EUROFLEETS2 Cruise Summary Report

Propagation of the saltwater inflow from December 2014 (PROSID2014)

R/V Salme, Cruise No. 2015_24,

21.10.2015 – 27.10.2015, Tallinn (Estonia) – Tallinn (Estonia)

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2015

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1 Summary

The cruise was used gathering hydrographic, chemical, biological and geological data in the Gulf of Finland, Eastern Gotland Basin and Northern Gotland Basin (Fig. 1) 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 changing ecosystem by the inflowing water in a row of 17 cruises during the year 2015 performed by the Leibniz Institute for Baltic Sea Research Warnemünde and the partners Thünen Institute of Baltic Sea Fisheries (Rostock, Germany) and Marine Systems Institute (Tallinn, Estonia).
It was found that the bottom water in the northern areas and the Gulf of Finalnd were not reached by the latest inflow activities so far. The only change detected in this areas were caused by uplifted and transported former bottom water of the Gotland Deep.

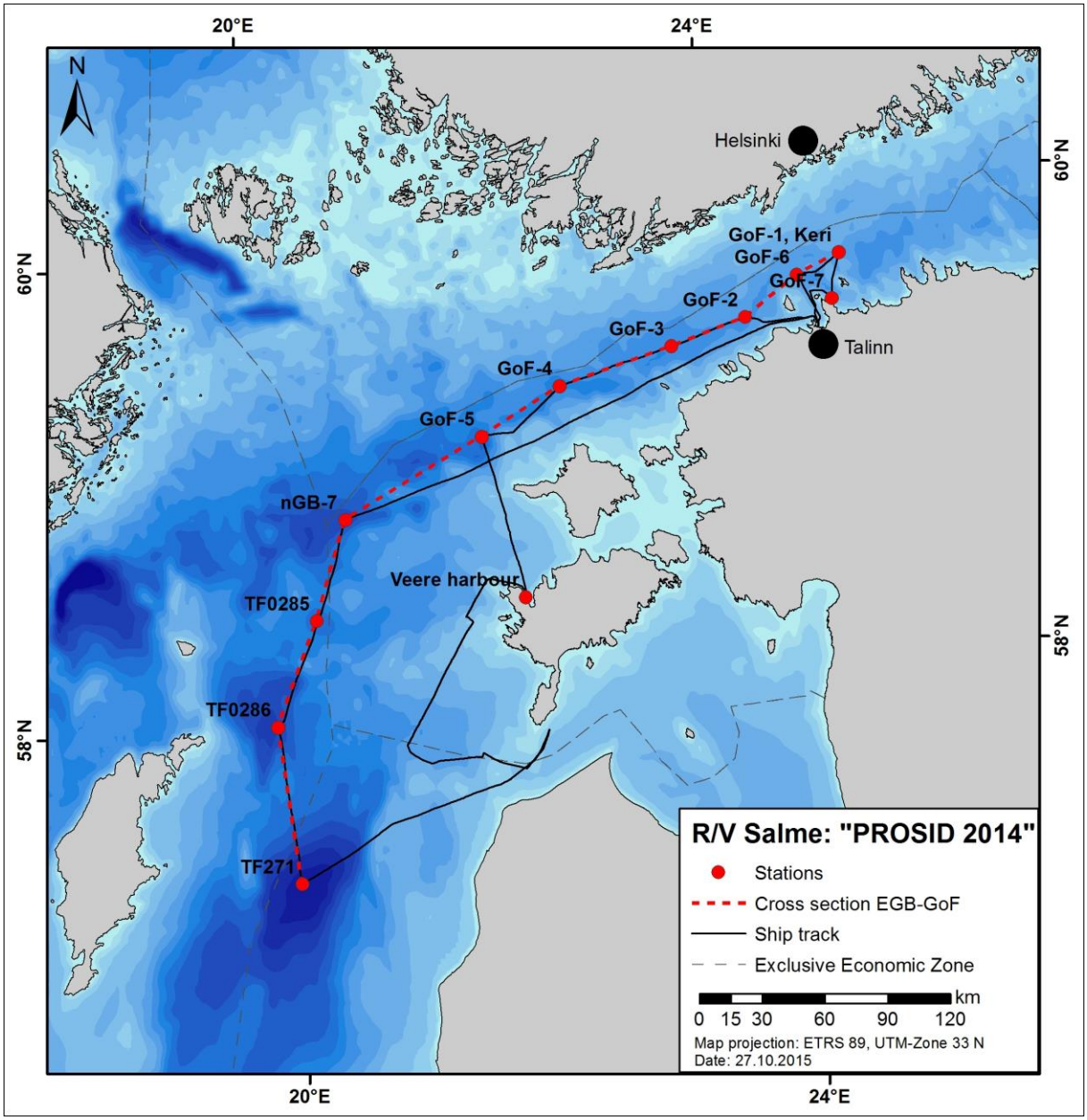


Fig. 1 Map of stations and ship track of cruise Salme 2015_024 from 21st to 27th October 2015. Red dots indicate the position of CTD stations with labels of the station name (Tab. 2)..

2 Research Objectives

1. How the saline and oxygen rich water masses of the MBI are distributed?
2. How do the properties of the hydrological regime have changed?
3. Is there any effect on the ecosystem?
4. Did a new stagnation period and thus the return of hypoxic conditions already started?
5. How much water and salt is transported through the Northern Baltic and into the Western Baltic and the Gulf of Finland, respectively?
6. Research and development of pH, Alkalinity and CO_2 sensor systems.

3 Narrative of the Cruise

The cruise was carried out with RV "Salme" from October 21st to 27th 2015. The area under investigation was limited by frequently bad weather periods to the Gulf of Finland, Northern Gotland Basin and the Gotland Deep, as single station in the Eastern Gotland Basin (Fig. 1). The other proposed working areas in the Eastern and Western Gotland Basin and Aland Deep had to be cancelled. The majority of stations is located along a SW-NE transect, describing the state in the succession of basins from the central Baltic to the Gulf of Finland as main information (Fig. 2). Sensor testing was done in all working areas and even bad weather periods, staying in the cover of peninsulas/harbours, could be used for these tasks.

The weather situation during the cruise was mainly windy (>4 Bft) cloudy and rainy with only one calm, sunny day (24th Oct.). It was influenced by the low pressure cells "Uli", "Valentin" and "Wymar" moving from the north Atlantic Ocean to northern Europe and ranging between 975-985 hPa. In combination with highpressure "Roswita" of up to 1035 hPa over eastern Europe, moving slowly north-eastwards, a northwesterly windforcing was dominating. The Wind speed ranged between 3 and 8 Bft (7-40 knots). Three times the cruise was hampered by strong wind conditions and we were forced to go in the cover for waiting on weather (Veere harbour, Saaremaa southwest and Tallinn harbour, cf. Tab. 2). Summed up about 60 % percent of the cruise was interrupted by these strong wind phases.

4 Preliminary Results

4.1 Deepwater layer temperatures

Deep water layer temperatures (bottom near depths) increases and decreases slightly in the central Baltic Proper during the year 2014 due to smaller salt water intrusions arriving in spring to summer 2014. The latest Major Baltic Inflow of December 2014 raised the bottom water temperatures in the central Baltic Sea. At all key stations the temperatures are still higher as the long-term mean. Figure 2 shows this penetration of inflowing water in the central part of the Eastern Gotland Basin with temperatures between 6-7 8 °C. The bottom water in the northern

areas and Gulf of Finland show temparatures below 6 °C and are not reached by the latest inflow activity so far.

	Aug. 2014	Febr. 2015	April 2015	Oct. 2015	Mean 1971/90
Bornholm D.	5.92 °C	7.15 °C	6.79 °C	---	6.1 °C
Gotland Deep	6.02 °C	6.71 °C	6.84 °C	6.86 °C	5.6 °C
Farö Deep	5.87 °C	6.17 °C	6.46 °C	6.52 °C	5.2 °C

The 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 km³ and 4 Gt (Mohrholz et al. 2015). This event exceeds the former events of 2003 and 1993 and influences since March 2015 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 13.42 shows slightly decreasing since spring 2015 at the Gotland Deep. At farther north areas, like the Farö Deep, the salinity as well slightly increases, but not yet influenced by the inflowing water. This increase is related to uplifted and transported former bottom water of Gotland Deep.

	Nov. 2014	Feb. 2015	April 2014	Oct. 2015
Gotland Deep	12.23	12.31	13.56	13.42
Farö Deep	11.60	11.81	12.06	12.23

4.2 Oxygen situation in the deep water

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. The Eastern Gotland Basin shows rapid oxygen since June 2015. In the moment oxygen concentration in the deep water layer is fallen below 1 ml/l after an maximum of 2.99 ml/l in the mid of April (Naumann 2015, cruise report EMB-100). The adjacent Northern Gotland Basin and Gulf of Finland show oxygen deficiency in the deep water with occurrence of hydrogen sulfide below 100 m water depth. In the Farö Deep the hydrogen sulfide values are decreasing, due to the arrival of uplifted former bottom water of the Gotland Deep, which was ventilated in summer 2014. Figure 2 and 3 visualizes this actual situation.

	Nov. 2014	Feb. 2015	April 2014	Oct. 2015
Gotland Deep	-1.71 ml/l	-0.92 ml/l	2.99 ml/l	0.02 ml/l
Farö Deep	-2.41 ml/l	-1.07 ml/l	H_2S	H_2S

In the deep waters of the central basins (>100 m water depth), the hydrographic situation is mirrored. The ventilations of the Eastern Gotland Basin since summer 2014 can be traced, but in the other areas stagnation and oxygen deficiency are still dominating. High oxygen consumption rates turned the Eastern Gotland Basin back into a hypoxic state already after 6 months after the starting ventilation of the Major Baltic Inflow of December 2014.

4.3 Analysis of methane and dinitrogenoxide in the central Baltic Sea

Analysis of methane, nitrous oxide and determination of methane oxidation rates in the deep waters of the central Baltic Sea: Methane (CH4) is a powerful greenhouse gas generated during anaerobic decay of organic matter. Usually most of the methane generated is oxidized by aerobic and anaerobic microbes in the water column and sediment thus hampering the escape of methane to the atmosphere. Nitrous oxide (N2O), another potent greenhouse gas, is produced as an intermediary compound in both nitrification and denitrification processes. These nitrogen processes are highly dependent on specific oxygen conditions. Eutrophication and hypoxia modify the dynamics of CH4 and N2O related processes.
In the framework of this study we investigated the effects of the Major Baltic Inflow event (December 2014) on the concentration of CH4, N2O and the microbial methane turnover in the water column of the central Baltic Sea.
Gas extractions from water samples were carried out onboard to determine CH4, N2O concentrations and the stable carbon isotopic composition of methane. Furthermore, 14C incubation experiments were performed in the onboard laboratory to investigate the pelagic methane turnover. The collected gas samples were analyzed using gas chromatography and isotope ratio mass spectrometry and the incubation experiments further processed at the laboratory of the University of Helsinki.
Only a minor part (25 %) of the originally planned work program could be realized due to the wheater conditions. The generated data will be integrated and published within a long term observation study of CH4 and N2O dynamics within the central Baltic Sea and will further support the process understanding of microbial methane oxidation in marginal seas.

4.4 Research and development of pH, Alkalinity and CO_2 sensor systems

Two different pH measurement techniques were applied and compared during the cruise. Christoph Staudinger performed pH measurements with a pH optode that was mounted to the CTD for in-situ measurements and also connected to the Ferry Box system of RV Salme. Jens Müller performed spectrophotometric pH measurements with two different laboratory-based set-ups: One for the measurement of discrete samples taken from 7 the CTD casts and another flow-through system that continuously measured surface water pH taken from the Ferry Box system. During the meeting with RV Poseidon the flow-through system was also

operated from Poseidon with water supply from IOW's pump CTD to obtain a high resultion spectrophotometric pH profile. All pH measurement systems worked well over the entire cruise period and a first comparison of the results shows a good agreement between the various techniques applied. Aside from some stations that could not be investigated, the challenging weather conditions did not hinder the pH measurements very much and the work with the Ferry Box system could be performed without major disruptions. In summary, the envisaged work could be performed satisfactory.
Furthermore it was planned to test and validate the new developed optodes for carbon dioxide and the sensor device at the „PROSID 2014" cruise. The sensor system should be applied to measure a stepwise profile at TF_271 at 5 depths and some continuouse profiles to investigate the hysteresis behaviour. During the cruise it was possible to measure two stepwise profiles at TF_271 and GoF_7 as well as continuouse profiles at GoF_4, GoF_6 and GoF_1. So it was possible to obtain more data than expected. The evaluation of the measured response of the carbon dioxide sensor showed an erratic increase of CO2 at around 40 m.

4.5 Additional programme

Water sampling for nurtrient analysis and flow cytometry measurements at nine stations in the working areas spanning from the Gotland Deep into the Gulf of Finland (responsible scientists: Dr. Inga Lips, Peeter Laas from MSI, Estonia) Sediment coring at two stations in the Gulf of Finland for pore water analysis of redox sensitive metals such as manganese and so on (responsible scientists: Dr. Olaf Dellwig, Florian Cordes from IOW, Germany).

5 Data and Sample Storage / Availability

All physical and chemical data measured during the cruise will be validated and archived at the oceanographic database of the IOW, which is accessible to the public. Furthermore the data will be made available to the public with the cruise report. Cores from Frahm-Lot will be archived at IOW Core Repository in Rostock (Germany). They will be available for sample requests to the public five years after the cruise.
Ultimately, gathered data will be analysed from the principal investigator Dr. David Meyer, the chief scientist Dr. Michael Naumann and the co-worker Dr. Peter Holtermann in strong cooperation with the experts for the Northern Baltic Proper - Gulf of Finland region such as Dr. Urmas Lips from the Marine System Institute (Tallinn). This cooperation also includes the access to all MSI buoy data. The data analysis will be carried out thoroughly and resulting manuscripts will be submitted to high-level peer-reviewed journals in the near future.

6 Participants

	Name	On board	Institution	Responsibility
1	Dr. Michael Naumann	21.10.-27.10.2015	IOW	chief scientist, Nutrient and H_2S sampling, sediment coring
2	Jens Müller	21.10.-27.10.2015	IOW	pH sensor development, pH measurements of discrete water samples
3	Dr. Taavi Liblik	21.10.-26.10.2015	Tallinn University of Technology	CTD measurements, maintenance
4	Villu Kikas	21.10.-26.10.2015	Tallinn University of Technology	CTD measurements, maintenance
5	Eva Fritzsche	21.10.-27.10.2015	Graz University of Technology	CO_2 and O_2 – trace oxygen sensor development
6	Christoph Staudinger	21.10.-27.10.2015	Graz University of Technology	pH and O_2 – trace oxygen sensor development
7	Dr. Gunnar Jakobs	21.10.-27.10.2015	University of Helsinki	Methane, N2O and Methane oxidation rates sampling
8	Irina Suhhova	26.10.-27.10.2015	Tallinn University of Technology	CTD measurements, maintenance
9	Fred Buschmann	26.10.-27.10.2015	Tallinn University of Technology	CTD measurements, maintenance

7 Station List

Stat.No.	Stat.Name	Latitude	Longitude	Lot-Depth [m]		Date	Time [UTC]	CTD cast(s)	Remarks
	Tallinn harbour	59°27,24'N	24°44,34'E		Begin	21.10.2015	5:25		Start of the cruise PROSID2014
1	GoF-2	59°32,2'N	24°08,4'E	83	Begin	21.10.2015	7:46	2015_024001	1 CTD, 5 PH samples,
					End	21.10.2015	8:05		1 H2S sample
2	GoF-3	59°27,4'N	23°29,4'E	95	Begin	21.10.2015	10:30	2015_024002	1 Frahmlot, 1 CTD,
					End	21.10.2015	11:45		8 pH samples, 2 H2S samples, 8 FC samples, 22 Nutrient samples
3	GoF-4	59°20,7'N	22°31,1'E	103	Begin	21.10.2015	14:42	2015_024003	1 CTD, 3 pH samples,
					End	21.10.2015	15:05		8 FC samples, 24 Nutrient samples
4	GoF-5	59°09,844'N	21°49,5403'E	144	Begin	21.10.2015	18:31	2015_024004	1 CTD, 4 H2S samples,
					End	21.10.2015	19:10		8 FC samples, 24 Nutrient samples
	transit					21.10.2015			bad weather, >2 m waves, strong SSW wind, going in the cover of Saaremaa
	Veere harbour	58°27,7'N	22°3,1'E	5,5	Begin	22.10.2015	1:17	2015_024005	wow - waiting on weather, 4 CTD, pH samples, pH sensor tests in the harbour
					End	23.10.2015	5:45	2015_024006	transit to TF271
								2015_024007	
								2015_024008	
	transit								bad weather, >2 m Waves, strong WNW (6 Bft, gusts 7 Bft), going in the cover of Saaremaa, SW
	Saaremaa southwest	57°55,01'N	22°4,56'E		Begin	23.10.2015	20:00		anchored, wow, CO2 sensor test
					End	24.10.2015	6:45		transit to TF271
5	TF0271	57°19,2'N	20°03,1E	242	Begin	24.10.2015	11:45	2015_024009	meeting R/V Poseidon 11:45-14:30 UTC
					End	25.10.2015	0:00	2015_024010	5 CTD, 42 Nutrient samples, 14 FC samples,
								2015_024011	15 Methane samples, 15 N2O samples,
								2015_024012	15 Methane oxydation rates samples,
								2015_024013	5 pH samples,
								2015_024014	CO2 sensor test 5 depths
								2015_024015	
6	TF0286	57°59,9'N	19°57,1'E	176	Begin	25.10.2015	6:03	2015_024016	position 3 km eastwards of planned coordinates
					End	25.10.2015	7:25		1 CTD, 16 Nutrient samples, 6 FC samples, 3 H2S samples, 6 pH samples, 8 Methane samples, 8 N2O samples, bad weather to do a 2nd cast taking the upper samples (<60 m)

Note, October 25th, 7:30 UTC: weather 5-6 Bft, 2 m waves, shortened program to avoid that the forecasted storm (30-35 kn NW) reaches us in the central northern Gotland Basin, direct track to Tallinn with some station on the way

Stat.No.	Stat.Name	Latitude	Longitude	Lot-Depth [m]		Date	Time [UTC]	CTD cast(s)	Remarks
7	TF285	58°26,4'N	20°19,8'E	121	Begin	25.10.2015	10:41	2015_024017	1 CTD, 24 Nutrient samples, 8 FC samples, 2 H2S samples, 8 pH samples, bad weather 2,5 m waves
					End	25.10.2015	11:00		
8	nGB-7	58°51,8'N	20°37,8'E	175	Begin	25.10.2015	14:08	2015_024018	1 CTD, 24 Nutrient samples, 8 FC samples,
					End	25.10.2015	14:40		4 H2S samples, 7 pH samples, bad weather 2,5 m waves, wind W 6-7 Bft
	transit								bad weather, stop of scientific program, going directly to Talinn
	Tallinn harbour				Begin	26.10.2015	5:00		wow, 6 Bft, gusts 7 Bft
					End	26.10.2015	18:10		starting again, central Gulf of Finland
9	GoF-6	59°41,19'N	24°37,26'E	84	Begin	26.10.2015	20:00	2015_024019	1 CTD, 21 Nutrient samples, 7 FC samples,
					End	26.10.2015	20:45		1 H2S sample, 8 pH samples
10	GoF-1	59°45,31'N	25°00,00'E	73	Begin	26.10.2015	22:35	2015_024020	1 CTD, 21 Nutrient samples, 7 FC samples,
					End	26.10.2015	23:15		1 H2S sample, 8 pH samples, 1 Frahmlot
11	GoF-7	59°33,88'N	24°52,97'E		Begin	27.10.2015	0:45	2015_024021	CO2, O2 sensor test 4 depths, 7 pH samples
					End	27.10.2015	5:45		
	transit								weather worsening again, wind 6 Bft, turning to NNW, afternoon 7 Bft
	Tallinn harbour	59°27,24'N	24°44,34'E		End	27.10.2015	7:45		End of cruise

Scientific equipment:
CTD + Rosette water sampler, towable CTD, pH and Alkalinity sensors, pH and CO_2 in situ sensors, Ferrybox – temperature, salinity, oxygen and conductivity measurements in surface waters, Frahm-Lot (sediment corer)

8 Acknowledgements

This work was supported by the European Union and Tallinn University of Technology, under the EUROFLEETS2 initiative. Finally, the author would like to thank the captain and the crew of the Salme-cruise 2015_14.

9 References

Mohrholz, V., Naumann, M., Nausch, G., Krüger, S., Gräwe, U., 2015. Fresh oxygen for the Baltic Sea – An exceptional saline inflow after a decade of stagnation. Journal of Marine Systems 148, 152-166.

10 Attachments

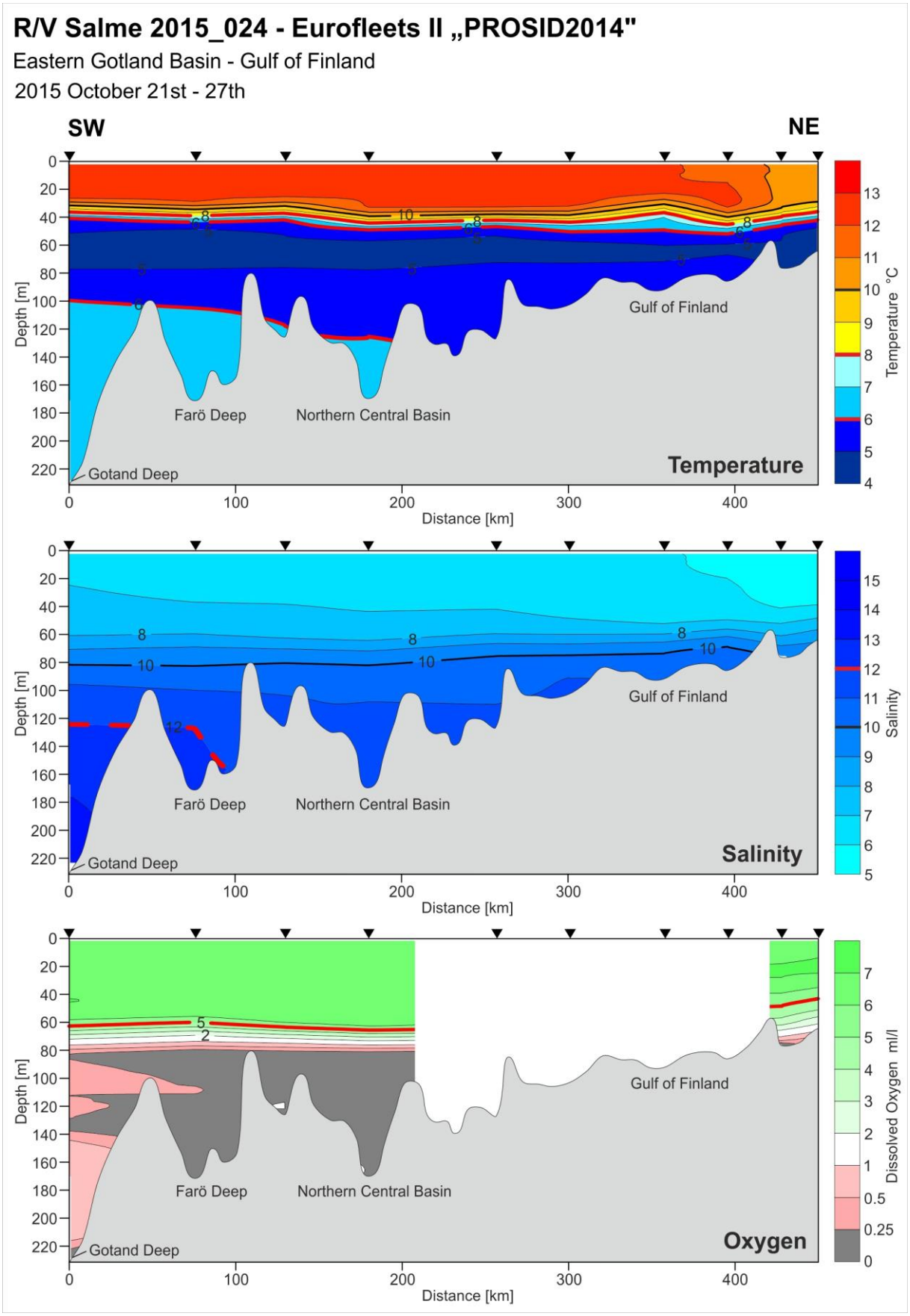
Table 1: Preliminary results of selected parameters in the near bottom water layer (unvalidated results)

Figure 2: Cross sections showing the hydrographic parameters temperature, salinity and oxygen in the water column of the key areas

Figure 3: Temperature, Salinity, Oxygen plot of stations in the central Baltic Sea and the Gulf of Finland

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

Area Date	Station Name /No.*	Temp. °C	Sal. psu	O_2 ml/l
Gotland Deep 24.10.2015	6.86	13.42	0.02	(no H_2S)
Farö Deep 25.10.2015	TFO286 /6	6.52	12.23	H_2S
Northern Gotland Basin 25.10.2015	nGB-7 /8	6.17	11.56	H_2S
Gulf of Finland 26.10.2015	GoF-1 /10	4.86	9.4	slightly H_2S



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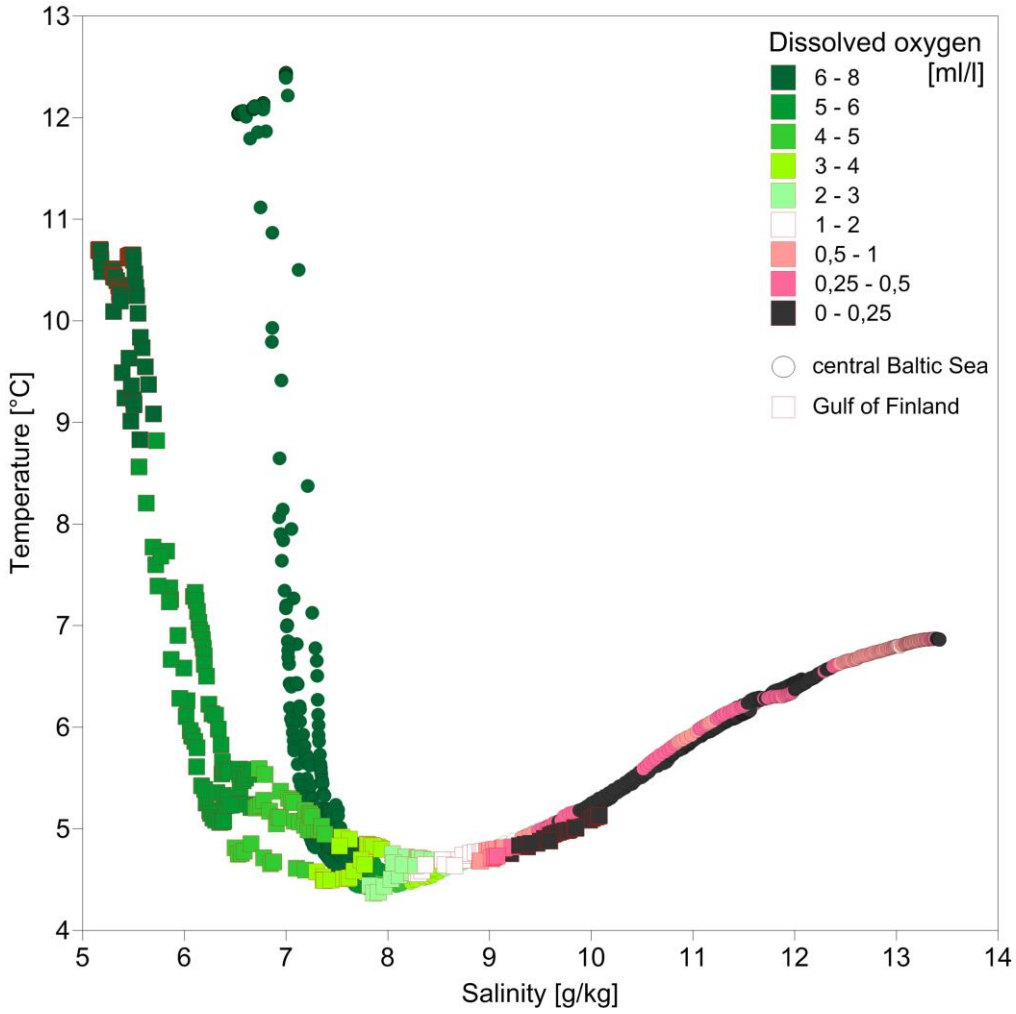

Fig. 3: Salinity, Temperature, Oxygen plot of stations in the central Baltic Sea (squares) and the Gulf of Finland (circles)

Warnemünde 22nd November 2015

Dr. Michael Naumann
(Scientist in charge)