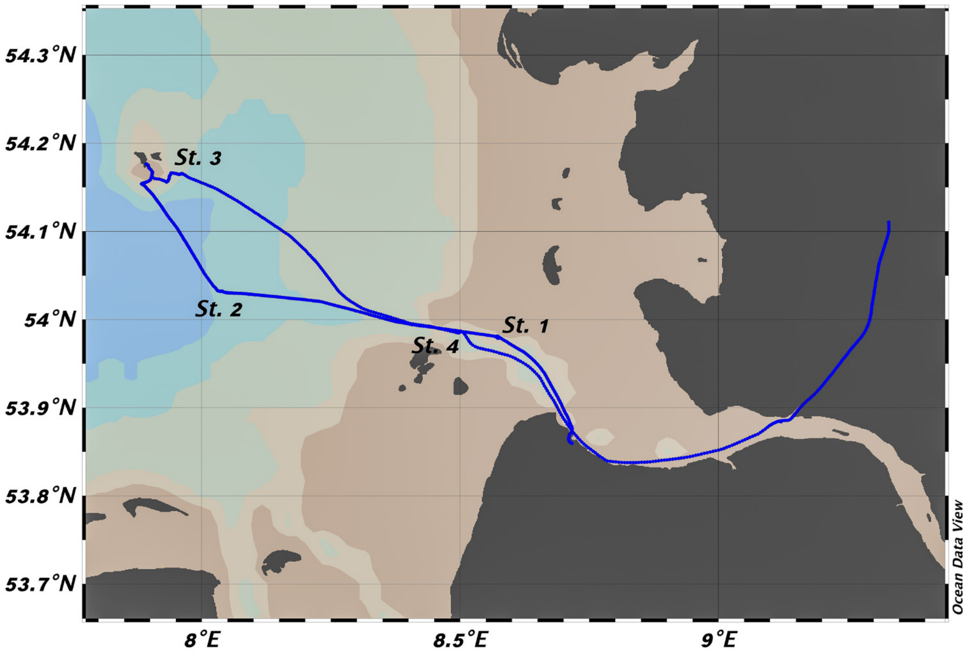

Fig. 4.3: Cruise track and station of Littorina on Stern_3

Fig. 4.4: RV Littorina in front of Cuxhaven (by E. Siewert)

Prior to steaming towards Helgoland, *Littorina* met with the two other ships *Uthörn* (AWI) and *Ludwig Prandtl* (HZG) at position 53.98 N, 8.57 E where instruments intercalibration took place. Real time communication among the three vessels was tested via Team Viewer. The poor internet access did not allow for a stable and successful communication. A vertical CTD cast was also performed. Following the meeting point, we continued to steam towards Helgoland. Heavy weather conditions allowed for only a second vertical CTD cast at position 54.03 N, 8.04 E prior to arrival in the port of Helgoland at 14:45 UTC. In the morning of 11 September, at 05:10 UTC we left Helgoland with strong southwesterly winds (Bft 6). Off the coast of Helgoland, at position 54.15 N, 7.93 E, a second intercalibration was performed. Here the three ships measured water properties for about 30 minutes. Again, a vertical CTD cast with water sample collection was performed. From the meeting station, we sailed alongside *Ludwig Prandtl* until approximately 07:30 UTC. We reached the pre-defined common point along the track at 08:40 UTC where the last vertical CTD cast was performed. On both days, along the cruise track (Fig. 4.3), water samples were collected at regular intervals (Tab. A.52). Sensors data logging and water sampling stopped at 11:10 UTC, prior arrival to the Nord-Ostsee-Kanal when we had to stop the water flow from the underway supply. We entered the channel at 11:30 UTC and reached Kiel west-shore at 20:30 UTC. Following the overnight stay, we sailed to the eastshore at 07:00 UTC.

Details on station list, the applied sensors and locations for data access can be found in Tab. A.5.2 and Tab. A.5.3.

4.3 Work at sea with RV *Ludwig Prandtl*

Holger Brix[1], Götz Flöser[1], Hannah Jebens[2], Wilhelm Petersen[1], Marc Peters[1]

[1]HZG
[2]AWI

The instrument setup on Monday 09 September was performed without major problems. The *Ludwig Prandtl* left Niedersachsenkai in Cuxhaven on Tuesday, 10 September, at 06:30 UTC; being in Cuxhaven lock from 06:40 - 07:04. Then the *Ludwig Prandtl* cruised to the shared station with other vessels (station P1) some km NW Cuxhaven, where a winch problem was discovered (winch had just been refurbished during a stay at the shipyard, worked only without load). As a consequence, no CTD vertical profiles could be taken during the entire cruise. As a partial remedy the water pump and the hose for vertical water sampling were detached from the CTD frame and operated manually to ensure that at least part of the vertical profile programme could be undertaken. This water supply was used for the FerryBox and the methane unit. The water supply was switched at stations to the *in-situ* pump. Thus, when working with the data, times of vertical profiles have to be excised manually according to Tab. A.5.4.

Four additional stations were taken on this day. A dissolved methane maximum of approx. 5 ppm was found on the (short) S-N leg of the cruise. The maximum location could not be probed due to technical problems in the dry lab during this part of the cruise (some equipment had fallen over due to heavy seas). This particular spot was revisited the next day and showed substantially higher values (up to 8.1 ppm).

On the second cruise day, weather conditions had deteriorated to a point where the captain urged early departure (actual: 05:15 UTC) and straight course to more sheltered waters. During the shared station (P6) off Helgoland, substantial wind and wave activity led to massive drift. During the course of the deep casts we had drifted from 45 m to approximately 30 m water depth, which led to the pump touching ground. No damage was sustained but mud was sucked in which impacted the sensors. Three more stations were occupied on the way back, with the last one (P9) approximately 400 m off the Cuxhaven FerryBox container location. Measuring directly at the container location was not feasible due to wind, wave and traffic conditions. After leaving P9, *Ludwig Prandtl* passed the container with minimum speed. *Ludwig Prandtl* docked in Cuxhaven, Alter Fischereihafen at 10:46 UTC.

The Picarro system for atmospheric pCO_2 and methane was continuously recording atmospheric data from Cuxhaven to Helgoland and back again. The inlet was positioned above the bridge of the *Ludwig Prandtl*, portside, at a height of approx. 6 m above sea level (Fig. 4.5).

Details on station list, the applied sensors and locations for data access can be found in Tab. A.5.4 and Tab. A.5.5.

Fig. 4.5: Position of air inlet on the RV Ludwig Prandtl for atmospheric methane measurements

4.4 Work at sea with RV *Uthörn*

Norbert Anselm[1], Ingeborg Bussmann[1], Yasin Cibuk[2], Madlen Friedrich[1], Sebastian Immoor[1], Thorben Otto[1], Emely Siewert[1]

[1]AWI
[2]Jacobs University

The *Uthörn* was in the shipyard in Cuxhaven, Hansa-Kai over the weekend. However on 09 September everything was ready for departure. We set up our equipment on Monday afternoon and left Cuxhaven on 10 September at 06:40 pm. The cruise started with our intercalibration station, where all three ships stayed closed together for 30 min. The cruise track is shown in Fig. 4.6. Our on the way sensors (pocket-FerryBox and methane sensor) were supplied with water from ships-supply. However, in contrast to previous cruises we have developed a pressure housing to which the hose from the ships-supply was attached as well as the in-situ pump. From this housing with a slight overpressure two lines were attached to the FerryBox and the degassing unit for methane. For the first two stations the in-situ pump was lowered manually, but afterwards we attached it into the middle of the rosette, and both instruments were lowered simultaneously. With this set-up a maximal depth of 15 m could be reached. Improvements for the in-situ pump should be a smaller volume of the tank, and a better pressure gauge to exactly determine the pressure. During the day the wind was increasing and we reached Helgoland at 15:00 UTC.

On the second cruise day, (11 September), we first had our common intercalibration station with water sampling and vertical profile. Then *Uthörn* was heading east and then back to our first intercalibration station. From there we had a long and rough way back to Bremerhaven, where we reached port at 18:00 UTC.

The ship-to-ship communication was only possible via ship-communication. The intended connection via team viewer was not possible due to limited internet access. The survey app has improved considerably, however in the laboratory with wet hands we still used the prepared papers.

The LosGatos system for atmospheric pCO_2 and methane was continuously recording atmospheric data from Cuxhaven to Helgoland and back to Bremerhaven. The inlet was positioned at the middle deck, portside and midship at the RV *Uthörn*, at a height of about 8 m above sea level (see Fig. 4.7).

The time offset for the atmospheric, under-way and vertical measurements was determined by switching the sources between high and low signals and determining the time until the changed signal levelled off again. For atmospheric measurements, a switch was made between ambient air and exhaled air with increased CO_2 content.

With a volume of approx. 10 Liter for the housing and 6.7 L for the tubings and a flow rate of 10 L/min, the turnover time (V/f) was 100 sec. Thus, we subtracted the turnover time (100 sec) from all timestamps of instruments inside the housing.

Vertical profiles of hydrographic parameters and methane were taken i) with CTD-519 attached to the rosette, the CTD was switched on / off at the respective stations and the data files are continuously but with time breaks. ii) with the pocket-FerryBox and water supply from the in-situ pump and iii) dissolved methane with the degassing unit and the water supply from also from the in-situ pump (see Fig. 4.8). The latter two instruments were running continuously; only the water supply was switched between on the way with ship's water supply and vertical with water supply from the in-situ pump. Thus, when working with the data, times of vertical profiles have to be excised manually according to the times provided in Tab. A.5.6.

Details on station list, the applied sensors and locations for data access can be found in Tab. A.5.6 and Tab. A.5.7.

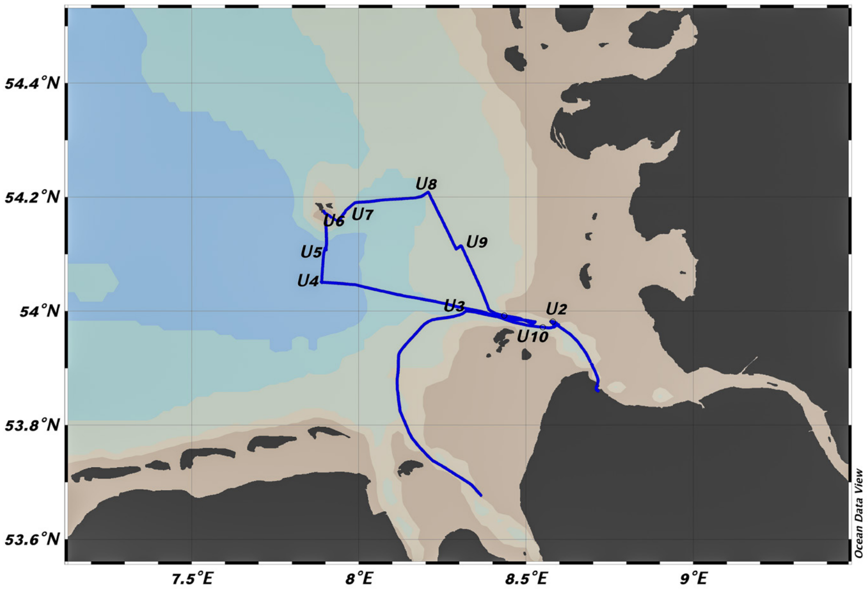

Fig. 4.6: Cruise track and station of RV Uthörn on Stern_3

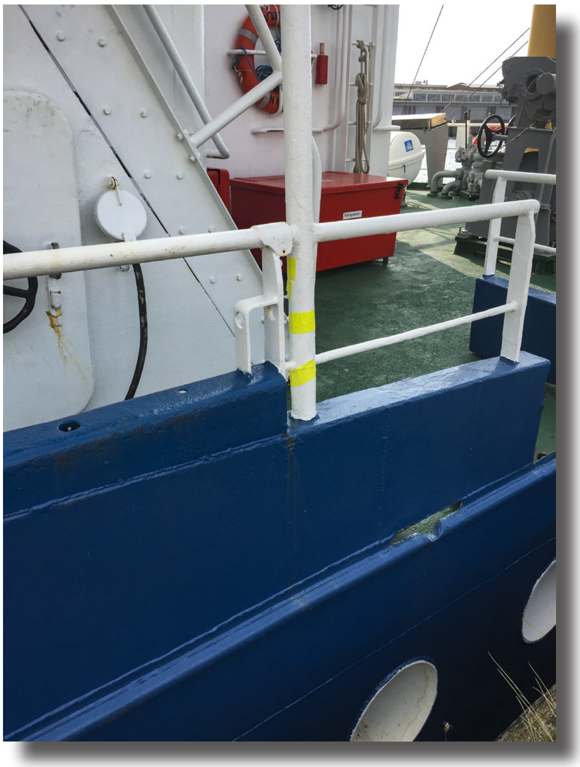

Fig. 4.7: Position of air inlet for atmospheric methane measurements on RV Uthörn

Fig. 4.8: Inlet of the in-situ pump within the Rosette at RV Uthörn

Preliminary results of Sternfahrt 3

With the support of our MOSES colleagues from GEOMAR, FZJ, and UFZ, we were able to measure atmospheric methane (and CO_2) during our cruise on all three ships. On the first day (10 September 2019) methane concentrations were uniformly low with 1.97 ± 0.01 ppm, Fig. 4.9). Wind was blowing from the West (280°) with 6.9 ± 2.5 m/sec. However, on the second day the wind was blowing from SSW (215°) and had also increased to a speed of 8.4 ± 3.1 m/sec (Fig. 4.9). This resulted in much higher atmospheric methane concentrations (2.11 ± 0.05 ppm) as compared to the first day (Fig. 4.9).

We assume that either this methane was transported from the main land towards the sea or an increased methane flux from the water led to the observed increase of atmospheric methane.

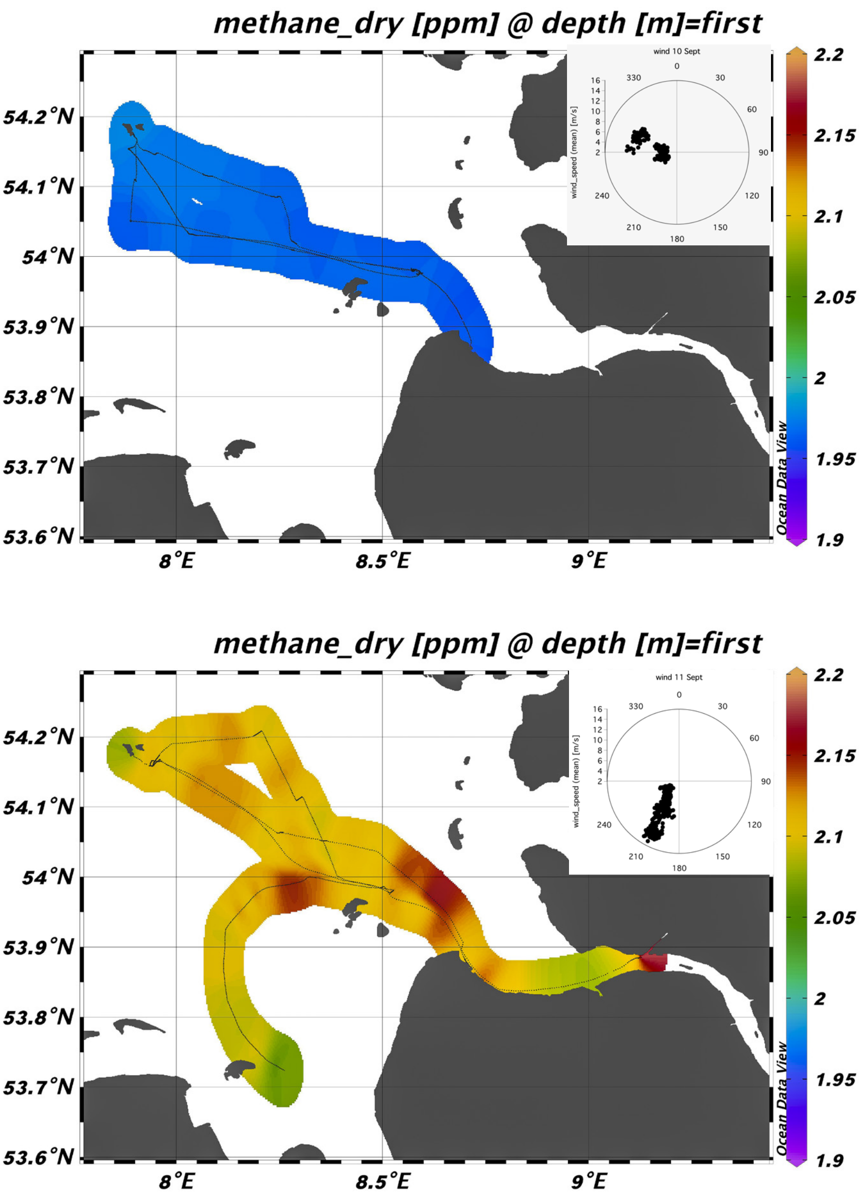

Fig. 4.9: Atmospheric methane concentrations and wind direction and speed in the study area; (a) on 10.09.2019 and (b) on 11.09.2019

5. IT SET-UP AT RV *UTHÖRN* ON STERNFAHRT 3

5.1 Network cabling

The ship-internal digital communication was realized by two switches at the bridge and in the laboratory with cable contact to the sensors on the working deck. This set-up turned out to be practical and good. The two switches were connected via the on-board *Uthörn* network, which turned out to be not practical in the future, because the ship network is not designed to support several additional scientific computers. In addition, all participants in this network have equal access to the ship's mobile Internet, which simply does not cope with this.

5.2 Network addressing

The recommendation for future cruise would be to set up fixed IP addresses for the measurement setups in each device/PC. To do this, an IP subnet, e.g. 192.168.0.x. would have to be set up. Each device and each PC must then be adjusted in the IPv4 settings accordingly, so that an address can be assigned manually. The addresses can then be selected from 192.168.0.[1-254]. It is important that each device receives a different IP address. It is also possible, for example, to select all measuring devices 20, 21, 22, ... and call all PCs 40, 41, 42, 43... in order to group them a little. In a table one can then collect which device has which IP address. So you have them ready right away to use VNC between devices. During our trip the IP addresses were assigned automatically by the DHCP server by coupling to the on-board network. However, this only makes one dependent on this technology and if you ever sail on another ship, you have to adapt everything again.

5.3 Internet connection

The use of the ship mobile network was not a success. In retrospect, we learned from the office that the „fast" 5GB volume of the LTE contract had already been used up by the ship at 14:35 on the Monday of assembly. However, the meter reading on board did not confirm this.

A recommendation for future cruises could be to set up a LTE modem. For example, Vodafone offers a so-called „Gigacube", an LTE modem with 50 GB volume per month and costs are only due when the modem is on. Such an LTE modem would then simply have to be in your local network and also get a local IP e.g. 192.168.0.10. On the computers/devices that are allowed to send something over the internet, you can enter 192.168.0.10 as gateway in the IPv4 settings. For all other devices the gateway is empty. In this way, it is also regulated which computers have access to the internet, as the „bridge computer".

5.4 Data exchange between the ships

Here two options are possible:

Variant a) Sharing the screens between the ships via „Teamviewer".

Sharing screens with other ships generally consumes quite a bit of bandwidth and volume because the whole screen is sent as an image several times per second. With real non-reduced

LTE and a good volume this could even work. (As it has been done on the second cruise). However, If the internet connection slows down due to poor reception at sea, it will of course break down quickly. The advantage is that you can exchange data and screens relatively quickly without having to programme anything.

Variant b) Transfer of data values

If you want to exchange data more reliably and also via small data connections, the question would be whether your measuring instruments could also output some of this digitally and a „collection programme“ sends a data set to the other ships or ashore every minute. For this, the data could be sent directly to the NRT database, where it will be sent later anyway. The other ships could also retrieve the data directly from there. These are all very small amounts of data.

Also, everyone could directly use https://dashboard.awi.de/ to display and compare the data. Also the Dashboard would generate less traffic than the variant a) above.

Of course, scripts would have to be programmed and the data would have to be fetched from the instruments or spoken to the manufacturers how this works. It is difficult to estimate this effort. However, at least the ferryboxes on RV *Polarstern* / MS *Helgoland* have an integrated mail function and the files are also available locally in easy-to-read text-only formats.

6. 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/overview.html) 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. In the web interface, the cruises can be searched using wildcards. Temperature data from cruise „Stern 2“ for example are searchable by „stern_2*temp“. 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 tables A3 ff for Sternfahrt 1, A4 for Sternfahrt 2 and A5ff for Sternfahrt 3.

Data in the AWI O2A Near-Realtime Database are level 0 data and therefore not necessarily quality checked yet. Even though ARGO plausibility checks may be applied to the data by the responsible data scientist, this option is facultative in NRT and not applied yet for the Stern_1-3 cruises.

Therefore, level 0 data in the AWI O2A NRT Database are actually processed (April – May 2020) 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 on nutrients, salinity, turbidity and methane will be published in World Data Center PANGAEA Data Publisher for Earth & Environmental Science (https://www.pangaea.de/) in 2020.

7. RESUME AND OUTLOOK

In 2019, three expeditions with 2 resp. 3 coastal research vessels each of the three marine Helmholtz Centres (AWI, GEOMAR and HZG) were successfully completed. In the following section we evaluate our activities and suggest improvements for future MOSES cruises.

The logistical effort of equipping three ships for a two-day expedition with equipment and scientists and organizing their arrival and departure was very demanding. Therefore, longer cruises (1 week) are planned for the next MOSES expeditions in 2020 to better balance effort and benefit.

During the trip itself, certain processes proved to be particularly critical, especially for the later evaluation of the data. The transition of the measuring instruments from „on the way“ mode to vertical profile measurements required a very precise and coordinated logging of the data in order to be able to evaluate the data sets later accordingly. In the next evaluations, an attempt will be made to establish a more efficient system that will allow the individual successive measurements to be recorded at an exact time.

Previous studies and experience had shown that the comparability of data between different sensors and institutes is not as easy as it should be. We first recognized this problem at our intercalibration workshops at the (outdoor) Cuxhaven FerryBox station (July 2018) and in Bremerhaven (October 2018) in the indoor aquaculture center. In order to address this significant problem of data comparability, inter-ship „intercalibration periods“ were carried out during the cruises, in which all participating vessels came as close as possible (50 m) to each other at the beginning and end of a measurement day and all sensors sampled the „same“ water body. These comparative measurements in different water masses (coastal and marine waters) proved to be extremely valuable for later data evaluation.

A further restriction for inter-institutional cruises emerged also during the cruises: It turned out that the coastal ships are not (yet) prepared to allow for real-time data transfer from the laboratories to the bridge and also not from ship to ship. Even though we were able to improve and consolidate this missing digital communication possibility within the ships and partly also between the ships (using our mobile phones), a within-ship and also a reliable ship-to-ship communication is definitively required, especially for the fast exchange of data (where are interesting places?) and must be a standard requirement for further inter-institutional cruises with multiple coordinated ships.

With respect to the overall data management: MOSES recognized quite early that interinstitutional research cruises require a sound and robust sensor management and metadata availability across institutions. To achieve this, a MOSES data management plan was built by GFZ. The first version of the plan was only partially adopted by the partners due to too complex sensor registration procedures, especially because existing sensor metadata information in the different institutions was not integrated. Thus, the sensor metadata and data registration for the cruises 2019 were mostly done by Google-Questionnaires and shared Google-Databases which could be specifically designed for the requirements of such complex inter-institutional campaigns. This allowed us to organize which sensors were located on which ship, as well as the respective sensor ID for later data import into the AWI-database (sensor. web….).

The second step was to get access not only to the sensor metadata but later also to the real sensor data and the sampling metadata. A first approach was to provide a single physical hard drive on each ship with the plan to task the scientists and the scientist-in-charge of each ship to ensure that all (raw) data and metadata of the samplings were stored on this hard drive at the end of each cruise. The result did not work out because in general only the datafiles were stored on the device without the important sampling metadata and necessary auxiliary data on the exact time of sensor deployment and recovery of a measurement, sensor handling etc.. This lack of information was the main reason for writing this cruise report. Thus, all participants could get an overview of which parameters have been measured on which ship.

The third step of each campaign was to upload all data into a joint data base with common unrestricted access for all partners. This also turned out to be not as easy as initially thought. A major problem in such interinstitutional and cross-discipline cruises is the diversity of the data from the individual sensors. There is actually no common standard how data files from individual sensors are structured or even coded. To merge these different datasets into a single database so that different parameters from different sensors, ships and institutes can be time-synchronized downloaded is time consuming and requires trained data-scientists which are often not available in the project groups and also not in MOSES.

As a further step, raw data have to be converted into quality-controlled data with defined and reliable accuracy and precision values. The steps to achieve this are also quite diverse and often not even available or not well implemented. Establishing such procedures and processes will be a major goal of the next few years in MOSES and Digital Earth. In this process, a close inter-institutional cooperation between the scientists and the staff of the IT centers is most important.

For our public outreach joint press releases of the participating institutes were published for Sternfahrt 1 and 2 at https://www.awi.de/ueber-uns/service/presse-detailansicht/presse/drei-forschungsschiffe-ein-auftrag.html and https://www.hzg.de/public_relations_media/news/081445/index.php.de. On the second cruise, we also made first attempts of a real time public relations with the MOSES Twitter account (@HelmholtzMoses) and these were more intensified during the last cruise. However, we realized that for the twitter account a specific person should be assigned and the response / reading of our account was not overwhelming…...

For 2020 two cruises (Sternfahrt 4 and 5) are planned with the same partners and ships. The focus will lie on the ship to ship communication and transfer of real-time data. In August/September, the focus is more on the continuation of measurements performed by partners along the Elbe and along the upper Elbe estuary.

For an overall review and summary of the results from the 2019 MOSES cruises, it has to be stated that these cruises were extremely challenging but also extremely successful on different levels. The most challenging part was the integration of different disciplines and institutions from the atmospheric over the terrestric to the aquatic realm in one campaign. Even though we often measure similar or even the same parameters, data handling and processing is often quite different among institutions and disciplines. MOSES significantly fosters this cross-discipline joint sampling, data handling and interpretation approach which is extremely elucidating with respect to an integrated understanding of processes and functional relationships in integrated systems.

On behalf of all scientific parties, we would like thank all captains and their crews for their support. Although our scientific approach required a high degree of flexibility in determining the cruise tracks, they were happy to test new approaches, apply new communication techniques and also to allow an exchange with the crews of the other coastal vessels.

APPENDIX

A.1 Teilnehmende Institute / Participating Institutions

A.2 Teilnehmer /Cruise Participants for Sternfahrt 1, 2 and 3

A.3 Tables for Sternfahrt 1

A.4 Tables for Sternfahrt 2

A.5 Tables for Sternfahrt 3

A.1 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTIONS

Tab. A.1: Participating institutions and their address

Institution	Address (all in Germany)
AWI	Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung Postfach 120161 27515 Bremerhaven
Geomar	GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel Wischhofstraße 1-3, 24148 Kiel
GFZ	Deutsches Geoforschungszentrum, Wissenschaftspark Albert Einstein Telegrafenberg 14473 Potsdam
HZG	Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung Max-Planck-Str. 1 21502 Geesthacht
UFZ	Helmholtz Centre for Environmental Research GmbH – UFZ Permoserstraße 15 04318 Leipzig
Uni Rostock	Universität Rostock Universitätsplatz 1 18055 Rostock

A.2 TEILNEHMER /CRUISE PARTICIPANTS FOR STERNFAHRT 1, 2 AND 3

Tab. A.2.1: Cruise participants of Sternfahrt 1

Ship	Name / Last name	Vorname / First name	Institut / Institute	Beruf / Profession
Littorina	Esposito	Mario	Geomar	Scientist
Littorina	Nehir	Münevver	Geomar	Doctoral researcher
Littorina	Dietrich	Peter	UFZ	Scientist
Littorina	Jetter	Linda	AWI	Student
Littorina	Sauerland	Oliver	Geomar	Captain
Littorina	Flindt	Danny	Geomar	First nautical officer
Littorina	Hagedorn	Günter	Geomar	Chief Technical Officer
Littorina	Tamm	Stefan	Geomar	Ship mechanic
Littorina	Hildebrandt	Frank	Geomar	Cook
Mya II	Bussmann	Ingeborg	AWI	Scientist
Mya II	Fischer	Philipp	AWI	Scientist
Mya II	Friedrich	Madlen	AWI	Scientist
Mya II	Fuchs	Hannes	GFZ	Scientist
Mya II	Kerschke	Dorit	GFZ	Scientist
Mya II	Schima	Robert	UFZ	Scientist
Mya II	Goblirsch	Tobias	Uni Rostock	Scientist
Mya II	Hildebrandt	Valentin	Reederei Laeisz	Captain
Mya II	Kai-Stephan	Kai-Stephan	Reederei Laeisz	Shipman
Ludwig Prandtl	Brix	Holger	HZG	Scientist
Ludwig Prandtl	Rust	Hendrik	HZG	Engineer
Ludwig Prandtl	Kopetzky	Raimo	HZG	Engineer
Ludwig Prandtl	Wichert	Viktoria	HZG	Scientist
Ludwig Prandtl	Schütze	Claudia	UFZ	Scientist
Ludwig Prandtl	Ködel	Uta	UFZ	Scientist
Ludwig Prandtl	Hartmann	Jan	AWI	Scientist
Ludwig Prandtl	Gerbatsch	Heiko	Reederei Laeisz	Captain
Ludwig Prandtl	Heinze	Detlef	Reederei Laeisz	Shipman

Tab. A.2.2: Cruise participants of Sternfahrt 2

Ship	Name / Last name	Vorname / First name	Institut / Institute	Beruf / Profession
Uthörn	Bussmann	Ingeborg	AWI	Scientist
Uthörn	Fischer	Philipp	AWI	Scientist
Uthörn	Friedrich	Madlen	AWI	Scientist
Uthörn	Ködel	Uta	UFZ	Scientist
Uthörn	Böger	Anna Lena	AWI	Student
Uthörn	Jardner	Dirk	Reederei Laisz	Captain
Uthörn	Neugebauer	Silvio	Reederei Laisz	Nautical Officer
Uthörn	Mühle	Eric	Reederei Laisz	Chief Technical Officer
Uthörn	Becker	Raimond	Reederei Laisz	Shipman
Uthörn	Vehlow	Ringo	Reederei Laisz	Shipman
Ludwig Prandtl	Brix	Holger	HZG	Scientist
Ludwig Prandtl	Pieplow	Tanja	HZG	Technician
Ludwig Prandtl	Peters	Marc	HZG	Technician
Ludwig Prandtl	Kopetzky	Raimo	HZG	Engineer
Ludwig Prandtl	Brandt	Tanja	UFZ	Scientist
Ludwig Prandtl	Jebens	Hannah	AWI	Technician
Ludwig Prandtl	Bornhöft	Helmut	Reederei Laisz	Captain
Ludwig Prandtl	Heinze	Detlef	Reederei Laisz	Shipman

Tab. A.2.3: Cruise participants of Sternfahrt 3

Ship	Name / Last name	Vorname / First name	Institut / Institute	Beruf / Profession
Littorina	Esposito	Mario	Geomar	Scientist
Littorina	Nehir	Münevver	Geomar	Doctoral Researcher
Littorina	Isaa	Sipan	Uni Bremen	Student
Littorina	Fatery A. Altahan	Mahmoud	Geomar	Student
Littorina	Flindt	Danny	Geomar	Captain
Littorina	Krause	Hinnerk Christian	Geomar	First Nautical Officer
Littorina	Ulferts	Geert Harm	Geomar	Ship Mechanic
Littorina	Peterson	Finn Lukas	Geomar	Ship Mechanic
Littorina	Schmitz	Hermann	Geomar	Cook
Ludwig Prandtl	Brix	Holger	HZG	Scientist
Ludwig Prandtl	Flöser	Götz	HZG	Scientist
Ludwig Prandtl	Petersen	Wilhelm	HZG	Scientist
Ludwig Prandtl	Peters	Marc	HZG	Technician
Ludwig Prandtl	Jebens	Hannah	AWI	Technician
Ludwig Prandtl	Gerbatsch	Heiko	Reederei Laisz	Captain
Ludwig Prandtl	Heinze	Detlef	Reederei Laisz	Shipman
Uthörn	Bussmann	Ingeborg	AWI	Scientist
Uthörn	Friedrich	Madlen	AWI	Scientist
Uthörn	Otto	Thorben	AWI	Student
Uthörn	Siewert	Emely	AWI	Student
Uthörn	Immoor	Sebastian	AWI	It
Uthörn	Anselm	Norbert	AWI	It
Uthörn	Cibuk	Yasin	Jacobs University	Student
Uthörn	Jardner	Dirk	Reederei Laisz	Captain
Uthörn	Neugebauer	Silvio	Reederei Laisz	First Nautical Officer
Uthörn	Mühle	Eric	Reederei Laisz	Chief Technical Officer
Uthörn	Vehlow	Ringo	Reederei Laisz	Shipman
Uthörn	Peper	Sven	Reederei Laisz	Shipman

A.3 TABLES FOR STERNFAHRT 1

Tab. A.3.1: Meeting points between research vessels and ferries, 16. and 17. April 2019

On the way / vertical	**Water / air**	**Parameter(s)**	**Responsible person**	**Instrument name**	**Sensor ID** at https://sensor.awi.de	**Remarks**
On the way	water	fb_740602:aoa_9999a: blue_alga, cryptophy, diatoms, green_alga, total_chlorophyll, yellow-sub, conductivity, salinity, temperature, oxygen, ph, saturation, oxygen_corr µmol/l, temperature, latitude, longitude	K. Carstens	FerryBox on MS *Helgoland* parallel to *Mya II*	vessel:ms_hel:fb_740602	automatically uploaded to sensor.web
On the way	water	Temp, sal, oxygen, ….	M. Friedrich	FerryBox on MS *Funny Girl*	vessel:ms_funnygirl:fb_hzg_0001	Data have to be selected according to time, time offset: -40 sec
stern1_vert_M7	*Mya II*	2019-04-16T11:02 54.1758; 7.8942	I. Bussmann.		Surface / bottom water samples,	Water samples for nutrients, salinity, turbidity
stern1_vert_P3	*Ludwig Prandtl*	2019-04-16T08:34 54.0952; 8.5067	H. Rust		Surface / bottom water samples	Water samples for nutrients, salinity, turbidity
stern1_ver_L3 / L4	*Littorina*	2019-04-16T08:31 54.1; 8.5	M. Nehir		Surface / bottom water samples	Water samples for nutrients, salinity, turbidity

Tab. A.3.2: Station list for *Littorina*, Stern_1 for water samples for nutrients (doi.org/10.1594/PANGAEA.912011) and salinity, turbidity and methane (doi.pangaea.de/10.1594/PANGAEA.910461).

Station ID	DateTime [UTC]	Latitude	Longitude	Bottom Depth [db]	remarks
L1	2019-04-16T07:00	54.12	8.68	2.0	Underway water supply
L2	2019-04-16T08:00	54.10	8.56	2.0	Underway water supply
L3	2019-04-16T08:31	54.10	8.50	1.9	Surface, Station 1
L4	2019-04-16T08:29	54.10	8.50	9.6	Bottom, Station 1
L5	2019-04-16T09:00	54.13	8.46	2.0	Underway water supply
L6	2019-04-16T09:12	54.16	8.50	2.3	Surface, Station 2
L7	2019-04-16T09:11	54.16	8.50	7.4	Bottom, Station 2
L8	2019-04-16T09:59	54.22	8.48	2.3	Surface, Station 3
L9	2019-04-16T09:57	54.22	8.48	9.3	Bottom, Station 3
L10	2019-04-16T10:00	54.22	8.48	2.0	Underway water supply
L11	2019-04-16T10:31	54.23	8.40	2.1	Surface, Station 4
L12	2019-04-16T10:29	54.23	8.40	12.2	Bottom, Station 4
L13	2019-04-16T11:00	54.23	8.30	2.0	Underway water supply
L14	2019-04-16T11:04	54.23	8.31	1.7	Surface, Station 5
L15	2019-04-16T11:02	54.23	8.31	13.2	Bottom, Station 5
L16	2019-04-16T11:53	54.21	8.15	2.1	Surface, Station 6
L17	2019-04-16T11:50	54.21	8.15	20.1	Bottom, Station 6
L18	2019-04-16T12:00	54.20	8.14	2.0	Underway water supply

Station ID	DateTime [UTC]	Latitude	Longitude	Bottom Depth [db]	remarks
L19	2019-04-16T12:32	54.18	8.04	1.6	Surface, Station 7
L20	2019-04-16T12:29	54.18	8.04	29.1	Bottom, Station 7
L21	2019-04-16T13:00	54.18	7.94	2.0	Underway water supply
L22	2019-04-16T13:05	54.18	7.94	2.3	Surface, Station 8
L23	2019-04-16T13:03	54.18	7.94	12.3	Bottom, Station 8
L24	2019-04-17T07:00	54.18	7.99	2.0	Underway water supply
L25	2019-04-17T08:00	54.21	8.21	2.0	Underway water supply
L26	2019-04-17T09:00	54.22	8.44	2.0	Underway water supply
L27	2019-04-17T10:00	54.11	8.46	2.0	Underway water supply
L28	2019-04-17T11:00	54.11	8.66	2.0	Underway water supply

Tab. A.3.3: Instruments on the *Littorina* on Stern_1

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
On the way	water	**Position**: Longitude_0001, latitude_0001, Speed_0001, course_over_ground_0001	M. Friedrich	via Ferrybox 751801	laboratory:moses_stern_1:pfb_awi_751801	no time offset !!!
On the way	water	**Hydrography**: flow_main_0001 temperature_sbe45_0001 conductivity_sbe45_0001, Salinity_sbe45_0001, pH_0001 temperature_phsensor_0001 oxygen_concentration_0001, Oxygen_saturation_0001, Temperature_0001, turbidity_0001, chlorophyll_0001	M. Friedrich	FerryBox pocket AWI 751801	Laboratory:moses_stern_1:pfb_awi_751801	Time offset: -120 sec
On the way	water	**Dissolved methane**: Methane_dry_0001, carbon_dioxide_dry_0001, Fit_flag_0001, methane_nmolL_0001	I. Bussmann	Ultraportable Greenhouse gas analyzer with degassing unit	Laboratory:moses_stern_1:losgatos_awi_1142, Laboratory:moses_stern_1:degasser_awi_dge3	Time offset: -120 - 84 = - 204 sec, conversion from ppm to nmol/L * 39.95, data for dge3 not in nrt

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
On the way	water	**Hydrography**: conductivity_17F102065 Depth_17h100268, Fdom_qsu_18a100471, Fdom_rfu_18a100471, Nlf_conductivity_17f102065, Odo_saturation_17h104627, odo_concentration_17h104627, Salinity_17f102065, specific_conductivity_17f102065, Total_dissolved_solids_17f102065, temperature_17f102065	M. Esposito, M. Nehir	EXO1	Laboratory:moses_stern_1:exo1_geomar_0001	Time offset: -120 sec
On the way	water	**Nitrate**: nitrate, salinity, temperature	M. Nehir	Opus UV	laboratory:moses_stern_1:opus_geomar_71f9	Time offset: -120 sec
On the way	water	**Nitrate**: nitrate, salinity temperature	M. Nehir	Suna	Laboratory:moses_stern_1:suna_geomar_345	Time offset: -120 sec
On the way	air	**Atmospheric CH4 and pCO2:** CH4[ppm], CH4Dry[ppm], CO2[ppm], CO2Dry[ppm], H2O[%]	J. Greinert T. Weiss	Picarro cfbds2040	vessel:geomar:crds_cfbds2040	Time offset: - 45 sec
On the way	water	**Hydrography**: temperature_1039, salinity_1039 Oxygen_1039, pressure_1039	M. Nehir, M. Friedrich	Seaphox	laboratory:moses_stern_1:seaphox_geomar_1039	Time offset: -120 sec

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
vertical	water	**Hydrography**: pressure_0001, temperature_0001, Conductivity_0001, Salinity_0001, sound_velocity_0001, Density_0001, ph_0001, oxygen_saturation_0001, oxygen_concentration_mll_0001, oxygen_concentration_0001	M. Friedrich	CTD rosette 10770210	laboratory:moses_stern_1:ctd_geomar_1070210	no time offset
vertical	water	**Nutrients + methane**		Water samples	doi.pangaea.de/10.1594/PANGAEA.910461	
On the way	water	**Hydrography**: IR_VAL_CH1 (value for the transmission IR channel in counts, . turbidity) UV_VAL (value of transmission for the UV channel in counts, dissolved organic) temperature (System temperature from measuring device in degree C): not in nrt pressure (mbar) **Position**: latitude, longitude	R. Wagner	CDOM UFZ 0001	laboratory:moses_stern_1:cdom_ufz_0001	Time offset: -120 sec,

Tab. A.3.4: Station List and Vertical profiles taken with CTD-AWI_578 and water samples for nutrients and methane on the *Mya II* on Stern_1. (Positions from D-ship, and calculated when speed was zero). Results can be found at https://doi.pangaea.de/10.1594/PANGAEA.910461.

Station ID	DateTime [UTC]	Latitude	Longitude	Bottom Depth [db] / #	remarks
M1	2019-04-16T05:34	53.8991	8.6992	Surface and bottom	from niskin bottle
M2	2019-04-16T06:49	53.9790	8.6000	Surface and bottom	from niskin bottle
M3	2019-04-16T07:57	53.9890	8.4171	Surface and bottom	from niskin bottle
M4	2019-04-16T08:44	54.0131	8.2826	Surface	from overflowing bucket
M5	2019-04-16T09:35	54.0792	8.1124	Surface	from overflowing bucket
M6	2019-04-16T10:08	54.1108	8.0291	Surface	from overflowing bucket
M7	2019-04-16T11:02	54.1758	7.8942	Surface	from niskin bottle

Tab. A.3.5: Instruments on the *Mya II* on Stern_1

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
On the way		**Position**: vessel:Mya_ii:dgps:lat, vessel:Mya_ii:dgps:lon	M. Friedrich	GPS-Receiver GP-150	vessel:Mya_ii:dgps	No time offset
On the way	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	M. Friedrich	Sea and Sun CTD 1413	laboratory:moses_stern_1:ctd_awi_1413	Time offset: -60 sec, from bucket and tube
On the way	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	Laboratory:moses_stern_1:losgatos_awi_1303	Time offset: -60 -138 = -198, conversion from ppm to nmol/L * 27.9

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
On the way	air	**Atmospheric methane and pCO2**: methane_in_air_0001, carbon_dioxide_air_0001, methane_dry_air_0001, carbon_dioxide_dry_air_0001, fit_flag_air_0001,	I. Bussmann	LosGatos greenhouse gas analyzer	laboratory:moses_stern_1:losgatos_awi_1303	Time offset: -198 sec, Instrument was switched between air and degasser, see above
On the way	air	**PAR, PM2.5**: Feinstaub, Windmessgerät, VIS-Spektrometer,	R. Schima/ R. Wagner, T. Goblirsch	PAR (Photosynthetic Active Radiation) Sensor, PM2.5 Feinstaubsensor, Windmessgerät (Richtung, Geschwindigkeit), VIS Spectrometer		Test sensors, data are not available
On the way	water	**Turbididty, CDOM**: turbidity_0001 cdom_0001 pressure_0001	R. Schima, R. Wagner	Proprietair sensor BOSP001	laboratory:moses_stern_1:proprietaire_rostock_bosp001	Time offset: not known, but small, sensor was connected directly to the ships seawater supply

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
vertical	water	**Hydrography**: pressure_03, Temperature_03, conductivity_03, oxygen_saturation_1555, chlorophyll_a_03, turbidity_03, Salinity_03, oxygen_concentration_mgl_1555, oxygen_concentration_mll_1555	M. Friedrich	Sea and Sun CTD 578	laboratory:moses_stern_1:ctd_awi_578	No time offset
vertical	water	**Nutrients + methane**	I. Bussmann	Water samples	https://doi.pangaea.de/10.1594/PANGAEA.910461	

Tab. A.3.6: Station list for *Ludwig Prandtl* on Stern_1 for water samples for nutrients and methane. Results can be found at https://doi.pangaea.de/10.1594/PANGAEA.910461

Station ID	DateTime [UTC]	Latitude	Longitude	Bottom Depth [db]	remarks
1b	2019-04-16T05:34	53.90	8.70	16.52	bottom
1s	2019-04-16T05:34	53.90	8.70	16.52	surface
2b	2019-04-16T06:50	53.98	8.60	12.86	bottom
2s	2019-04-16T06:50	53.98	8.60	12.86	surface
3b	2019-04-16T08:20	54.10	8.51	14.37	bottom
3s	2019-04-16T08:20	54.10	8.51	14.37	surface
4b	2019-04-16T09:07	54.10	8.40	16.02	bottom
5b	2019-04-16T09:48	54.11	8.30	16.35	bottom
5s	2019-04-16T09:48	54.11	8.30	16.35	surface
6b	2019-04-16T10:42	54.13	8.14	19.90	bottom
6s	2019-04-16T10:42	54.13	8.14	19.90	surface
7b	2019-04-16T11:32	54.15	8.00	35.98	bottom
7s	2019-04-16T11:32	54.15	8.00	35.98	surface
8b	2019-04-16T12:12	54.16	7.91	16.07	bottom
8s	2019-04-16T12:12	54.16	7.91	16.07	surface
	2019-04-17T07:30	54.16	7.91	36.25	Station 9
	2019-04-17T08:03	54.15	8.02	32.34	Station 10
	2019-04-17T08:50	54.13	8.16	21.48	Station 11
	2019-04-17T09:31	54.11	8.30	17.89	Station 12
	2019-04-17T10:02	54.10	8.40	17.11	Station 13

Station ID	DateTime [UTC]	Latitude	Longitude	Bottom Depth [db]	remarks
9b	2019-04-17T10:34	54.10	8.48	15.02	bottom
9s	2019-04-17T10:34	54.10	8.48	15.02	surface
10b	2019-04-17T11:26	53.99	8.57	9.73	bottom
10s	2019-04-17T11:26	53.99	8.57	9.73	surface
11b	2019-04-17T12:30	53.90	8.70	19.90	bottom
11s	2019-04-17T12:30	53.90	8.70	19.90	surface

Tab. A.3.7: Instruments on the *Ludwig Prandtl* on Stern_1

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
On the way	air	**Position**: latitude_0001, longitude_0001	G. Flöser	D-Ship *Prandtl*	laboratory:moses_stern_1:d_ship_*Prandtl*_01	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	laboratory:moses_stern_1:weather_station_hzg_1957ps001	no time offset
On the way	water	**Position**: latitude_0001 longitude_0001	H. Rust	FerryBox	laboratory:moses_stern_1:fb_hzg_orion	no time offset
On the way	water	**Hydrography**: cdom_cyclops_0001, chlorophyll_a_0001, oxygen_concentration_aanderaa_0001, oxygen_saturation_0001 ph_meinsberg_ega_0001 Salinity_0001, total_alcalinity_contros_fia_ta_0001, ph_contros_fia_ta_0001, turbidity_0001, temperature_citadel_0001	H. Rust	FerryBox	laboratory:moses_stern_1:fb_hzg_orion	Time offset: -20 sec

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
On the way	water	**Dissolved Methane (nmol/L)**: isotopic_13C_methane_raw_corr_0001, isotopic_13C_methane_30s_corr_0001, isotopic_13C_methane_2min_corr_0001, isotopic_13C_methane_5min_corr_0001, water_corr_0001, carbon_dioxide_total_0001, isotopic_13C_carbon_dioxide_raw_corr_0001, isotopic_13C_carbon_dioxide_30s_corr_0001, isotopic_13C_carbon_dioxide_2min_corr_0001, isotopic_13C_carbon_dioxide_5min_corr_0001, methane_nM_0001,[nmol/l]	J. Hartmann	Picarro 2043 + Degasser	laboratory:moses_stern_1:picarro_awi_2043	Time offset: 6900 sec, including - 20 sec (Ferrybox), due to wrong time in sensor
On the way		**Alkalinity**: pco2_corr_contros_hydroc_0001 xco2_corr_contros_hydroc_0001	G. Flöser, H. Rust	HydroC CO2 FT TA Contros 0617001	laboratory:moses_stern_1:co2ft_hzg_0617001	Time offset: -20 sec
On the way	air	**Atmospheric pCO2**: pressure_04, latitude_04, longitude_04, speed_04, course_over_ground_04, water_04,[mmol/mol], carbon_dioxide_04,[µmol/mol], carbon_dioxide_dry_04,[µmol/mol] quality_flag_04	U. Ködel	Licor 8100	laboratory:moses_stern_1:licor_ufz_8100	no time offset

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
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, oxygen_saturation_01	H. Rust	CTD 313	laboratory:moses_stern_1:ctd_hzg_313	no time offset
vertical	water	**Nutrients + methane**	I. Bussmann	Water samples	https://doi.pangaea.de/10.1594/PANGAEA.910461	

A.4 TABLES FOR STERNFAHRT 2

Tab. A.4.1: Intercalibration table for Stern_2

ID	Datetime (start)	Datetime (end)	Latitude (N)	Longitude (E)	Bottom depth [m]	Remarks
Intercal 1	2019-06-25T07:20	2019-06-25T07:46	53.8867	8.7140	10	Median position of *Uthörn*, distance between ships: 508 m
			53.8829	8.7183		Median position of *Ludwig Prandtl*
vert_U2		2019-06-25T08:08	53.8844	8.7155	11	
P1		2019-06-25T07:37	53.8832	8.7197	13	
Intercal 2	2019-06-26T 07:00	2019-06-26T07:25	54.1501	7.8991		Median position of *Uthörn*, distance between ships: 65 m
			54.1496	7.8996		Median position of *Ludwig Prandtl*
vert_U5		2019-06-26T07:25	54.1472	7.8992	50	
P-05		2019-06-26T07:05	54.1507	7.8966	49	

Tab. A.4.2: Station list for the *Ludwig Prandtl*, Stern_2 for water samples for nutrients (doi.org/10.1594/PANGAEA.912011) and salinity, turbidity and methane (https://doi.pangaea.de/10.1594/PANGAEA.910461)

Station ID	DateTime [UTC]	Latitude	Longitude	Bottom depth [m]	Remarks
01	2019-06-25T07:37	53.8832	8.7197	13	
02	2019-06-25T08:15	53.8847	8.7183	13	
03	2019-06-25T12:08	53.9563	8.0563	23	
04	2019-06-25T02:47	54.0258	8.0602	25	High methane concentrations
05	2019-06-26T07:05	54.1507	7.8966	49	
06	2019-06-26T09:02	54.3064	8.0492	19	
07	2019-06-26T10:40	54.1101	8.1764	18	
08	2019-06-26T11:29	54.1068	8.2846	15	

Tab. A.4.3: Instruments on the *Ludwig Prandtl* on Stern_2

On the way / vertical	Water / air	Parameter(s)	Respon-sible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
On the way		**Position**: latitude_0001, longitude_0001	G. Flöser	D-Ship *Prandtl*	laboratory:moses_stern_2:d_ship_*Prandtl*_01	No time offset,
On the way		**Position**: latitude_0001, longitude_0001	H. Rust	FerryBox	laboratory:moses_stern_2:fb_hzg_orion	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	laboratory:moses_stern_2:weather_station_hzg_1957ps001	No time offset
On the way	water	**Dissolved methane**: 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 1303 + Degasser dge4 (data not used)	laboratory:moses_stern_2:losgatos_awi_1303:*	Time offset: - 94 sec - 300 sec -> -394 sec, conversion ppm to nmol/L: * 19.33
On the way	water	**Hydrography**: cdom_cyclops_0001, oxygen_concentration_aanderaa_0001, oxygen_saturation_0001, ph_meinsberg_ega_0001, salinity_0001, temperature_citadel_0001	H. Rust	FerryBox	laboratory:moses_stern_2:fb_hzg_orion:*	Time offset: -20 sec
On the way	water	**Hydrography**: pressure_01, temperature_406, chlorophyll_a_awi_211t0078, turbidity_16157, conductivity_17060902, salinity_17060902, oxygen_saturation_224140948, oxygen_concentration_mg_l_224140948 [mg/l], oxygen_concentration_ml_l_224140948,[ml/l]	H. Brix	CTD-1413	laboratory:moses_stern_2:ctd_awi_1413:*	Time offset: -300 sec, Placed into a water water pipe

On the way / vertical	Water / air	Parameter(s)	Respon-sible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
On the way	air	**Atmospheric CH4, pCO2, and other gases**: Air pressure [mbar], CO2 [ppm]], methane [ppm], CO [ppm], N2O [ppm], Ammonia [ppm], humidity [% Vol]	U. Ködel	FTIR	laboratory:moses_stern_2:ftir_ufz_112228	
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-313	laboratory:moses_stern_2:ctd_hzg_313	
On the way	water	**Alkalinity**: co2_corr_contros_hydroc_0001 xco2_corr_contros_hydroc_0001	H. Brix, G. Flöser	HydroC CO2FT 0617001	laboratory:moses_stern_2:co2ft_hzg_0617001	Time offset: -20 sec
On the way	water	**Turbidity**, cDOM: turbidity_0001 Cdom_0001, pressure_0001	R. Schima	Proprietair Rostock BOSP001	laboratory:moses_stern_2:proprietaire_rostock_bosp001	Time offset: -20 sec
vertical	water	**chlorophyll, turbidity, salinity, methane**	G. Flöser, I. Bussmann	Water samples	https://doi.pangaea.de/10.1594/PANGAEA.910461	

Tab. A.4.4: Station list for *Uthörn* Stern_2, for water samples for nutrients (https://doi.pangaea.de/10.1594/PANGAEA.912011) and salinity, turbidity and methane (https://doi.pangaea.de/10.1594/PANGAEA.910461)

Station ID	DateTime (UTC)	Latitude	Longitude	Bottom depth [m]	Remarks
U1	2019-06-25T07:46	53.8849	8.7148	10	
U2	2019-06-25T08:08	53.8844	8.7155	11	
U3	2019-06-25T12:03	54.0252	8.0608	23	High methane conc.
U4	2019-06-25T14:05	54.1104	8.0997	22	
U5	2019-06-26T07:25	54.1472	7.8992	50	
U6	2019-06-26T08:44	54.0249	8.0620	21	
U7	2019-06-26T10:35	53.9872	8.3312	17	
U8	2019-06-26T13:03	53.7812	8.1651	9	

Tab. A.4.5: Instruments on the *Uthörn* on Stern_ 2

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
On the way		**Position**: Longitude, latitude **Weather**: air_temperature, barometric_pressure, speed, true_wind_direction, true_wind_speed	M. Friedrich	D-Ship	vessel:uthoern:weather	No data
On the way	water	**Dissolved methane**: Methane_conc_estimate_0001 (in ppm) Methane_pch4_0001, methane_xch4_0001	Ph. Fischer	Kongsberg methane sensor	laboratory:moses_stern_2:ch4_awi_0319001	Time offset: - 65 sec for basin only
On the way	water	**Dissolved methane**: Methane_dry_0001, carbon_dioxide_dry_0001, fit_flag_0001, methane_nmolL_0001,[nmol/l]	I. Bussmann	LosGatos greenhouse gas analyzer 1142 and degasser dge_3 (data not used)	laboratory:moses_stern_2:losgatos_awi_1142	Time offset: -65 -119 = -184 sec, conversion ppm to nmol/L * 29.314
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, ph_0001, temperature_phsensor_0001, oxygen_concentration_0001, oxygen_saturation_0001, temperature_0001, turbidity_0001, chlorophyll_0001, methane_dry_0001, carbon_dioxide_dry_0001, fit_flag_0001	M. Friedrich	Pocket FerryBox	laboratory:moses_stern_2:pfb_awi_751801	Time offset: - 76 sec (-65 - 11, only for the ferrybox), The sensors for pH, turbidity and chlorophyll were not working properly.

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
On the way	water	**Hydrography**: Pressure_03, temperature_03, conductivity_03, oxygen_saturation_1555, chlorophyll_a_03, turbidity_03, salinity_03 oxygen_concentration_mgl_1555 oxygen_concentration_mll_1555	M. Friedrich	CTD-578	laboratory:moses_stern_2:ctd_awi_578	Time shift: -65 sec for basin only
On the way	air	**Atmospheric pCO:**2 CO2 [µmol mol-1], carbon_dioxide_dry_04,[µmol/mol],	U. Ködel	Licor 8100	laboratory:moses_stern_2:licor_ufz_8100	
vertical	water	**Hydrography**: cdom_0001, temperature_0001, salinity_0001, oxygen_concentration_0001, oxygen_saturation_0001, chlorophyll_a_0001, turbidity_0001	M. Friedrich	CTD-519	laboratory:moses_stern_2:ctd_awi_519:*	
vertical	water	(chlorophyll), turbidity, salinity, methane	I. Bussmann	Water samples	https://doi.pangaea.de/10.1594/PANGAEA.910461	

A.5 TABLES FOR STERNFAHRT 3

Tab. A.5.1: Intercalibration table for Stern_3

ID	Datetime (start)	Datetime (end)	Latitude	Longitude	Bottom depth [m]	Parameters	Remarks
Intercal 1	2019-09-10T08:30	2019-09-10T08:50	53.9798	8.5737	10.3		Median position *Littorina,* Distance to *Prandtl* 229 m
			53.9814	8.5715	10.9		Median position *Prandtl* Distance to *Uthörn* 314 m
			53.9815	8.5763			Median position *Uthörn* Distance to *Littorina* 255 m
U2	2019-09-10T08:51	2019-09-10T09:48	53.9818	8.5804	10.8	Water samples from rosette	Rosette with CTD, pump, sediment
L1	2019-09-10T08:58	2019-09-10T08:59	53.9800	8.5800	9.2	Nutrients, methane	
L2	2019-09-10T08:59	2019-09-10T08:59	53.9800	8.5800	3.0	Nutrients, methane	
L2_T1		2019-09-10T09:00	53.9800	8.5800		Turbidity, salinity	On the way, L2_T1
P1	2019-09-10T08:30	2019-09-10T09:32	53.98300	8.5680	7.5	Sediment, methane	Details see table A.5.4
Intercal 2	2019-09-11T05:40	2019-09-11T06:00	54.1599	7.9367			Median position *Littorina* Distance to *Prandtl* 410 m
			54.1588	7.9427			Median position *Prandtl* Distance to *Uthörn* 259 m
			54.1609	7.9444			Median position *Uthörn* Distance to *Littorina* 514 m
U6	2019-09-11T05:40	2019-09-11T06:00	54.1589	7.9403	39.0		intercalibration, under way systems
U7	2019-09-11T06:06	2019-09-11T06:22	54.1658	7.9482	37.0	water samples	Water samples from rosette and pump, pump attached to rosette,
P6	2019-09-11T05:34	2019-09-11T06:26	54.1570	7.9390	43.0	methane	Details see table A.5.4

ID	Datetime (start)	Datetime (end)	Latitude	Longitude	Bottom depth [m]	Parameters	Remarks
L5	2019-09-11T06:02	2019-09-11T06:02	54.1700	7.9400	39.2	Nutrients, methane	
L6	2019-09-11T06:06	2019-09-11T06:06	54.1700	7.9400	4.2	Nutrients, methane	
L7	2019-09-11T06:10		54.1700	7.9400		Nutrients, methane	On the way, L7

Tab. A.5.2: Discrete water samples taken on board of *Littorina* on Stern_3 (St: sample from the CTD rosette at the station, On the way: sample from the water tank where sensors were deployed in)

Station name	Water sample label name	Station ID	Date Time (start)	Date Time (end)	Latitude	Longi-tude	Depth [m]	parameters
St1	L1	stern3_vert_L1	2019-09-10T08:58	2019-09-10T08:58	53.98	8.58	9.2	Nutrients, methane
St1	L2	stern3_vert_L2	2019-09-10T08:59	2019-09-10T08:59	53.98	8.58	3.0	Nutrients, methane
On the way	L2_T1	stern3_ow_L2_T1	2019-09-10T09:00		53.98	8.58		Turbidity, salinity
St2	L3	stern3_vert_L3	2019-09-10T12:10	2019-09-10T12:10	54.03	8.04	23.0	Nutrients, methane
St2	L4	stern3_vert_L4	2019-09-10T12:12	2019-09-10T12:12	54.03	8.04	3.0	Nutrients, methane
St3	L5	stern3_vert_L5	2019-09-11T06:02	2019-09-11T06:02	54.17	7.94	39.2	Nutrients, methane
St3	L6	stern3_vert_L6	2019-09-11T06:06	2019-09-11T06:06	54.17	7.94	4.2	Nutrients, methane
On the way	L7	stern3_ow_L7	2019-09-11T06:10		54.17	7.94		Nutrients, methane
On the way	L8	stern3_ow_L8	2019-09-11T07:30		54.12	8.11		Nutrients, methane
On the way	L9	stern3_ow_L9	2019-09-11T08:30		53.99	8.46		Nutrients, methane
St4-CTD cast	L10	stern3_vert_L10	2019-09-11T08:43	2019-09-11 08:43	53.98	8.50	3.0	Nutrients, methane
St4-CTD cast	11	stern3_vert_L11	2019-09-11T08:41	2019-09-11 08:41	53.98	8.50	7.0	Nutrients, methane
On the way	L11_T2	stern3_ow_L11_T2	2019-09-11T08:50		53.98	8.51		Turbidity, salinity
On the way	L12	stern3_ow_L12	2019-09-11T09:30		53.91	8.68		Nutrients, methane
On the way	L13	stern3_ow_L13	2019-09-11T10:30		53.85	8.96		Nutrients, methane

Station name	Water sample label name	Station ID	Date Time (start)	Date Time (end)	Latitude	Longi- tude	Depth [m]	parameters
On the way	L14	stern3_ow_147	2019-09-11T11:10		53.88	9.12		Nutrients, methane
On the way	L11_T3	stern3_ow_L11_ T3	2019-09-11T11:10		53.88	9.12		Turbidity, salinity

Tab. A.5.3: Instruments on the *Littorina* on Stern_3, sampling frequency was always 1 sec

On the way / vertical	Water / air	pP	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
On the way	air	**Position**: Course_over_ground_0001, latitude_0001, longitude_0001, speed_0001	M. Esposito/ M.Friedrich	via Ferrybox 750701	Laboratory:moses_stern_3:pfb_hzg_750701	time offset: - 57 min = -3420 sec (pfb: UTC + 1 and 3 min delay)
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	H. Rust / M. Esposito	Ferrybox	laboratory:moses_stern_3:pfb_hzg_750701	time offset: - 59 min = -3540 sec (pfb: UTC + 1 and 3 min delay, and - 2 min from tube) no depth profiles
On the way	water	**Hydrography**: conductivity_17F102065, depth_17h100268, fdom_qsu_18a100471, fdom_rfu_18a100471, nlf_conductivity_17f102065 Odo_saturation_17h104627, odo_concentration_17h104627, salinity_17f102065, specific_conductivity_17f102065, total_dissolved_solids_17f102065, turbidity_18e100560, tss_18E100560 Temperature_17f102065,	M. Nehir	EXO1	Laboratory:moses_stern_3:exo1_geomar_0001	time offset: -120 sec
On the way	water	**Oxygen**: Temperature_1039, salinity_1039, oxygen_1039, pressure_1039	M. Nehir	SeapHOx	laboratory:moses_stern_3:seaphox_geomar_1039	time offset: -120 sec
On the way	water	**Dissolved methane**: raw_CH4, corrected_CH4, pressure_sensor_temperature, pressure_millibar	M.Nehir	ProOceanus Methane sensor	laboratory:moses_stern_3:methane_geomar_37-477-25	time offset: -120 sec

On the way / vertical	Water / air	pP	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
On the way	water	**Nitrate**: salinity, temperature	M. Nehir	Opus UV, 1 min frequency	laboratory:moses_stern_3:opus_geomar_71f9	time offset: -120 sec
On the way	water	**pCO2**:	M. Esposito	ControsHydroC		2 min time offset, test sensor
On the way	water	**pH**	M. Esposito	Optode pH		2 min time offset, test sensor
On the way	water	**pH**: ph_P0235, temperature_0001	M. Nehir	SAMI pH	laboratory:moses_stern_3:sami_ph_geomar_p0235	time offset: -120 sec
On the way	water	**Nitrate**	M. Esposito	LOC Nitrate, 20 min frequency		2 min time offset, test sensor
On the way	water	**Dissolved methane**: Methane_dry_0001, carbon_dioxide_dry_0001, fit_flag_0001 methane_nmolL_0001	Bussmann I	Los Gatos 2029	laboratory:moses_stern_3:losgatos_awi_2029	time offset: -120 - 119 = - 239 sec, conversion ppm to nmol/L * 20.171
On the way	air	**Atmospheric CH4 and pCO2**	J. Greinert	Picarro	vessel:geomar:crds_cfbds2040	
vertical	water	**Hydrography**: pressure_0001, salinity_0001,temperature_0001, :oxygen_saturation_0001, oxygen_concentration_mll_0001, oxygen_concentration_0001, pH_0001, density_0001, sound_velocity_0001	M. Esposito	CTD rosette	Laboratory:moses_stern_3:ctd_geomar_111: -> laboratory:moses_stern_3:ctd_geomar_1070210	
vertical	Water	**Water samples for methane, nutrients, turbidity, salinity**		Water samples	https://doi.pangaea.de/10.1594/PANGAEA.910461	

Tab. A.5.4: Vertical profiles and station list of *Prandtl* on Stern_3. Results can be found at https://doi.pangaea.de/10.1594/PANGAEA.910461

Station ID	Datetime (start)	Datetime (end)	Latitude	Longitude	Bottom depth [m]	Remarks
P1	2019-09-10T08:30	2019-09-10T 09:32	53.983	8.568	8	Sediment sampling 8:40; 8:51: switch pump from horizontal sampling to deep cast water sampling; 8:54 2 m depth, CH4 takes time to reach a stable value; 8:59 4m; 9:05: 7m; 9:12: 2m; 9:19: end deep cast
P2	2019-09-10T10:34	2019-09-10T11:01	54.018	8.291	12	Deep cast start switch 10:38; 2m: 10:39; 6m: 10:42; 11m: 10:45; 2m: 10:52; 10:53: switch back to regular water supply; 10:55: sediment sampling; end: 10:57
P3	2019-09-10T11:29	2019-09-10T11:57	54.086	8.250	17	Water supply switched at 11:31; 11:32: 2m; 11:36: 8m ;11:38:16m, CH4 values show distinct increase at bottom; 11:44: switch to regular water supply; 11:46: sediment sample
P4	2019-09-10T12:35	2019-09-10T13:05	54.115	8.087	22	Water supply switch: 12:37; 12:37: 2m; 12:42: 10m; 12:46: 20m; 12:49: retrieval to 10m; 12:51 switch to regular supply; 12:56: sediment sample
P5	2019-09-10T13:34	2019-09-10T14:05	54.148	7.956	43	Water supply switch: 13:39; 13:39: 2m; 13:44: 10m; 13:46: 34m (max. cable length, hose has 50m), probe at depth for more than 10 min to allow for Alk measurement; 13:01 recovered; 13:03: switch back to regular supply
P6	2019-09-11T5:34	2019-09-11T6:26	54.157	7.939	43	Methane sensor started to work at 06:11: switch to vertical; 2m 06:14; 20m 06:17; 30m, hit bottom 06:24; 2m 06:25: switch to regular supply
P7	2019-09-11T7:32	2019-09-11T8:01	54.063	8.244	16	Water supply switch at 07:36; 07:38: 2m; 07:47: 7m; 07:48: 15m; 07:56: 2m; 07:58, back to regular supply
P8	2019-09-11T8:19	2019-09-11T8:41	54.053	8.351	12	8:22: switch to profiling water supply; 8:24: 2m; 8:27: 7m; 8:29: 15m; 8:39: switch back to regular supply
P9	2019-09-11T10:13	2019-09-11T10:24	53.882	8.700	15	Comparison to Cuxhaven FB, ca. 400m (?) off. No deep cast, after station slow drive by container.

Tab. A.5.5: Instruments on the *Ludwig Prandtl* on Stern_3

On the way / vertical	Water / air	Parameter(s)	Respon-sible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
On the way		**Position**: latitude_0001, longitude_0001	G. Flöser	D-Ship	laboratory:moses_stern_3:d_ship_*Prandtl*_01	
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	laboratory:moses_stern_3:weather_station_hzg_1957ps001	No time offset
On the way	water	**Position**: latitude_0001, longitude_0001	G. Flöser	FerryBox	laboratory:moses_stern_3:fb_hzg_orion	No time offset
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	laboratory:moses_stern_3:fb_hzg_orion	Time offset: - 20 sec,

On the way / vertical	Water / air	Parameter(s)	Respon-sible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
On the way	water	**Dissolved methane:** 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 dge4 (data not used)	Laboratory:moses_stern_3:losgatos_awi_1303	Time offset: - 94 (degasser + Analyser), - 300 sec for water flow off-set (10 L bucket with a flow of 2L/min) -> 394 sec, Conversion ppm to nmol/L * 21,771 Vertical profiles have to be excised according to the times given in Tab. A5.4
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 von N. Brüggemann, FZJ	laboratory:moses_stern_3:picarro_awi_cfads2156	Time offset: -18 sec and -1 h on 10.9.2019
On the way	water	**Alkalinity**: pco2_corr_contros_hydroc_0001	G. Flöser	HydroC CO2 FT TA Contros 0617001	laboratory:moses_stern_3:co2ft_hzg_0617001	Time offset: -20 sec
vertical	water	**Alkalinity**: pco2_corr_contros_hydroc_0001	G. Flöser	HydroC CO2 FT TA Contros 0617001	laboratory:moses_stern_3:co2ft_hzg_0617001	Time offset: -20 sec, Vertical profiles have to be excised according to the times given in Tab. A.5.4
vertical	water	**Sample_id, water_depth** **Salinity, turbidity**	I. Bussmann	Water samples	doi.pangaea.de/10.1594/PANGAEA.910461	
vertical	sediment	**Methane**	I. Bussmann	Grab sampler	doi.pangaea.de/10.1594/PANGAEA.910461	

On the way / vertical	Water / air	Parameter(s)	Respon-sible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
vertical	water	**Hydrography**: Temperature, salinity, oxygen, pH, chlorophyll, turbidity	G. Flöser	CTD	laboratory:moses_stern_3:ctd_hzg_313	Fb: 1 min Zeitkonstante, zu ungenau für Tiefenprofil, CTD did not work
vertical	water	**Dissolved methane**: methane_dry_water_0001 carbon_dioxide_dry_water_0001 fit_flag_water_0001 methane_in_water_0003,[nmol/l]	I. Bussmann	Same set up as for on the way sampling (see above) but vertical water supply ,	Laboratory:moses_stern_3:losgatos_awi_1303	Time offset: - 94 (degasser + Analyser), - 300 sec for water flow off-set (10 L bucket with a flow of 2L/min) -> 394 sec Conversion ppm to nmol/L * 21,771 Vertical profiles have to be excised according to the times given in Tab. A5.4
vertical	water	**Hydrography**: cdom_cyclops_0001, chlorophyll_a_0001, oxygen_saturation_0001, ph_meinsberg_ega_0001, salinity_0001, turbidity_0001 temperature_citadel_0001	G. Flöser	Same set up as for on the way sampling (see above) but vertical water supply	laboratory:moses_stern_3:fb_hzg_orion	Time offset: - 20 sec, Vertical profiles have to be excised according to the times given in Tab. A.5.4

Tab. A.5.6: Vertical profiles taken by *Uthörn* on Stern_3

Station name	Datetime (start)	Datetime (end)	Latitude (N)	Longitude (E)	Bottom depth [m]	Parameters	Remarks
stern3_vert_U1	2019-09-10T08:30		53.9818	8.5749	10	On the way systems	intercalibration
		2019-09-10T08:50	53.9817	8.5797	11		intercalibration
stern3_vert_U2	2019-09-10T08:51	2019-09-10T09:48	53.9818	8.5804	11	Rosette with CTD, pump, sediment	Water samples from rosette
stern3_vert_U3	2019-09-10T11:09	2019-09-10T11:34	54.0092	8.2847	21	Pump attached to rosette, sediment	Water samples from pump
stern3_vert_U4	2019-09-10T13:17		54.0512	7.8878	37	Pump attached to rosette, sediment	Water samples from pump
stern3_vert_U5	2019-09-10T14:08	2019-09-10T14:19	54.1000	7.8983	39	Pump attached to rosette	Water samples from pump
stern3_vert_U6	2019-09-11T05:40	2019-09-11T06:00	54.1589	7.9403	39	Under way systems	intercalibration
stern3_vert_U7	2019-09-11T06:06	2019-09-11T06:22	54.1658	7.9482	37	Pump attached to rosette, water samples	Water samples from rosette and pump
stern3_vert_U8	2019-09-11T07:16	2019-09-11T07:38	54.2011	8.1871	21	Pump attached to rosette	Unsuccessful sediment sampling, Water samples from pump

Station name	Datetime (start)	Datetime (end)	Latitude (N)	Longitude (E)	Bottom depth [m]	Parameters	Remarks
stern3_vert_U9	2019-09-11T08:28	2019-09-11T08:49	54.1091	8.2911	17	Pump attached to rosette, sediment	Water samples from pump
stern3_vert_U10	2019-09-11T10:16	2019-09-11T10:38	53.9777	8.5188	10	Pump attached to rosette,	Water samples from rosette and pump

Tab. A.5.7: Instruments on the *Uthörn* on Stern_3

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
On the way		**Position and weather**: Longitude, latitude, depth, temperature, barometric_pressure, speed, true wind direction, true wind speed	N. Anselm	D-ship	vessel:uthoern	
On the way	water	**Position**: latitude_0001, longitude_0001, speed_0001 course_over_ground_0001	M. Friedrich	FerryBox pocket AWI 751801	laboratory:moses_stern_3:pfb_awi_751801	No time offset
On the way	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	M. Friedrich	FerryBox pocket AWI 751801	laboratory:moses_stern_3:pfb_awi_751801	Time offset: -100 sec Data file starts at 10.9 00:00, but the water flow for the FerryBox started around 7:20. Vertical profiles have to be excised according to the times given in Tab. 18
On the way	water	**Dissolved methane**: methane_dry_0001, carbon_dioxide_dry_0001, fit_flag_0001, methane_nmolL_0001	I. Bussmann	Ultraportable Greenhouse gas analyzer with degassing unit (dge_3, data not used)	Laboratory:moses_stern_3:losgatos_awi_1142	Time offset: -100 - 119 = - 219 sec, Conversion from ppm to nmol/L * 39,507 Vertical profiles have to be excised according to the times given in Tab. A.5.6
On the way	air	**Atmospheric CH4 and pCO2**: Carbon_dioxide_air_0001, methane_dry_0001, methane_in_air_0001	I. Bussmann	Microportable Greenhouse Gas Analyzer von M. Koschorek	laboratory:moses_stern_3:losgatos_awi_4300	Time offset: -18 sec

On the way / vertical	Water / air	Parameter(s)	Responsible person	Instrument name	Sensor ID at https://dashboard.awi.de/data-xxl/overview.jsp	Remarks
vertical	water	**Hydrography**: flow_main_0001 Temperature_sbe45_0001, conductivity_sbe45_0001, salinity_sbe45_0001, ph_0001 Temperature_phsensor_0001, oxygen_concentration_0001,[µmol/], oxygen_saturation_0001, temperature_0001, turbidity_0001, chlorophyll_0001	M. Friedrich	FerryBox pocket AWI 751801	laboratory:moses_stern_3:pfb_awi_751801	time offset: - 100 sec Vertical profiles have to be excised according to the times given in Tab. A.5.6
vertical	water	**Dissolved methane**: Methane_dry_0001, carbon_dioxide_dry_0001, fit_flag_0001, methane_nmolL_0001	I. Bussmann	Same set up as for on the way sampling (see above) but vertical water supply ,	Laboratory:moses_stern_3:losgatos_awi_1142	Time offset: 100 + 119 = - 219 sec, conversion: CH4c_ppm * 39,507 => nmol/L, Vertical profiles have to be excised according to the times given in Tab. A.5.6
vertical	water	**Hydrography**: cdom_0001, temperature_0001, salinity_0001, oxygen_concentration_0001,oxygen_saturation_0001,pressure_0001, chlorophyll_a_0001, turbidity_0001	M. Friedrich	CTD-519	laboratory:moses_stern_3:ctd_awi_519	
vertical	water	**Salinity, turbidity**	G. Flöser, I. Bussmann	Water samples	https://doi.pangaea.de/10.1594/PANGAEA.910461	
vertical	water	**Dissolved methane**	I. Bussmann	Water samples	dhttps://doi.pangaea.de/10.1594/PANGAEA.910461	
vertical	sediment	**Dissolved methane**	I. Bussmann	Grab sampler	https://doi.pangaea.de/10.1594/PANGAEA.910461	

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