

# Leibniz Institute for Baltic Sea Research Warnemünde

## SECOS project & MBI December 2014 research cruise

FS „Elisabeth Mann Borgese“

Cruise- No. EMB-100

9<sup>th</sup> – 23<sup>th</sup> April 2015

Western and Central Baltic Sea

This report is based on preliminary data

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## Part II – measurements of the propagation of the Major Baltic Inflow of December 2014

### 1. Basic information

Ship:	FS Elisabeth Mann Borgese
Nationality:	Germany
Operating Authority:	Baltic Sea Research Institute Warnemünde (IOW)
Cruise:	EMB-095
Date:	16.-23.04.2015
Master:	Volker Ziegner
Number of crew:	11
Chief scientist:	Dr. Michael Naumann
Number of research staff:	9

#### Geographical area in which ship has operated:

Bornholm Sea and Eastern Gotland Basin

#### Purpose of the cruise

measurement programmes to follow the Major Baltic Inflow of December 2014, additional Monitoring cruise in the framework of HELCOM programme

#### Research staff:

	Name	On board	Institution	Responsibility
1	Michael Naumann	16.02.-23.04.2015	IOW	CTD, chief scientist
2	Mayya Gogina	16.02.-23.04.2015	IOW	Benthos sampling + analysis, Dissolved oxygen
3	Jana Wölfel	16.02.-23.04.2015	IOW	Trace gas, Sediment analysis, QM laboratory analysis
4	Sebastian Beier	16.02.-23.04.2015	IOW	CTD, CTD-maintenance, Mooring
5	Malte Pallentin	16.02.-23.04.2015	IOW	Mooring, Technical support
6	Frank Pohl	16.02.-23.04.2015	IOW	Multicorer, Sediment sampling
7	Florian Cordes	16.02.-23.04.2015	University of Rostock	Nutrients
8	Claudia Morys	16.02.-23.04.2015	University of Rostock	Sediment sampling & analysis
9	Natalie Steiner	16.02.-23.04.2015	University of Rostock	Benthos sampling & analysis, Dissolved oxygen

#### Scientific equipment:

CTD + Rosette water sampler, Secchi disk, nutrient analyser, oxygen analyser, Multicorer, VanVeen grab sampler, Equilibrator/sensor system for CH<sub>4</sub>, CO<sub>2</sub> and N<sub>2</sub>O measurements in surface waters, Benthic lander system, Mooring GODESS, Mooring TRBM (Trawl Resistant Bottom Mount)

## 2. General remarks and preliminary result:

The second part of this EMB 100 cruise was used gathering hydrographic, chemical, biological and geological data in the Bornholm Basin and Eastern Gotland Basin to follow the environmental change in the deep-water of the central Baltic Sea caused by the Major Baltic Inflow of December 2014. These measurements secure a high resolution dataset of the propagation of the inflowing water in addition to a series of five monitoring expeditions performed annually by the Leibniz Institute for Baltic Sea Research Warnemünde and former scientific expeditions in 2015. The cruise was carried out with FS “Elisabeth Mann Borgese“ from April 16<sup>th</sup> to 23<sup>rd</sup> 2015 and contributes to IOW’s long term data series in the central Baltic Sea as well as the HELCOM COMBINE program. The data acquired are used for regular national and international assessments of the state of the Baltic Sea, are analysed in numerous publications, and provide the scientific basis for measures to be taken for the protection of the ecosystem Baltic Sea.

The area under investigation covered the Baltic Sea between Bornholm Sea and the northern part of the Eastern Gotland Sea (Fig. 1). The majority of stations is located along a SW-NE transect, describing the state in the succession of basins from the western to the central Baltic as main information (Fig. 4). In the Eastern Gotland Basin additional stations were sampled to get an area-wide overview of the physical, chemical and biological state of the arrival of inflowing water masses. A mooring of hydrographic sea bottom sensors was recovered at the Bornholm Deep, but damaged by fishery activities with no useful data recordings and a lost ADCP-snsor. The mooring “GODESS” equipped with multiple hydrographic and chemical sensors was recovered and again deployed on 21th April at the Gotland Deep. The GODESS-data shows very well the arrival time of the inflow in this area.

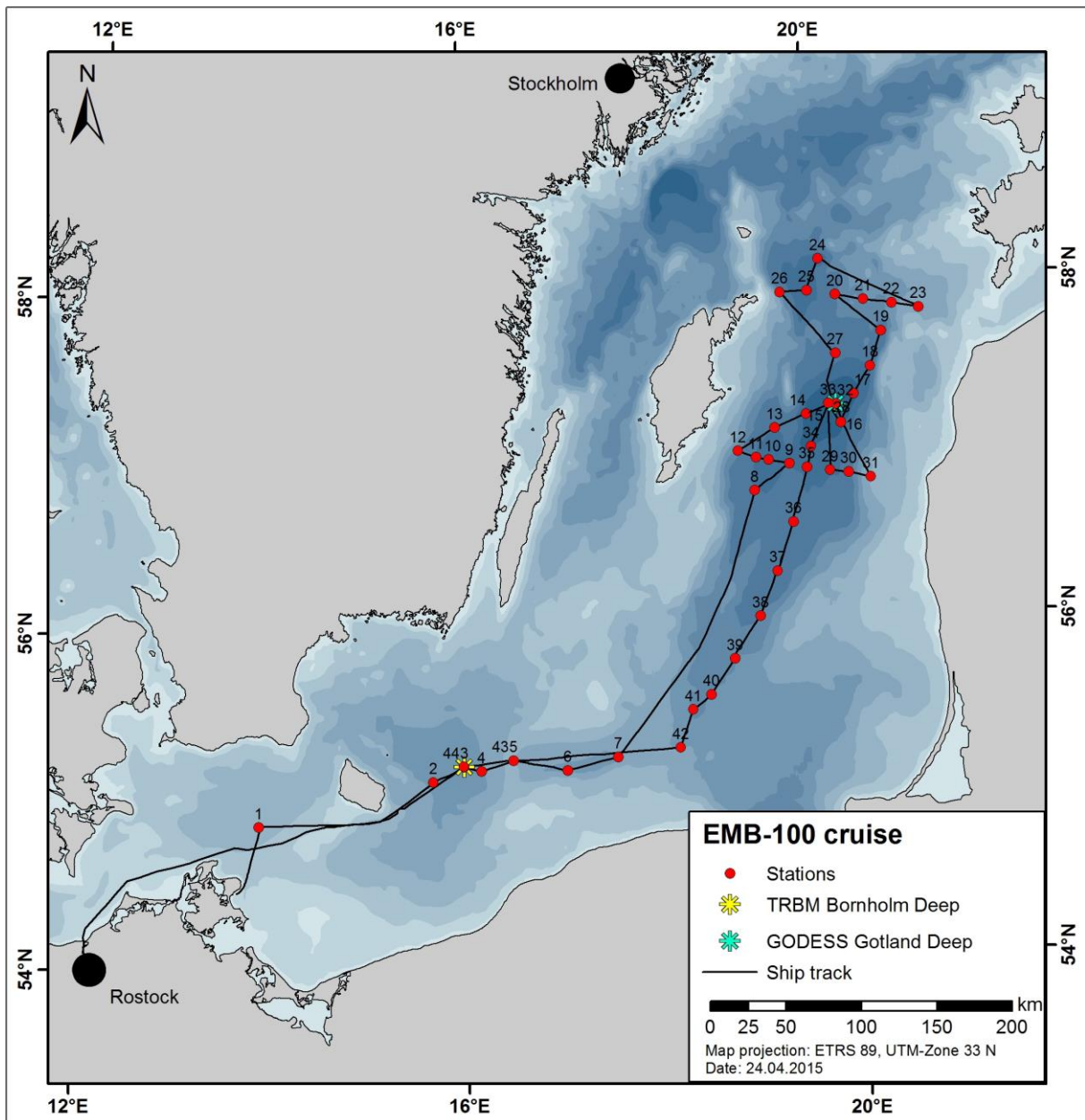


Figure 1: Map of stations and ship track of cruise EMB-100 part II from 16<sup>th</sup> to 23<sup>rd</sup> April 2015. Red dots indicate the position of CTD stations with labels of the station number (Tab. 3).

- The **weather situation** during the cruise was often changing between sunny and calm phases up to weather periods of strong winds of limited working activities. It was influenced by the low pressure cells “Leo” and “Michael” moving from the north Atlantic Ocean to northern Europe at the beginning of the cruise. Afterwards Highpressure “Oxana” of up to 1035 hPa over central Europe, moving slowly north-eastwards, was dominating with relatively calm weather. Air pressure ranged between 1006 and 1024 hPa during the cruise. The Wind speed changed often and ranged between 1 and 8 Bft (0-39.1 knots). Wind directions changed between all directions but nearly 2/3 of the cruise western to northern directions are dominating.

At the 16<sup>th</sup> April strong westerly winds of 25-33 knots (7 Bft) hampered the start of the second part of the cruise, staying anchored in the Prorer Wiek bay in the cover of Rügen island. Next morning with lowering winds the work started with recovery of moorings of the SECOS project at the Arkona Basin. Air temperature ranged between 4.3 °C (18<sup>th</sup> Apr.) in the Slupsk Channel up to 9.6 °C (16<sup>th</sup> Apr.) in the Prorer Wiek. The following hydrographical and hydrochemical characteristics have been observed during the cruise (cf. Tables 1, Figures 3 to 6):

- **Surface temperatures** varied slightly between 4.5 °C (Farö Deep) and 12.8 °C (Mecklenburg Bight). In all investigated areas of the Baltic Sea, temperatures are well above the long-term mean after a record year of sea surface temperatures in the Baltic Sea (SIEGEL et al. 2015) and extreme mild winter 2014/2015 with a cold sum of only 19.8 Kd (the 7<sup>th</sup> warmest since 1948) at the weather station Warnemünde. The water column is mixed completely down to the halocline (see fig. 4). Warming has already started in the Bornholm Basin.
- **Deep water layer temperatures** (bottom near depths) increases and decreases slightly in the central Baltic Proper during the last year due to smaller salt water intrusions in spring to summer 2014. Actually the Bornholm Deep is affected by warm bottom water due to the recent inflow of December 2014, but actual already slightly decreasing. At all key stations the temperatures are still higher as the long-term mean. Figure 4 shows the penetration of inflowing water at the central part of the Eastern Gotland Basin with temperatures below 8 °C, which could be classified as inflow water with origin of the Kattegat area. Former bottom water of the Bornholm Basin reached the area in advance with higher temperatures (NAUMANN 2015, cruise report EMB-095).

	Febr. 2014	Aug. 2014	Febr. 2015	April 2014	Mean 1971/90
Bornholm D.	8.65 °C	5.92 °C	7.15 °C	6.79 °C	6.1 °C
Gotland Deep	6.36 °C	6.02 °C	6.71 °C	6.84 °C	5.6 °C
Farö Deep	5.76 °C	5.87 °C	6.17 °C	6.46 °C	5.2 °C

- The recent major Baltic inflow from December 2014 is the third largest that have occurred since 1880 and has an estimated inflow volume and salt transport of 198 km<sup>3</sup> and 4 Gt (MOHRHOLZ et al. 2015). This event exceeds the former events of 2003 and 1993 and influences since March 2014 the deep basins around Gotland. After ten years of stagnation this intrusions is documented by a increasing **salinity in the bottom layer** in the central Baltic Proper. The actual value of 13.56 at the Gotland Deep is the second highest value of salinity after the largest inflow of 1951 at this position. At farther north areas, like the Farö Deep, the salinity as well slightly increases, but not yet influenced by the inflowing water.

	Nov. 2013	Nov. 2014	Feb. 2015	April 2014
Gotland Deep	12.07	12.23	12.31	13.56
Farö Deep	11.43	11.60	11.81	12.06

- Thus, the **oxygen situation in the deep water** of central basins (>100 m water depth) documents this recent inflow activity of 2014 very well. Hydrogen sulphide concentrations (expressed as negative oxygen equivalents) in the near-bottom layer were high in November 2013 as maximum stage of the stagnation period and decreased drastically in the Eastern Gotland Basin (Gotland Deep, Farö Deep). Northern parts and the Western Gotland Basin are not effected by this intrusions so far, but the high volume of the December event will most probably turn the entire Baltic deepwater conditions from anoxic to oxic, with widespread consequences for marine life and biogeochemical cycles. Figure 4 visualize the propagation of the inflowing highly saline water from the Bornholm Basin via the Stolpe Sill to the southwestern part of the Eastern Gotland Basin. At the Gotland Deep oxygen values of 2.99 ml/l were measured, which is well above the 2 ml/l limit of oxygen deficiency (DIAZ & ROSENBERG 1995). Figure 3 shows the aerial extent of oxygen deficiency and hydrogen sulphide in the near bottom layer of the Baltic Sea. Hydrogen sulphide is nearly dissolved in the Eastern Gotland Basin as an impact of the MBI December 2014. At the Gotland Deep higher live of sprat and cod are observed bottom near in 200-240 m depth by the live view camera of the CTD probe. In addition the polychaete *Bylgides sarsi* (juvenile stage) was detected in a benthic sediment sample. These species are flushed within the inflowing water into this former hostile areas.

	Nov. 2013	Nov. 2014	Feb. 2015	April 2014
Gotland Deep	-8.75 ml/l	-1.71 ml/l	-0.92 ml/l	2.99 ml/l
Farö Deep	-7.74 ml/l	-2.41 ml/l	-1.07 ml/l	H <sub>2</sub> S

- In the deep waters of the **central basins** (>100 m water depth), the hydrographic situation is mirrored. The ventilation of the Eastern Gotland Basin since summer 2014 caused decreasing phosphate concentrations (table 1). The values are halved or even more decreased since November 2013.
- Samples for **phytoplankton** were collected for later analysis in the laboratory.
- **Additional program:**  
 One complete depth profile of station TF271 for al longterm data collection of CT, AT, and pH (photospectrometric)(responsible scientist: Dr. B. Schneider)  
 Equilibrator/sensor system for continuous measurement of CH<sub>4</sub>, CO<sub>2</sub>, and N<sub>2</sub>O in surface waters using off-axis integrated cavity output spectroscopy (responsible scientist: Prof. G. Rehder, Jan Werner).  
 Water samples for CH<sub>4</sub> and N<sub>2</sub>O measurements in different water depths at 12 stations along the cruise track. Part of a Phd work on studies about greenhouse gas conversion in marine systems with distinct oxygen dynamics (responsible scientist: Prof. G. Rehder, Jan Werner).  
 In the Gotland Deep (station TF271) are water samples from the oxic and anoxic water layer taken for a long-term study of redox-sensitive trace-elements such as iron and

manganese. The main aim of the study is to assess the impact of the inflow from December 2014 on the concentrations of the dissolved species Fe(II) and Mn(II) (responsible scientist: Dr. D. Meyer).

In the Bornholm and Eastern Gotland Basin are 5 samples (TF213, TF259, TF271, TF286, GB\_BATRE) of sea bed sediments taken to analyse the resettlement of foraminifera due to the impact of the Major Baltic Inflow of December 2014 (responsible scientist: Dr. M. Moros).

Attachments:

Tables 1: Preliminary results of selected parameters in the near bottom water layer  
(unvalidated results)

Figures 2: detailed Track chart

Figure 3: Areas of oxygen deficiency and hydrogen sulphide in the near bottom layer of the Baltic Sea.

Figure 4-6: Cross sections showing the hydrographic parameters temperature, salinity and oxygen in the water column of different key areas

Table 2: List of stations

Attachment 9: Protocol of mooring deployment „GODESS”, 21<sup>st</sup> April 2015

Warnemünde 8<sup>th</sup> May 2015

Dr. Michael Naumann  
(scientist in charge)

Table 1: Deep water layer (bottom near layer depths)

Area Date	Station Name /No.*	Temp. °C	Sal. psu	O <sub>2</sub> ml/l	PO <sub>4</sub> µM	NO <sub>3</sub> µM
Bornholm Deep 05.02.2015	TFO213/3, 44	6.97	19.67	3.83	1.29	10.63
Stolpe Channel 06.02.2015	TFO222/6	7.05	16.14	4.46	1.67	9.00
SE Gotland Basin 12.02.2015	TFO259/41	5.76	11.87	2.19	2.21	4.72
Gotland Deep 10.02.2015	TFO271/15, 28, 33	6.84	13.56	2.99	1.82	7.55
Farö Deep 09.02.2015	TFO286/25	6.46	12.06	H <sub>2</sub> S	3.66	0

\* see attached map

\*\* hydrogen sulphide was found in samples but couldn't be measured during this cruise



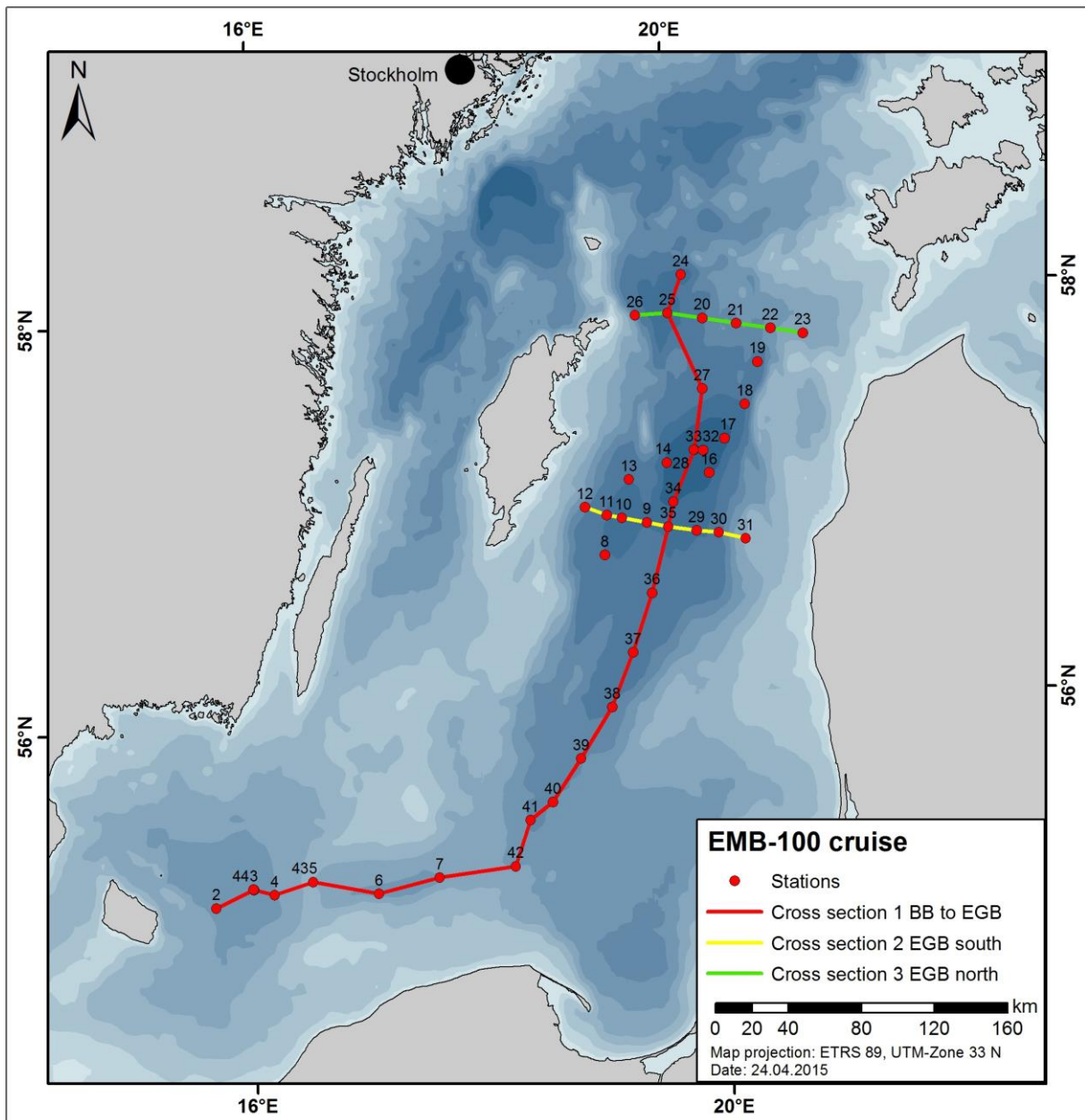


Fig. 2: Stations (labeled with station number -> Tab. 3) and shown cross sections in the central Baltic Sea

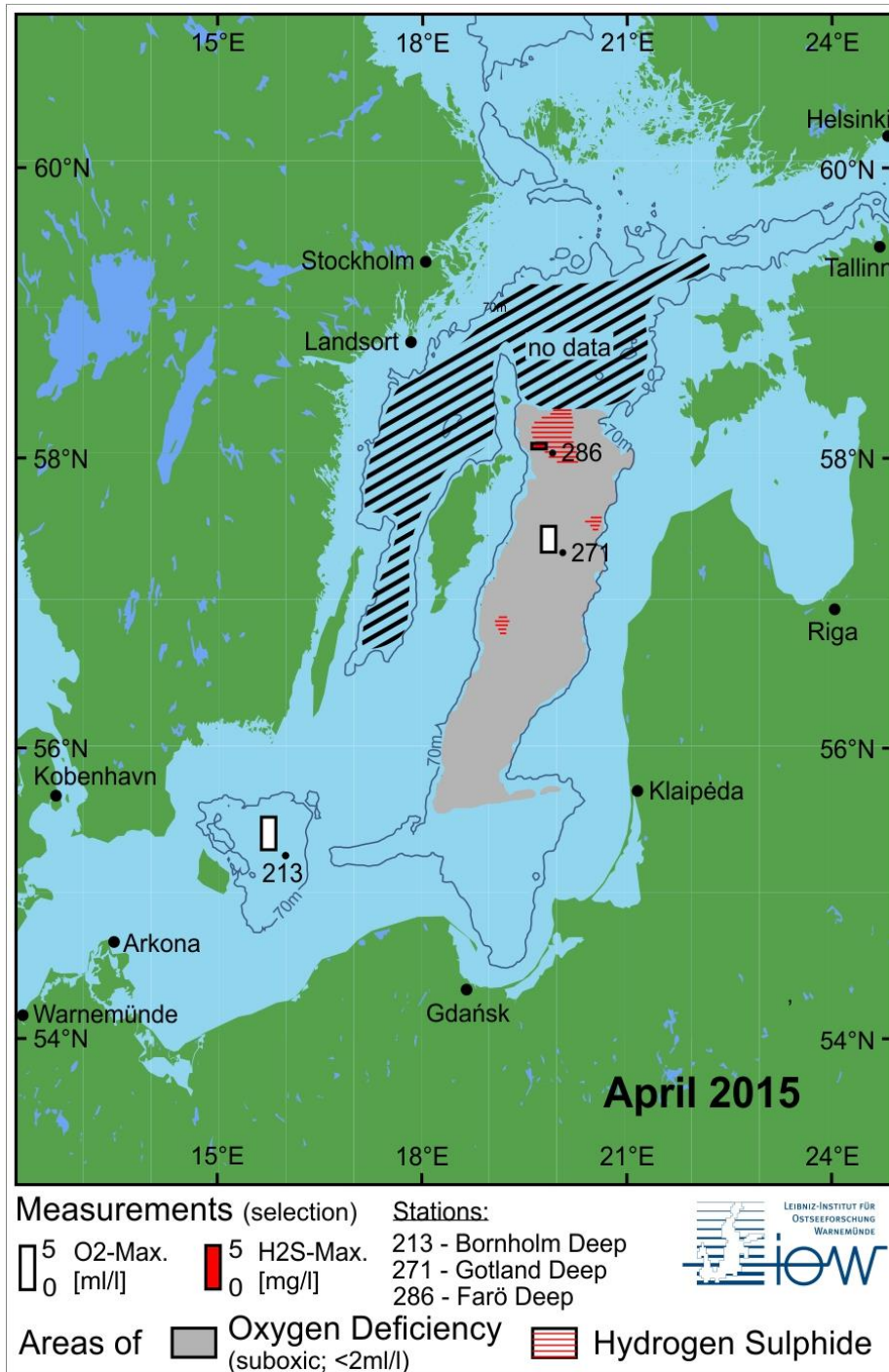


Fig. 3: Areas of oxygen deficiency and hydrogen sulphide in the near bottom layer of the Baltic Sea. Bars show the maximum oxygen and hydrogen sulphide concentrations of the key stations Bornholm Deep, Gotland Deep and Farö Deep in April 2015; the figure contains additionally the 70 m -depth line

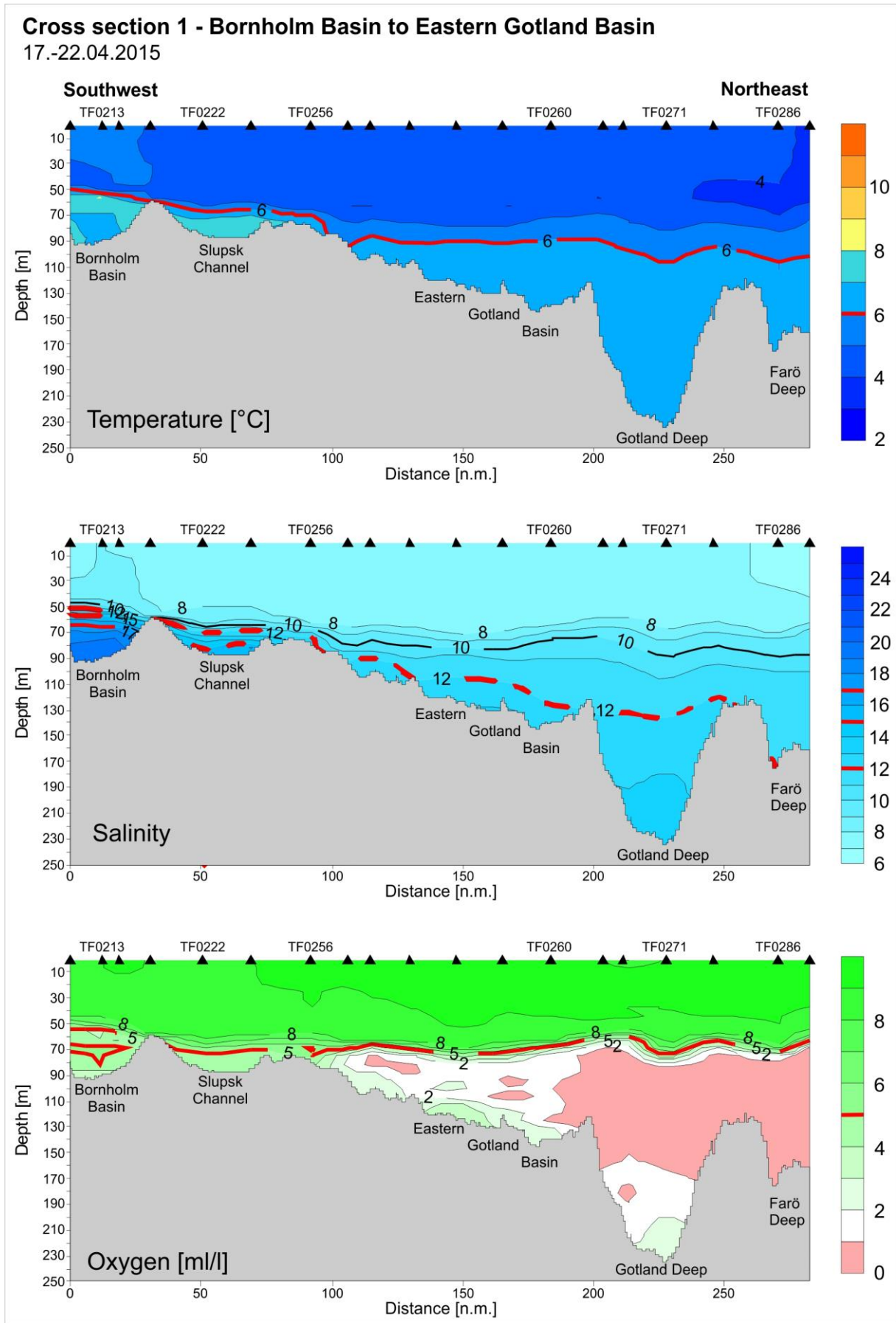


Fig. 4: Cross section 1 - Bornholm Basin to northern parts of the Eastern Gotland Basin

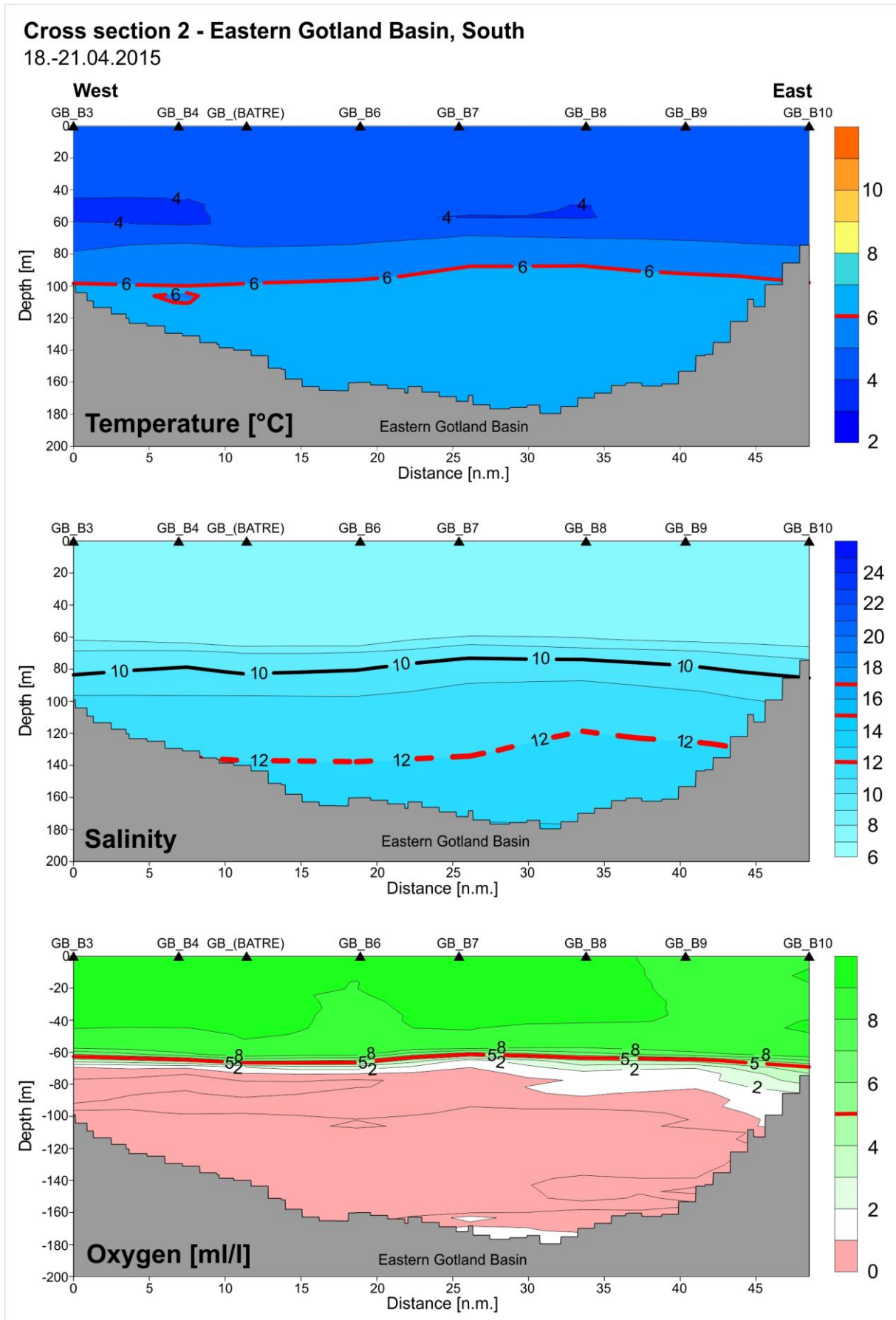


Fig. 5: Cross section 2 from west to east in the southern part of the Eastern Gotland Basin



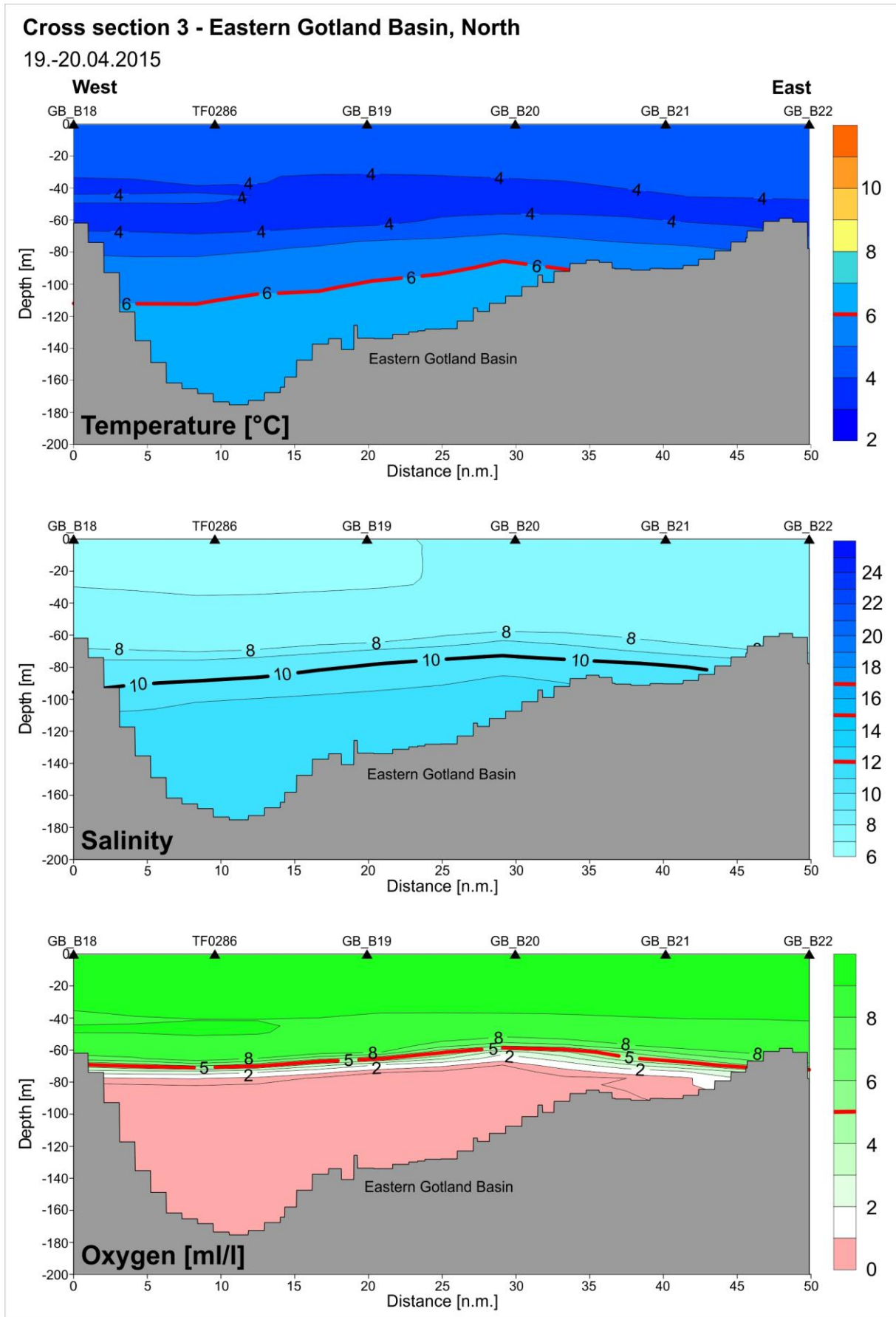


Fig. 6: Cross section 3 from west to east in the northern part of the Eastern Gotland Basin

Tab. 2: List of stations, mooring recovery and deployments carried out during the cruise EMB-100.

Stat. No.	Stat. Name	Latitude	Longitude	Depth [m]		Date	Time [UTC]	CTD cast(s)	Remarks
	Saßnitz,	anchored	roadstead		Begin	16.4.2015	12:25		staff exchange, waiting on weather
					End	16.4.2015	0:00		Start EMB100 part II
1	ABBoje	54°53,2191N	13°51,2283E		Begin	17.4.2015	4:00		recovery of moorings, benthic landers
					End	17.4.2015	4:50		
2	TF0214	55°09,5869N	15°39,6197E	93,77	Begin	17.4.2015	11:00	V0017F01	4 samples (O2, Nutrients)
					End	17.4.2015	11:20		
3	TF0213	55°14,9546N	15°59,1389E	89,84	Begin	17.4.2015	12:35	V0018F01	mooring recovery with dragged anchor
					End	17.4.2015	17:30		11 samples (O2; Nutrients); 1xMuC; 2xVan Veen grab samples (Bio, Geo)
4	TF0221	55°13,3086N	16°10,0544E	82,58	Begin	17.4.2015	18:20	V0019_01	4 samples (O2; Nutrients)
					End	17.4.2015	18:35		
5	TF0224	55°16,9863N	16°30,0051E	62,75	Begin	17.4.2015	20:00	V0020F01	3 samples (O2; Nutrients)
					End	17.4.2015	20:20		
6	TF0222	55°12,9830N	17°03,9851E	90,4	Begin	17.4.2015	22:30	V0021F01	5 samples (O2, Nutrients)
					End	17.4.2015	22:45		
7	SC_E	55°17,1554N	17°35,5821E	84,2	Begin	18.4.2015	1:10	V0022F01	9 samples (O2, Nutrients)
					End	18.4.2015	1:30		
8	GB_B1	56°49,9577N	19°11,0216E	162,1	Begin	18.4.2015	15:05	V0023F01	2 samples (O2, Nutrients)
					End	18.4.2015	15:40		
9	GB_B6	56°58,7900N	19°34,6361E	165,7	Begin	18.4.2015	17:15	V0024F01	4 samples (O2, Nutrients)
					End	18.4.2015	17:50		
10	GB_(BATRE)	57°00,5704N	19°21,2973E	174,6	Begin	18.4.2015	18:35	V0025F01	5 samples (O2; Nutrients); 1xVan Veen grab sample (Bio, Geo)
					End	18.4.2015	19:25		
11	GB_B4	57°01,7018N	19°13,3496E	160,9	Begin	18.4.2015	20:00	V0026F01	no sampling
					End	18.4.2015	20:30		
12	GB_B3	57°04,3891N	19°01,6080E	114,2	Begin	18.4.2015	21:25	V0027F01	no water sampling,
					End	18.4.2015	22:40		4xVan Veen grab samples (Bio)
13	GB_B12	57°11,7878N	19°26,5169E	162,8	Begin	19.4.2015	0:15	V0028F01	no sampling
					End	19.4.2015	0:40		
14	GB_B13	57°15,9681N	19°47,7814E	205,8	Begin	19.4.2015	2:05	V0029F01	5 samples (O2, Nutrients)
					End	19.4.2015	2:45		
15	TF0271	57°19,2078N	20°02,9910E	237,6	Begin	19.4.2015	4:00	V0030F01	mooring GODESS - recovery with dragged anchor,
					End	19.4.2015	13:55	V0030F02	4xCTD - 25 samples (O2, Nutrients, Gas, Che),
								V0030F03	1xMuC,
								V0030F04	4xVan Veen grab (Geo, Bio)

Stat. No.	Stat. Name	Latitude	Longitude	Depth [m]		Date	Time [UTC]	CTD cast(s)	Remarks
16	GB_B14	57°12,1216N	20°10,2570E	232,12	Begin	19.4.2015	14:50	V0031F01	9 samples (O2, Nutrients)
					End	19.4.2015	15:30		
17	Gotland_NE	57°21,9683N	20°20,0391E	216,98	Begin	19.4.2015	16:40	V0032F01	4 samples (O2, Nutrients)
					End	19.4.2015	17:20		
18	GB_B15	57°31,4943N	20°32,6326E	157,08	Begin	19.4.2015	18:35	V0033F01	3 samples (O2, Nutrients)
					End	19.4.2015	19:05		
19	GB_B16	57°43,6949N	20°41,4247E	136,09	Begin	19.4.2015	20:45	V0034F01	no sampling
					End	19.4.2015	21:15		
20	GB_B19	57°57,7896N	20°12,9894E	10,22	Begin	19.4.2015	23:50	V0035F01	1 sample (O2, Nutrients)
					End	20.4.2015	0:15		
21	GB_B20	57°55,4142N	20°31,3662E	98,57	Begin	20.4.2015	1:30	V0036_01	no sampling
					End	20.4.2015	1:45		
22	GB_B21	57°53,2553N	20°50,0988E	90,13	Begin	20.4.2015	2:55	V0037_01	no sampling
					End	20.4.2015	3:15		
23	GB_B22	57°50,9657N	21°07,8730E	77,81	Begin	20.4.2015	4:25	V0038F01	no sampling
					End	20.4.2015	4:50		
24	GB_B24	58°11,0284N	20°03,0216E	160,47	Begin	20.4.2015	10:10	V0039F01	4 samples (O2, Nutrients)
					End	20.4.2015	10:40		
25	TF0286	57°59,9898N	19°53,9968E	192,47	Begin	20.4.2015	12:05	V0040F01	13 samples (O2, Nutrients)
					End	20.4.2015	13:15		1xMuC (Geo, Bio)
26	GB_B18	57°59,9795N	19°35,9432E	119,39	Begin	20.4.2015	14:15	V0041F01	no sampling
					End	20.4.2015	14:45		
27	TF0270	57°36,9672N	20°10,0023E	142,21	Begin	20.4.2015	17:25	V0042F01	11 samples (O2, Nutrients, Gas)
					End	20.4.2015	18:00		
28	TF0271	57°19,1975N	20°03,0233E	236,88	Begin	20.4.2015	19:45	V0043_01	PIP-Test GODESS sensors
					End	20.4.2015	22:25	V0043H02	3 samples (O2, Nutrients)
								V0044F01	
29	GB_B8	56°55,4031N	20°01,1759E	163,53	Begin	21.4.2015	0:40	V0045F01	3 samples (O2, Nutrients)
					End	21.4.2015	1:10		
30	GB_B9	56°54,3471N	20°13,0196E	144,49	Begin	21.4.2015	1:55	V0046F01	11 samples (O2, Nutrients),
					End	21.4.2015	3:40		4xVan Veen grab (Bio)
31	GB_B10	56°51,9568N	20°27,2539E	61,7	Begin	21.4.2015	4:35	V0047F01	2 samples (O2, Nutrients),
					End	21.4.2015	5:45	V0047F02	1xVan Veen grab (Bio)
32	GODESS	57°18,902N	20°08,003E		Begin	21.4.2015	8:20		GODESS deployment
					End	21.4.2015	9:10		
33	TF0271	57°19,2009N	20°02,9539E	235,75	Begin	21.4.2015	9:35	V0048F01	4 samples (O2, Nutrients)
					End	21.4.2015	10:15		
34	TF0272	57°04,3024N	19°49,7870E	206	Begin	21.4.2015	11:55	V0049F01	4 samples (O2, Nutrients),
					End	21.4.2015	12:30		meeting r/v ARANDA
35	GB_B7	56°57,1055N	19°46,1639E	181,34	Begin	21.4.2015	13:20	V0050F01	4 samples (O2, Nutrients)
					End	21.4.2015	13:50		

Stat. No.	Stat. Name	Latitude	Longitude	Depth [m]		Date	Time [UTC]	CTD cast(s)	Remarks
36	TF0260	56°37,9552N	19°34,9692E	143,89	Begin	21.4.2015	16:05	V0051F01	4 samples (O2, Nutrients)
					End	21.4.2015	16:40		
37	TF0263	56°20,7964N	19°22,6879E	132,9	Begin	21.4.2015	18:30	V0052F01	12 samples (O2, Nutrients, Gas),
					End	21.4.2015	19:40		2xVan Veen grab (Bio)
38	TF0250	56°05,0350N	19°09,9510E	123,87	Begin	21.4.2015	21:25	V0053F01	3 samples (O2, Nutrients)
					End	21.4.2015	21:55		
39	TF0253	55°50,3806N	18°52,0215E	100,14	Begin	21.4.2015	23:40	V0054F01	9 samples (O2, Nutrients, Gas),
					End	22.4.2015	0:40		4xVan Veen grab
40	TF0255	55°37,9999N	18°35,9975E	94,71	Begin	22.4.2015	2:10	V0055F01	1 sample (O2, Nutrients)
					End	22.4.2015	2:35		
41	TF0259	55°32,9574N	18°24,0093E	89,52	Begin	22.4.2015	3:30	V0056F01	10 samples (O2, Nutrients, Gas),
					End	22.4.2015	4:50		3xVan Veen grab, 1x MuC (Bio, Geo)
42	TF0256	55°19,6089N	18°15,0667E	78,99	Begin	22.4.2015	6:10	V0057F01	7 samples (O2, Nutrients, Bio)
					End	22.4.2015	6:40		
43	TF0224	55°16,9873N	16°30,0927E	62,3	Begin	22.4.2015	12:10	V0058_01	no sampling
					End	22.4.2015	12:25		
44	TF0213	55°15,0141N	15°58,9801E	89,4	Begin	22.4.2015	14:10	V0059F01	4 samples (Bio)
					End	22.4.2015	14:35	V0059F02	
	Marienehe harbour					23.4.2015	6:15		End of cruise



Attachment 9: Protocol of mooring deployment „GODESS”, 21<sup>st</sup> April 2015

Briese Schifffahrts Gmb & Co. KG  
Abtlg. Forschungsschifffahrt  
FS "Elisabeth Mann Borgese"



**VERANKERUNGSPROTOKOLL**

<b>Datum:</b>	21.04.2015	<b>Beginn:</b>	08:50	<b>Ende:</b>	09:07	<b>UTC</b>
<b>Gerät:</b>		<b>GODESS</b>		<b>Reise EMB</b>		<b>100</b>
<b>Code Name:</b>		<b>GODESS</b>				
<b>Lottiefe:</b>	Wassertiefe	249,7 m				
<b>Wetter:</b>	Wind:	360°		9,9 m/s		
	Strömung:	S		0,4 kn		
<b>Absetzposition:</b>	<b>Breite:</b>	57°18,902'N		(WGS 84, DGPS)		
<b>Gerät</b>	<b>Länge:</b>	020°08,003' E				
<b>Grundleine:</b>	<b>Breite:</b>	57°19,074'N				
(Ende)	<b>Länge:</b>	020°07,924' E				
	Richtung:	345°		(vom Gerät)		
	Länge:	300 m				
<b>Oberfläche:</b>		keine Oberflächenmarkierung				
<b>Bemerkungen:</b>		Der Releaser befindet sich am Ende der Grundleine!!!				

*Ziegner*  
V. Ziegner  
Kapitän

*M. Naumann*  
M. Naumann  
Exp.-Leiter

Verteiler: Reederei  
EMB  
IOW  
Fahrtlfr.