LEIBNIZ INSTITUTE FOR BALTIC SEA RESEARCH WARNEMÜNDE

Leibniz Institute for Baltic Sea Research Warnemünde

C r u i s e R e p o r t

r/v " Alkor"

Cruise- No. AL451

This report is based on preliminary data

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1. **Cruise No.:** AL451

2. **Dates of the cruise:** from 26.02.2015 to 10.03.2015

3. **Particulars of the research vessel:**
   Name: Alkor
   Nationality: Germany
   Operating Authority: GEOMAR

4. **Geographical area in which ship has operated:**
   Central Baltic Sea (Gotland Basin)

5. **Dates and names of ports of call**
   Ventspils (Latvia). 01-02 March 2015 and 07-09 March 2015

6. **Purpose of the cruise**
   The original scientific goal of this cruise, conducted in the framework of the WGL/Pakt project ILWAO-II, was the investigation of the role of internal waves for basin-scale vertical mixing in the deep basins of the Baltic Sea. In agreement with IOW's board, however, it was decided to devote a substantial part of the cruise time to the observation of one of the rare major saline inflow events that reached the central Baltic Sea exactly at the time of this cruise. In addition to the physical measurements, microbiological and chemical investigations were conducted, focusing on the role of methane-oxidizing bacteria in pelagic redoxclines.

7. **Crew:**
   Name of master: J.-U. Lass
   Number of crew: 11

8. **Research staff:**
   Chief scientist: Umlauf, Lars

   Scientists: Basurak, Berkay
   Becherer, Johannes
   Gräwe, Ulf
   Jurgenowski, Philpp
   Krause, Stefan
   Lappe, Chris
   Power Guerra, Nicole
   Schmale, Oliver
   Siegel, Herbert

   Engineers: Heene, Toralf
   Pallentin, Malte

   Technicians:

9. **Co-operating institutions:**
   GEOMAR (Kiel)
   University of Hamburg

10. **Scientific equipment**
    (see attached cruise report)

11. **General remarks and preliminary result**
    (see attached cruise report)

Cruise description

The scientific crew for this cruise consisted of seven physical oceanographers working on mixing processes and marine optics, two marine chemists plus one student assistant focusing on methane oxidizing bacteria at oxic-anoxic interfaces, and two technicians responsible for instrumentation and mooring work. The main goals of this cruise were (a) the investigation of mixing processes in the interior and near the lateral slopes of the Gotland basin, and (b) their impact on methane turnover and particle layers in the vicinity of redoxclines. A large part of the cruise was, however, also devoted to the observation of the oxic inflow waters that had entered the western Baltic Sea in December 2014 during one of the largest inflow events ever recorded. Fortuitously, the arrival of these water masses in the Gotland Basin coincided with our cruise dates such that we had the unique opportunity to investigate the dynamics of one of these rare events in unprecedented detail.

The entire study area according to the permission by the coastal states Sweden and Latvia is shown in Fig. 1 with coordinates listed in Tab. 1. Due to the focus on the inflow event, however, the observational program was restricted to study area 1 (Gotland Basin). A list of all stations visited during this cruise is compiled in Tab. 2 and graphically shown in Fig. 2. Naming conventions for transects connecting two stations are listed in Tab. 3.

Instrumentation and Methods

Physical measurements

The key instrument of the physical observational program was a MSS90-L microstructure profiler from ISW (Germany), equipped with two airfoil shear probes for turbulence measurements, a fast FP07 thermistor, a Seapoint turbidity sensor, and precision CTD sensors. More than 370 full-depth profiles were obtained with this instrument during transects and in the vicinity of fixed stations (see summary in Tab. 6), yielding a detailed description of stratification and mixing parameters in the study area.

Our SBE 911plus CTD system (Seabird Electronics, USA) was equipped with SBE 3 and SBE 4 temperature and conductivity sensors, and a SBE 43 oxygen sensor. Turbidity and fluorescence were observed with a type FLNTURTD sensor from Wetlabs (USA), whereas PAR and SPAR were recorded using the sensor types OSP200L4S and QSR-2200 from Biospherical Instruments (USA). All sensors were embedded in a rosette system with a set of 10 free-flow bottles from Hydrobios (Germany). All CTD casts obtained during AL451 are compiled in Tab. 5; a more detailed summary of all chemical, microbiological, and optical measurements is shown in Tabs. 8 and 9. Finally, basin-scale CTD surveys were conducted with the help of a towed and undulating CTD system (ScanFish from Eiva, Denmark) as described in Tab. 7.

Attached to the CTD rosette was a Wetlabs AC-S in-situ spectrophotometer for the optical characterization of particle layers in the water column, focusing on the turbidity maxima in the vicinity of redoxclines. Absorption and scattering properties were studied based on in-situ measurements using the AC-S, and laboratory measurements of particle absorption from water samples. The latter were used to determine the concentration of optically active water constituents like chlorophyll-a (Chl-a) and suspended particulate matter (SPM) as well as of absorption of particulate matter (ap) and yellow substance (CDOM) to validate the AC-S measurements. Selected samples were also taken for SEM (scanning electron microscopy) and EDX to determine the element composition. The transparency and ocean color were determined using a Secchi disc and the Forel scale to estimate winter values for the validation of the ecological model ERGOM. All optical measurements are summarized in Tabs. 5 and 8.

Velocity data in the upper 80-100 m of the water column were provided by a permanently operating 300-kHz vessel-mounted ADCP (Broadband from RD Instruments, USA). Near-bottom velocity data, not accessible with this instrument, were obtained by a 600-kHz ADCP (Broadband from RD Instruments) that was equipped with a purpose-built wing, which allowed the instrument to be towed behind the ship at a distance of 20-40 m from the bottom (towed and lowered ADCP: TL-ADCP). This instrument was deployed simultaneously with the MSS90 profiler during the transect work (see Tab. 6).

Beyond these ship-based measurements, also a number of moorings were deployed during this cruise (see summary in Tab. 4). The design of these moorings is shown in the appendix at the end of this document. All moorings were recovered before the end of the cruise, except for the GODESS profiling system that, after a short-term deployment from 28 Feb until 05 Mar, was moored again in the afternoon of 05 Mar for a long-term deployment. The planned recovery is mid of April during cruise EMB100 with R/V Elisabeth Mann Borgese.

Chemical and microbiological measurements

Water samples for the following analyses were taken using the CTD/rosette system described above.

1. Methane Analyses. A 600 ml subsample from each water-column sample bottle was transferred into pre-evacuated 1100 ml glass bottles. The dissolved methane was extracted by the use of a vacuum degassing line. A subsample of the gas was transferred into 10 ml pre-evacuated crimp-top glass vials containing 4 ml of supersaturated salt solution (Schmale et al., 2012). The methane concentration was determined using a gas chromatograph (Trace GC, Thermo Fisher Scientific Inc.) equipped with a flame ionization detector. After the cruise the gas subsamples will be analyzed in the IOW home laboratory for 13C CH_4 values using a MAT 253 isotope-ratio mass spectrometer (Thermo Fisher Scientific Inc.).

2. Methane oxidation rate measurements. Water samples were directly transferred from the sampler bottle into 600 ml incubation bottles, and sealed bubble-free with natural rubber septa. Methane was injected into the water samples, which were incubated near in situ temperatures for 3 days in the dark. The microbial activity was stopped by injection of 500 µl sodium hydroxide (50% (w/w)). After the cruise, methane oxidation rates will determined at the IOW home laboratory following the method of Jakobs et al. (2014).

3. Quantification of methane oxidizing bacteria. For bacteria quantification water samples were collected in 50-ml sterile plastic tubes. Samples were fixed with methanol-free formol (2%) for at least 2.5 to max. 4 hours. Subsequently, a 50-ml, 10-ml, and 1-ml subsample from each water sample were filtered on Nucleopore filters (Whatman, pore size 0.2 µm) with a maximum pressure of -100 mbar. Filters were stored in Eppendorf tubes at -20°C until further processing. After the cruise, the quantity of methane oxidizing bacteria (MOB) will be determined from filtered microbes using Catalysed Reporter Deposition Fluorescence In Situ Hybdridization (CARD-FISH) followed by tyramide signal amplification (Pernthaler et al., 2002). In addition to CARD-FISH filters will be counter stained with 4´,6´-diamidino-2-phenylindole (DAPI). CARD-FISH and DAPI-stained cells will be enumerated using epifluorescence microscopy (Zeiss AxioImager.M2).

Chronological description of cruise activities

R/V Alkor left pier 8 in Warnemünde harbor on 26 Feb at 07:00 UTC, as scheduled, with all 12 participants and fully functional instrumentation on board. During moderate winds and fair weather, the ship approached station AB (station positions are compiled in Tab. 2) in the Arkona Basin around 14:00 UTC to recover a "Tripod" bottom lander (see Section "Moorings" below) that had been deployed during a previous cruise. The surface markers of the lander could, however, not be spotted at the expected location, and the mooring recovery could therefore not be carried out as planned. A CTD profile (see Tab. 5) was taken with the instrument platform of the GODESS profiler system and the AC-S optical sensor package attached to the CTD rosette for inter-calibration purposes. At approximately 15:00 UTC the ship continued its way to the central Baltic Sea.

The first operation in the Gotland Basin was a CTD survey of the south-eastern and central parts of the study area, aimed at investigating the spreading of the saline and oxic waters that entered the Western Baltic Sea in the beginning of December 2014 during the large inflow event mentioned above. After arrival at station BX02 on 27 Feb 12:00 UTC, CTD casts were taken at this and the following stations: BX01, BX03, B9, B8, BX04, TF272, BX05, and BX06 (in this order). After the end of these measurements, at 23:30 UTC, the ship moved to station P, where mooring work was planned for the next morning.

Mooring work at station P started in the morning of 28 Feb with the deployment of the GODESS profiler system and a nearby mooring line with an upward looking 300-kHz ADCP, located in the middle of the water column ("Midwater ADCP", see Tab. 4). All mooring work was completed by 09:00 UTC, when the ship moved to the nearby station TF271 to perform a number of CTD casts. Notable during these casts was in particular the presence of an oxic near-bottom layer underneath sulfidic waters that provided, for the first time since the beginning of the inflow event, evidence for the arrival of the inflow waters at this key station in the center of the Gotland Basin.

CTD profiling was completed by approximately 11:00 UTC, when the ship started a 3-hour transit to station BX01 for further mooring deployments. After arrival at 14:30 UTC, a small bottom frame (named "ADCP frame 600 kHz", see Tab. 4) with a 600-kHz ADCP, a CTD logger, and an oxygen sensor was deployed in order to monitor the temporal variability of the saline inflow at this bottle-neck location. Following the mooring work, a 15:00 UTC, a CTD profile was taken at station BX01 before the ship continued to station BX02 (arrival at 16:00 UTC).

On transect T1 (starting at station BX02, see Tab. 3), turbulence microstructure measurements were undertaken across a submarine channel in the vicinity of the mooring that was assumed to topographically guide the inflowing water masses. After the end of these measurements, at approximately 22:30 UTC, the ship proceeded to station BX06 where a CTD-cast was taken at approximately 00:45 UTC on 01 Mar 2015. At 01:30 UTC, a new microstructure transect (T2, see Tab. 3) was started from station BX08 towards station BX05, which continued as transect T3 from BX05 towards TF272. Due to gradually increasing winds, however, these measurements had to be interrupted at 08:00 UTC before station TF272 was reached. Winds around 6 Bf from the side prevented the ship from being kept on track. The meteorological forecast suggested winds to increase further up to Bf 7-8 during the rest of the day such that after one further CTD profile at station BX05, all measurements had to be discontinued. In agreement with the captain, it was decided to visit the nearby harbor of Ventspils (Latvia) until weather conditions had improved, and the observational program could be resumed. Ventspils was reached at approximately 15:00 UTC.

The ship left Ventspils habor on 02 Mar at 07:00 UTC, heading for station BX05. After arrival at this station, a number of CTD profiles including water samples for the analysis of oxygen, methane, and optical properties were obtained. Starting 13:30 UTC, an ADCP bottom frame ("Aquadopp Frame", see Tab. 4) and a mooring line with CTD loggers and other instrumentation ("TC Chain", Tab. 4) were deployed at this station. Both moorings were connected by a ground line. At 14:00 UTC, one more CTD profile was taken at BX05 before a short series of microstructure measurements in the vicinity of this station was started. At 16:00 UTC, these measurements were completed, and the Alkor moved to the eastern starting point (BX08) of transect T2 (arrival around 17:00 UTC).

During the evening and night, microstructure measurements were conducted on transect T2, and immediately afterwards on transect T3 until approximately 23:00 UTC, when the transect was completed. The next microstructure transect was planned on T1. It started after arrival of the ship at station BX02 on 03 Mar at 01:45 UTC, and was completed 6.5 hours later at approximately 08:15 UTC near station BX07. To connect these turbulence measurements with chemical and microbiological parameters, the Alkor approached the central station (BX01, arrival 09:00 UTC) of this transect, where a number of CTD profiles were taken until 10:30 UTC.

Following these measurements, the Alkor proceeded from Station BX01 to the central station TF271, where CTD profiling started at 14:30 UTC. At 15:30 UTC, after the end of these CTD casts, turbulence microstructure measurements in the vicinity of P were initiated. 49 profiles were taken during one complete inertial cycle (~14 hours) until 07:15 UTC in the morning of 04 Mar 2015. During these measurements, the ship moved on short transects (length: 2 nm), centered at station P, against wind and waves. After moving to the nearby station TF271, starting from 07:00 UTC CTD profiles were taken to monitor the temporal changes of inflow water that, at this time, had already filled up the Gotland Basin up to a depth of 200 m.

The observational program continued with two microstructure transects, named T4 and T5 (see Tab. 3), across the eastern slope of the basin, aimed at investigating the dynamics of the rotationally influenced dense bottom current leaning on the slopes. After completion of the microstructure measurements on these transects, CTD profiles were obtained at the two stations BX11 and BX14, respectively. On the last transect, T5, we operated the TL-ADCP, towed behind the ship between 30 and 40 m above the bottom simultaneously with the microstructure profiler. This instrument yielded high-resolution velocity measurements above and inside the dense bottom current that would have been difficult to obtain with any other method. The measurements on transects T4 and T5 were completed by approximately 20:45 UTC on 04 Mar 2015, when the ship started approaching station BX08, which formed the eastern end point of transect T2. Microstructure measurements on this transect started at 21:45 UTC, were shortly interrupted for a CTD cast at its endpoint BX05, and resumed on the connecting transect T3 (Tab. 3).

Measurements on this transect, however, had to be interrupted at 04:00 UTC in the early morning of 05 Mar 2015 in order to reach position P just in time for the planned mooring work. At 06:00 UTC, the releaser of the GODESS profiler system was triggered, and the mooring could be successfully recovered within less than one hour. Immediately afterwards, the nearby mooring “Midwater ADCP” could be recovered without problems as well. All mooring work was completed already by 07:30 UTC. A first check suggested that all instruments worked correctly. The Alkor then approached station BX11, located on transect T4, to obtain a series of CTD profiles, including water samples for chemical and microbiological analyses. After CTD profiling was completed (around 09:30 UTC), microstructure and near-bottom velocity observations with the towed and lowered ADCP were carried out along T4 until approximately 14:15 UTC. In the meantime, after a maintenance and re-programming, the GODESS mooring was ready for the next (long-term) deployment with recovery planned during a following cruise (EMB100 from 16 to 26 April 2015). The Alkor reached the mooring position P at 14:45 UTC, and the GODESS profiler system was deployed without problems by 15:30 UTC.

After a short transit to station BX15, which forms the eastern endpoint of transect T6, microstructure measurements along this transect started at 16:45 UTC. Also here, the TL-ADCP was used simultaneously with microstructure profiling. The survey on this northernmost transect was complete shortly after 21:00 UTC, when the Alkor moved to station BX17. This point marks the northern endpoint of transect T7, ranging from North to South along the lateral slope of the basin at a depth of 170-180 m. Using the MSS90 turbulence profiler and again the towed and lowered ADCP, the first section (named T7a) was completed at approximately 01:00 UTC on 06 March 2015, when position BX18 was reached.

In the vicinity of station BX18, however, an unexpected accident occurred that resulted in the loss of one of the microstructure profilers (MSS068). Although the course of events could not be fully reconstructed, it appears that during the transect, the TL-ADCP touched the swift bottom current associated with the inflowing water masses, and was advected underneath the freely falling microstructure profiler. The wing of the TL-ADCP then may have cut the cable of the profiler. All following microstructure measurements were conducted with our replacement profiler MSS038 with nearly identical functionality.

After this unfortunate event, the regular observational program was resumed with CTD profiles including water samples at station B8 (completed by 08:15 UTC). At 10:00 UTC, during force 6-7 winds from southwest, the ScanFish transect TSF1 between points SF02 and SF01 was initiated to obtain a basin-scale view of the halocline and redoxcline structure during the inflow event. The end of this transect was reached at approximately 17:15 UTC, after which station TF271 was approached to investigate changes in the center of the basin induced by the inflow event with a CTD profile. During the rest of the night from 06 to 07 Mar, CTD profiles including water samples were taken at station BX03, followed by the short microstructure transect T1a near the southern end of study area 1.

We used the short period of low wind conditions in the morning of 07 Mar to recover the mooring “ADCP Frame 600” at station BX01 between 06:00 and 06:30 UTC. After a 2.5-hour transit to station BX05, the releaser of the second mooring (“Aquadopp frame” plus “CTD chain”) was triggered around 09:00 UTC but the releaser unit failed to reach the surface. It was decided to recover the mooring by “dredging” the ground line, which succeeded at the first attempt, although parts of the releaser line hit the propeller during recovery. All mooring components could, however, be recovered without damage by 10:30 UTC.

Winds increasing above 15 m/s, and predictions for even stronger winds until Monday morning, forced us to interrupt the observational program again, and to seek shelter in the nearby harbor of Ventspils. Arrival was at approximately 15:00 UTC on 07 Mar 2015. Wind conditions did unfortunately not improve over the week-end, such that measurements could not be resumed. The Alkor left Ventspils harbor on Monday morning (09 Mar 2015) at 07:00 UTC, heading for Warnemünde. Cruise AL451 was completed at 10 Mar 2015 at approximately 14:00 UTC, when the Alkor docked at pier 8 in Warnemünde harbor. Demobilization was completed in the morning of 11 Mar 2011.

Maps

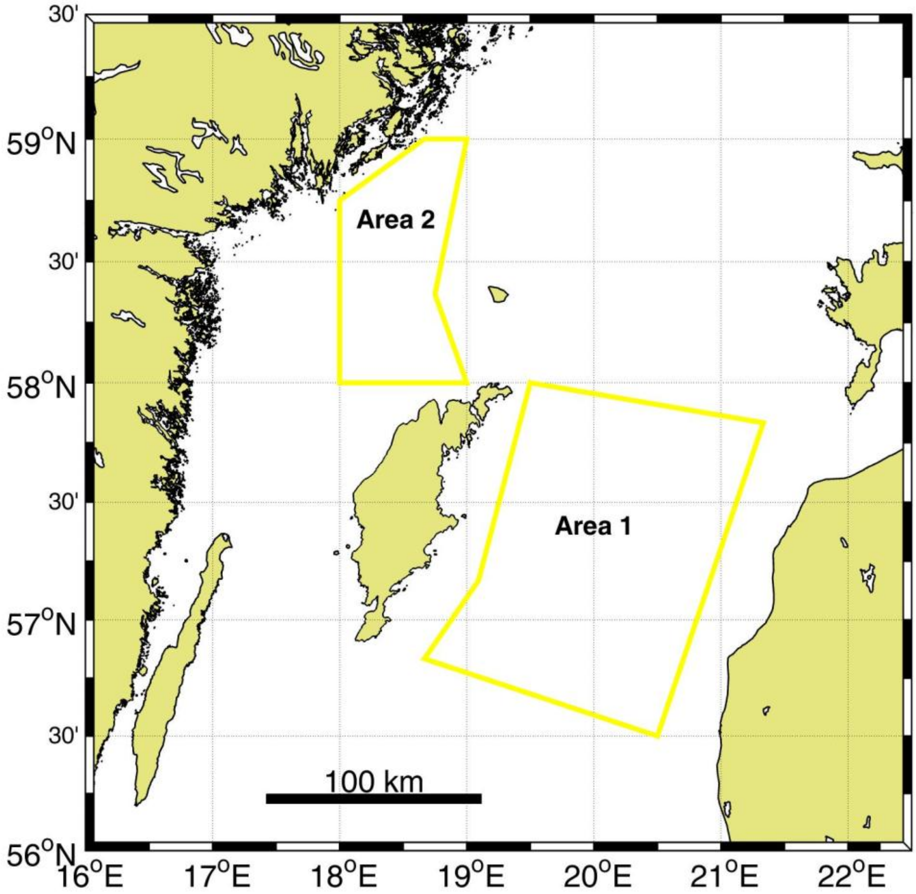

Fig. 1. Study areas for AL451 according to permissions by coastal states. For coordinates, see Tab. 1. Measurements were conducted only in Area 1.

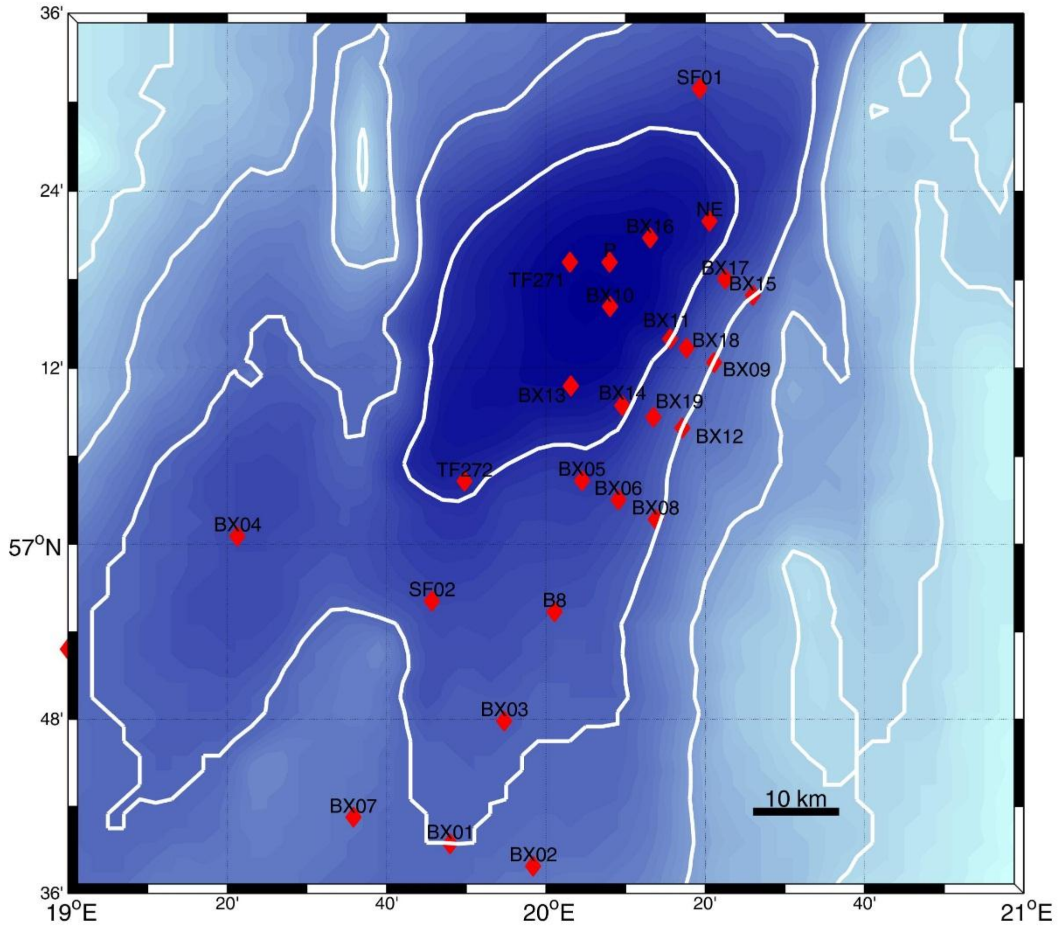

Fig. 2. Map of stations in study area 1. For coordinates, see Tab. 2

Results

"Major Baltic Inflows" are intrusions of large amounts of oxygen-rich, salty waters from the North Sea that have the potential to ventilate the deep waters of the central Baltic Sea. They are, however, rare events, observed only approximately every 10 years (in recent decades) as a result of particular meteorological and hydrographic conditions. During this cruise, by little more than lucky coincidence, we had the unique chance to observe one of the largest events of this type ever recorded exactly at the time when it entered the Gotland Basin in the heart of the Baltic Proper. For this reason, the focus of the cruise was shifted towards the investigation of this inflow event at the expense of the originally planned investigation of internal-wave mixing.

Physical measurements

The character of the physical dataset is best illustrated with an example of our microstructure measurements on the eastern slope of the basin, to which the inflowing water masses were deflected by the Coriolis force. The signature of the inflow water is clearly visible in the upper panels of Figs. 3 and 4, showing microstructure data for transect T5 that was occupied in the afternoon and evening of 04 Mar 2015 between stations BX12 and BX13 (see Tabs. 3, 6, and Fig. 2). These panels reveal the presence of a warm and salty (thus dense) water mass inside a near-bottom layer of approximately 20 m thickness, leaning on the lateral slope of the basin.

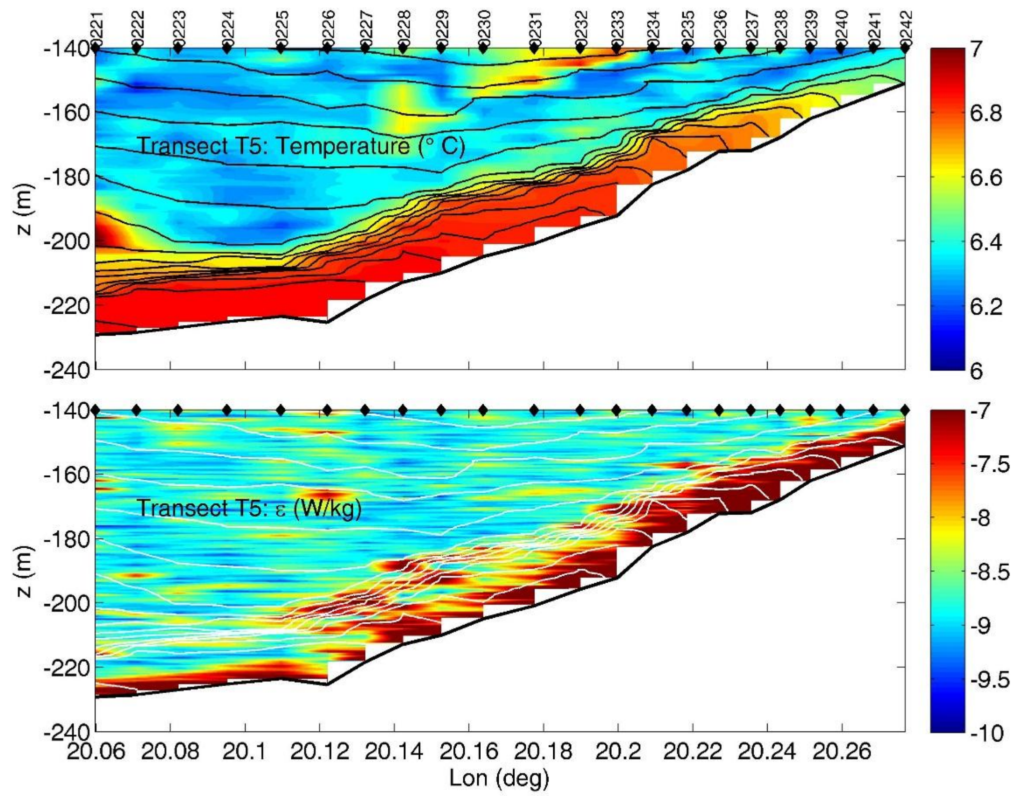

Fig. 3. Temperature (upper panel) and turbulence dissipation rate (on logarithmic scale) from microstructure measurements on transect T5 (see Tab. 3 and map in Fig. 2). Contour lines indicate isopycnals, plotted at 0.1 kg/m^3 intervals. Black markers indicate locations of individual casts.

The tilted density interface is indicative for a geostrophically balanced flow component, suggesting a current flowing along the topography of the eastern slope towards north-east (see Fig. 2). This is confirmed by our velocity measurements with the TL-ADCP that was towed approximately 20-40 m above the bottom, simultaneously with the microstructure measurements (Fig. 5). Velocities in the near-bottom layer are seen to be highest on the sloping part of the topography, reaching approximately 0.25 m/s. Note that velocity measurements inside this thin bottom current, at more than 200 m depth, were only possible with the help of the towed and lowered ADCP-system developed for this purpose.

The lower panel in Fig. 3 shows vigorous near-bottom turbulence associated with the dense bottom flow, suggesting that bottom friction is a key player in the dynamical balance [*Umlauf and Arneborg*, 2009a; b]. Turbulent patches inside the strongly stratified interface indicate shear-instabilities, thus pointing at entrainment and mixing of ambient and inflowing water masses. The interface region is therefore likely to be a region of enhanced chemical and microbial activities.

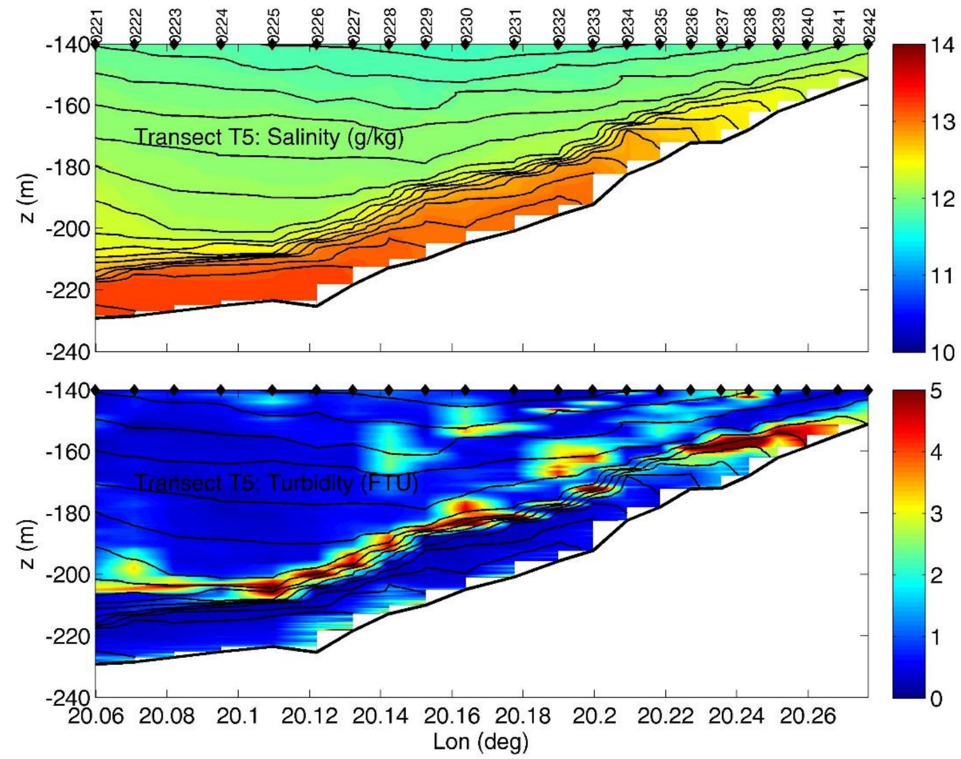

Fig. 4. As in Fig. 3, but now salinity (upper panel) and turbidity are shown

The turbidity measurements shown in the lower panel of Fig. 4 reveal an interesting phenomenon that appeared in similar form in all our measurements. At the interface between the oxic near-bottom layer and sulfidic layer above, we find a pronounced turbidity maximum that seems to indicate some (currently unknown) product of microbiologically-mediated redox reactions. Similar turbidity maxima are well-known features also in the main redoxcline, located between the oxic surface waters and the sulfidic deeper layers, and therefore are likely to be a generally relevant indicator for redox reactions. The bio-geochemical processes leading to these turbidity zones are, however, still unclear but our data suggest that they may be generated on times scales of only a few days.

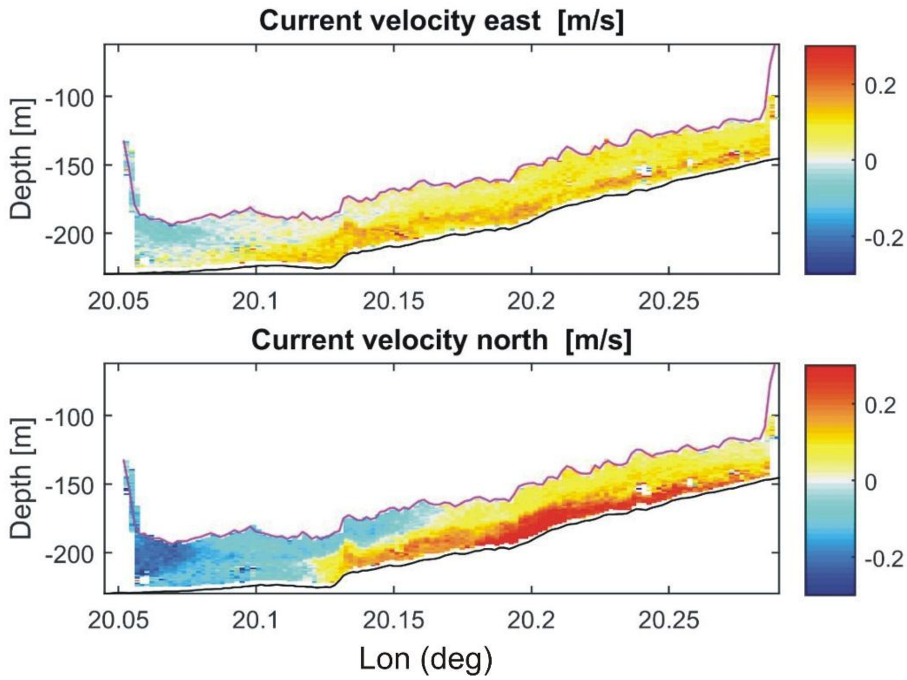

Fig. 5. Near-bottom velocities observed by the TL-ADCP on transect T5, simultaneously with the microstructure measurements shown in Figs. 3 and 4.

The oxygen content of the inflow waters that could not be observed with the microstructure profiler is revealed in Fig. 6, showing a CTD profile taken at station BX14 immediately after the microstructure measurements on transect T5 were completed. Note that station BX14 is located on transect T5 at slightly more than 200 m depth, i.e. fully inside the inflow pathway seen in Figs. 3-5. Fig. 6 shows the presence of an approximately 25-m thick near-bottom layer with oxygen content below 1 ml/l, indicating that at this stage of the inflow only a small amount of oxygen is imported into the deep layers of the Gotland Basin. Clearly visible also in this profile is the strong turbidity maximum inside the interface between oxic and anoxic waters. Slightly enhanced turbidity may also be discerned close to the bottom, where it most likely mirrors the re-suspension of sediment due to the strong near-bottom turbulence visible in Fig. 3.

Marine optics

The physical observations were complemented by optical measurements, allowing to distinguish between layers of differently absorbing and scattering particles. These measurements are summarized in Tab. 8 below. The surface water was dominated by low concentrations of absorbing phytoplankton with significant chlorophyll maxima. In the anoxic regions, high concentrations of small yellow particles with low but significant spectral absorption were dominant, leading to strong scattering and thus to the large turbidities found in the CTD and microstructure measurements. Above the redoxcline and in the bottom water, absorbing particles were dominant with a reduced signal in scattering and turbidity discoloring the filters brownish. The Secchi depth varied between 10 m in the Arkona Sea and 13-16 m in the Gotland Sea, which indicates a rather high transparency for a winter situation.

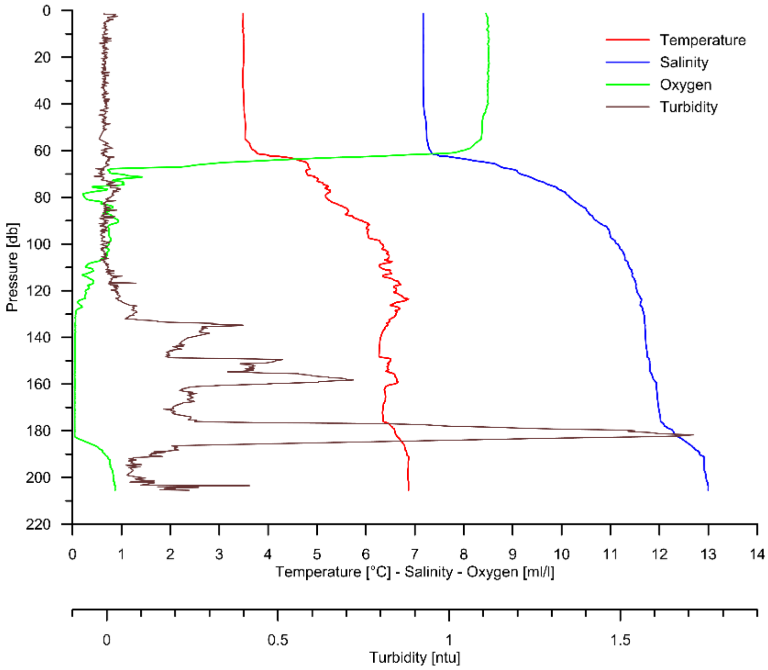

Fig. 6. CTD profile taken on station BX14 (see Fig. 2) directly after the end of the microstructure measurements on transect T5.

Fig. 6 shows an example of the vertical variability of the total absorption coefficient *a* at 411 nm and the scattering coefficient *b* at 671 nm for a CTD profile taken at the central station TF271. The differences between *a* and *b* are most pronounced at these wavelengths (for the absorption coefficient *a* in particular in the short wavelength range because the larger particle absorption increases to lower wavelengths and scattering is highest in the anoxic waters with small particles coloring the filters light yellow). The larger particles are located in the halocline, just above the redoxcline, and in the bottom layer. Water samples of these regions colored the filters grey-brownish. The highest concentration of small particles was found in the top and the bottom of the anoxic water layer.

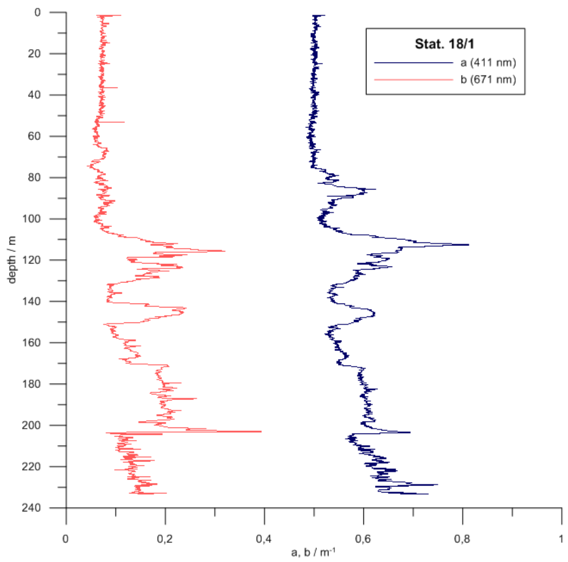

Fig. 7: Total absorption coefficient *a* at 411 nm and the scattering coefficient *b* at a wave length of 671 nm for CTD cast V0018F01 at station TF271 (see Tab. 5).

Methane turnover

The general methane (CH_4) concentration pattern in the western Gotland basin shows increasing concentrations with increasing water depth (Jakobs et al., 2014). A strong concentration gradient is present in the suboxic water body. Previous studies identified microbial methane oxidation within the transition zone between oxic and anoxic water in water depths between 90 and 100 m. This process seems to be important in restricting the methane flux from the deep methane reservoir into the surface water.

The saltwater inflow during cruise AL451 offered the opportunity to study the impact of such an event on the microbial methane turnover and the deep water methane budget. Therefore, samples were taken along a transect following the inflow direction from the south of the basin towards the center (station list is given in Tab. 9). Using a multidisciplinary approach, combining gas chemistry and microbiology, we examined the response of the microbial community to the advection of oxygenated in-flow water by determining the microbial methane oxidation rates and the abundance of methane oxidizing bacteria (MOB) throughout the water column. Top priority was given to the sampling across the two interfaces between (1) the oxic surface water and the anoxic methane rich deep water and (2) the anoxic methane rich deep water and the oxic inflow water near the seafloor.

Compared to the deep anoxic water body, the salt water inflow shows relatively low methane concentrations. The strong methane concentration gradient between these two water bodies may indicate microbial methane consumption within the interface as observed in previous studies conducted in the upper suboxic transition zone in about 100 m water depth (Jakobs et al, 2014). Detailed samples taken for methane oxidation rate measurements and MOB CARD-FISH analyses will help to describe the response of the methane oxidizing bacterial community to oxygen-rich inflows of salt water into anoxic water bodies.

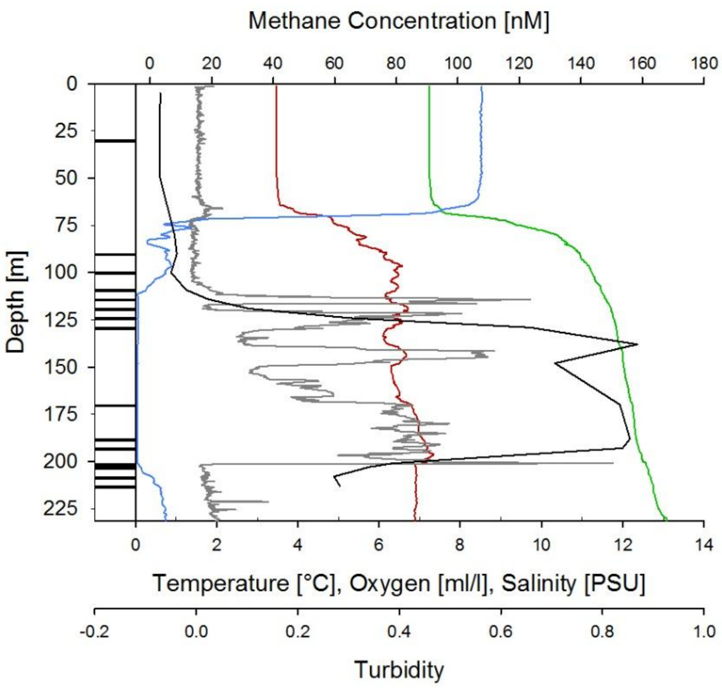

Figure 8. Vertical profiles of temperature (red line), salinity (green line), turbidity (gray line), oxygen (blue line) and methane concentration (black dots). Station identical to that shown in Fig. 7.

Tables

Table 1. Study areas according to permission of coastal states (see map in Fig. 1)

	Corner point	Latitude	Longitude
Area 1	1	58°00.00’N	19°30.00’E
	2	57°50.00’N	21°20.00’E
	3	56°30.00’N	20°30.00’E
	4	56°50.00’N	18°40.00’E
	5	57°10.00’N	19°05.50’E
Area 2	1	58°00.00’N	18°00.00’E
	2	58°00.00’N	19°00.00’E
	3	58°22.00’N	18°45.00’E
	4	59°00.00’N	19°00.00’E
	5	59°00.00’N	18°40.00’E
	6	58°45.00’N	18°00.00’E

Table 2. Station names and nominal positions

Name	Lon (deg)	Lat (deg)	Lon (dec)	Lat (dec)
AB	13°51.228'E	54°52.929'N	13.8538	54.88215
P	20°08.000'E	57°19.200'N	20.1333333	57.32
NE	20°20.533'E	57°21.983'N	20.3422167	57.3663833
TF271	20°03.000'E	57°19.200'N	20.05	57.32
TF272	19°49.800'E	57°04.300'N	19.83	57.071667
B8	20°01.113'E	56°55.381'N	20.018543	56.923021
BX01	19°47.979'E	56°39.439'N	19.7996419	56.6573225
BX02	19°58.406'E	56°37.886'N	19.9734322	56.6314412
BX03	19°54.786'E	56°47.886'N	19.9130954	56.7980967
BX04	19°21.260'E	57°00.564'N	19.354336	57.009403
BX05	20°04.518'E	57°04.344'N	20.0753	57.0724
BX06	20°09.090'E	57°03.036'N	20.1515	57.0506
BX07	19°35.832'E	56°41.250'N	19.5972	56.6875
BX08	20°13.776'E	57°01.698'N	20.2296	57.0283
BX09	20°21.096'E	57°12.396'N	20.3516	57.2066
BX10	20°08.040'E	57°16.182'N	20.134	57.2697
BX11	20°15.600'E	57°13.992'N	20.26	57.2332
BX12	20°17.130'E	57°07.938'N	20.2855	57.1323
BX13	20°03.138'E	57°10.794'N	20.0523	57.1799
BX14	20°09.600'E	57°09.474'N	20.16	57.1579
BX15	20°25.968'E	57°16.956'N	20.4328	57.2826
BX16	20°13.062'E	57°20.850'N	20.2177	57.3475
BX17	20°22.512'E	57°18.048'N	20.3752	57.3008
BX18	20°17.670'E	57°13.374'N	20.2945	57.2229
BX19	20°13.524'E	57°08.658'N	20.2254	57.1443
SF01	20°19.320'E	57°30.924'N	20.322	57.5154

SF02	19°45.708'E	56°56.112'N	19.7618	56.9352

Table 3. Location of MSS and ScanFish transects. For coordinates of start and end points, see Tab. 2.

Name	Point 1	Point 2
T1	BX02	BX07
T1a	BX02	BX01
T2	BX05	BX08
T3	TF272	BX05
T4	BX09	BX10
T5	BX12	BX13
T6	BX15	BX16
T7a	BX17	BX18
T7b	BX18	BX19
TSF1	SF01	SF02

Table 4. List of mooring deployments. Deployment times indicate the time of bottom contact of the main mooring component.

Name	Position	Deployment	Recovery
GODESS	P	28-Feb-2015 09:10	05-Mar-2015 06:03
Midwater ADCP	P	28-Feb-2015 10:01	05-Mar-2015 07:16
ADCP Frame 600	BX01	28-Feb-2015 14:43	07-Mar-2015 06:02
Aquadopp Frame	BX05	02-Mar-2015 13:37	07-Mar-2015 10:20
TC Chain (groundline to Aquadopp)	BX05	02-Mar-2015 13:54	07-Mar-2015 10:20
GODESS	P	05-Mar-2015 16:23	April 2015 (planned)

Table 5. List of CTD casts. For station positions, see Tab. 2.

Station	**Time (UTC)**	**Date**	**Cast ID**	**AC-S**
AB	14:46	2/26/2015	V0001F01	yes
BX02	12:06	2/27/2015	V0002F01	yes
BX02	12:16	2/27/2015	V0002F02	yes
BX01	13:26	2/27/2015	V0003F01	yes
BX03	14:47	2/27/2015	V0004_01	yes
B9	16:14	2/27/2015	V0005_01	yes
B8	17:12	2/27/2015	V0006F01	yes
BX04	19:31	2/27/2015	V0007F01	yes
TF272	21:24	2/27/2015	V0008F01	yes
BX05	22:26	2/27/2015	V0009F01	yes
BX06	23:03	2/27/2015	V0010F01	yes
TF271	9:31	2/28/2015	V0011F01	yes
TF271	9:45	2/28/2015	V0011F02	yes
TF271	10:25	2/28/2015	V0011F03	yes
TF271	10:39	2/28/2015	V0011F04	yes
BX01	15:00	2/28/2015	V0012_01	yes
BX06	0:56	3/1/2015	V0013_01	yes
BX05	8:48	3/1/2015	V0014F01	yes
BX05	12:11	3/2/2015	V0015F01	yes
BX05	12:24	3/2/2015	V0015F02	yes
BX05	13:07	3/2/2015	V0015F03	yes
BX05	14:08	3/2/2015	V0015F04	yes
BX01	9:10	3/3/2015	V0016F01	yes
BX01	9:20	3/3/2015	V0016F02	yes
BX01	10:10	3/3/2015	V0016F03	yes
TF271	14:35	3/3/2015	V0017F01	yes
TF271	7:00	3/4/2015	V0018F01	yes
TF271	7:10	3/4/2015	V0018F02	yes
TF271	8:06	3/4/2015	V0018F03	yes
TF271	8:16	3/4/2015	V0018F04	yes
BX11	14:20	3/4/2015	V0019F01	yes
BX14	20:35	3/4/2015	V0020_01	yes
BX05	0:46	3/5/2015	V0021_01	yes
BX11	8:33	3/5/2015	V0022F01	yes
BX11	8:44	3/5/2015	V0022F02	yes
BX11	9:15	3/5/2015	V0022F03	yes
B8	7:03	3/6/2015	V0023F01	yes
B8	7:14	3/6/2015	V0023F02	yes
B8	8:05	3/6/2015	V0023F03	yes
TF271	20:03	3/6/2015	V0024F01	yes
BX03	0:26	3/7/2015	V0025F01	yes
BX03	0:36	3/7/2015	V0025F02	yes
BX03	1:11	3/7/2015	V0025F03	yes

Table 6. List of MSS casts on fixed stations and on transects. The last column indicates transects with the lowered and towed ADCP (TL-ADCP). For positions and definition of transects, see Tabs. 2 and 3.

Name	Casts	Start	End	TL-ADCP
T1	1-39	28-Feb-2015 16:15	28-Feb-2015 22:08	no
T2	39-55	01-Mar-2015 01:35	01-Mar-2015 04:29	no
T3	56-71	01-Mar-2015 04:43	01-Mar-2015 06:45	no
BX05	72-77	02-Mar-2015 14:47	02-Mar-2015 15:52	no
T2	78-93	02-Mar-2015 16:58	02-Mar-2015 19:48	no
T3	94-109	02-Mar-2015 20:01	02-Mar-2015 23:00	no
T1	110-149	03-Mar-2015 01:46	03-Mar-2015 08:08	no
P	150-198	03-Mar-2015 15:34	04-Mar-2015 05:54	no
T4	199-220	04-Mar-2015 09:40	04-Mar-2015 13:30	no
T5	221-242	04-Mar-2015 15:37	04-Mar-2015 19:42	yes
T2	243-260	04-Mar-2015 21:46	05-Mar-2015 01:06	no
T3	261-276	05-Mar-2015 01:17	05-Mar-2015 03:57	no
T4	277-301	05-Mar-2015 10:06	05-Mar-2015 14:17	yes
T6	302-326	05-Mar-2015 16:45	05-Mar-2015 21:08	yes
T7a	327-343	05-Mar-2015 22:12	06-Mar-2015 00:58	yes
T7b	351-356	06-Mar-2015 04:04	06-Mar-2015 04:58	no (incomplete)
T1a	357-376	07-Mar-2015 02:33	07-Mar-2015 05:32	no

Table 7. ScanFish Transects. Times indicate ScanFish water contact and recovery on board, respectively.

Name	Start	End
TSF1	05-Mar-2015 10:02	05-Mar-2015 17:17

Table 8. List of stations with samples taken for SPM, particle and CDOM absorption as well as Secchi disk depth. Stations correspond to the CTD cast ID (first column) are compiled in Tab. 5.

Cast ID	SPM	CDOM	Particle absorption	Secchi depth
V0001F02	X	X	X	X
V0002F02	X	X	X	
V0003F02	X	X	X	X
V0011F02	X	X	X	X
V0011F04	X	X	X	
V0015F02	X	X	X	X
V0015F04	X	X	X	
V0016F02	X	X	X	X
V0016F03	X	X	X	
V0018F02	X	X	X	X
V0018F03	X	X	X	
V0018F04	X	X	X	
V0022F02	X	X	X	X
V0022F03	X	X	X	
V0023F02	X	X	X	X
V0023F03	X	X	X	
V0025F02	X	X	X	
V0025F03	X	X	X	

Table 9. List of stations with samples taken for gas concentration analyses (CH_4), determination of methane oxidation rates (CH_4 oxidation rates) and MOB CARD-FISH studies. Stations corresponding to the CTD cast IDs (first column) are compiled in Tab. 5.

Cast ID	CH_4	O_2	CH_4 oxid. rates	MOB CARD-FISH
V0011F02	X	X		X
V0011F04	X			X
V0015F02	X	X		
V0015F04	X			X
V0016F02	X	X	X	X
V0016F03	X	X	X	X
V0018F02	X		X	X
V0018F03	X	X	X	X
V0018F04	X		X	X
V0022F02	X	X		
V0022F03	X	X		
V0023F02	X	X	X	X
V0023F03	X	X	X	X
V0025F02	X	X		
V0025F03	X	X		

References

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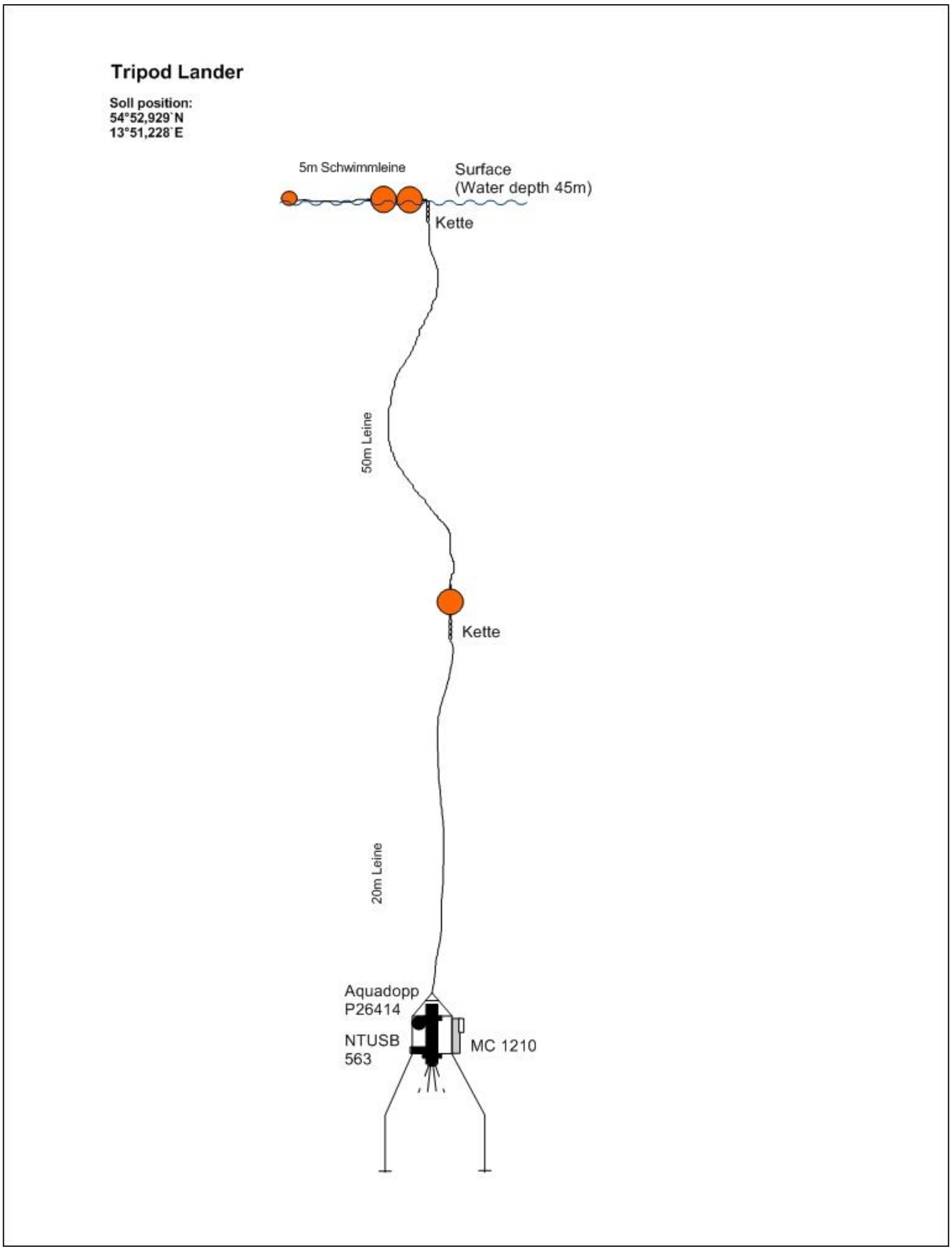
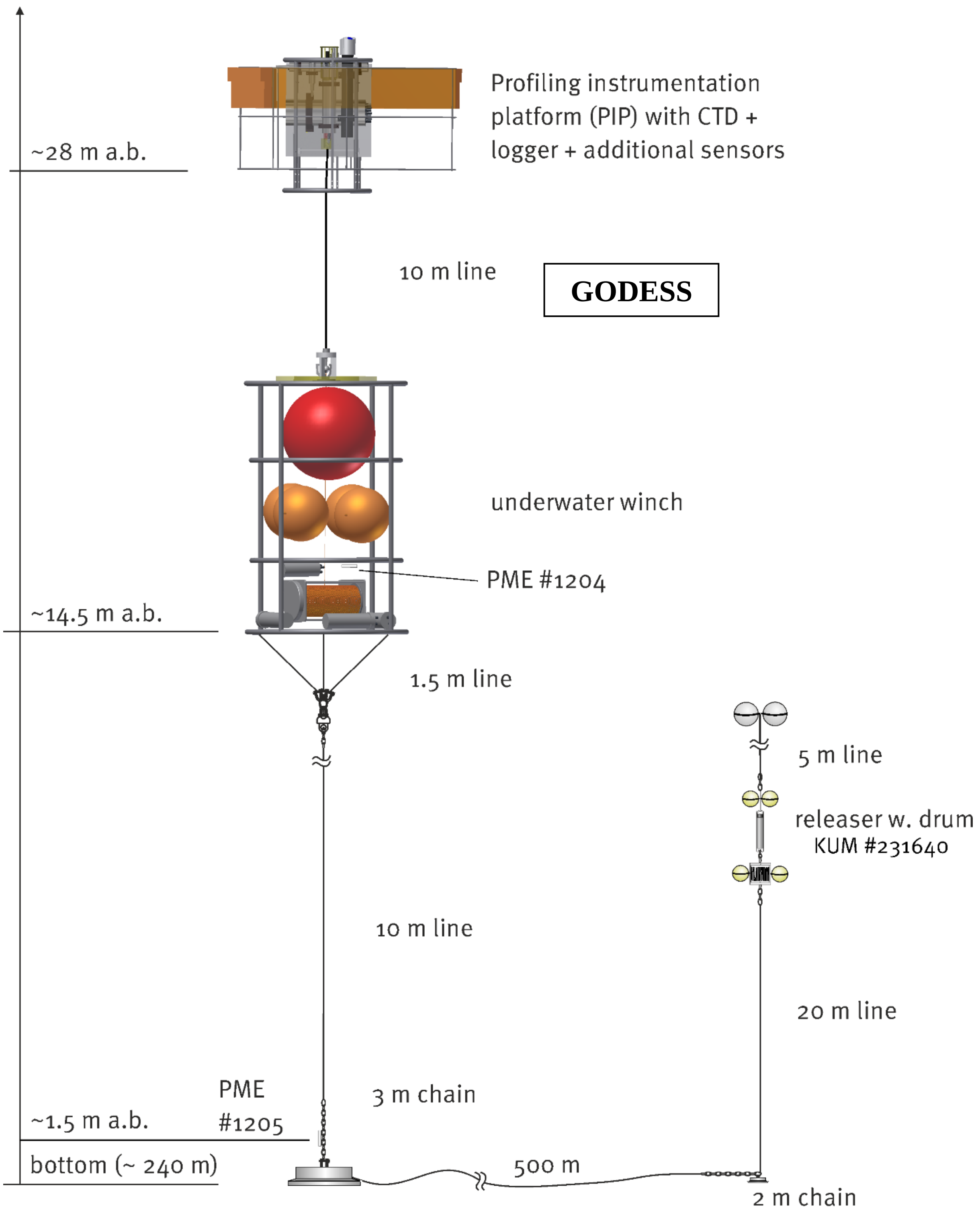
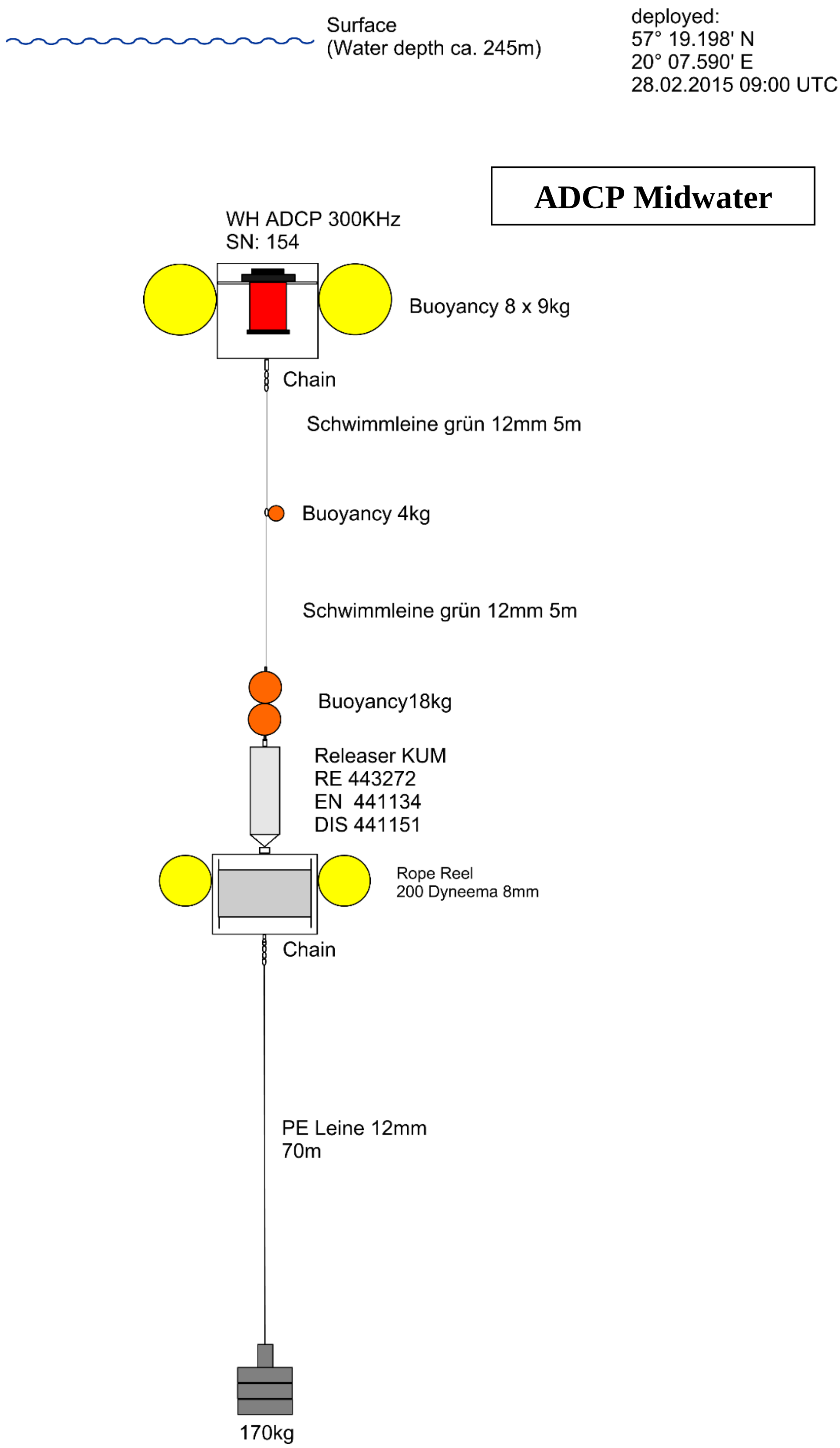
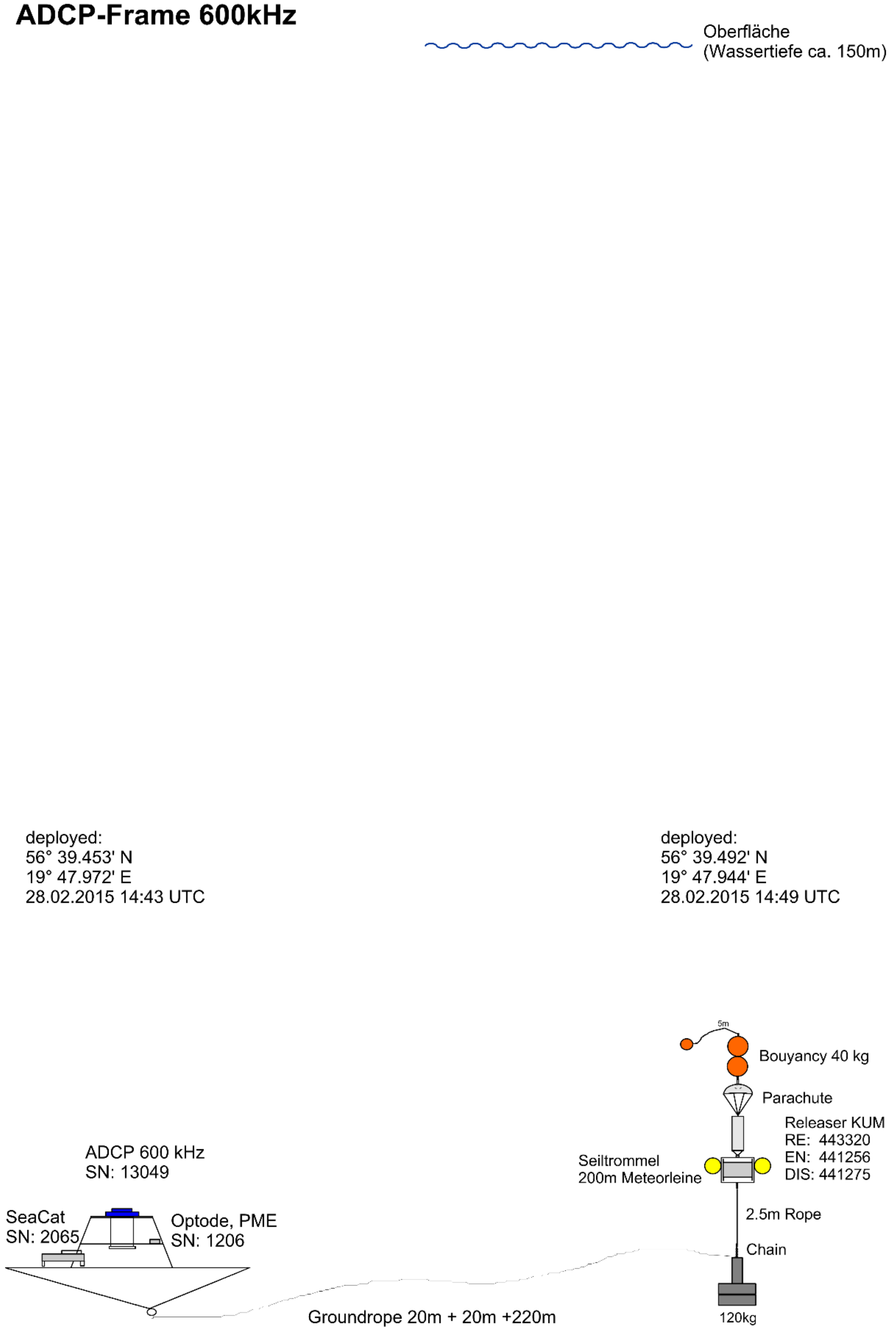
Moorings


Tripod Lander
Soll position:
54°52,929´N
13°51,228´E
5m Schwimmleine
Surface
(Water depth 45m)
Kette
50m Leine
Kette
20m Leine
Aquadopp
P26414
NTUSB
563
MC 1210


~28 m a.b.
Profiling instrumentation
platform (PIP) with CTD +
logger + additional sensors
10 m line
GODESS
underwater winch
PME #1204
~14.5 m a.b.
1.5 m line
5 m line
releaser w. drum
KUM #231640
10 m line
20 m line
PME
#1205
3 m chain
~1.5 m a.b.
bottom (~ 240 m)
500 m
2 m chain


Surface
(Water depth ca. 245m)
deployed:
57° 19.198' N
20° 07.590' E
28.02.2015 09:00 UTC
ADCP Midwater
WH ADCP 300KHz
SN: 154
Buoyancy 8 x 9kg
Chain
Schwimmleine grün 12mm 5m
Buoyancy 4kg
Schwimmleine grün 12mm 5m
Buoyancy18kg
Releaser KUM
RE 443272
EN 441134
DIS 441151
Rope Reel
200 Dyneema 8mm
Chain
PE Leine 12mm
70m
170kg

ADCP-Frame 600kHz



Aquadopp+TC-Kette