Eurofleets+

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CRUISE REPORT

CABLE

RV ARANDA, CABLE-1 AND CABLE-2

04.04.– 09.04.2022 AND 09.10.-14.10.2022

HELSINKI– HELSINKI

Taavi Liblik

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1 Summary

Two cruises were arranged to study the circulation and current structure of the Baltic Sea.

The main objectives/activities of the leg-1 cruise were: deploy current-meter moorings to the central Baltic Sea; deploy wave buoys and current meter mooring to the Gulf of Finland; replace wave buoy near Gotland Island; recover Argo float in the Eastern Gotland Basin; conduct vertical profiling and sampling for nutrient analyses in the zonal transect in the Baltic Proper and at the transect from the southern Baltic to the Gulf of Finland; collect surface sediment samples and sediment cores from selected stations. It has to be noted that in addition to the Eurofleets+ funded four days, the cruise was funded by two days by FMI. Thus, cruise lasted altogether 6 days and additional tasks (compared to the Eurofleets+ CABLE proposal) were carried out. We experienced unusually strong wind for the spring season in the CABLE leg-1. Work was stopped two times due to heavy wind and high waves. However, all planned activities were carried out.

The main objectives/activities of the leg-2 cruise were: recover current-meter moorings from the central Baltic Sea; replace wave buoy near Gotland Island; recover Argo float in the Eastern Gotland Basin; conduct vertical profiling and sampling for nutrient analyses in the zonal transect in the Baltic Proper and at the transect from the southern Baltic to the Gulf of Finland; replace mooring in the H2O station; collect surface sediment samples and sediment cores from selected stations for the co-pi project DOMUSe. In addition to the Eurofleets+ funded five days (four days for CABLE and one day for DOMUSe), the cruise was funded by two days by FMI. Thus, cruise lasted altogether 7 days and additional tasks (compared to the Eurofleets+ CABLE proposal) were carried out. Weather allowed us to work most of the time and all planned activities were carried out.

Students training were carried out onboard. Four CTD-operator licences were issued after training.

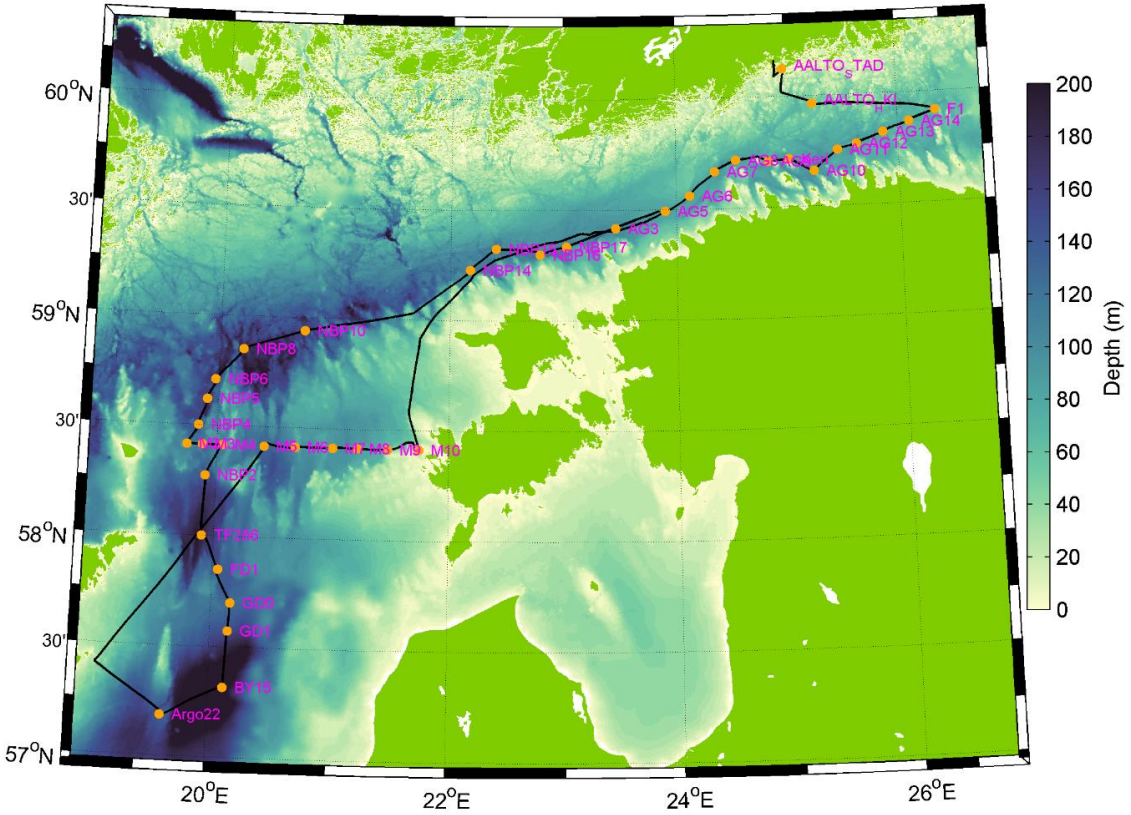

Fig. 1.1 Working area and track chart of R/V ARANDA CABLE cruise leg-1.

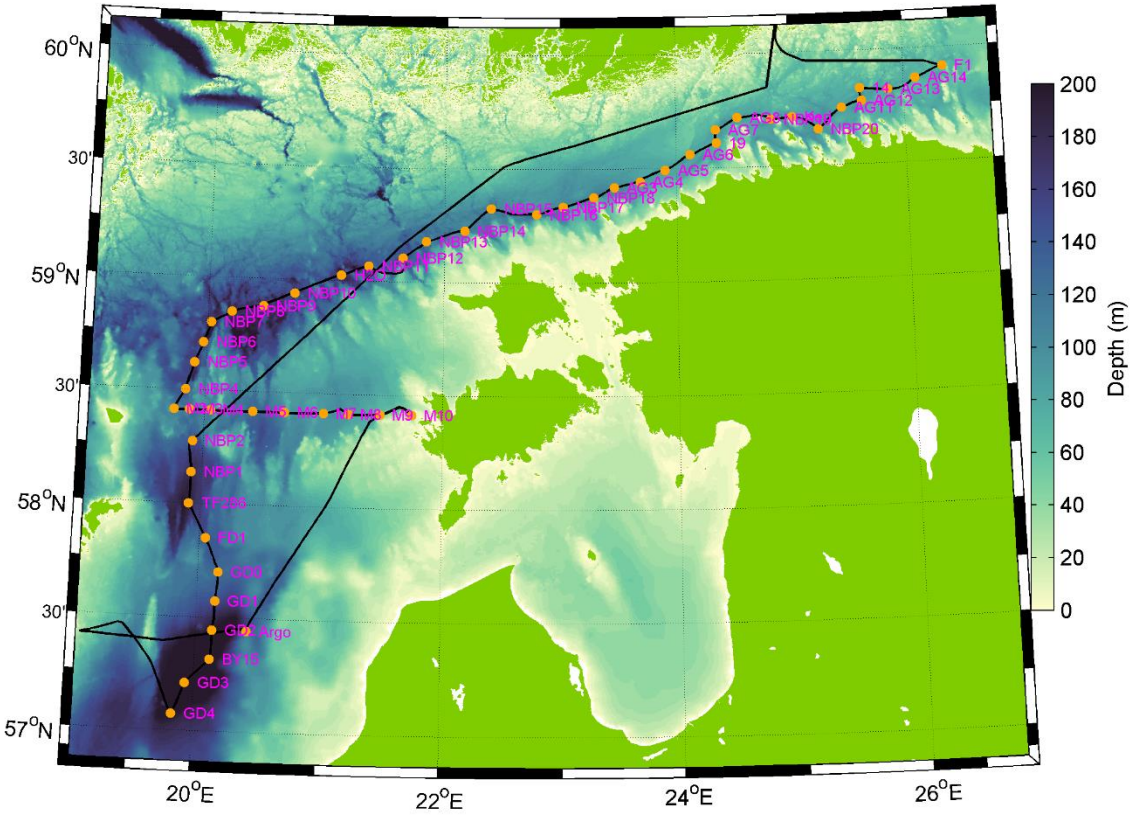

Fig. 1.2 Working area and track chart of R/V ARANDA CABLE cruise leg-2.

2 Research Programme/Objectives

There were two main activities of the field work planned in CABLE: 1) Deployment and recovery of moorings in the Central Baltic Sea; 2) Profiling and sampling at stations. The primary goal was to deploy/recovery of moorings and profiling/sampling was done as much as time schedule and weather allowed.

Due to the COVID-restrictions the originally planned cruises in 2021 spring and autumn were postponed to 2022. In the meantime we investigated currents in the Baltic Proper (Liblik et al., 2022). As a result of the new findings we decided to shift the mooring array to further north. The main purpose of the change was the fact that the simulation results hinted Farö sill as important spot for deep water exchange between Central Baltic Proper and Northern Baltic Proper. Thus, the mooring array was deployed at the zonal transect shown in figure 1.1. Ten moorings were deployed instead of twelve as planned originally. The reason for the slightly reduced program was related to the one year delay of the experiment and to the fact that Russian institution was excluded from the experiment due to invasion in Ukraine. For practical reasons moorings M2-M4 were deployed/recovered by German research vessels and M1 was deployed by VOTO

(Voice of the Ocean). M5-M10 were deployed/recovered from Aranda. Deployments and recoveries of all moorings (M1-M10) were successful.

As planned, rest of the vessel time was used for water and sediment sampling. The collected dataset allows us to investigate the scientific questions raised in the Eurofleets+ proposal:

What are the mean and seasonal horizontal and vertical current patterns at the selected cross-section? What are the mean meridional transports through this cross-section? What is the quantified contribution of forcing factors (particularly wind) in driving the sub-surface currents? b) What are the connections between the sub-surface circulation in the Central Baltic Sea and the changes in the water properties in the Northeastern Baltic Sea? c) What is the spatial and temporal variability of the current structure? What is the kinetic energy distribution at the selected cross-section? d) How good are the simulation skills of the available state-of-the-art numerical ocean circulation models in the area? e) What is the impact of current structure and gradients in physical variables to the distribution of vegetative cells and cysts of Scrippsiella complex in the Eastern Baltic Sea?

In addition, the research program of the co-pi project DOMUSe (led by Alexandra Loginova) were conducted in the CABLE leg-2.

3 Narrative of the Cruise

3.1. Leg-1

04.04.2022

After departure from Archipelago, we gathered for safety drill and scientists meeting.

First, two wave buoy moorings (AALTO_STAD and AALTO_HKI) were deployed by FMI. ADCP current profiler was deployed to the AALTO_HKI as well. We also conducted CTD profiling for testing and training purposes in both locations. The first CTD station had index 57.

After the deployments, we headed east to the Estonian national monitoring station F1, from where we started a section along the thalweg of the Gulf of Finland towards the west. From selected stations, nutrient samples and surface sediments were collected. Early career students started training of the CTD system.

One person felt sick (fever) in the evening and he isolated himself in the cabin. He made a COVID test, which was negative.

Table 1. Stations made on 4th April

CTD index	Hour UTC	Minute UTC	CTD station count	Station name	Moorings/float
57	6	36	1	AALTO_STAD	Wave buoy deployment (FMI)
58	9	40	2	AALTO_HKI	Wave buoy and ADCP deployment (FMI)
59	15	0	3	F1	
60	17	15	4	AG14	
61	19	10	5	AG13	
62	20	42	6	AG12	
63	22	30	7	AG11	

05.04.2022

We continued towards west and conducted measurements at the thalweg of the section.

Air temperature varied in the range of 0 to +1 °C and wind from south and southeast, mostly with speed of 10-15 m/s prevailed until 08:00 UTC. After that the wind turned to west and its speed increased over 20 m/s. We stopped working, when the vessel was not able to keep its position at the station AG4. Wind speed stayed over 20 m/s for eight hours and was around 25 m/s for few hours. We continued heading towards west, but with speed of 2-3 knots. Weather improved at night and we headed towards M10 station (near Vilsandi Island).

Measurements in the Gulf of Finland revealed weak haline and inversed thermal stratification and elevated Chl-a values in the upper layer. Deep layer was isolated by well defined halocline. There was longitudinal salinity gradient, both in the upper layer and in the deep layer. Likewise, temperature and oxygen gradient observed in the deep layer along the gulf. Dissolved oxygen was around 3 mg/l in the easternmost part of the section, but zero in the easternmost part of the section.

Table 2. Stations made on 5th April

CTD index	Hour UTC	Minute UTC	CTD station count	Station name
64	0	5	8	AG10
65	1	22	9	Keri

66	3	5	10	AG9
67	4	30	11	AG8
68	5	45	12	AG7
69	7	13	13	AG6
70	9	0	14	AG5

06.04.2022

Today we deployed moorings across the Baltic Proper. It was quite challenging in the morning as waves were still quite high, but it calmed down in the afternoon. It went more or less smoothly, except at M8, where we deployed the mooring first too early- failure with releasing of the mooring. We collected the mooring again and deployed it again. In all stations, CTD profiles and water samples for nutrient analysis were collected.

After mooring deployments, we decided to leave the section and head to south, in order to reach the Argo float in daylight next day.

Table 3. Stations made on 6th April

CTD index	Hour UTC	Minute UTC	CTD station count	Station name	Moorings/floats
71	5	6	15	M10	Single point current meter (TalTech)
72	8	22	16	M9	ADCP+CTD (LIAE)
73	11	30	17	M8	ADCP (TalTech)
74	17	0	18	M7	ADCP (SMHI)
75	20	0	19	M6	ADCP (FMI)
76	22	35	20	M5	ADCP (FMI)

07.04.2022

We started work near Gotland Island, recovered wavebuoy and deployed new one. Secondly, we picked up Argo float southwest from the Gotland Deep. CTD-profile at the pickup location was conducted to calibrate the Argo float sensors. In the afternoon, we started the section from Gotland Deep (BY15) towards Gulf of Finland. There was moderate wind 6-12 m/s from southwest during the day.

Water column was well mixed down to the halocline in the Baltic Proper. Although Chl-a fluorescence still showed slightly elevated values in the upper layer. Anoxia was established below the sharp halocline. Small intrusion of warmer and saltier water was found in the depth of 110 in the Gotland Deep. The intrusion contained small amount of oxygen, unlike the water below and above the feature.

Table 4. Stations made on 7th April

CTD index	Hour UTC	Minute UTC	CTD station count	Station name	Moorings/floats
				Gotland Wave buoy	Wave buoy (FMI)
77	11	48	21	Argo22	Argo float (FMI)
78	14	0	22	BY15	
79	16	55	23	GD1	
80	19	0	24	GD0	
81	20	35	25	FD1	
82	23	8	26	TF286	

08.04.2022

We continued the cruise with CTD stations in the Farö Deep and completed the zonal section (M2-M4). We used another CTD to record the last meters above seafloor at M3. After M2 we continued towards the Gulf of Finland. Strong SW wind and high waves made us stop sampling after station NBP10. Thus, we headed towards the Gulf of Finland and hoped to continue sampling if the weather improves.

We noted that there is an offset in the pressure sensor of the main CTD: -1.4 db. It used to be -0.7 db in March 2022 according to FMI.

Table 5. Stations made on 8th April.

CTD index	Hour UTC	Minute UTC	CTD station count	Station name
83	2	7	27	NBP2
84	3	56	28	M4
85	5	15	29	M3
86	6	52	30	M2
87	8	15	31	NBP4
88	10	0	32	NBP5
89	11	30	33	NBP6
90	13	20	34	NBP8

09.04.2022

We continued sampling at station NBP14. We made a repeat CTD profile (the first profile was made on the 5th of April) at AG5. A comparison of profiles revealed the vertical mixing and weakening of the stratification had occurred in the upper part of the water column. The deep layer was fresher compared to the previous measurement, indicating the reversal of estuarine circulation (Liblik et al., 2013) due to southwesterly wind impulse. After AG5 we headed to Helsinki and arrived there around 17:00 UTC. Before arrival to Helsinki we gathered for scientists meeting.

3.2. Leg-2

08-10.10.2022

We gathered onboard on 8th October, but left harbor on 9th October. Due to windy weather forecast in first days of the cruise, we decided to do the most weather sensitive works later. Thus, we headed straight to the Baltic Proper and started with the CTD section towards south from the station NBP2 on 10th October. Several CTD probes (SBE19plus, SBE16plus, SBE37-ODO from TalTech) were attached to the RV Aranda

Rosette for calibration purposes. Likewise, two gliders (from VOTO and FMI) were piloted to the station for the calibration. Besides regular water sampling, sediment cores for the co-pi project activities were carried out in next station (NBP1). Quite strong (15-17 m/s) southerly-southwesterly wind generated high waves in the evening, but we managed to continue with CTD-stations while moving towards south.

Table 6. Stations made on 10th October.

CTD index	Hour UTC	Minute UTC	Latitude	Longitude	CTD station count	Station name
393	8	50	58.2733	19.91	1	NBP2
394	10	40	58.1367	19.91	2	NBP1
395	15	32	58	19.899	3	TF286
396	18	5	57.85	20.05	4	FD1
397	20	37	57.7	20.1667	5	GD0
398	22	7	57.5722	20.15	6	GD1
399	23	56	57.4444	20.135	7	GD2

11.10.2022

We continued CTD and water sampling in stations BY15, GD3 and GD4. After that we headed to west to service wavebuoy of FMI. After latter we headed back to the Gotland Deep area to catch the Argo float of FMI. It was quite tricky to catch the float as waves were still high. After recovery we made CTD cast for calibration purposes of the float. Next we headed to the M10 station, west of Vilsandi Island.

Table 7. Stations made on 11th October.

CTD index	Hour UTC	Minute UTC	Latitude	Longitude	CTD station count	Station name	Moorings/floats
400	1	41	57.3167	20.125	8	BY15	
401	3	56	57.21	19.93	9	GD3	
402	6	0	57.0717	19.83	10	GD4	
					Gotland Wave buoy	Wave buoy (FMI)	Wave buoy service
404	14	35	57.4432	20.4168	11	Argo	Argo float recovery

12.10.2022

We started working at the M10 station early morning. As the mooring did not have releaser system, we pulled the mooring out by dragging. The moored single point current meter was in healthy state and we immediately downloaded the data. After recovery, we did regular CTD station.

Next we recovered moorings from M9, M8, M7, M6 and M5 station. All releasers worked well and recovery operations went smoothly. Recovered acoustic current meters were in good condition. We competed the zonal section by profiling and sampling the M2 and M3 station. Next we started long section from NBP4 station towards Gulf of Finland.

Table 8. Stations made on 12th October.

CTD index	Hour UTC	Minute UTC	Latitude	Longitude	CTD station count	Station name	
405	6	59	58.4125	21.7400	12	M10	Mooring carrying single point current meter recovered
406	8	29	58.4125	21.4736	13	M9	Moorings carrying acoustic current meter recovered
407	10	39	58.4125	21.2071	14	M8	
408	13	5	58.4125	21.0000	15	M7	
409	15	6	58.4125	20.6743	16	M6	
410	16	50	58.4125	20.4079	17	M5	
411	19	8	58.4125	20.0500	18	M4	
412	20	20	58.4125	19.8750	19	M3	
413	21	36	58.4125	19.7434	20	M2	
414	22	30	58.5000	19.8340	21	NBP4	
415	23	45	58.6200	19.9000	22	NBP5	

13.10.2022

We continued profiling and water sampling along the section towards Gulf of Finland. Sediments cores were taken from H2O station for the co-pi project. We also replaced deep water mooring carrying SBE37 probe at 200 m depth in the H2O station. The recovered probe was attached to the RV Rosette in the NBP11 station and parallel measurements were conducted for calibration purposes.

Table 9. Stations made on 13th October

CTD index	Hour UTC	Minute UTC	Latitude	Longitude	CTD station count	Station name
416	1	5	58.7100	19.9700	23	NBP6
417	2	13	58.8000	20.0300	24	NBP7
418	3	15	58.8500	20.2000	25	NBP8
419	4	56	58.8800	20.4650	26	NBP9
420	6	23	58.9400	20.7300	27	NBP10
421	8	28	59.0236	21.1225	28	H2O
424	14	26	59.0674	21.3535	29	NBP11
425	17	0	59.1038	21.6443	30	NBP12

426	18	13	59.1792	21.8428	31	NBP13
427	20	0	59.2279	22.1724	32	NBP14
428	21	32	59.3250	22.4000	33	NBP15
429	23	35	59.3000	22.7900	34	NBP16

14-15.10.2022

We continued profiling and water sampling along the section towards Gulf of Finland and arrived to the easternmost station F1 around midnight. Sediment cores were collected for the co-pi project at the station Keri. After station F1 we headed back to Helsinki and arrived there early morning on 15th October. Only underway measurements (meteorological measurements, thermosalinograph) were collected on the way.

Table 10. Stations made on 14th October

CTD index	Hour UTC	Minute UTC	Latitude	Longitude	CTD station count	Station name
430	0	46	59.3333	23.0200	35	NBP17
431	2	16	59.3750	23.2833	36	NBP18
432	3	20	59.4175	23.4595	37	AG3
433	4	30	59.4433	23.6850	38	AG4
434	5	50	59.4933	23.9017	39	AG5
435	7	3	59.5600	24.1200	40	AG6
436	8	15	59.6088	24.3502	41	19
437	9	15	59.6667	24.3467	42	AG7
438	10	24	59.7183	24.5367	43	AG8
439	12	0	59.7083	24.8300	44	NBP19
440	13	0	59.7162	25.0141	45	Keri
442	16	19	59.6600	25.2400	46	NBP20
443	17	34	59.7517	25.4517	47	AG11
444	18	40	59.7783	25.6267	48	AG12
445	19	38	59.8333	25.6161	49	14
446	20	50	59.8242	25.8654	50	AG13
447	22	44	59.8701	26.1040	51	AG14
448	23	58	59.9161	26.3427	52	F1

4 Preliminary Results

4.1. Water sampling with CTD/Rosette

We observed weak haline and inversed thermal stratification and elevated Chl-a values in the upper layer in the Gulf of Finland in April. The water column was well mixed down to the halocline in the Baltic Proper. Anoxia was established below the sharp halocline in the Baltic Proper while ca 3 mg/l oxygen concentration was observed in the near-bottom layer of the central Gulf of Finland. There was a longitudinal gradient of oxygen, salinity, and temperature in the deep layer between the central Gulf of Finland and northern Baltic Proper. Likewise, a gradient existed in the upper layer: water in the gulf was colder and fresher.

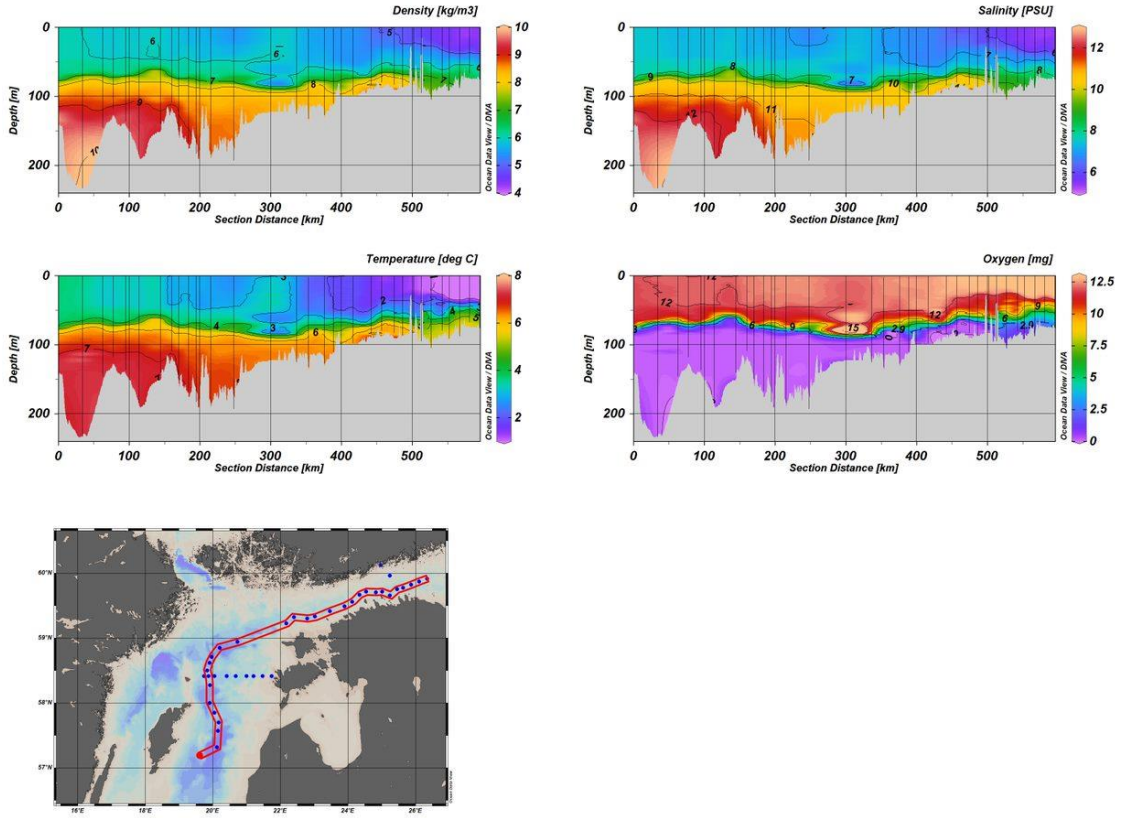

Fig. 4.1. Vertical section of temperature, salinity, density and dissolved oxygen from the Gotland Deep to the Gulf of Finland in April 2022.

Seasonal stratification was still present in the whole section from the Gotland Deep to the Gulf of Finland in October. Anoxia was established below the sharp halocline in the Baltic Proper. Oxygen depletion started at lower salinity in October compared to spring indicating the seasonal oxygen consumption. Temperature and salinity in the deep layer of the Gotland Deep had only slightly changed since April likely due to vertical mixing. Thus, no remarkable arrival of new water occurred in the Gotland Deep. Downwelling event were observed at the eastern coastal slope of the Baltic Proper.

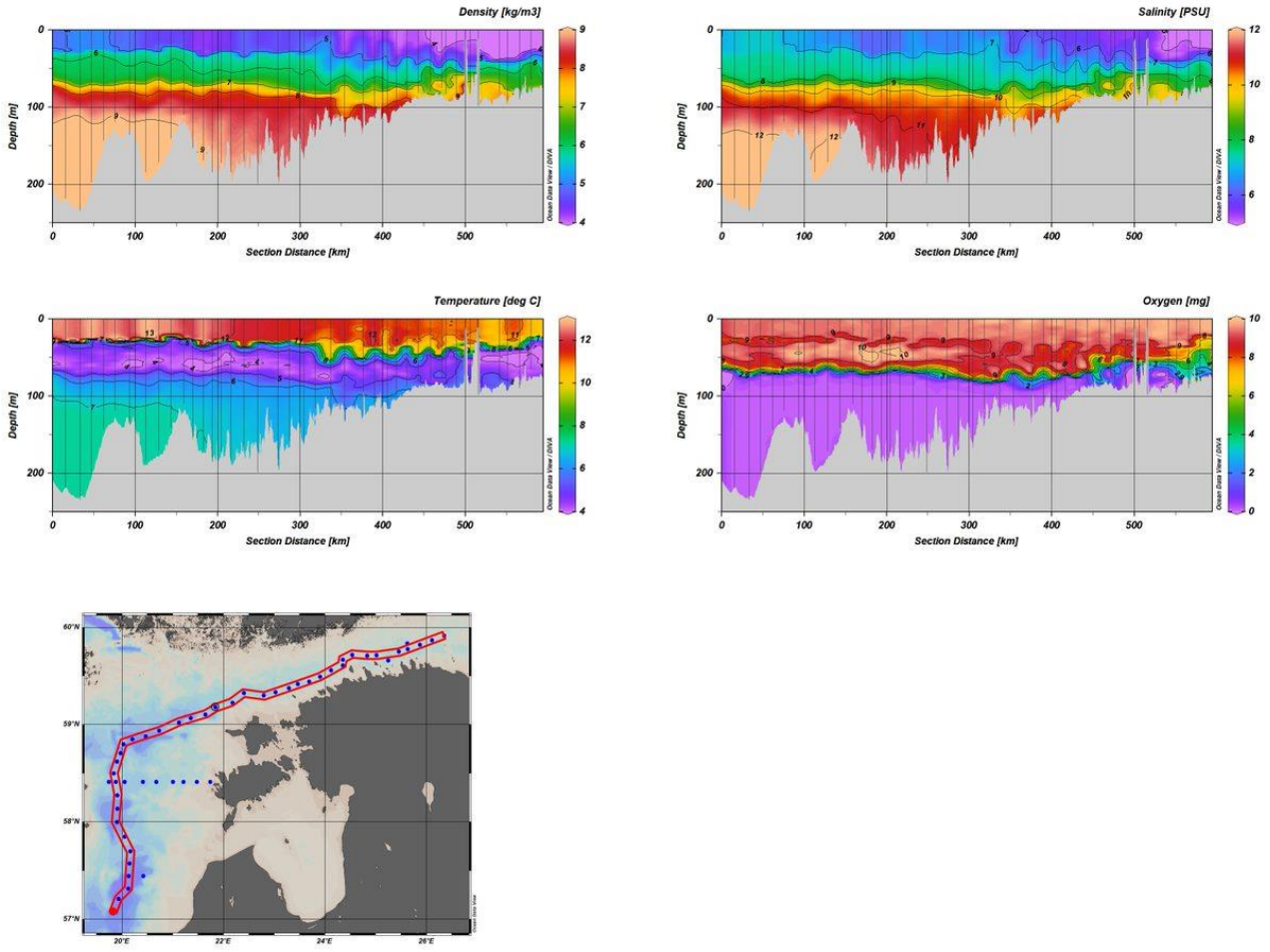

Fig. 4.2. Vertical section of temperature, salinity, density and dissolved oxygen from the Gotland Deep to the Gulf of Finland in October 2022.

4.2. Current measurements

Various processes can be seen in the preliminary processed data of the current measurements. Stronger current were observed closer to the coast at the M9 and M10 station. Strong barotropic current were observed at M9 in early March. Otherwise current was baroclinic at M9 and in other deeper stations. Upwelling yet with compensating onshore flow in the deep layer were observed at the M9. Intermediate layer current and subhalocline current was of usually in opposite direction in the section. In summer period the current structure was often three-layered, i.e. there was current shear maxima both in the seasonal therocline and in the halocline. Currents were weaker (compared to nearshore areas) further offshore at stations M6 and M5.

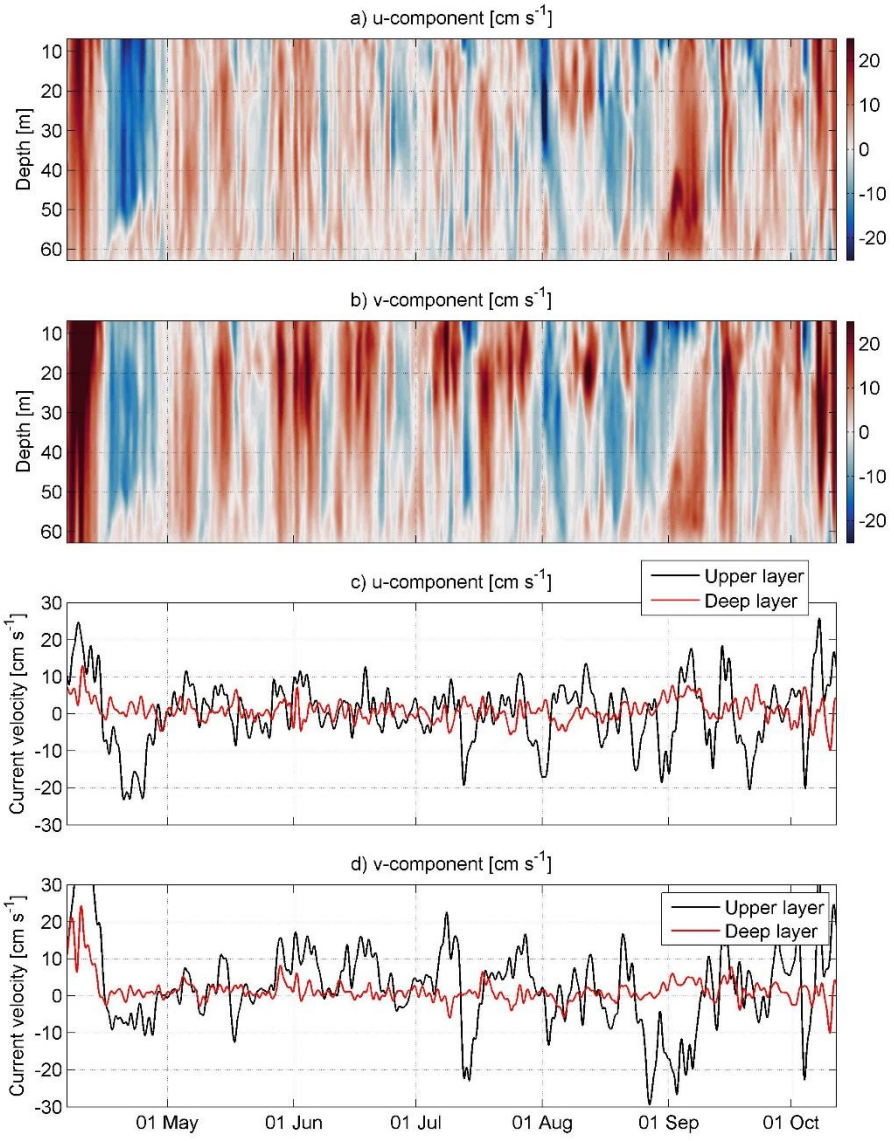

Fig. 4.3. Time-series of current low-passed u-component and v-component at M9.

5 Data and Sample Storage / Availability

FMI and TalTech process and compile the shipborne CTD and sampling data. TalTech also collects the ADCP raw data and applies the uniform data processing routines for all the time-series. After that TalTech will make the data available for everyone.

6 Participants

LEG-1

No.	Name	Early career (Y/N)	Gender	Affiliation	On-board tasks
1	Taavi Liblik	N	M	TalTech	Chief scientist
2	Villu Kikas	Y	M	TalTech	Moorings, CTD/sediment sampling assistance
3	Fred Buschmann	N	M	TalTech	Moorings, oxygen sampling, CTD/sediment sampling assistance
4	Oliver Samlas	Y	M	TalTech	CTD watch
5	Sirje Sildever	Y	F	TalTech	Sediments, assist with water sampling
6	Simo Siiriä	N	M	FMI	CTD, underway data, Argo float
7	Tuomo Roine	N	M	FMI	Moorings, CTD
8	Maris Skudra	Y	M	LIAE	Moorings, CTD
9	Miks Papirtis	Y	M	LIAE	Moorings, CTD
10	Diana Maslova	Y	F	TalTech	Water sampling, assist with sediments
11	Kai Salm	Y	F	TalTech	CTD watch, dissimination
12	Erkka Ilonen	N	M	FMI	Moorings, CTD
13	Kristian Pärt	Y	M	TalTech	Sediments, water sampling
14	Sami Pusa	N	M	FMI	Moorings, CTD watch

LEG-2

No.	Name	Early career (Y/N)	Gender	Affiliation	On-board tasks
1	Taavi Liblik	N	M	TalTech	Chief scientist
2	Villu Kikas	Y	M	TalTech	Moorings, CTD/sediment sampling assistance
3	Fred Buschmann	N	M	TalTech	Moorings, oxygen sampling, CTD/sediment sampling assistance
4	Enriko Siht	Y	M	TalTech	CTD watch
5	Sirje Sildever	Y	F	TalTech	Water sampling
6	Kimmo Tikka	N	M	FMI	CTD, underway data, Argo float
7	Tuomo Roine	N	M	FMI	Moorings, CTD
8	Marlene Kaljumäe	Y	F	TalTech	Water sampling
9	Miks Papirtis	Y	M	LIAE	Moorings, CTD
10	Kai Salm	Y	F	TalTech	CTD watch, dissimination
11	Erkka Ilonen	N	M	FMI	Moorings, CTD
12	Kinga Maria Hoszek	Y	F	IOPAN	Sediments, water sampling
13	Katarzyna Gomula	Y	F	FMI	Sediments, water sampling

All participants were funded by Eurofleets+.

TalTech Tallinn University of Technology, Tallinn, Estonia

FMI Finnish Meteorological Institute, Helsinki, Finland

LIAE Latvian Institute of Aquatic Ecology, Riga, Latvia

IOPAN The Institute of Oceanology of the Polish Academy of Sciences, Sopot, Poland

7 Acknowledgements

I would like to thank the scientific team and the ship crew for their good collaboration.

8 References

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