Leibniz Institute for Baltic Sea Research Warnemünde

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

r/v "E. M. Borgese"

Cruise- No. EMB089

This report is based on preliminary data

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1.Cruise No.: EMB 089

2.Dates of the cruise: from 08.11.2014 to 18.11.2014

3.Particulars of the research vessel:

Name: E.M. Borgese
Nationality: Germany
Operating Authority: Leibniz Institute of Baltic Sea Research Warnemünde (IOW)

4.Geographical area in which ship has operated:

Baltic Sea between Kiel Bight and Baltic Proper

5.Dates and names of ports of call

Sassnitz 04.11. – 05.11. 2014

6.Purpose of the cruise

Monitoring in the frame of the HELCOM COMBINE Programm,

7.Crew:

Name of master: Uwe Scholz
Number of crew: 11

8.Research staff:

Chief scientist:
Dr. Martin Schmidt, IOW
Scientific Crew:

Donath	Jan
Hand	Ines
Pötzsch	Michael
Sadkowiak	Birgit
Weinreben	Stefan
Merz	Elisa
Karle	Mattis
Salland	Nora
Hehl	Uwe
Pohl	Frank

9.Co-operating institutions:

All institutions dealing with HELCOM monitoring programmes

10.Scientific equipment

CTD SBE 911+ with doubled sensors, SBE oxygen sensor and WETLABS Fluorometer, PAR - sensor
Electronic Reversing Thermometer
Rosette with water samplers
Plankton nets, WP2 net, filtration set
Van Veen grab, dredge
Autoanalyser, Photometer, Titrino 716
Ships weather station (WERUM), Thermosalinograph

11. General remarks and preliminary result

The cruise started in Rostock-Marienehe with calm weather conditions. The two hights Quendresa I and II stretching from the Balkan towards the Balticum and the low Roswitha over the British islands governed south-westerly winds between 3-5 Bft. Sunny conditions, good visibility and low sea state permitted fast station work. The western stations between Kiel Bight and Bornholm Gatt are worked during the first 3 days. At 10th Nov. evening, there was a crew exchange in Saßnitz. Station work continued next morning and stations were worked in the Arkona Sea, the Bornholm Gatt and the Bornhom Sea and finally in the Baltic Proper. At this time, the high perssure area Robin over the Bothnian Sea and the low pressure area Stephanie over the North Atlantic were responsible for easterly winds up to 7 Bft in company with cloud covered skies, little rain and low visibility. In the morning of 12th Nov. the sea state required interruption of station work for some hours but could be resumed after a few hours. Net sampling at station TF0213 in the Bornholm Basin was not possible. The main station in the Gotland Basin was reached in the evening of 13th Nov.. Unfortunately, due to the high sea state, the permanent hydrographic mooring could not be maintained. In the night from 15th to 16th Nov. the low Thea centered over Wales developed a front related to winds of up to 8 Bft, cloud covered skies and low visibility. Again, plankton sampling in the Bornholm Basin had to be skipped, but decreasing sea state in the Arkona Basin permitted continued station work. The hydrographic transect from the Arkona Basin to Kiel Bight could be worked repeatedly.

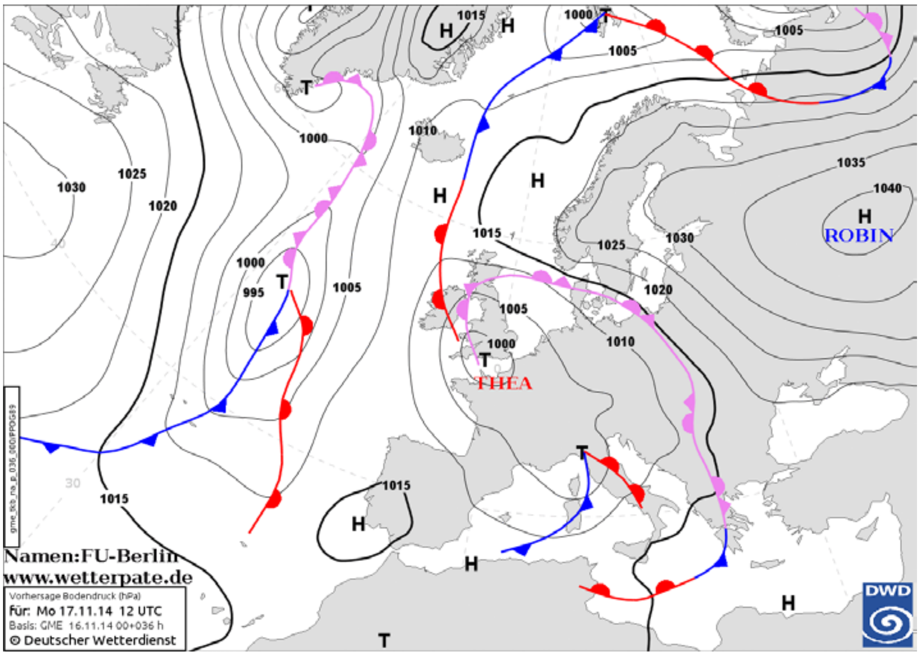

Figure 1: A typical pressure distribution for the period of the cruise. A high pressure area over eastern europe in combination with low perssure areas over Great Britain produce prevailing easterly winds. (http://www.skystef.be) Persistent easterly winds tend to empty the Baltic Sea which is a precondition for Baltic inflow events.

The Figures 1-4 comprise some aspects of the meteorological conditions during the cruise.

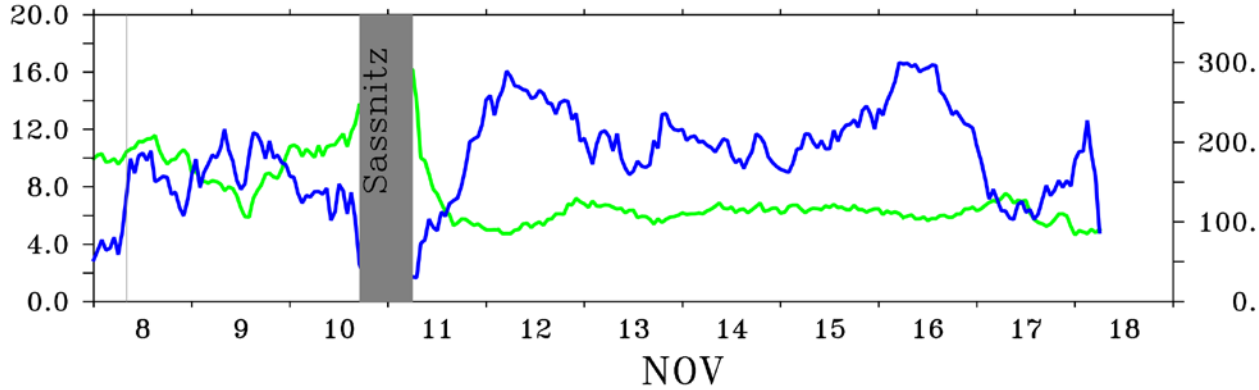

Figure 2: Wind speed in m/s (blue line, left scale) and wind direction (green line, right scale) at ships position during the cruise. Note the prevailing easterly winds. In gusts, wind speed exceeds the mean value by about 40%.

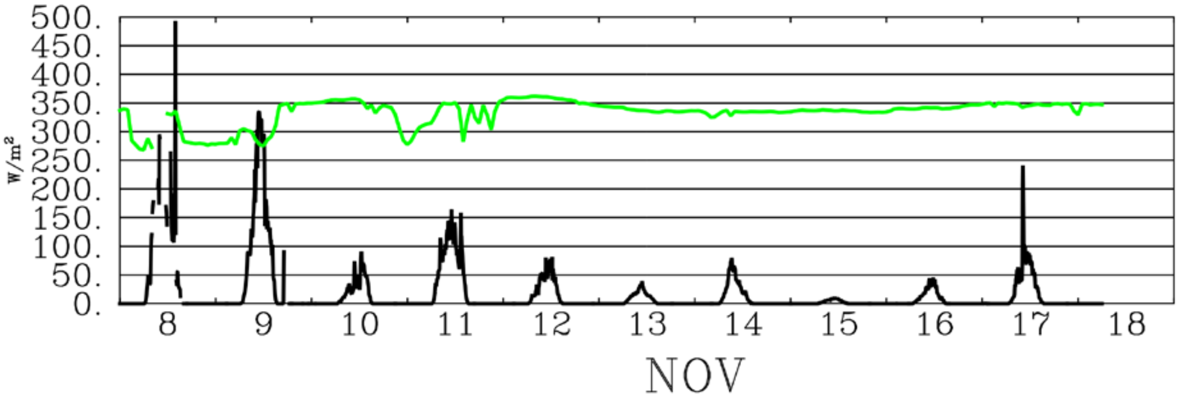

Figure 3: Solar radiation (black line) and downward long wave radiation (green line) at ships position during the cruise. Solar radiation becomes negligible during the major part of the cruise. Downward long wave radiation is overcompensated by upward radiation, since the sea surface temperature is larger than the atmosphere temperature.

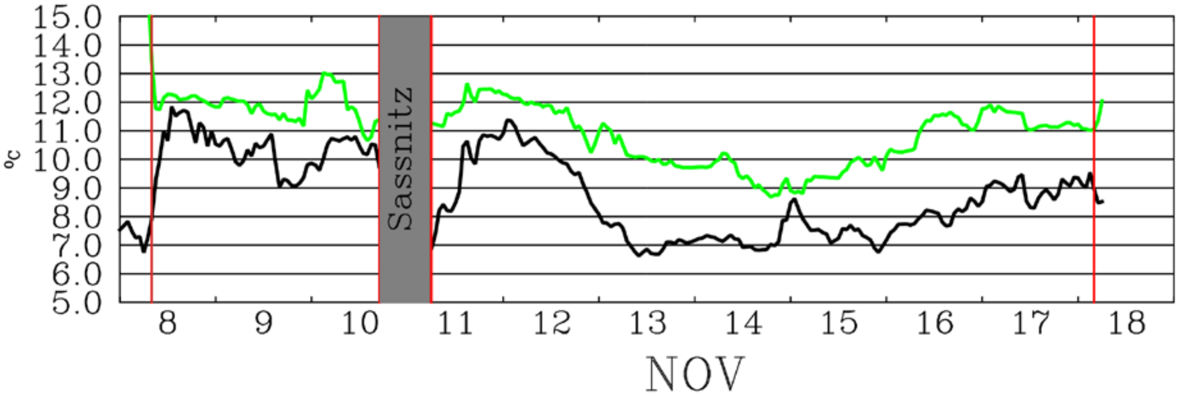

Figure 4: Air temperature (black line) and sea surface temperature (green line) at ships position during the cruise. Since the sea surface temperature exceeds the air temperature, the radiation budget of the ocean is negative – the strong autumn cooling. Evaporation and sensible heat flux enhance this tendency.

Station work at each station started with a CTD-cast (SBE 911+ with double sensors set for temperature and conductivity, SBE oxygen sensor and WETLABS Fluorometer) including water sampling for oxygen and nutrient measurements. Light conditions are determined with a PAR sensor. To account for changes of the solar radiation during the cast a similar sensor is mounted at ships bridge. At selected stations, phytoplankton samples were taken, Secci-depth was determined (during day time) and 3 l water were filtered. The filters are frozen in liquid nitrogen for processing in the laboratory. Additionally, zooplankton samples were taken with a WP2 net within the euphotic zone, and above and below the halocline. At some stations TF0018. TF0012, TF0010, TF0360, TF0030, TF0109, TF0152, and TF 00160 benthic samples are taken with a van Veen grab (three holes per station) and a dredge.

Oxygen in samples is determined with a 716 DMS Titrino III, for H_2S determination the photometric Ethylen blue method is used. Nutrients (nitrate, nitrite, phosphate and silicate) are determined with an Autoanalyser Evolution III (Allicance Instruments), for ammonium the photometric method is used.

Underway measurements are carried out with ships thermosalinograph and ships weather station, data are stored and can be gained from the “dship”-data base.

The hydrographic conditions met **west of Darß Sill** are typical for the season and mostly influenced from autum cooling. Accordingly, colder but less saline water overlays warmer but more saline water. Surface salinity varies from about 18 in the Kiel Bight to 9 at Darß Sill. Surface temperature is uniform about 12°C. Bottom salinity exceeds 25 in the Kiel Bight but falls to 18 west of Darß Sill. The bottom salinity is enhanced compared with that found during the last years. Remarkably, oxygen is almost exhausted in the bottom layer in the Lübeck Bight and at the benthos station TF0018 off Kühlungsborn.

East of Darß Sill surface salinity is about 8.2 and decreases to 6.8 in the Gotland Basin. In the **Arkona Basin** bottom salinity (> 21) is enhanced considerably compared with the previous year, but the thickness of the bottom layer (< 24) rarely exceeds 3 to 4 m thickness. Oxygen concentration is slightly depleted in the bottom layer. The **Bornholm Gatt** bottom water is warm and has enhanced salinity upt to 24.

The most common species of **benthic organisms** on all stations in the **western Baltic** is *Artica islandica*. More than 100 individuals were counted in the dredges on the stations TF0010, TF0360 and TF0109. The dredge sample of TF0109 includes more than 100 individuals of *Macoma balthica*. TF0160 was the only station were *Mytilus edulis* were found alive. Beside these three Mollusca, two species of Echinodermata could be proved: *Ophiura spp*. (more than 100 individuals in the dredges of TF0010 and TF0360) and *Asterias rubens,* only found in the dredge of TF0360 (more than 100 individuals). Other detected species like *Praunus inermis* and *Cerastoderma glaucum* were found in specified amount on certain stations. The biological condition of the organisms and their habitat seems intact, except at station TF 0012, where a lot of dead mussel shells were noticed.

The thermocline depth in the **Bornholm Basin** is 30 m, the surface temperature is about 12°C and a salinity of about 7.9. Below the surface layer there is some winter water (see Fig. 11) with a core temperature below 6°C followed by a warmer layer with temperature varying rapidly aroud 12°C but some patches are 15°C warm. Water in this layer has had obviously surface contact during summer and can be understood as the result of intermittent inflow of warmer and saline water. In turn, the bottom water is colder, stagnant, more saline and contains almost no oxygen towards the bottom.

At stations through **Stolpe Channel** towards the Central Gotland Basin the thermocline is almost eroded and surface cooling reaches the winter water layer. There is only some minor left over from the warm suface water of the summer stratification. The winter water core is varying from about 50 m depth to 70 m depth in the north, the minimum temperature amounts 4.2°C at station TF0271.

Between **Stolpe Channel** and station **TF0263** the whole water column is oxic, but in water below 70m depth oxygen is almost exhausted. At station TF0263 and TF0260 also H2S is found in the deep layers, surprisingly oxygen and H2S seem to coexist there. A redoxcline, i.e., a layer below which the oxygen concentration is zero, is found at stations TF0275 to TF0285. At TF0271 the redoxcline is located at a depth of about 120m, the water column is anoxic below. Near the redoxcline the typical turbidity maximum is found. Towards the north the redoxcline depth is shallower.

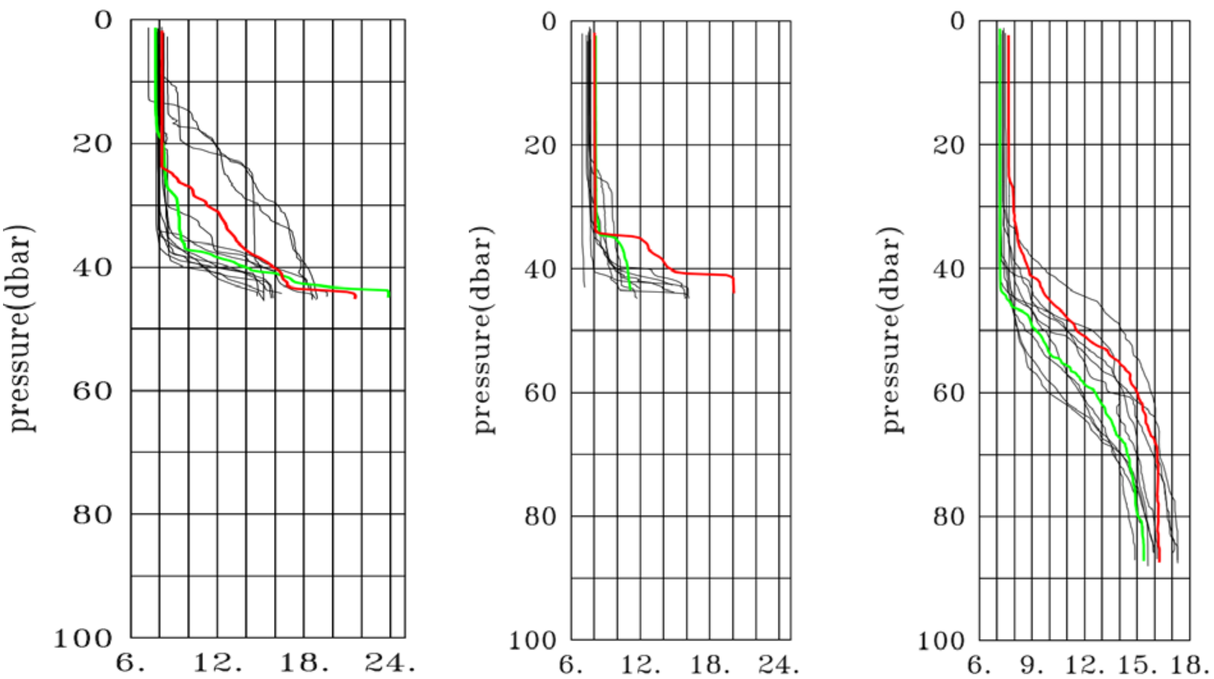

Figure 5: Vertical salinity profiles from November cruises between 2002 and 2014. left: Arkona Basin, TF0113, middle: Bornholm Gatt, TF0144, right: Bornholm Basin, TF0213. Black: profiles from the years 2002-2012, green: 2013, red: 2014.

In the **Gotland Basin** the thermocline depth has strong lateral gradients, also the isotherms and isohalines below the winter water have strong vertical elevations, see Figure 13. This indicates geostrophic subsurface currents, i.e., most probably Baltic Eddies. Also the inversions in the oxygen profile at station TF0263 or TF0285 can be considered as the result of strong subsurface currents. In numerical circulation models such eddies are observed if dense water flows from the Stople Channel into the Gotland Basin. Patches of dense water enclosed by an eddy-like flow follow mainly isobath and may encircle the deep basin several times while sinking down.

During the year 2014, a Baltic inflow event was observed from previous cruises (i.e., IOW, July 2014) measuring a replacement of anoxic waters in the Central Gotland Basin by oxic waters. However, the last cruise of the Swedish monitoring programm (SMHI, 2014) reported that anoxic conditions in the Central Gotland Basin are established again. This fast revovery of anoxic conditions is an important process in the Baltic Sea ecosystem.

Comparing example profiles from the Arkona Basin (TF0113), the Bornhom Gatt (TF0144) and the Bornholm Basin (TF0213) with those from previous years (Fig. 5) the remnants of this inflow are visible. Bottom salinity in the Bornholm Gatt is significantly enhanced and the salinity in the Bornholm Basin reveals as enhanced over the whole profile. The profile from 2014 is within the span of typical profiles of the last 12 years and salinity is generally less than that observed before the last major inflow 2003.

Figure 6 compares the 2014 conditions with the findings in the central Gotland Sea in Nov. 2013. The inflow event has ventilated the area between Stolpe Channel and station TF0263, but has had less effect more northward. At station TF0271, winter water is significantly warmer in 2014 (~1 degree), but its core is found at the same depth like 2013. Surface salinity is slightly enhanced by .4 to 6.8, bottom salinity is rised only by .2. to 12.27. The major salinity enhancement took place below the halocline between 60 m to 150 m depth which indicates, that the most inflowing water stratified into intermediate layers. Above the 150 m level, the inflowing water was warmer, below this level the inflowing water was cooler than the 2013 water body. Remarkably, there is no trace of the relatively warm bottom water found 2013. So it must have been displaced during the inflow. The layer with steep oxygen decline is lifted upwards, but the redoxcline depth is similar to 2013. The measured concentrations of H_2S is much smaller, but the turbudity, especially in the deeper layers is strongly enhanced.

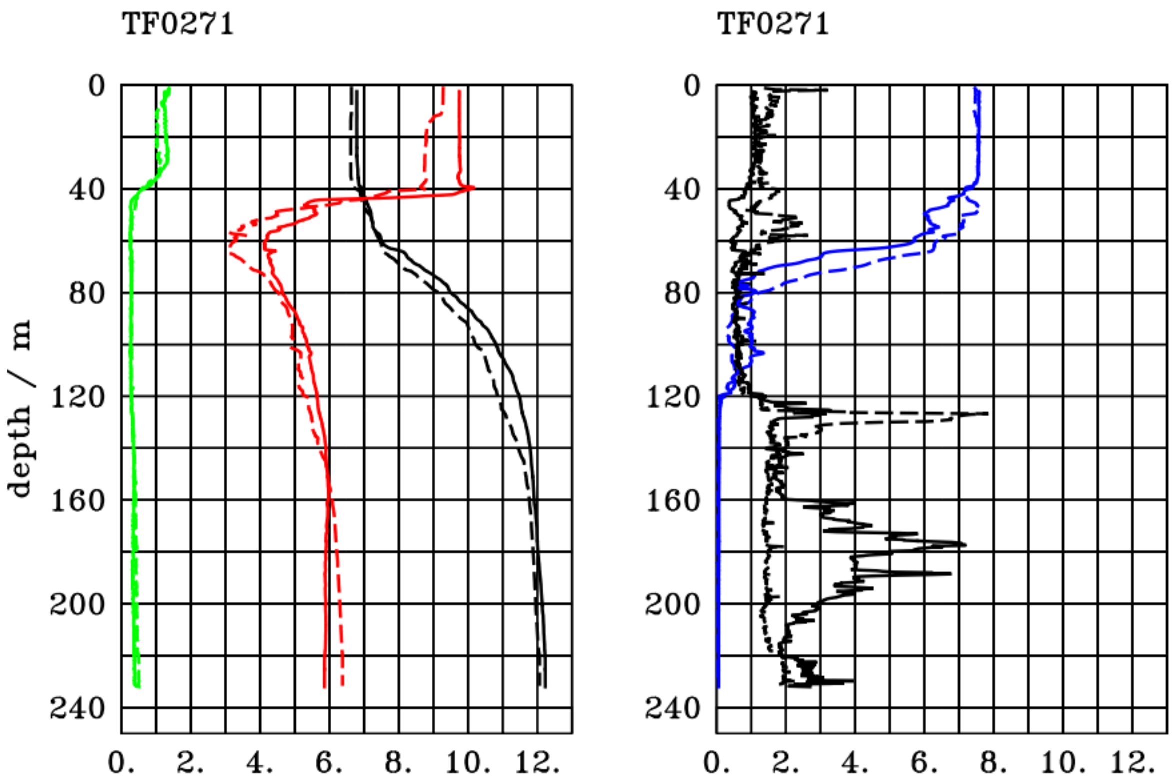

Figure 6: Vertical profiles from November 2013 (dashed lines) and 2014 (full lines) at station TF0271. Left figure: black: salinity, green: fluorescence, red: temperature. Right figure: blue: dissolved oxygen, black: turbidity.

In the **Fårö Deep** and the **Landsort Deep** the surface layer is penetrating down to the winter water layer. The core of the winter water is at 60 m depth, water is anoxic with H_2S below 100 m depth. Also the **Karlsö Deep** is anoxic. Here the redoxcline is elevated to a depth of 70 m, below this depth H_2S is found. Hence, west of Gotland H_2S reaches the base of the winter water.

Everywhere in the surface layer phosphate, nitrogen and silicate are present. The phosphate concentration varies only slightly between 0.2 and 0.4 µmol/l. The underway fluorescence data show that some phytoplankton development is supported by this nutrient pool (see Figure 7). Even in the oxic surface layers about 50% of the dissolved inorganic nitrogen (DIN) is found as ammonium, probably excreted by zooplankton. Near the bottom, most DIN is nitrified almost completely, when the bottom water is oxygenated, but when oxygen is exhausted and H_2S is formed, no nitrate but high ammonium concentrations are found.

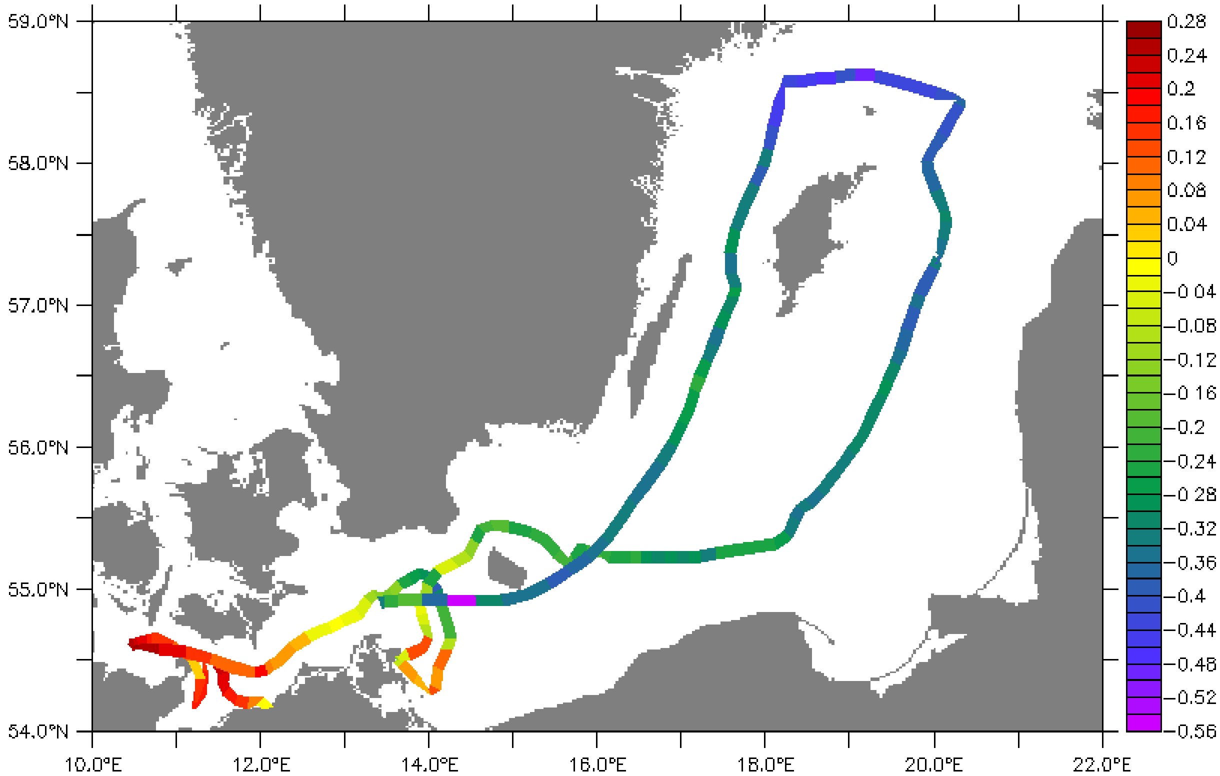

Figure 7: Logarithm of the fluorescence as measure for the surface chlorophyll-a concentration.

West of Darß Sill and in the Arkona Basin the surface water N/P ratio is less than 2 but reaches values of 7 in the Gotland Basin. In the bottom water the N/P ratio is more constant and varies between 3.5 and 4.5. Outstanding phosphate surface concentrations are found in shallow and semienclosed areas like the **Lübck Bight** and the **Pommeranian Bight**. Remarkably, although vertical mixing is strong during autumn, bottom oxygen is almost exhausted in the Lübeck Bight and strongly depleted in the Pommeranian Bight. The enhanced nutrient concentrations indicate some nutrient loads finally resulting in the suboxic bottom water.

The section between the Kiel Bight and the Arkona Basin could be worked twice, in the beginning and the end of the cruise. For a comparison see Figure 10. It shows the outflow situation, characterized by the west-ward propagation of less saline water in the surface layer. At the same time more saline water from the Kattegat propagates east-ward in the bottom layer and reaches Darß Sill.

Table 1: Salinity, Temperature, oxygen and nutrient development near bottom TF0271

year	2001	2002	2003	2004	2005	2006	2007	2008*	2009*	2010	2011*	2012	2013	2014
S	12.03	12.15	12.78	12.92	12.71	12.65	12.79	12.56	12.45	12.39	12.23	12.17	12.07	12.23
T	6.25	6.53	4.92	6.26	5.95	5.94	6.65	6.32	6.31	6.42	6.43	6.42	6.38	5.86
$2H_2S$	-4.74	-7.43	1.77	-1.73	-3.75	0.16	-4.9	-5.20	-5.93	-7.01	-7.57	-7.44	-8.75	-1.71
PO_4	7.30	6.08	2.20	4.45	5.03	2.45	4.80	7.05	4.5	6.05	7.15	6.8	11.55	3.13
DIN			11.56		19.89	6.41	17.0			32.60		39.83	42.4	13.33
SIO_4	86.8		40.2	64.1				89.2	87.6	94.2	104.4	111.0	126.8	61.4

*: no autum data, data from Jan./Feb. cruise next year are shown.

Table 2: Surface layer (0 - 10m)

Area	Station	Tempera-ture	Salinity	PO_4^{3-}	NO_2^{3-} * DIN	SiO_4
Date	Name/ No. **	°C	PSU	µmol/dm³	µmol/dm³	µmol/dm³
Kiel Bight	TF0360/08 09.11.2014	12.03	18.28	0.32	0.04 0.18	13.8
Meckl. Bight	TF0012/03 08.11.2014	12.27	15.70	0.2	0.08 0.22	11.8
Lübeck Bight	TF0022/06 08.11.2014	12.16	17.84	0.66	0.23	18.1
Arkona Basin	TF0113/17 10.11.2014	12.31	8.16	0.3	0.43 0.78	9.3
Pom. Bight	TF0160/24 10.11.2014	10.64	7.53	0.47	1.8	10.4
Bornholm Deep	TF0213/38 12.11.2014	11.91	7.67	0.23	0.08 0.32	5.7
Stolpe Channel	TF0222/40 12.11.2014	11.42	7.30	0.17	0.11	5.9
SE Gotland Basin	TF0259/42 13.11.2014	11.23	7.34	0.25	0.52 0.72	6.2
Gotland Deep	TF0271/49 13.11.2014	9.75	6.80	0.24	0.55 1.08	11.1
Fårö Deep	TF0286/51 14.11.2014	8.98	6.57	0.3	0.76 0.98	11.4
Landsort Deep	TF0284/53 15.11.2014	9.37	6.47	0.38	1.55 1.67	12.5
Karlsö Deep	TF0245/55 15.11.2014	9.58	6.99	0.33	0.36 0.51	6.5

* Σ NO_2^- + NO_3; NO_2 was present only in traces in most areas under investigation
** See maps

Table 3: Bottom-near water layer

Area	Station	Depth	Temp.	Salinity	O_2	PO_4^{3-}	NO_2^{3-} * DIN	SiO_4
Date	Name/ No. **	m	°C	PSU	cm³/dm³	µmol/dm³	µmol/dm³	µmol/dm³
Kiel Bight	TF0360/08 09.11.2014	17.0	12.99	24.24	4.44	0.76	3.35 4.27	18.2
Meckl. Bight	TF0012/03 08.11.2014	23.0	13.39	23.54	4.32	0.89	4.19 4.86	20.0
Lübeck Bight	TF0022/06 08.11.2014	22.0	13.82	22.99	0.22	1.8	4.86	54.6
Arkona Basin	TF0113/17 10.11.2014	44.5	12.62	21.54	4.90	0.73	3.82 5.11	16.6
Pom. Bight	TF0160/24 10.11.2014	13.0	13.59	12.62	1.92	1.55	7.60	37.6
Bornholm Deep	TF0213/48 12.11.2014	87.25	6.66	16.27	0.38	1.50	9.68 9.83	49.0
Stolpe Channel	TF0222/40 12.11.2014	89.0	8.73	13.51	2.36	1.44	7.51	33.3
SE Gotland Basin	TF0259/42 13.11.2014	86.0	5.31	10.26	0.62	2.43	4.94 5.19	45.3
Gotland Deep	TF0271/49 13.11.2014	234.0	5.86	12.23	-1.71	3.13	0.19 13.33	61.4
Fårö Deep	TF0286/51 14.11.2014	189.0	5.79	11.60	-2.41	3.2	0.15 15.47	72.3
Landsort Deep	TF0284/53 15.11.2014	430.0	5.20	10.45	-0.95	2.65	0.28 6.94	61.6
Karlsö Deep	TF0245/55 15.11.2014	106.3	5.03	9.75	-1.25	3.2	0.17 9.24	60.3

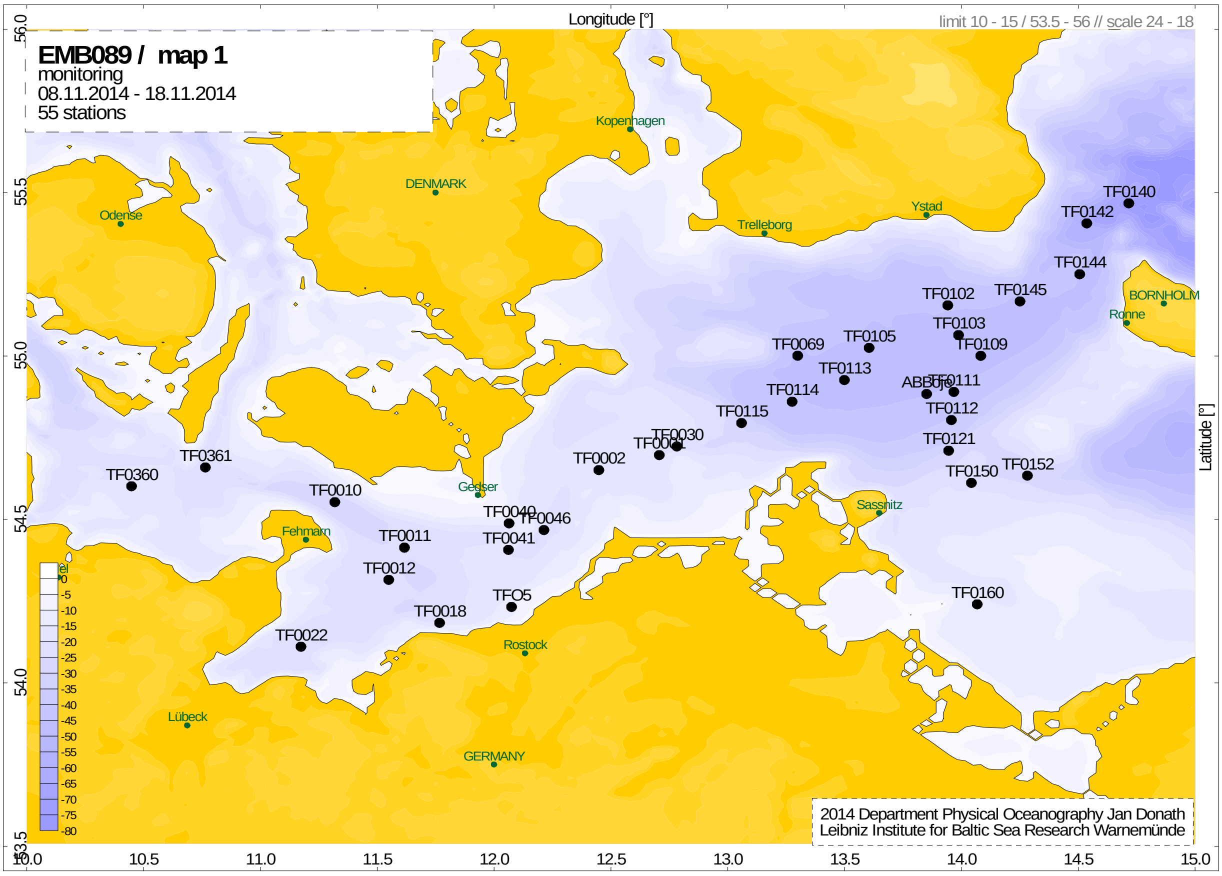

Figure 8.: Station map

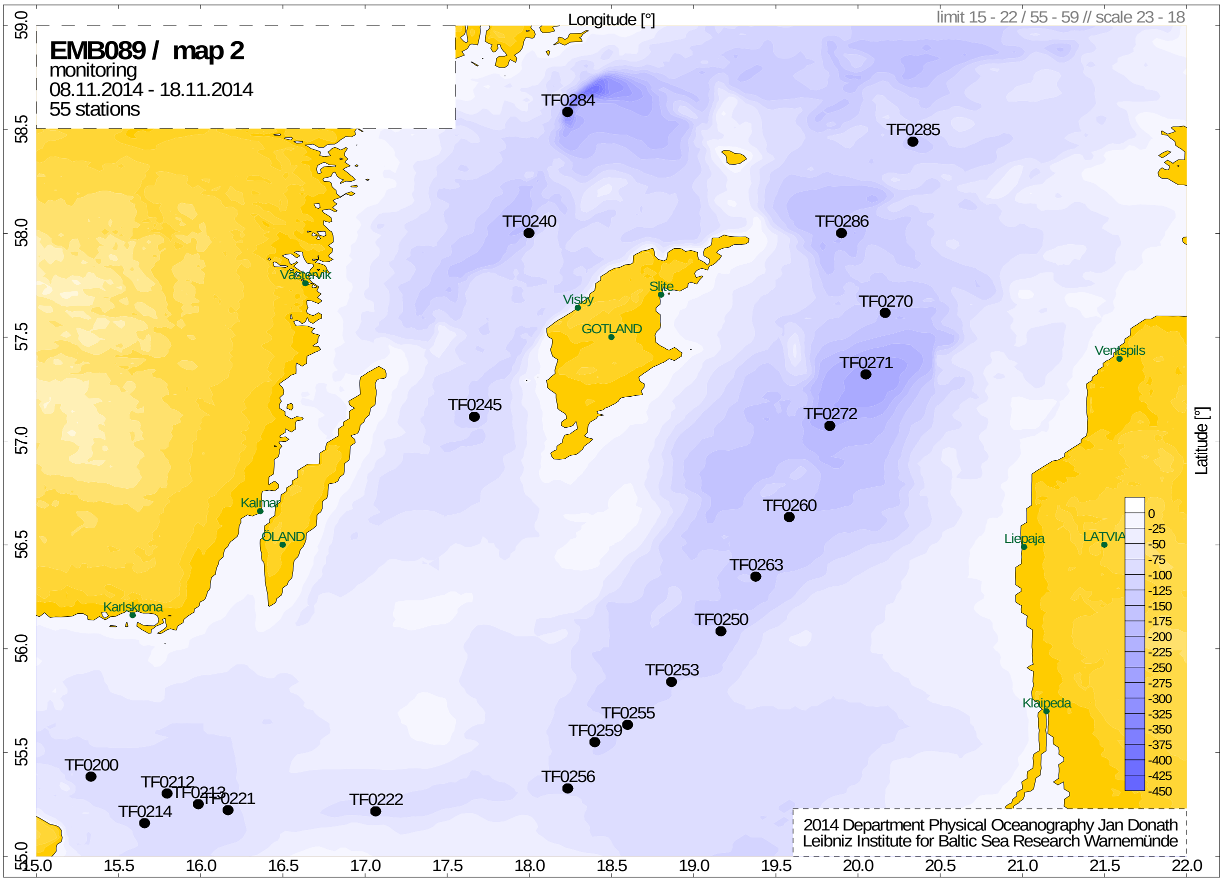

Figure 9.: Station map

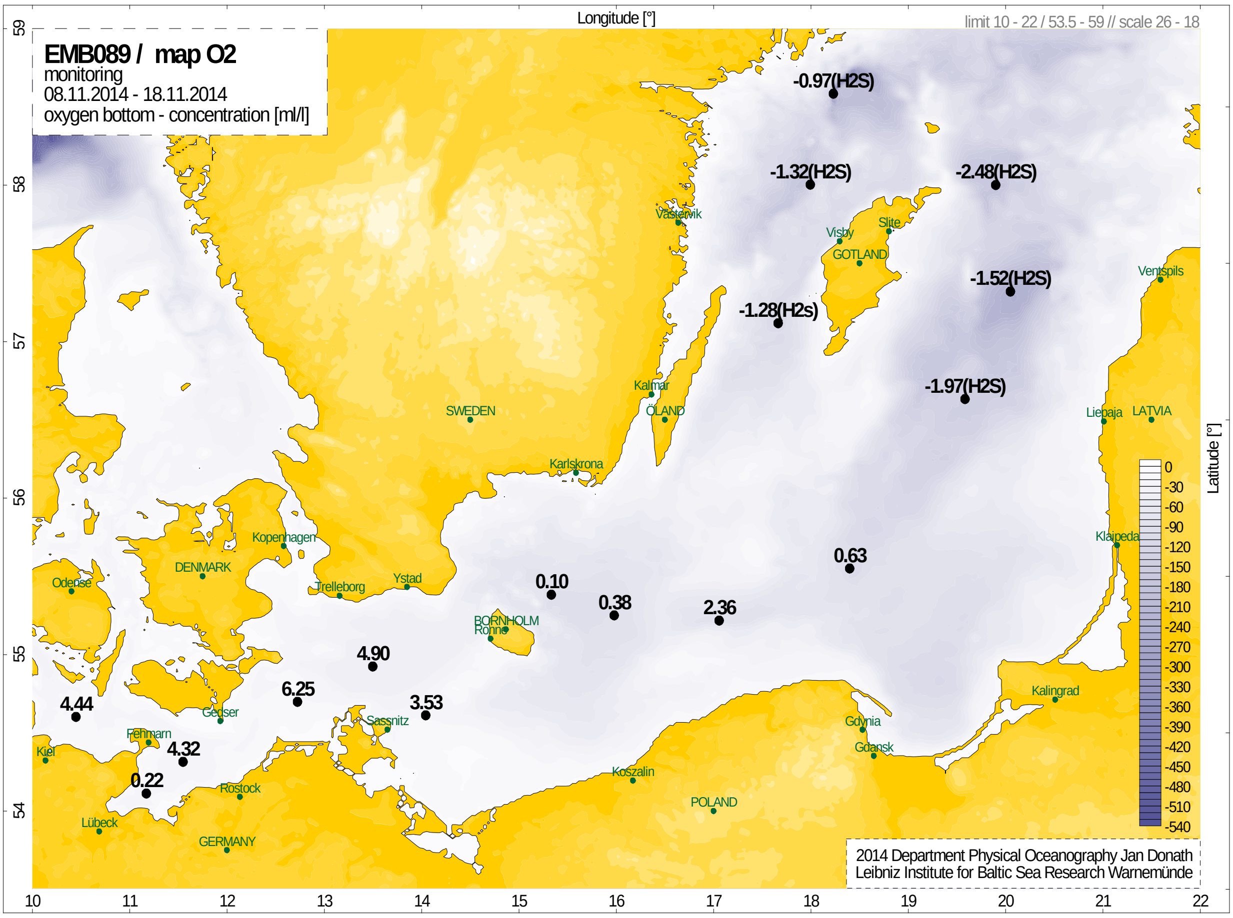

Figure 9.: Bottom oxygen concentration at selected stations. Negative values correspond to hydrogen sulphide.

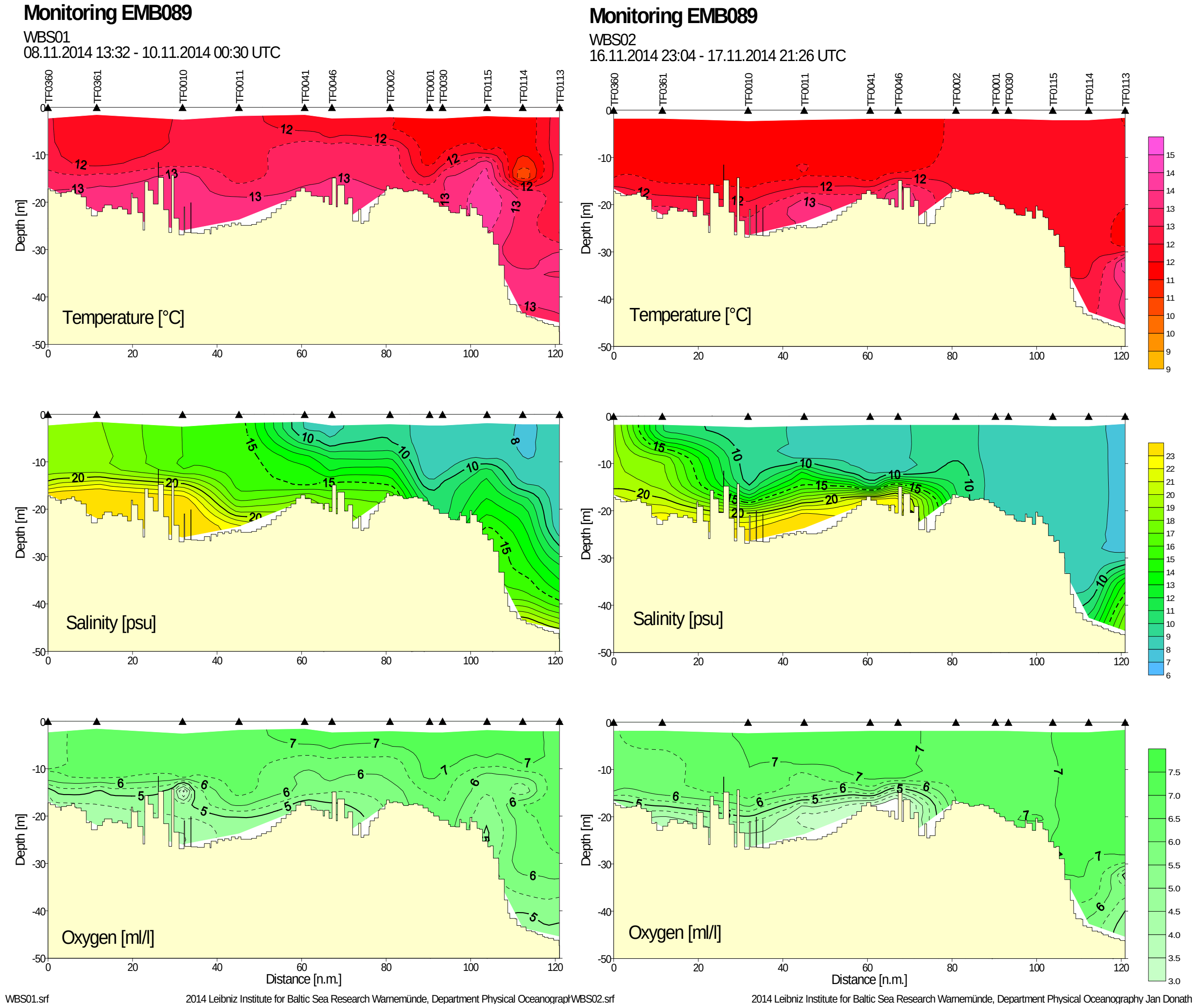

Figure 10 Section from Kiel Bight to the Arkona Basin worked in the beginning and the end of the cruise. Note the outflow situation, i.e., west-ward propagation of less saline water at the surface driven by prevailing easterly winds and the east-ward propagation of saline bottom water within five days.

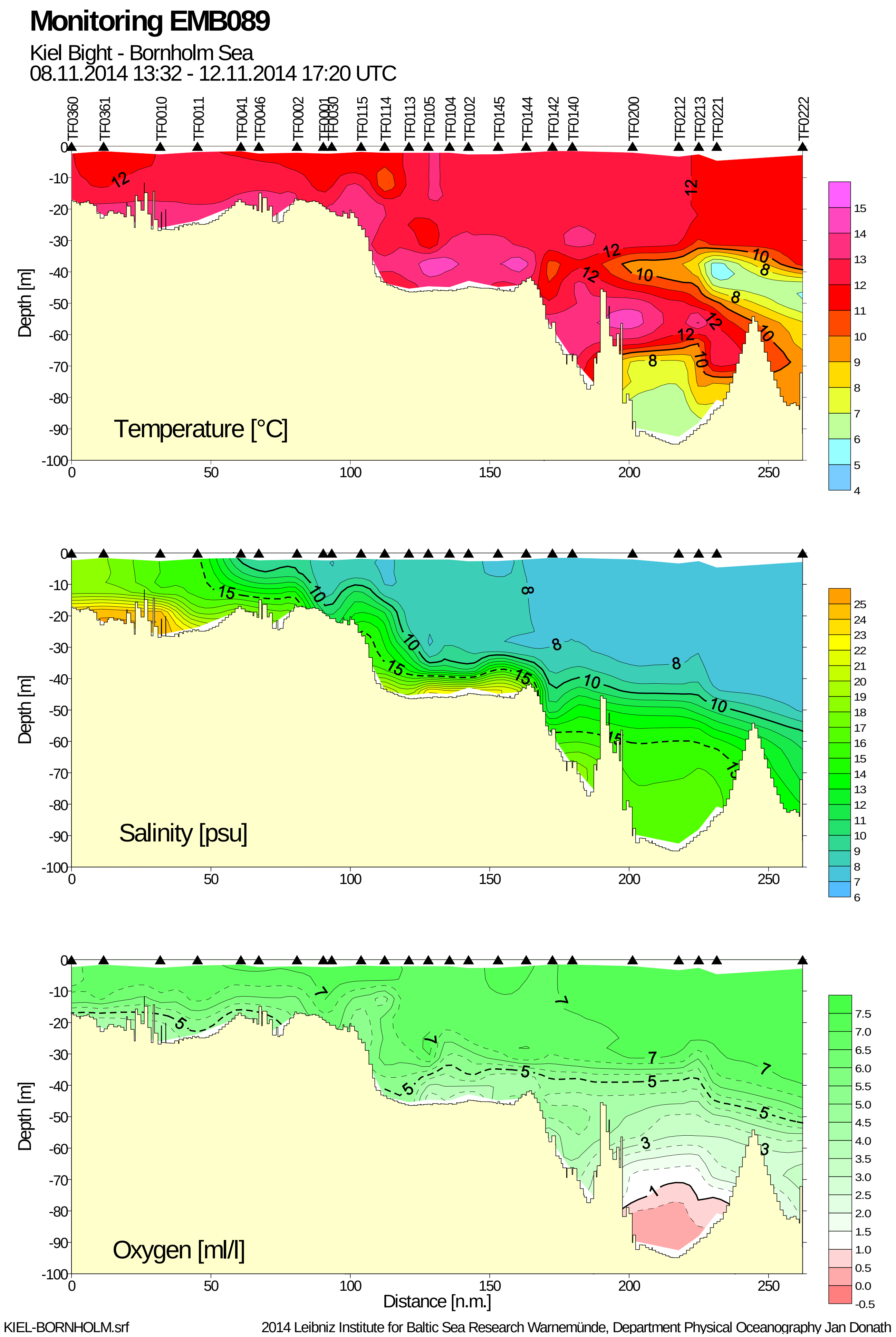

Figure 11.: Hydrographic section from Kiel Bight to Bornholm Basin

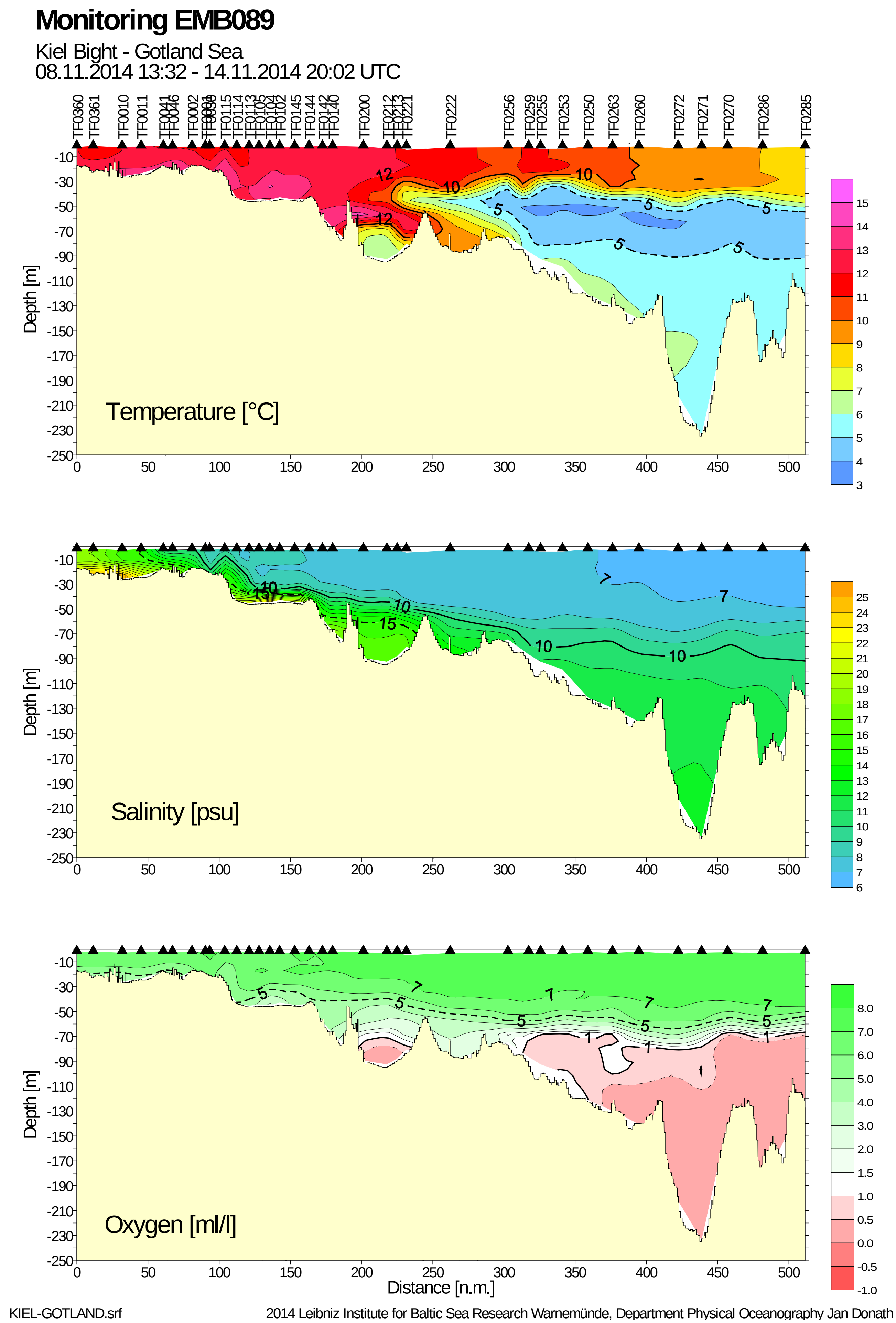

Figure 12.: Hydrographic Section from Kiel Bight to Eastern Gotland Basin

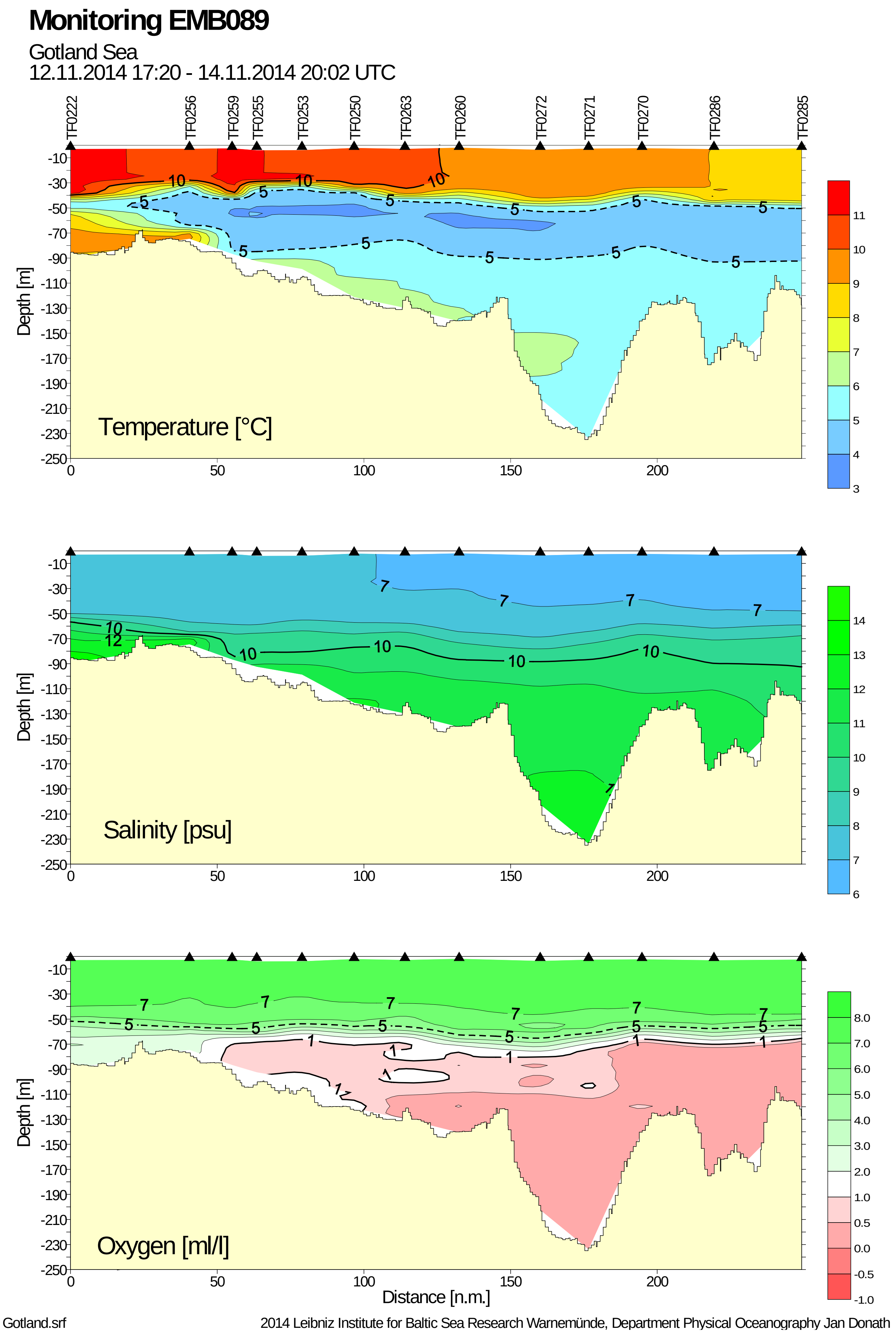

Figure 13.: Detailed hydrographic section in the Gotland Basin