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. EMB117

This report is based on preliminary data

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1. **Cruise No.:** EMB 117

2. **Dates of the cruise:** from 06.11.2015 to 17.11.2015

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:**
   Western Baltic to northern Baltic Proper

5. **Dates and names of ports of call**
   Saßnitz 09.11. – 10.11. 2015

6. **Purpose of the cruise**
   Monitoring in the frame of the HELCOM COMBINE Program, Long term data program of IOW

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
Kreuzer	Lars
Jeschek	Jenny
Tiedt	Lukas
Hehl	Uwe
Glockzien	Ines

9. **Co-operating institutions:**
   All institutions dealing with HELCOM monitoring programmes, University of Rostock

10. **Scientific equipment**
    CTD SBE 911+ with doubled sensors, SBE oxygen sensor and WETLABS ECO FLNTU Fluorometer/turbidity sensor
    PAR/SPAR – sensor, SBE-35 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

Narrative of the cruise and measurements

The cruise started in Rostock-Marienehe after a longer period with calm conditions. But at the second day of the cruise the dominating high pressure area Ulrike (later Viva) became displaced southward giving room for a sequence of intense low pressure areas and the related cyclonic frontal systems are propagating fast eastward as Albert, Binrasheed, Carsten, the Dieters I and II, Eugen, Frank I and II Gunvald and finally ex-Hurrican Kate, see Figure 7. The latter was only a C1 storm but brought high precipitation. Stormy westerly winds are dominating the cruise, with a typical sequence of the wind direction jumping fast to southwest and turning back to northwest slowly, see Figure 1. Station work had to be interrupted Nov. 8th. Nevertheless, except station TF0069 all scheduled station work in the western part of the Baltic Sea could be carried out. Because of permanent gale winds, after a crew exchange in Saßnitz in the evening of Nov. 9th the ship headed directly towards the Gotland Basin. There the hydrographic mooring including two sediment traps could be recovered and redeployed successfully. Station work was resumed there in Nov 11th. At noon of Nov 12th station work had to be interrupted again until the next day. The Landsort Deep and the stations west of Gotland could not be worked also the stations in the southern Gotland Basin had to be skipped. Finally a section from the Bornholm deep through the Arkona Basin towards the Belt Sea could be worked repeatedly.

Station work was organised like follows: a station starts with a CTD-cast (SBE 911+ with double sensors set for temperature and conductivity, SBE oxygen sensor and WETLABS Fluoro/turbiditymeter) including water sampling for oxygen and nutrient measurements. Light conditions are determined with a PAR sensor. The quality of the hydrographic measurements is controlled by the double sensor equipment of the CTD. Additionally, the temperature sensors are compared regularly with a highly stable SBE-35 thermometer, for the control of salinity measurements water samples are taken to be measured later in the laboratory with an AUTOSAL 8400.

At selected stations phytoplankton samples are taken, Secci-depth is determined and 3 l water is filtered. The filters are frozen in liquid nitrogen for processing in the lab. 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, benthic samples are taken with a van Veen grab (three holes per station) and a dredge.

Oxygen is determined with a 716 DMS Titrino III, for H2S determination the photometric methylene blue method is used. Nutrients (nitrate, nitrite, phosphate and silicate) are determined with an Autoanalyser FlowSys (Allicance Instruments), for ammonium the manual photometric method is used.

Underway measurements are carried out with ships thermosalinograph and ships weather station. Data are stored in the DSHIP system

As a pilot project for the determination of molecular weight and molecular size of dissolved organic phosphorus (DOP), different fractions of DOP in the surface water are separated with nano- and ultra filtration.

Preliminary results

The meteorological conditions are dominated by strong winds exceeding more or less permanently 10 m/s wind speed. Wind direction is changing around west.

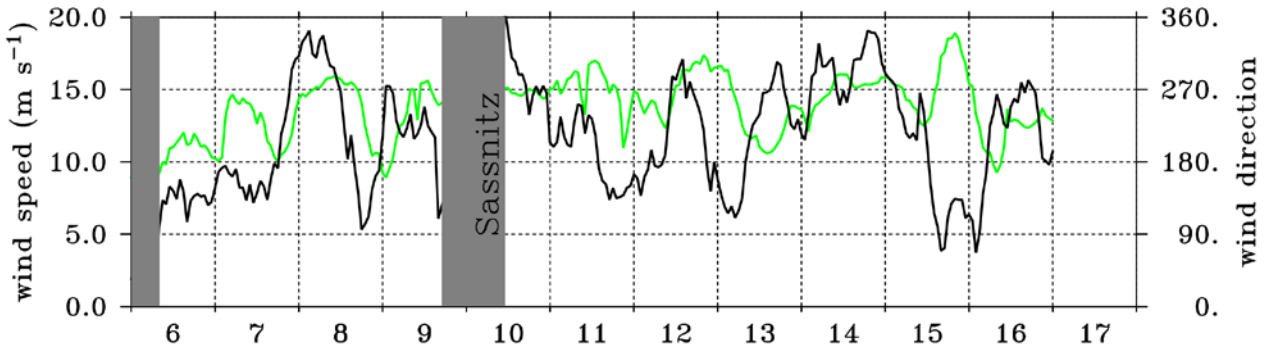

Figure 1: Hourly averages of wind speed (black) and wind direction (green) measured with the ship weather station.

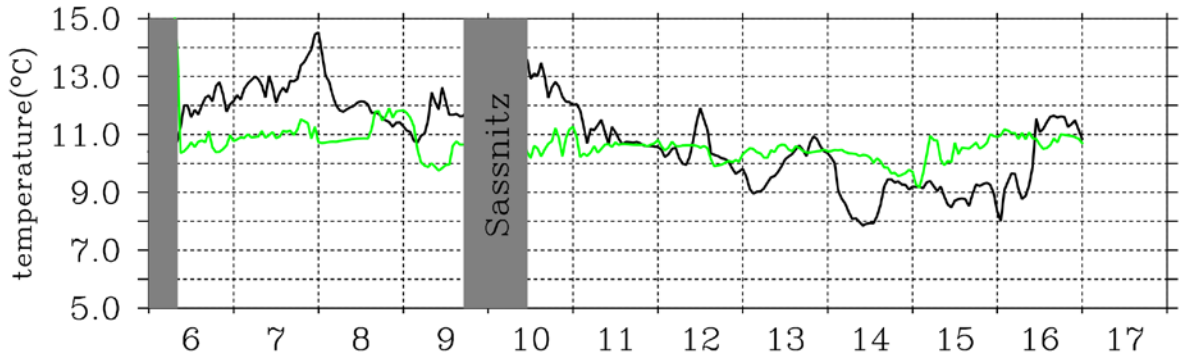

Figure 2: Hourly averages of air temperature (black) and sea surface temperature (green) measured with the ship weather station and the thermosalinograph.

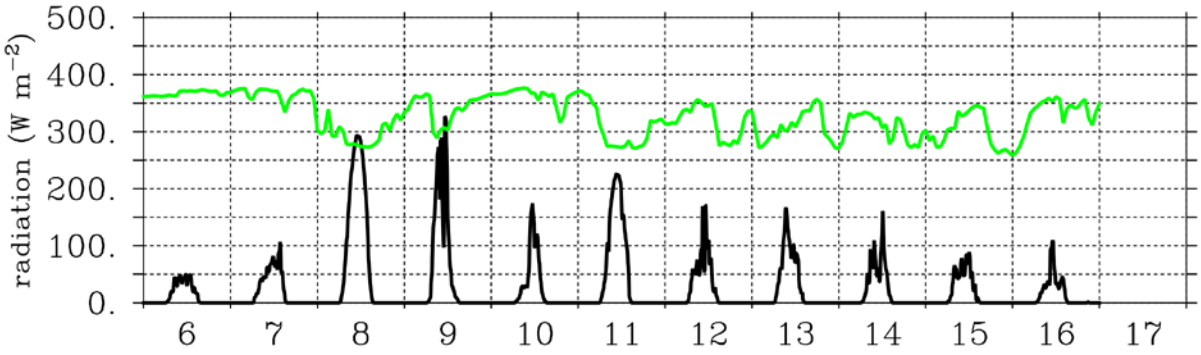

Figure 3: Hourly averages of solar radiation (black) and downwelling infrared radiation (green) measured with the ship weather station.

In the Central Baltic the air temperature already falls below the sea surface temperature. Due to the permanent cloud cover solar radiation is small even for this time of the year. This implies surface cooling and together with the strong wind a deepening of the thermocline.

The hydrographic conditions met **west of Darß Sill** are typical for the season. 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 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 and decreases to 6.9 in the Gotland Basin. In the Arkona Basin the thickness of the bottom layer with enhanced salinity (< 24) rarely exceeds 3 to 4 m, temperature and salinity characteristics are similar to the Mecklenburg Bight. Oxygen concentration is slightly depleted above the bottom layer but not near the bottom indicating that possibly some minor overflow over Darß Sill happened recently refreshing the water in the bottom layer.

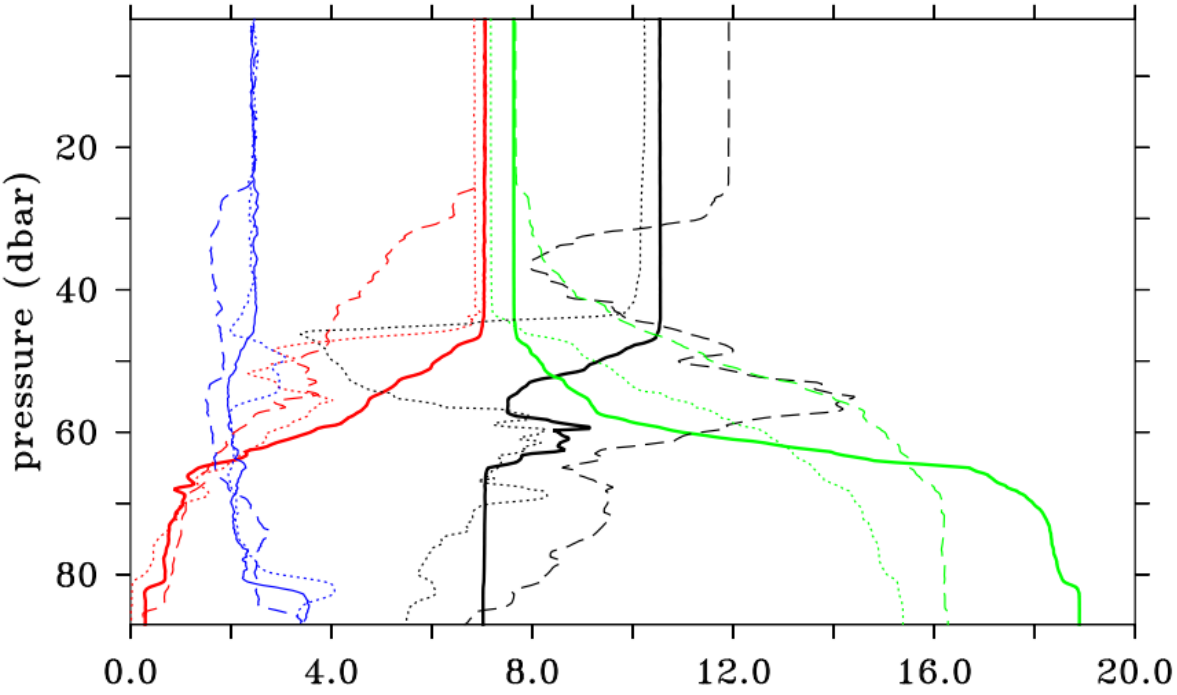

Figure 4: Vertical profiles in the Bornholm Basin (TF0213. Black: temperature [°C], red: oxygen concentration [ml/l], green: salinity, blue: turbidity. Cyan crosses: 2 x H_2S. The numeric scale is the same for all quantities. The dashed lines stand for the same quantities, but for the year 2014, the dotted lines for 2013 repectively.

The hydrographic conditions met in the **Bornholm Basin** are very unusual. The thermocline is at about 50m depth, winter water is completely absent, see Figure 6. The profiles shown in Figure 4 are taken after the severe storm. There is a weak intrusion of warmer water at about 60m depth, below, the temperature is approximately uniform. Stratification and stability of the water column is solely related to salinity. This differs completely from the findings of 2013 and 2014, where the upper temperature minimum was related to winter water and the temperature is decreasing below 60m depth.

In the **Central Gotland Basin** the thermocline depth is about 40 m. The core of the winter water is found at about 60 m depth. The minimum temperature of about 4.5°C is elevated compared with 3.1°C in November 2013 or even below that value in other years. Below the depth of the temperature minimum, oxygen becomes rapidly depleted. In 80m depth the water is hypoxic, but shows intrusion of oxic water down to 220m depth. Below that depth there is a well mixed bottom layer, the water is anoxic but contains still nitrate and no H_2S. Only at station TF0286 some H_2S was found below 90m depth.

The hydrographic conditions are determined by the major Baltic inflow event about one year ago which caused a partial ventilation of the deep Gotland Basin waters. Figure 5 shows vertical profiles of selected hydrographic variables from station TF0271, full lines for 2015, dashed lines for 2014. Comparing the findings from 2015 with those of 2014, note the strong enhancement of the bottom salinity by about 1.3 and the oxygen renewal below 120m depth.

To see the strong changes due to the inflow event, Table 1 shows the long term development in the bottom water at station TF0271. In November 2014 conditions were outstanding as results of a long stagnant period, low salinity, high amount of H_2S in relation to a large nutrient pool. DIN is found exclusively in the form of ammonium. As a result of the inflow, in November 2015 salinity is enhanced considerably, H_2S is oxidised and partly replaced, phosphate is bound partly in particles and ammonium is oxidised to nitrate. Compared with 2014, the N/P ratio is reduced from about 4 to about 2. This may indicate that denitrifying bacteria encounter good conditions, namely available nitrate under low oxygen concentrations, so enhanced denitrification takes place within the bottom waters.

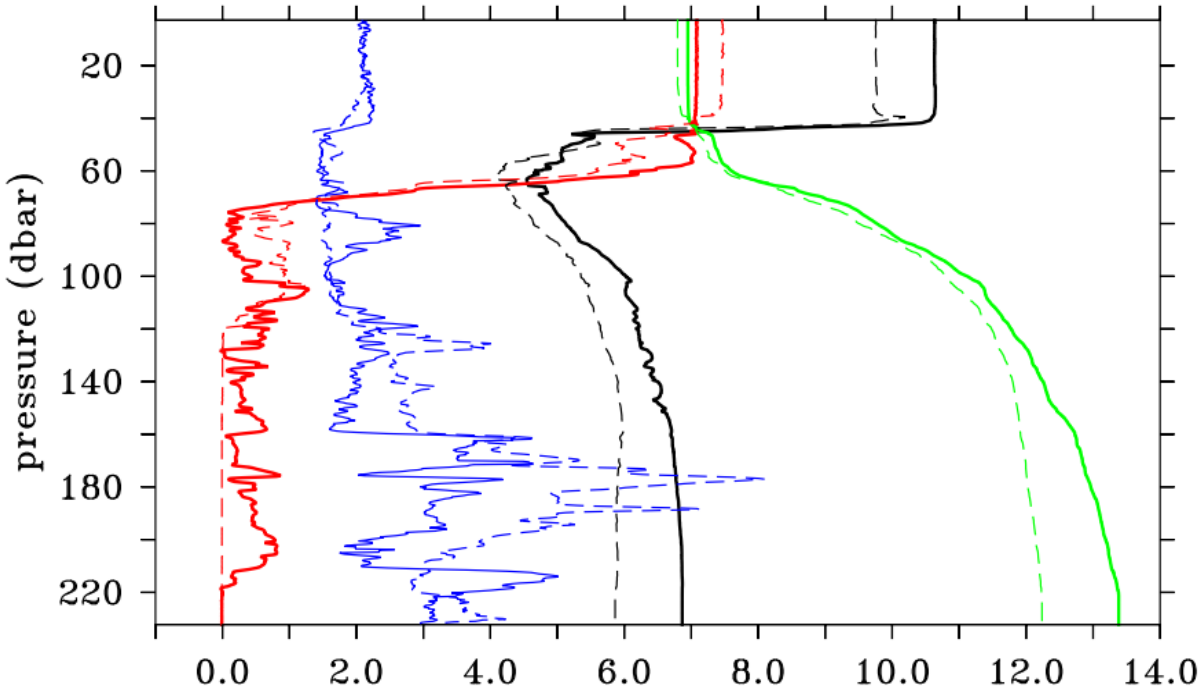

Figure 5: Vertical profiles in the Central Gotland Basin (TF0271. Black: temperature [°C], red: oxygen concentration [ml/l], green: salinity, blue: turbidity. Cyan crosses: 2 x H_2S. The numeric scale is the same for all quantities. The dashed lines stand for the same quantities, but for the year 2014.

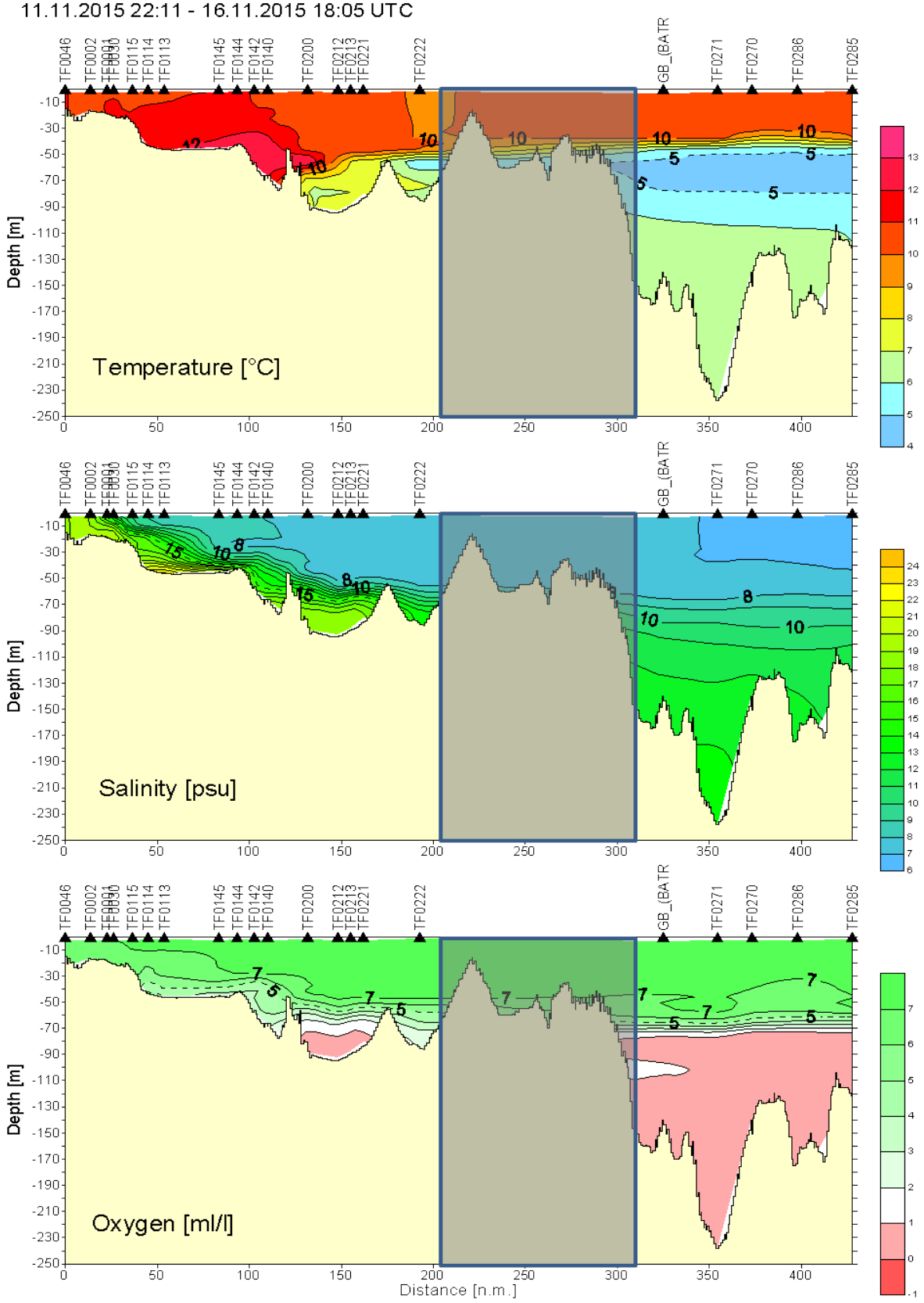

Figure 6: Hydrographic Section of temperature, salinity and oxygen concentration from Fehmarn Belt to the Gotland Basin. In the shaded area the interpolated figure is not supported by data. (Figure by J. Donath, IOW.)

A pre-inflow period

The cruise takes place during a pre-inflow period. In the beginning of the cruise, sea level near Landsort is very low but is rising rapidly during the cruise under the influence of the long lasting strong westerly winds, Figure 7. These wind events are related to a high pressure area Ulrike over Southern Europe and a chain of low pressure areas moving fastly eastward.

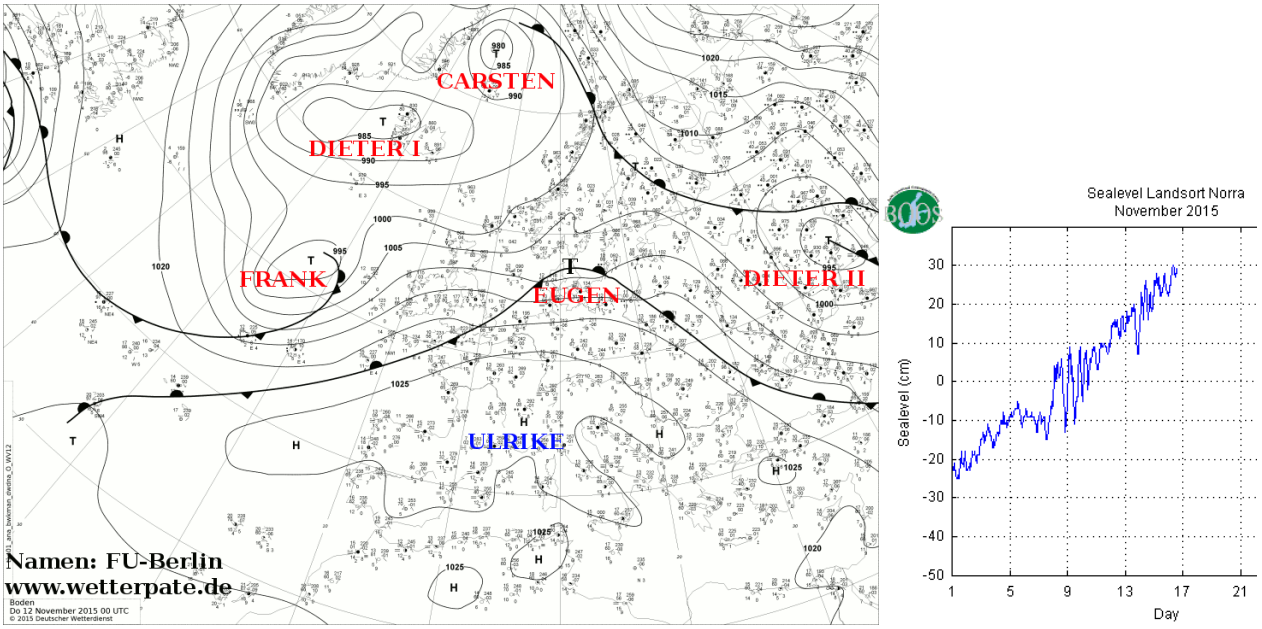

Figure 7: Left: Sketch of the chain of low pressure areas guided eastward by the high Ulrike. (by courtesy from FU-Berlin) Right: rapidly rising sealevel at Landsort (Boos).

The transport into the Baltic Sea brings water with higher salinity from the Kattegat into the Belt Sea. Partly, it is able to flow over the Darß Sill and is found in the Arkona Basin in the end of the cruise. Figure 8 shows the development of a pre-inflow situation. Some saline dense water has passed Darß Sill, the 15-isohaline is rised to 20m depth and bottom salinity is about 22. West of Darß Sill salinity is enhanced in the whole water column.

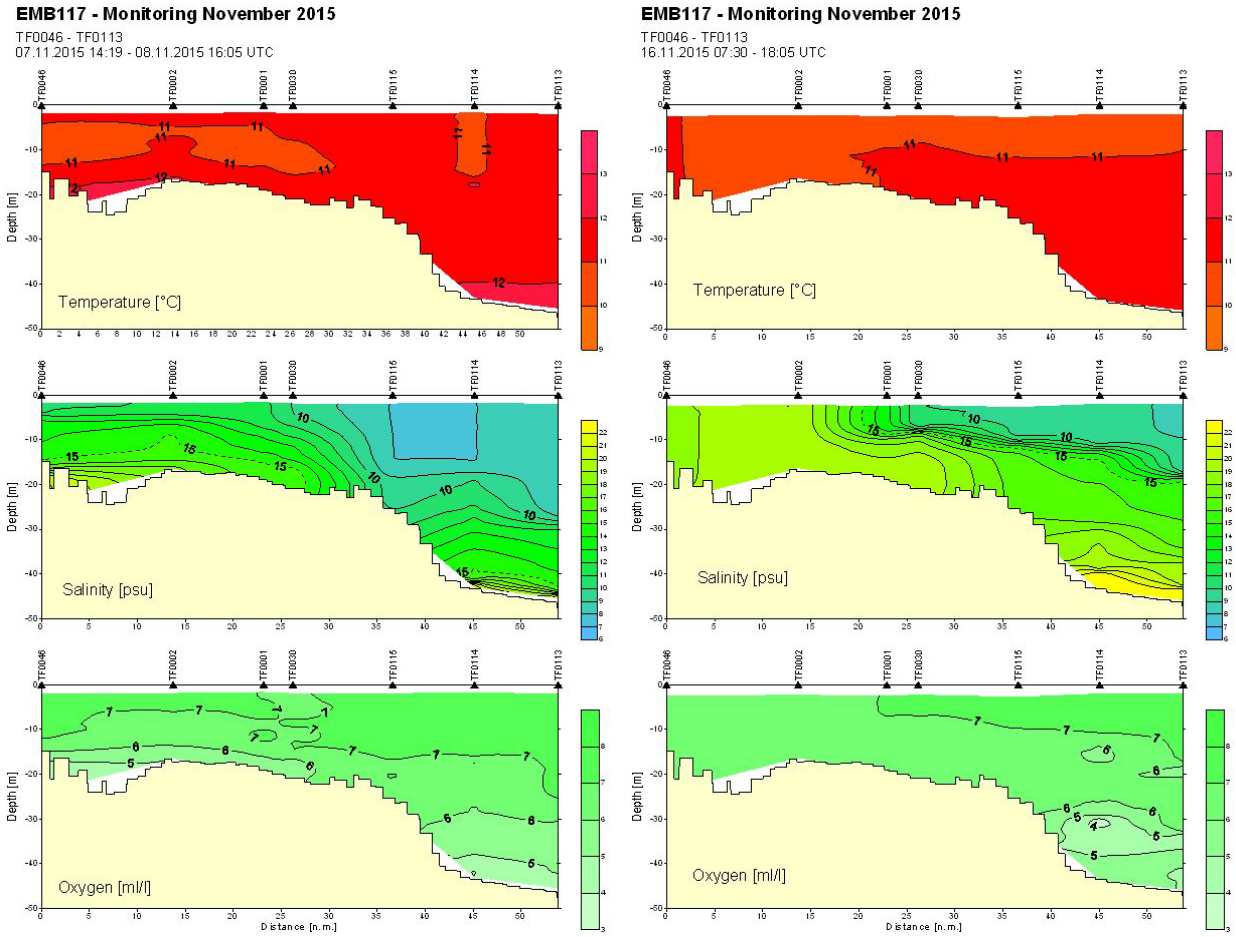

Figure 8: Development of a pre-inflow situation between 6th and 16th of November. Left: Section for temperature, salinity and oxygen concentration from Mecklenburg Bight to Arkona Basin Nov. 6th. Right: the same for Nov. 16th. Note the saline water that has passed Darß Sill. The oxygen depleted water in about 30m depth is most probably old bottom water rised by the inflowing water. (Figure by J. Donath, IOW.)

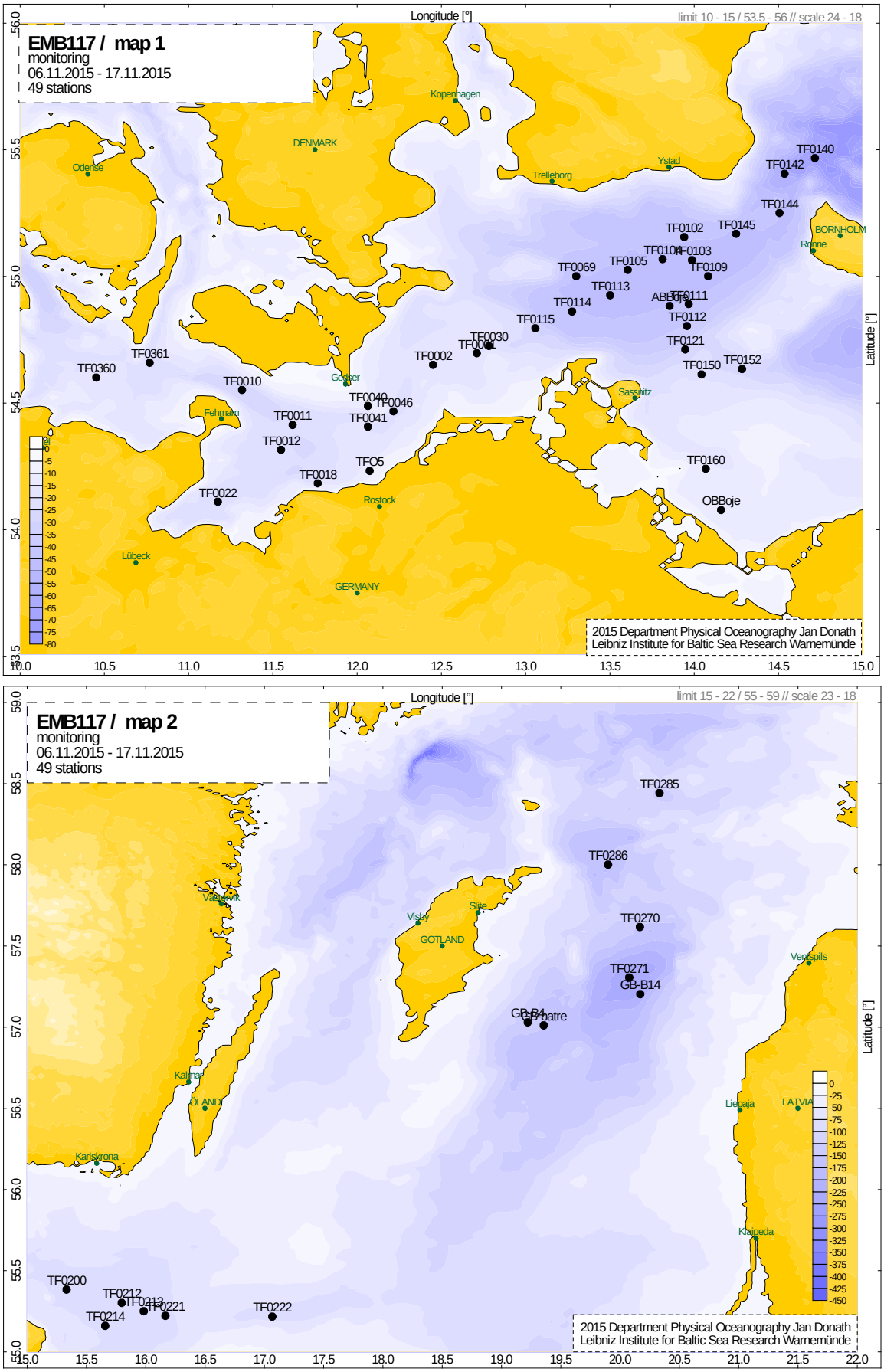

Figure 9: Map of stations (Figure by J. Donath, IOW.)

Appendix: Tables

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

year	2001	2002	2003	2004	2005	2006	2007	2008*	2009*	2010	2011*	2012	2014	2015
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	13.38
T[°C]	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	6.86
O_2/H_2S [µmol/l]	-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	0.08
PO_4 [µmol/l]	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	3.12
DIN [µmol/l]			11.56		19.89	6.41	17.0			32.60		39.83	42.4	6.92
SIO_4 [µmol/l]	86.8		40.2	64.1				89.2	87.6	94.2	104.4	111.0	126.8	60.6

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

Tables 2 - 3: Preliminary results for selected parameters in the surface layer and the near bottom layer

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/l	µmol/l	µmol/l
Kiel Bight	TF0360/08 07.11.2015	10.89	15.84	0.43	0.03 0.34	5.9
Meckl. Bight	TF0012/03 06.11.2015	10.68	13.52	0.38	0.09 0.24	5.1
Lübeck Bight	TF0022/06 08.11.2015	10.35	13.78	0.28	0.09	4.4
Arkona Basin	TF0113/17 08.11.2015	11.82	8.32	0.26	0.17 0.43	4.5
Pom. Bight	TF0160/30 09.11.2015	9.92	7.89	0.44	0.1	15.8
Bornholm Deep	TF0213/38 15.11.2015	10.54	7.63	0.31	0.46 0.66	3.2
Stolpe Channel	TF0222/40 15.11.2015	9.91	7.34	0.44	1.50	8.9
SE Gotland Basin	TF0259/42					
Gotland Deep	TF0271/31 11.11.2015	10.67	6.95	0.22	0.73 0.87	11.4
Fårö Deep	TF0286/33 12.11.2015	10.43	6.54	0.18	0.94 1.13	10.5
Landsort Deep	TF0284/56					
Karlsö Deep	TF0245/58					

* 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	ml/l	µmol/l	µmol/l	µmol/l
Kiel Bight	TF0360/08 07.11.2015	17.0	12.21	20.27	3.37	1.47	5.90 7.75	27.1
Meckl. Bight	TF0012/03 06.11.2015	23.5	11.85	21.16	5.17	0.8	2.91 4.10	16.6
Lübeck Bight	TF0022/06 06.11.2015	21.5	12.29	20.66	3.86	1.62	5.15	27.5
Arkona Basin	TF0113/17 08.11.2015	44.5	12.03	21.53	4.39	1.08	4.22 7.12	19.0
Pom. Bight	TF0160/30 09.11.2015	13.5	9.91	7.91	7.42	0.42	0.08	16.4
Bornholm Deep	TF0213/48 15.11.2015	87.25	7.02	18.89	0.37	2.26	11.32 11.52	62.1
Stolpe Channel	TF0222/40 15.11.2015	88.0	6.73	13.94	2.05	1.75	10.13	40.5
SE Gotland Basin	TF0259/42	86.0						
Gotland Deep	TF0271/31 11.11.2015	232.0	6.86	13.38	0.08	3.12	3.88 6.92	60.8
Fårö Deep	TF0286/33 12.11.2015	188.0	6.54	12.26	-1.14	3.02	0.4 7.79	61.6
Landsort Deep	TF0284/	432.0						
Karlsö Deep	TF0245/	105.8						