CRUISE REPORT

R/V Aranda

Cruise 04/2019

BONUS INTEGRAL WINTER

28 February - 11 March 2019

This report is based on preliminary data and is subject to changes.

R/V Aranda, cruise report 04/2019

BONUS INTEGRAL WINTER -cruise

28 February – 11 March 2019

Chief Scientist: Heidi Pettersson / Finnish Meteorological Institute

1. General description of the cruise

The cruise was the first of two research cruises in the BONUS INTEGRAL -project. This first cruise on R/V Aranda in the winter season will be followed by a research cruise on the German R/V Elisabeth Mann Borgese in the early summer 2019. The goal of the BONUS INTEGRAL project (2017-2020) funded within BONUS Blue Baltic call is to demonstrate and exploit the potential added value of the marine ICOS stations (Integrated carbon observation system) and similar instrumentation for the ecosystem state assessment of the Baltic Sea as a contribution to a state-of-the-art improved HELCOM monitoring. The project website is https://www.io-warnemuende.de/integral-home.html.

The purpose of the two research cruises is to provide seasonal maps for the partial pressures of carbon dioxide (pCO_2), methane (pCH_4) and nitrous oxide (pN_2O) in the Baltic Sea, especially for the Gulf of Bothnia from where there are only few observations of these parameters. A wider spatial coverage contributes to the evaluation of presentability of the continuously monitored carbon system and trace gas parameters on voluntary observing ships (VOS) that operate on certain routes in the area. Another objective is to study the carbon system in the Gulf of Bothnia.

One ice station for ice thickness studies was included in the BONUS INTEGRAL WINTER cruise, as well as buoy maintenances. There was one port call during the cruise, when the ship visited Oulu, Finland for reparations.

Map of the cruise is shown in Figure 1. In addition to the 32 stations visited, semi-continuous measurements of pCO_2, pCH_4, pN_2O, oxygen (O_2), pH, carbon monoxide (CO), sea surface salinity (SSS) and temperature (SST), Chlorophyll-a and chromophoric dissolved organic matter (CDOM) were made between the stations. In certain areas the spatial distribution was studied in more detail: the changes from the shore to open sea areas were monitored in the western parts of the Gulf of Finland, in the area near Kokemäenjoki, Finland and Ångermanälven, Sweden, the latter two in the Bothnian Sea.

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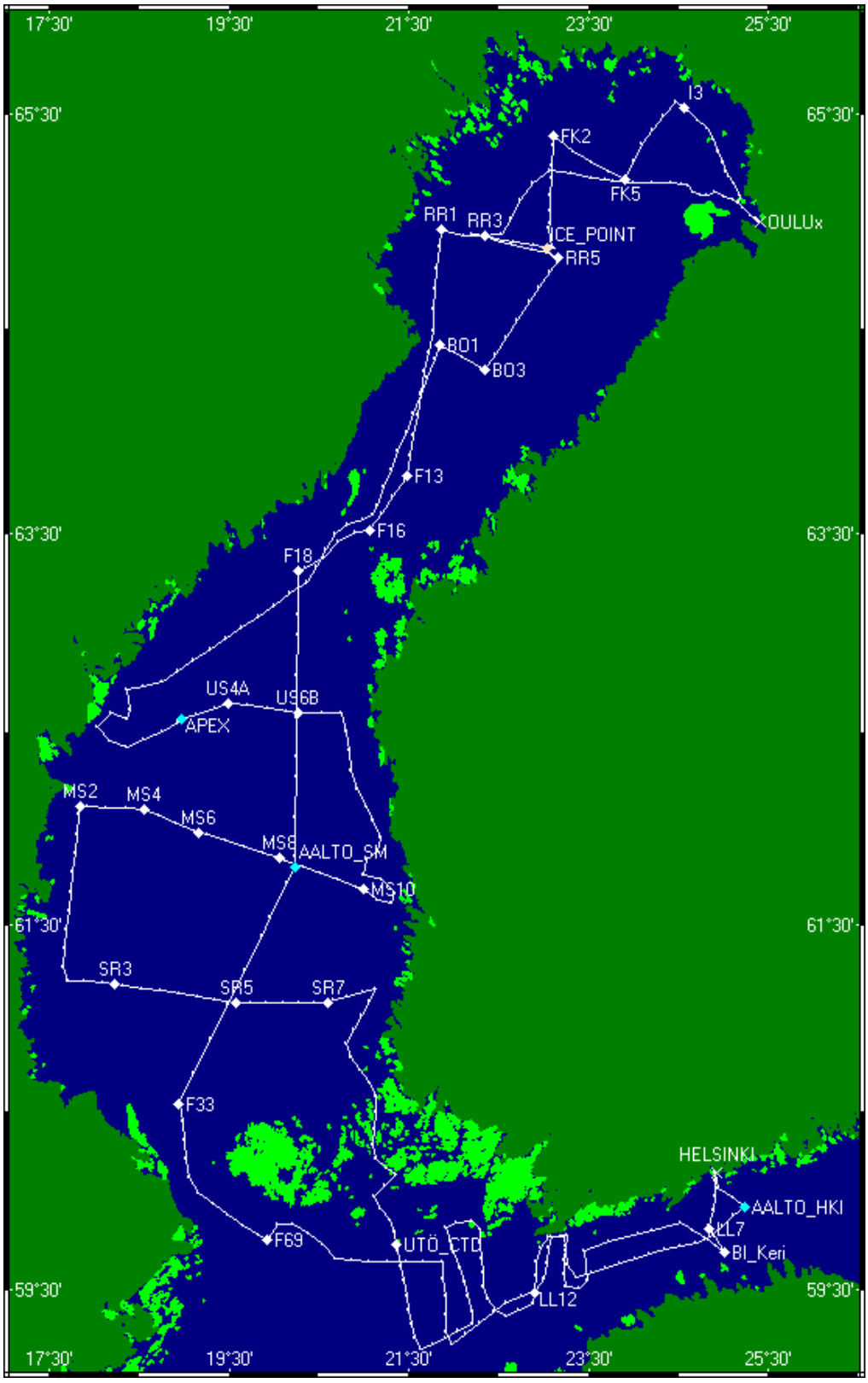

Figure 1. Track and stations of the BONUS INTEGRAL WINTER cruise 28 February - 11 March 2019.

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2. Participants

BONUS INTEGRAL partners from Finnish Meteorological Institute (FMI), Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Institute of Oceanology, Polish Academy of Science (IOPAN) and Helmholtz Centre for Ocean Research Kiel (GEOMAR) took part in the cruise. Nutrient analysis was commissioned from Finnish Environment Institute (SYKE).

In addition to FMI, IOW, GEOMAR and IOPAN contributed to this report.

Table 1. List of participants.

Scientific crew	Time on board	Organisation
Heidi Pettersson	28.02. - 11.03.2019	FMI
Milla Johansson	28.02. - 11.03.2019	FMI
Martti Honkanen	28.02. - 11.03.2019	FMI
Jonni Lehtiranta	28.02. - 11.03.2019	FMI
Tuomo Roine	28.02. - 11.03.2019	FMI
Pekka Kosloff	28.02. - 11.03.2019	FMI
Ilkka Lastumäki	28.02. - 11.03.2019	SYKE
Jenny Friedrich	28.02. - 11.03.2019	IOW
Daniel Pönich	28.02. - 11.03.2019	IOW
Jens Müller	28.02. - 11.03.2019	IOW
Anette Kock	28.02. - 11.03.2019	GEOMAR
Katarzyna Koziorowska	28.02. - 11.03.2019	IOPAN
Monika Lengier	28.02. - 11.03.2019	IOPAN

3. Observations

3.1 Environmental conditions

The ice charts in the beginning and in the end of the cruise are plotted in Figure 2. There was a warmer period just before the cruise and part of the Bay of Bothnia was

nearly ice-free. During the cruise the ice cover in the Bay of Bothnia started to grow again covering finally practically the whole Bay.

The wind speed and direction, air pressure and air temperature is plotted in Figure 3. The wind speed (10 min average) varied from nearly calm to 19 m/s during the cruise: three high wind events from north were encountered.

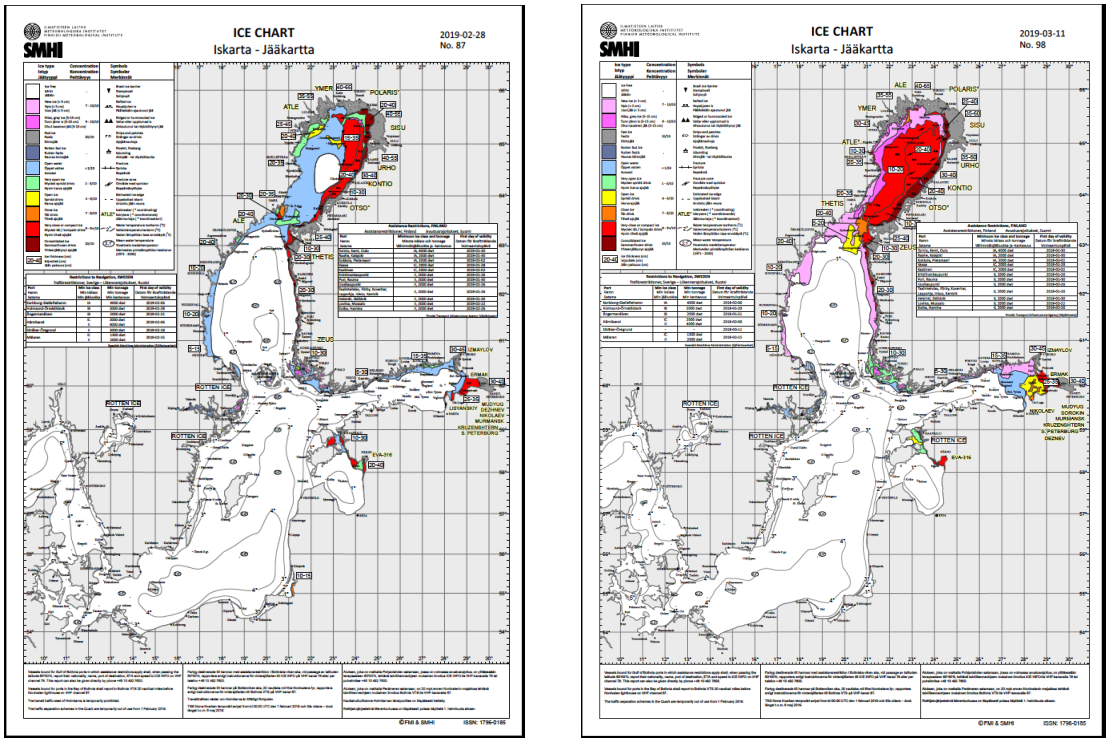

Figure 2. Ice charts on 28 February 2019 and on 11 March 2019. Source: FMI and SMHI ice services.

3.2 Hydrography

The temperature, salinity, density and oxygen profiles at each station are given in the Appendix.

In the middle of the Gulf of Finland the water was mixed down to a depth of 15 metres (stations LL7 and BI_KERI), while in the western part of the Gulf of Finland and at the edge of the Archipelago Sea (stations LL12 and UTO_CTD) the mixed layer was 30-35 metres deep.

In the Bothnian Sea the mixed layer was generally 40-70 metres deep, but variations in surface layer temperatures can be seen near the coasts (stations SR7, MS2 and MS10) and especially in the northern parts of the Bothnian Sea and Quark where colder and less saline water at the surface was observed (stations US4A, F16 and F18).

The mixed layer was 30-45 metres deep in the Bay of Bothnia. The temperature in the mixed layer was slightly above 0°C in the middle of the basin, while it was below 0°C nearer to the coast of Sweden (stations RR1 and RR3) and at the northernmost station I3 in the region of fast ice (marked with grey in the ice charts of Figure 2).

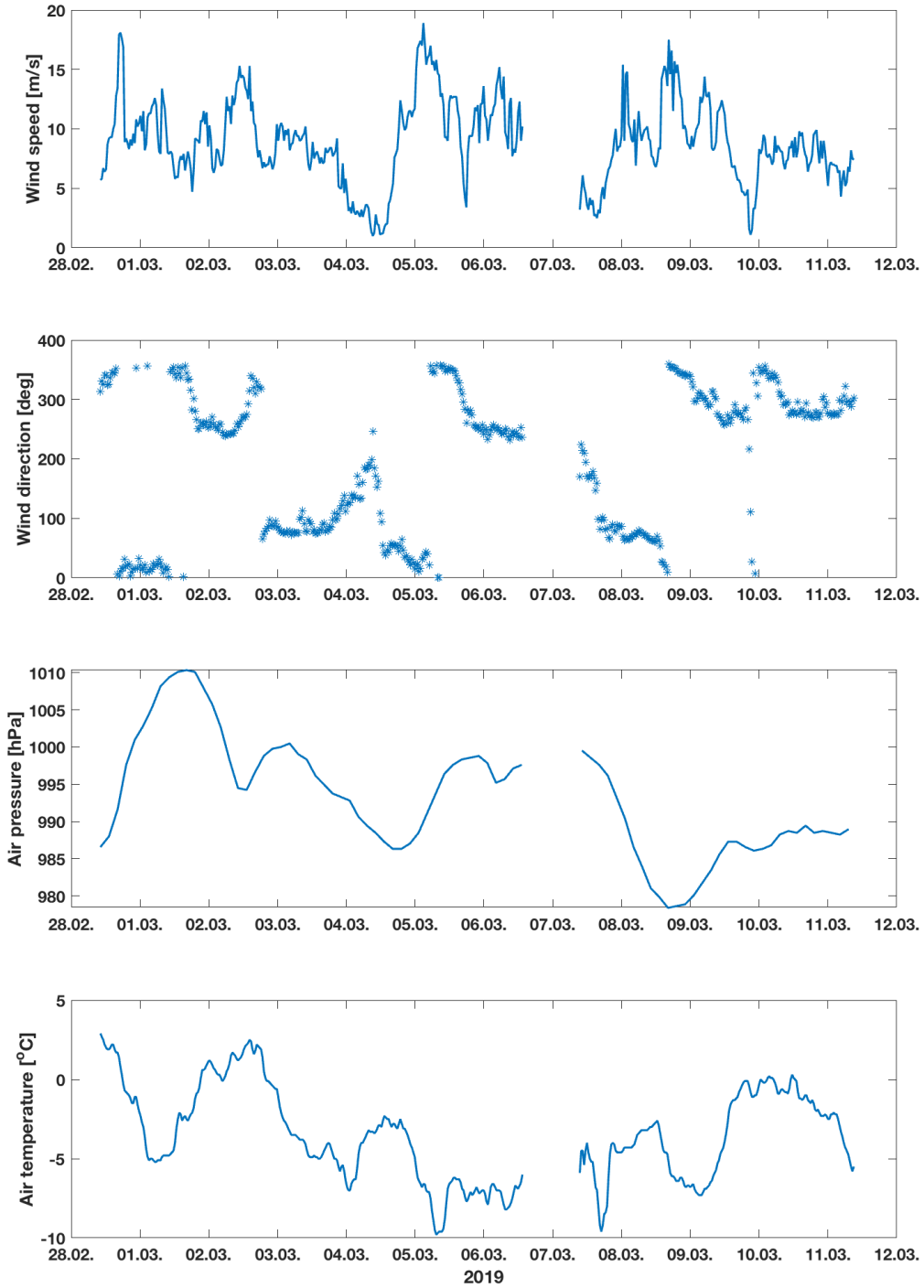

Figure 3. Meteorological conditions during the cruise.

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3.3 Flow-through measurements

Several sensors and analysers were attached to the flow-through system of the ship for monitoring the trace gases, pH, SSS, SST, Chlorophyll-a and CDOM in the surface water along the cruise track.

The IOW bubble equilibrator system consisting of the equilibrator and off-axis integrated cavity output spectroscopy sensors measured the concentrations of nitrous oxide (xN_2O), carbon monoxide (xCO), methane (xCH_4) and carbon dioxide (xCO_2). Oxygen (O_2) was measured with an oxygen optode. Also air samples were taken and analysed in regular intervals with the same analysers.

Three KM Contros HydroC sensors were attached to the flow-through system: one for the partial pressure of methane (IOW) and two for the partial pressure of carbon dioxide (FMI and IOW).

The pH of the surface water was measured with two KM Contros HydroFIA spectrophotometric sensors (IOW).

The sea surface salinity was monitored with the ship's SBE45 sensor attached to the flow-through system. The sea surface temperature was monitored with the ship's SBE38 sensor installed in the intake of the seawater near the bottom of the ship. The Chlorophyll-a and CDOM sensors were installed for the cruise by SYKE.

The flow-through measurements were done mainly in the open sea areas in the Gulf of Finland, Northern Baltic Proper and Bothnian Sea. The pump of the flow-through system was extremely sensitive for ice and was blocked as soon as there where a thin layer of ice.

The flow-through measurements will be further analysed at the respective institutes.

3.4 Water samples

Water samples were taken at the stations at selected depths with rosette bottles attached to the CTD-sonde. The deepest layer near the bottom was sampled with a separate sampler for nutrient analysis. Some water samples of the surface water were taken along the track from the flow-through system for nutrient and trace gas analysis.

The concentration for dissolved inorganic carbon (DIC) was analysed on board with an AIRICA analyser by IOW. pH was analysed with the KM Contros HydroFIA sensors attached to the flow-through system (IOW).

Filtered water samples were stored in a freezer for analysis of dissolved organic phosphorus (DOP) and particulate organic phosphorus (POP) for further analysis at IOW. Also samples for isotopes, CH_4, N_2O and total alkalinity (TA) analysis at IOW were taken.

Water samples were filtrated for particulate organic carbon (POC) and particulate organic nitrogen (PON) analysis. The sample filters were frozen and dried. Filtered

water samples were stored for analysis of dissolved organic carbon (DOC) and dissolved organic nitrogen (DON). The final analysis of these samples will be made after the cruise at IOPAN.

Nutrients, nitrate (NO_3), nitrite (NO_2), phosphate (PO_4), total nitrogen (TN), total phosphorus (TP) and silicate (SiO_4) were analysed on board by SYKE. The vertical profiles of total phosphorus and total nitrogen are shown in Figure 4. Clear differences in total phosphorus between different basin can be seen: the values are smallest in the Bay of Bothnia and grow further south: the values are highest in the Gulf of Finland. In the case of total nitrogen, the values are highest in the Gulf of Finland - eastern parts of the Northern Baltic Proper and in the surface water at the northernmost station I3.

4. Ice measurements

A radar server that captures the radar video signal together with control signals was attached to the secondary outputs of the ship radar in order to monitor the ice coverage in the area the ship was during the cruise. FMI develops and uses the same technique for ice monitoring at several coastal radar stations at the Finnish shoreline.

The ice thickness in front of the ship was measured with an installation that included Geonics EM-31 electromagnetic sensor and a Noptel CM3 laser distance sensor. A video camera was mounted at the bow for monitoring the sensors and for analysis of the ice cover. The kayak that housed the sensors was suspended from the horizontal boom at the bow of the ship, roughly two metres above the water/ice surface. The sensor was operational in the Bay of Bothnia, the sea area that had an ice cover.

On the ice station in the Bay of Bothnia (ICE_POINT/MEATLOAF, Figure 1 and Table 2), the EM installation was used to measure the profile of an ice ridge in an area of very compact ice. The thickness of the ice ridge was measured by drilling at several places in order to verify the EM measurements.

5. Recovery/deployments of buoys

An Argo float of FMI (APEX, Figure 1), autonomous salinity and temperature profiler was recovered 04.03.2019 from the northern part of the Bothnian Sea.

Two Directional Waveriders were deployed, one at the station AALTO_SM in the Bothnian Sea, and the other at station AALTO_HKI in the Gulf of Finland. The wave buoys are part of FMI's operational wave measurement network. A bottom mounted acoustic sensor for current and wave measurements was deployed near the wave buoy in the Gulf of Finland.

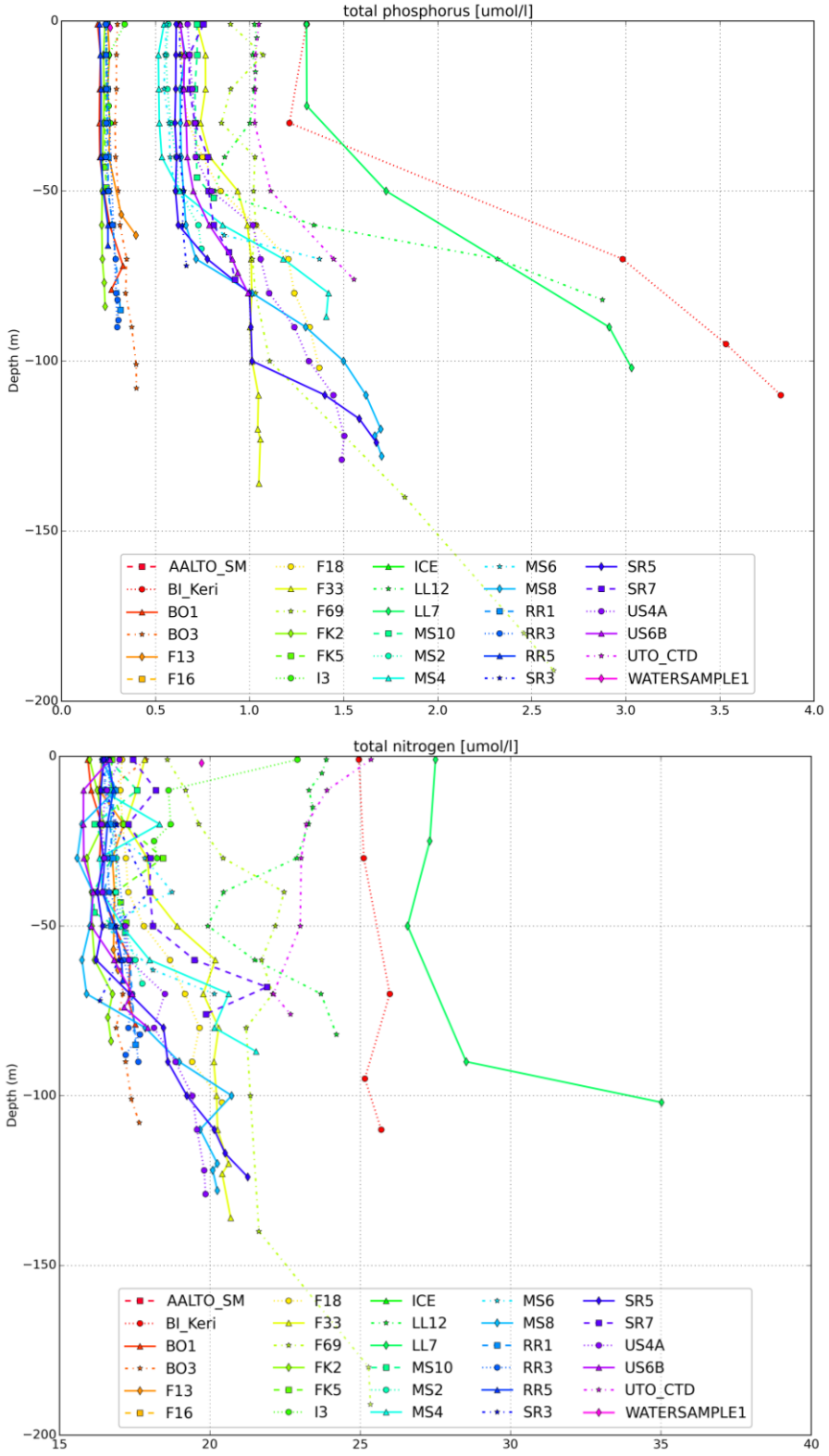

Figure 4. Vertical profiles of total phosphorus (upper panel) and total nitrogen (lower panel) at the stations.

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Table 2. List of stations and observations. In addition to the stations, flow-through measurements of trace gases, SSS, SST, CDOM and Chlorophyll-a were measured semi-continuously.

Index	Station	Coordinates [WGS-84]	Depth [m]	Date [UTC]	Time	Observations
0134	LL7	N59.5079 E024.5027	106.00	20190228	1259	CTD, NUT
0135	BI_KERI	N59.4305 E025.0091	114.00	20190228	1543	CTD, NUT
0136	LL12	N59.2900 E022.5379	86.00	20190301	0437	CTD, NUT
0137	UTO_CTD	N59.4529 E021.2199	79.00	20190301	2135	CTD, NUT, ORG, FOS, CAR
0138	SR7	N61.0501 E020.3581	81.00	20190302	1103	CTD, NUT, ORG, FOS, CAR
0139	SR5	N61.0500 E019.3723	130.00	20190302	1536	CTD, NUT, ORG, FOS, CAR
0140	SR3	N61.1100 E018.1381	75.80	20190302	2107	CTD, NUT, ORG, FOS, CAR
0141	MS2	N62.0700 E017.5076	71.00	20190303	0410	CTD, NUT, ORG
0142	MS4	N62.0606 E018.3311	92.00	20190303	0720	CTD, NUT, ORG, FOS, CAR
0143	MS6	N61.5902 E019.0981	75.00	20190303	1032	CTD, NUT, ORG, FOS, CAR
0144	MS8	N61.5100 E020.0331	136.00	20190303	1417	CTD, NUT, ORG, FOS, CAR
0145	MS10	N61.4101 E020.5979	56.00	20190303	1938	CTD, NUT, ORG, FOS, CAR
0146	US6B	N62.3602 E020.1579	85.00	20190304	0434	CTD, NUT, ORG, FOS, CAR
0147	US4A	N62.3900 E019.2940	135.00	20190304	0755	CTD, NUT, ORG, FOS, CAR
0148	BO1	N64.2498 E021.5070	84.00	20190305	0850	CTD, NUT, ORG, FOS, CAR
0149	BO3	N64.1812 E022.2059	115.00	20190305	1135	CTD, NUT, ORG, FOS, CAR
0150	RR5	N64.4998 E023.0991	70.60	20190305	1724	CTD, NUT, ORG, FOS, CAR, AT
0151	RR3	N64.5613 E022.2107	96.60	20190305	2240	CTD
0152	WATERSMPL1	N65.1315 E025.0292	13.00	20190307	1209	NUT, pH, CAR
0153	I3	N65.3210 E024.3333	32.00	20190307	1614	CTD, NUT, ORG, FOS, CAR, AT
0154	FK5	N65.1213 E023.5283	52.00	20190307	2131	CTD, NUT, ORG, FOS, CAR, AT
0155	FK2	N65.2400 E023.0649	91.00	20190308	0039	CTD, NUT, ORG, FOS, CAR, AT
0156	MEATLOAF	N64.5287 E023.0394	54.00	20190308	0630	CTD, ice station
0157	RR3	N64.5582 E022.2018	94.00	20190308	1404	CTD, NUT, ORG, FOS, CAR, AT
0158	RR1	N64.5767 E021.5147	84.00	20190308	1657	CTD, NUT, ORG, FOS, CAR, AT
0159	F13	N63.4703 E021.2876	67.50	20190309	0012	CTD, NUT, ORG, FOS, CAR, AT
0160	F16	N63.3109 E021.0379	48.00	20190309	0238	CTD
0161	F18	N63.1886 E020.1637	108.00	20190309	0515	CTD, NUT, ORG, FOS, CAR, AT
0162	AALTO_SM	N61.4800 E020.1376	106.70	20190309	1435	CTD, wave buoy
0163	F33	N60.3200 E018.5631	140.00	20190309	2240	CTD, NUT, ORG, FOS, CAR
0164	F69	N59.4699 E019.5580	198.00	20190310	0522	CTD, NUT, ORG, FOS, CAR
0165	AALTO_HKI	N59.5792 E025.1400	64.00	20190311	0543	CTD, wave buoy

CTD:	salinity, temperature, oxygen, fluorescence
NUT:	NO_2, NO_3, PO_4, SiO_4, TN, TP
FOS:	DOP, POP
ORG:	DOC, DON, POC, PON
CAR:	pH, CT, CH_4, N_2O, isotopes
AT:	total alkalinity

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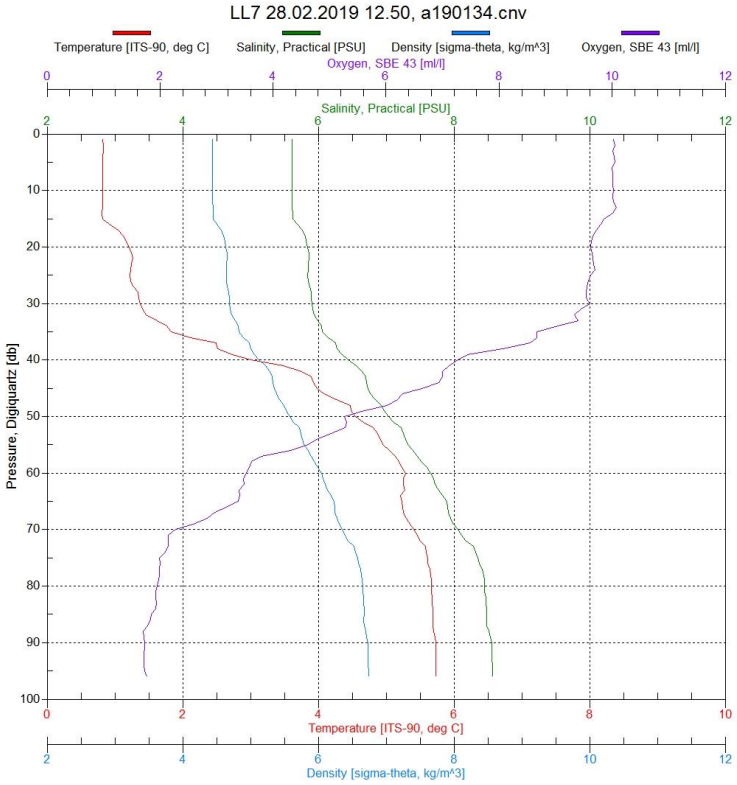
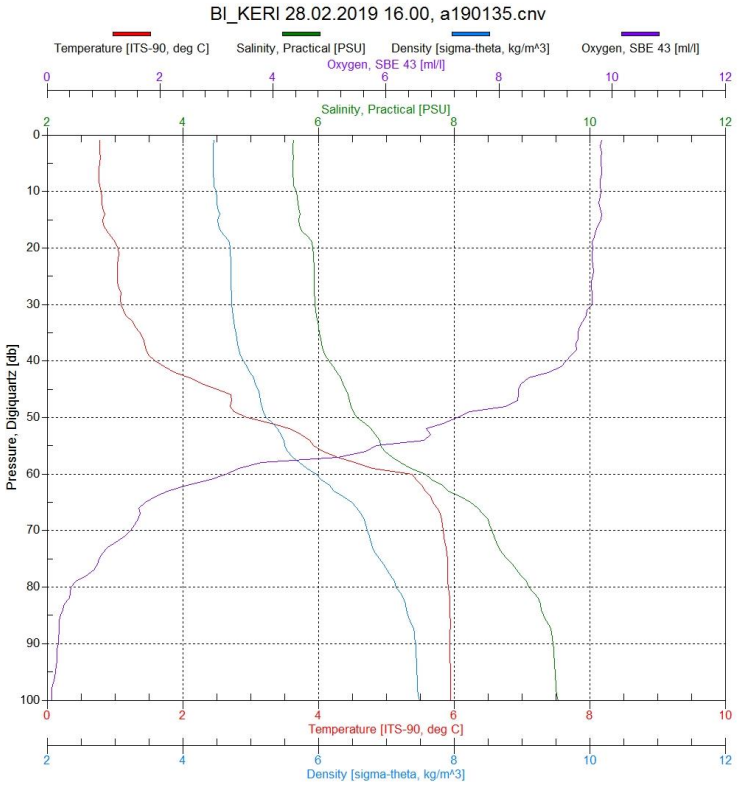
Appendix: vertical profiles of temperature, salinity, density and oxygen. N.B. The oxygen values are not calibrated.





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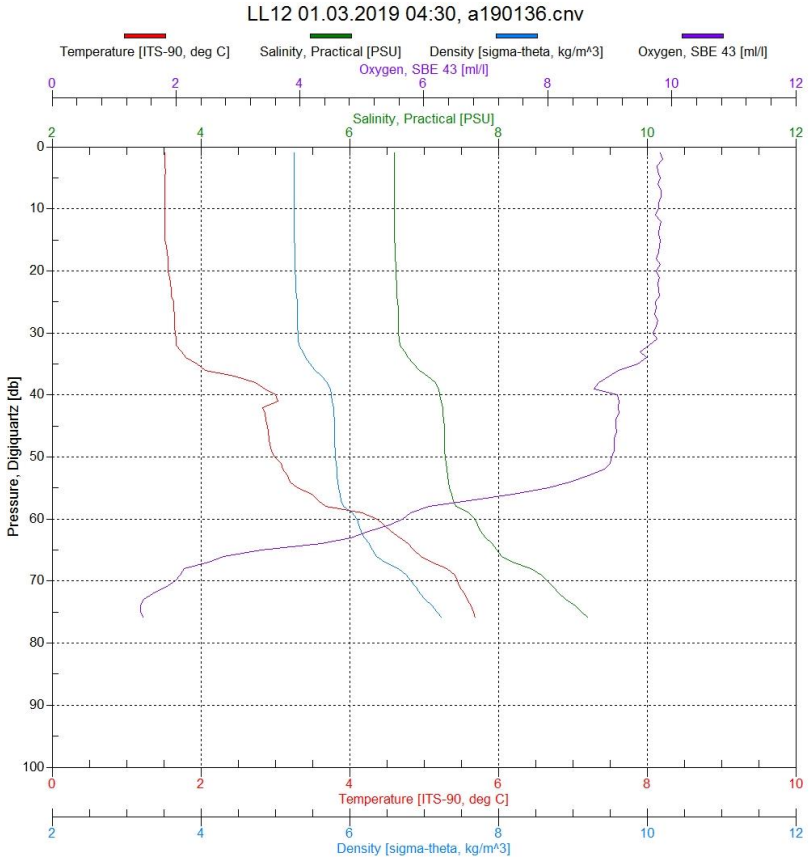

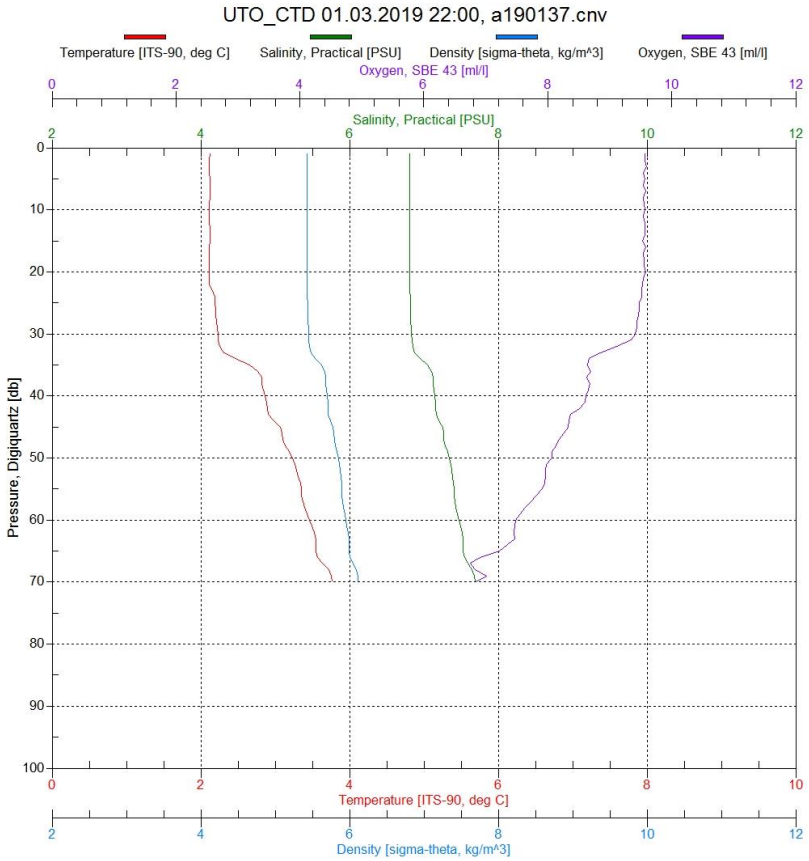

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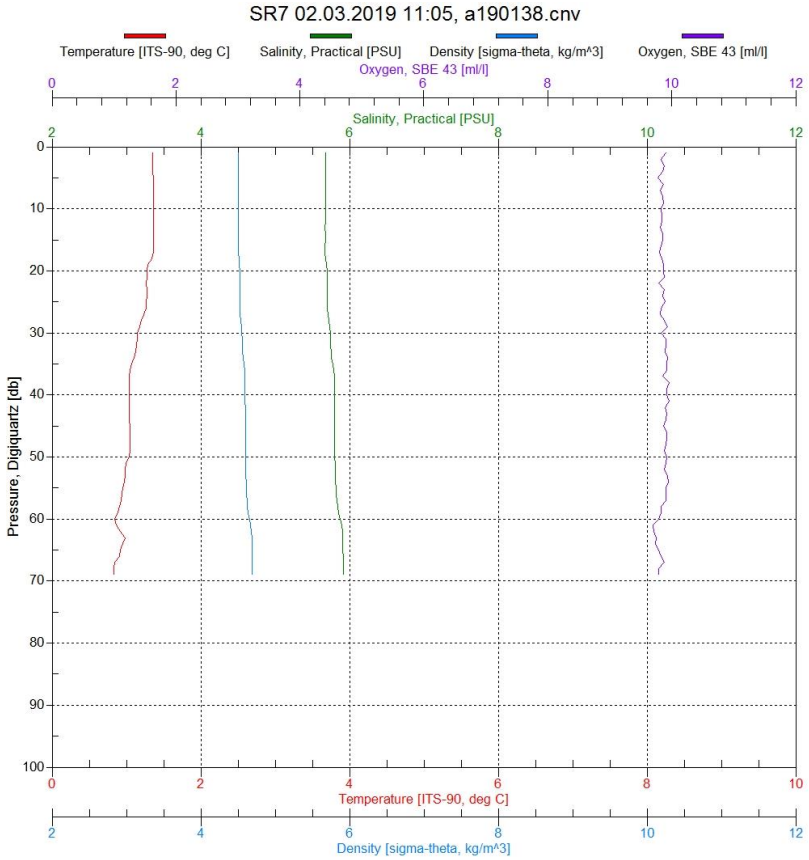

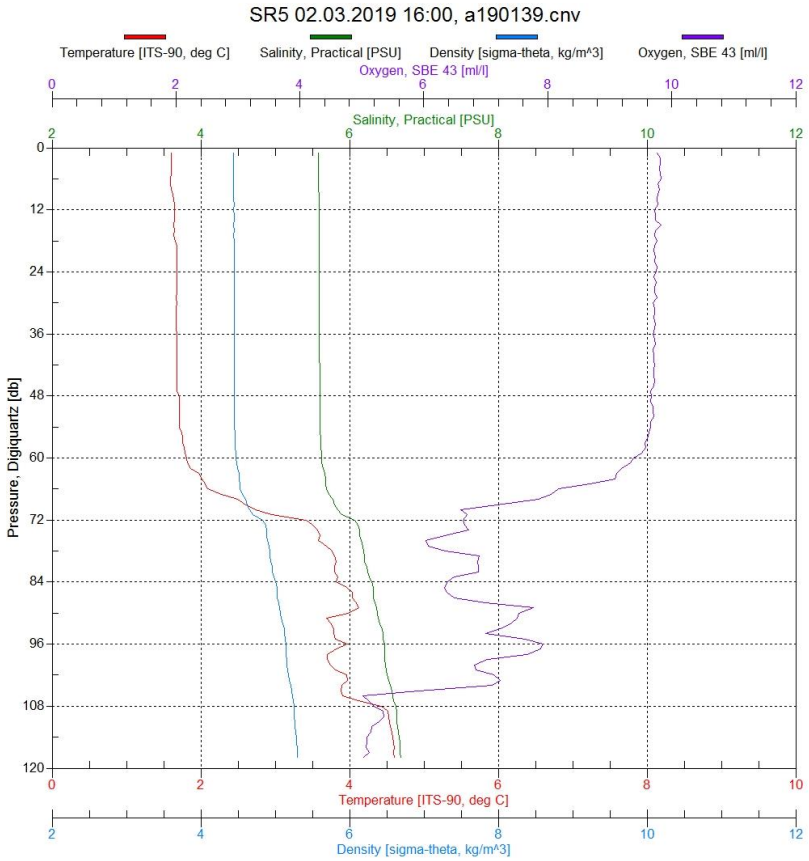

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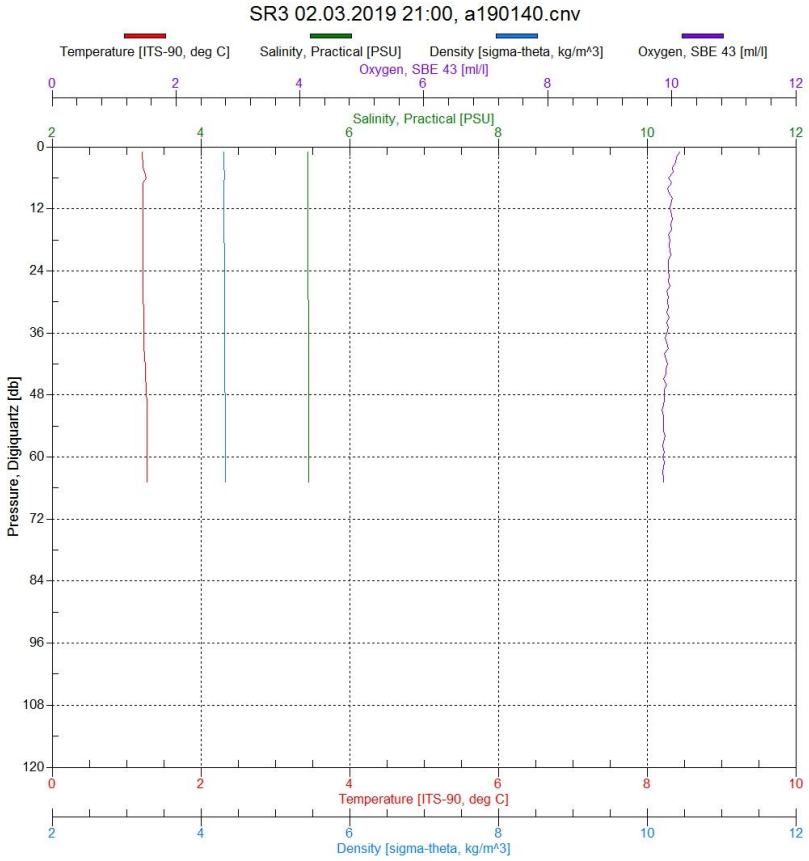

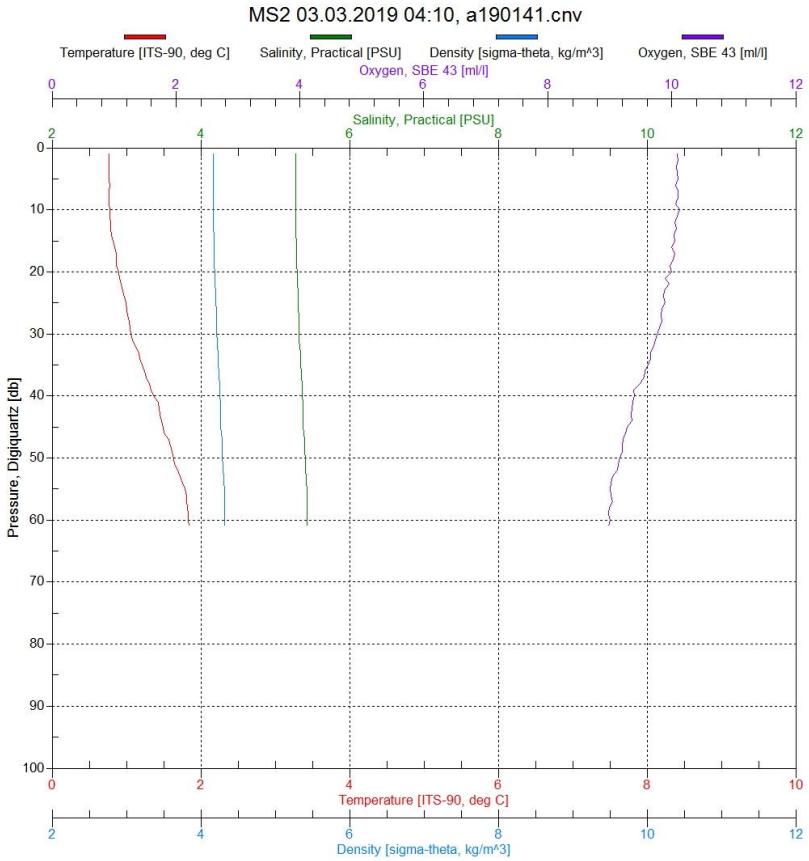

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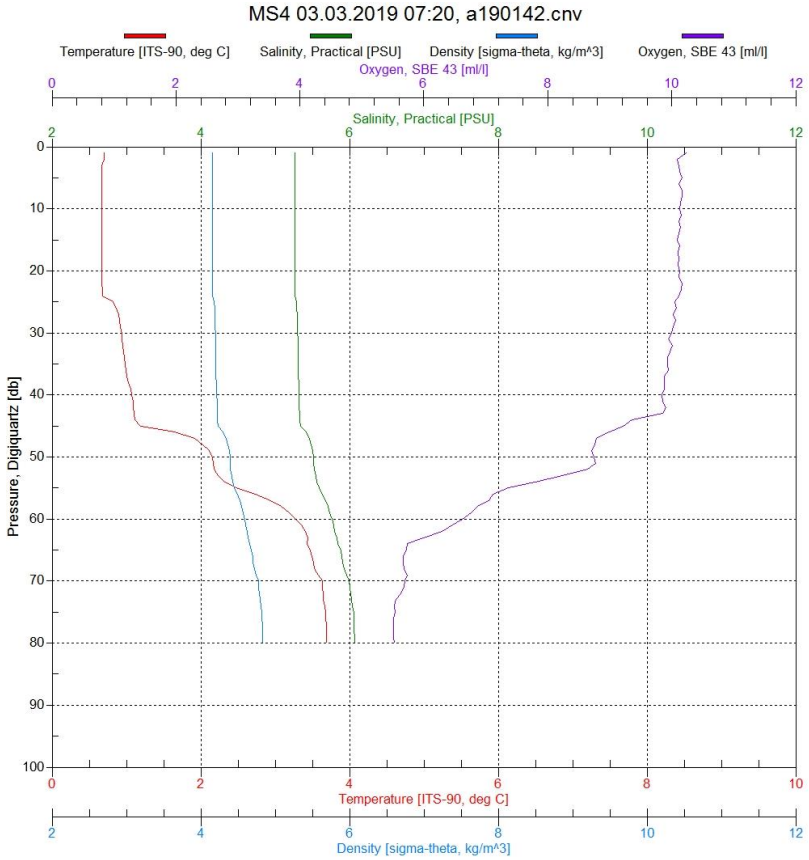

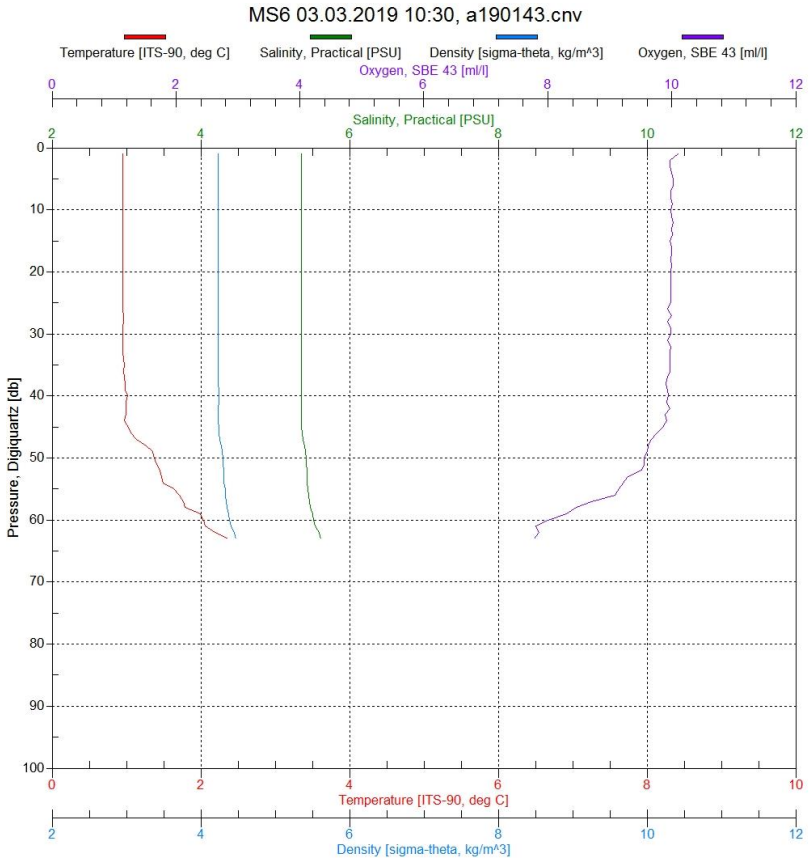

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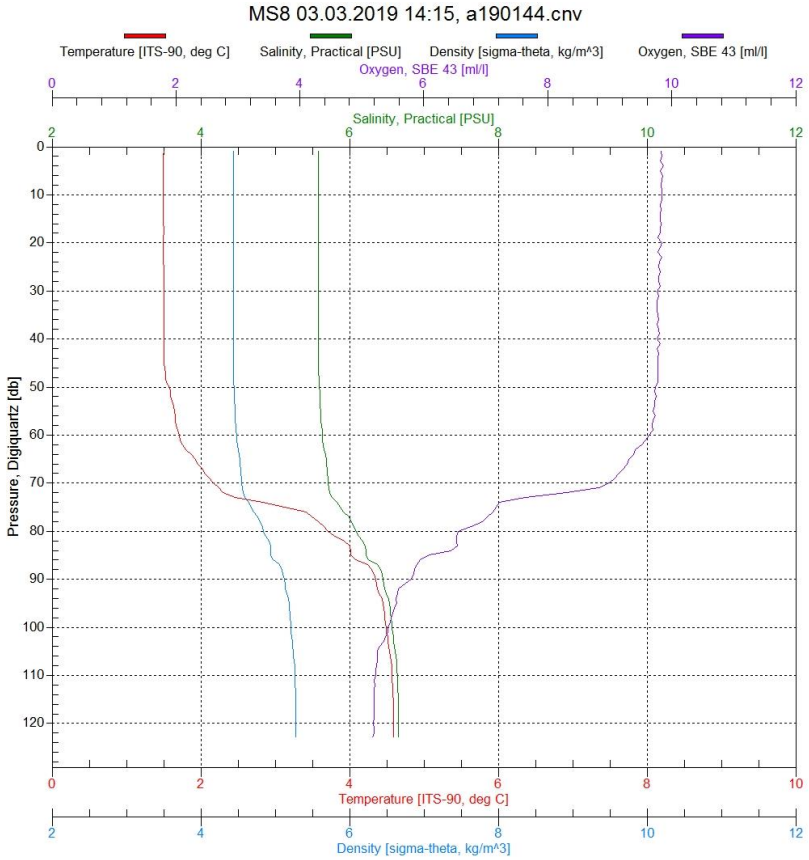

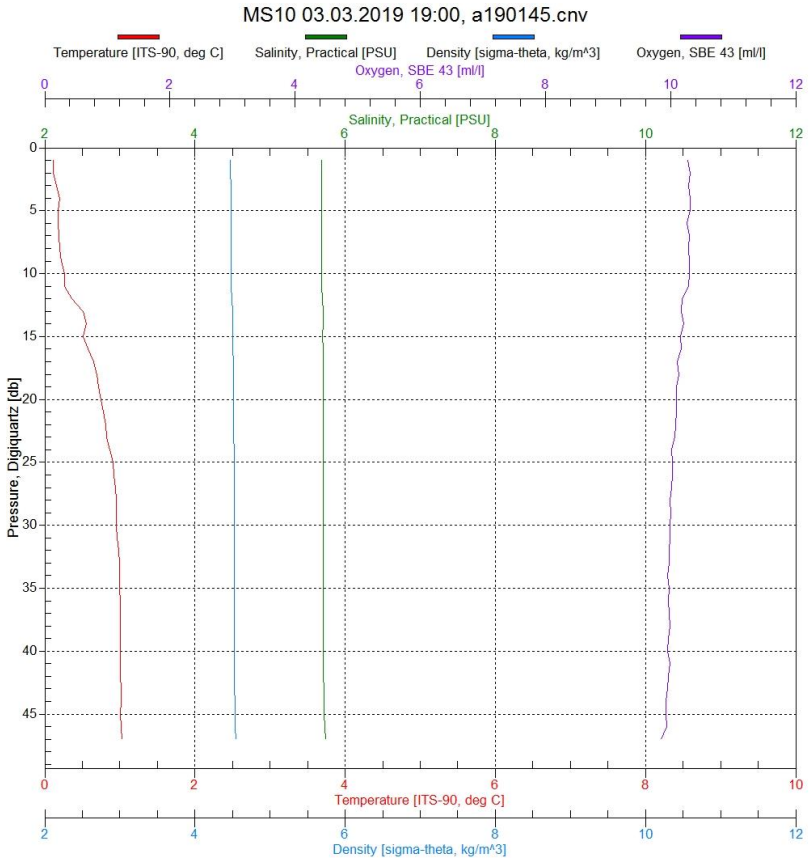

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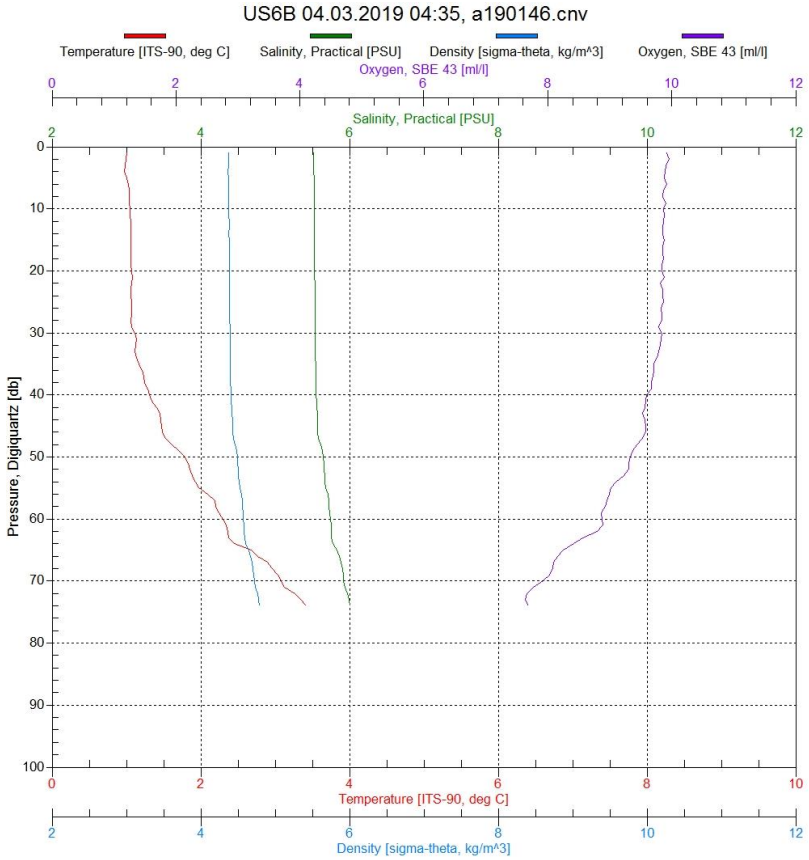

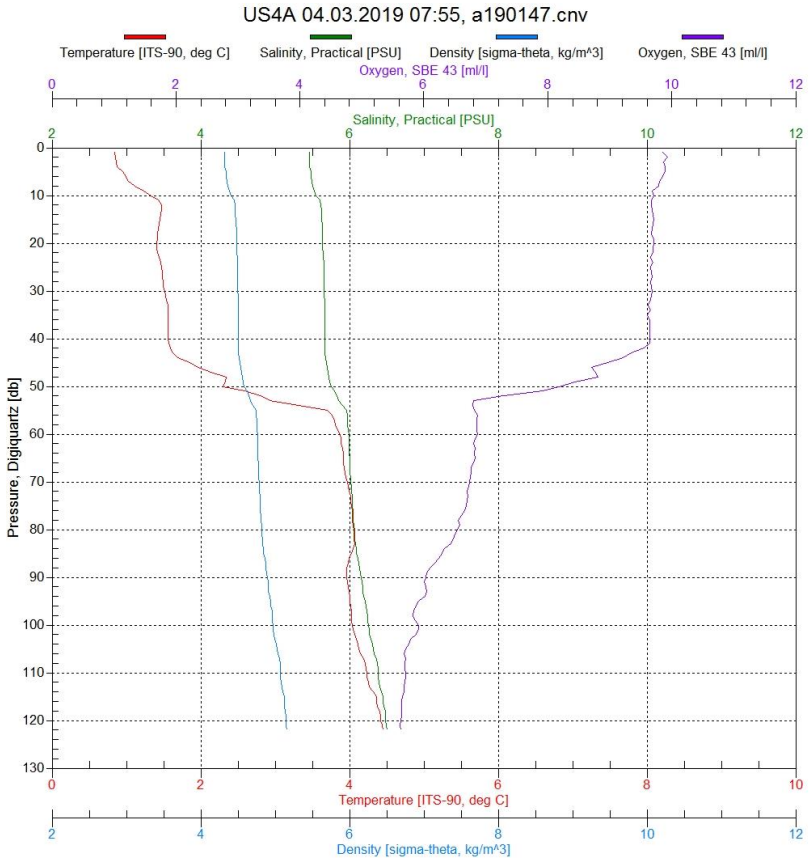

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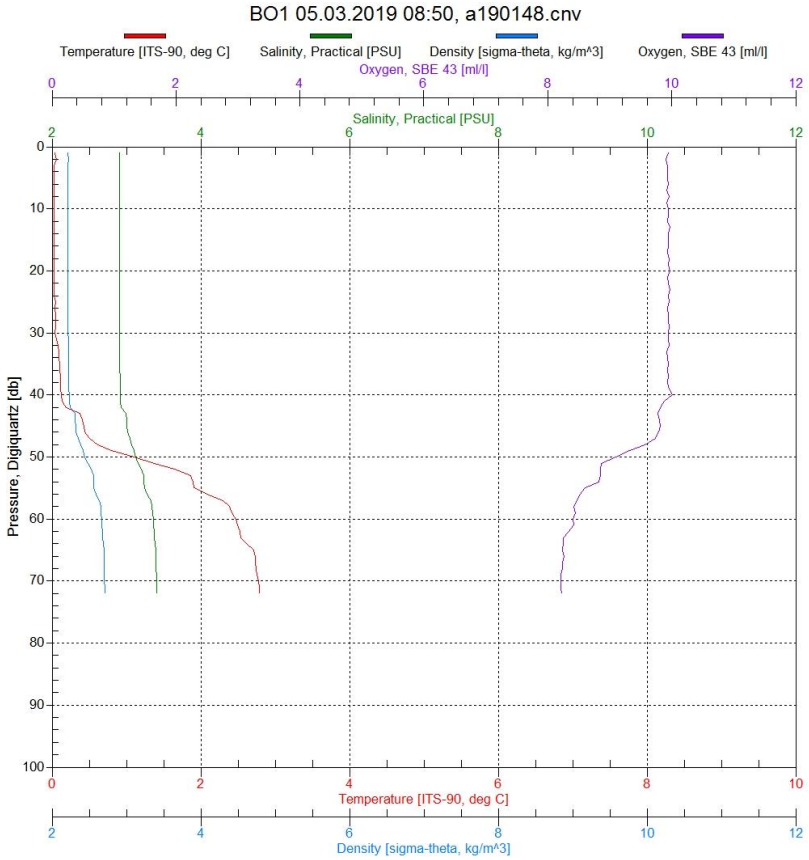

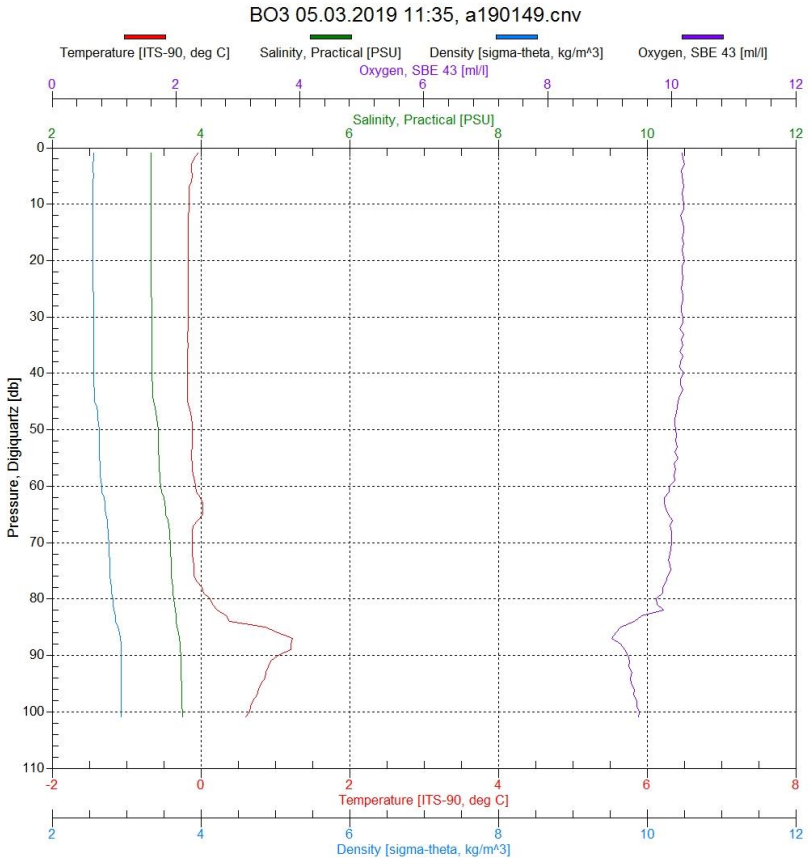

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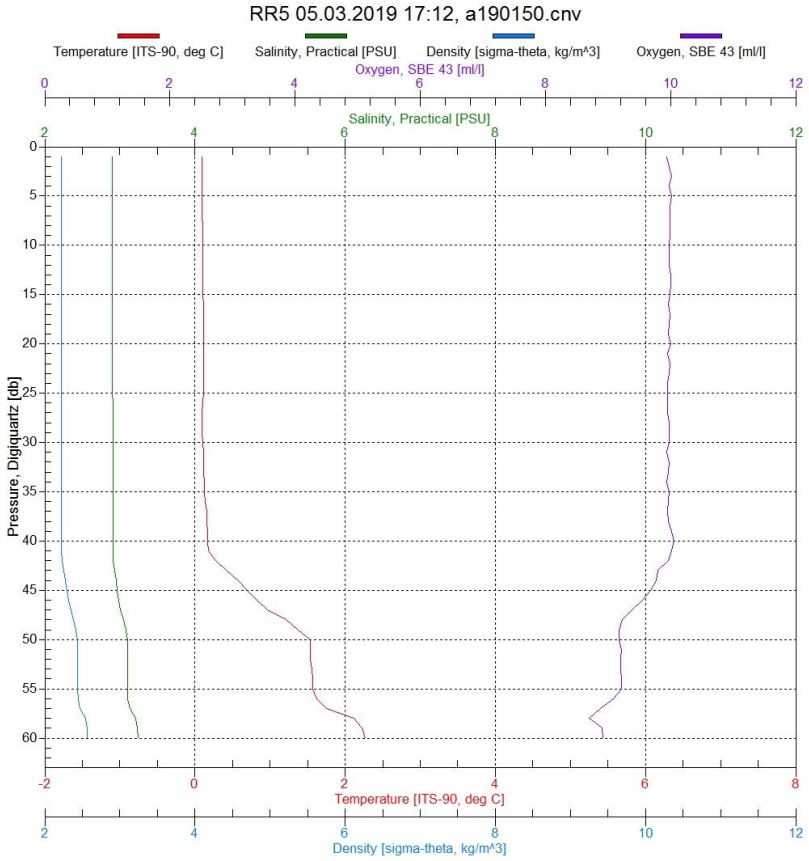

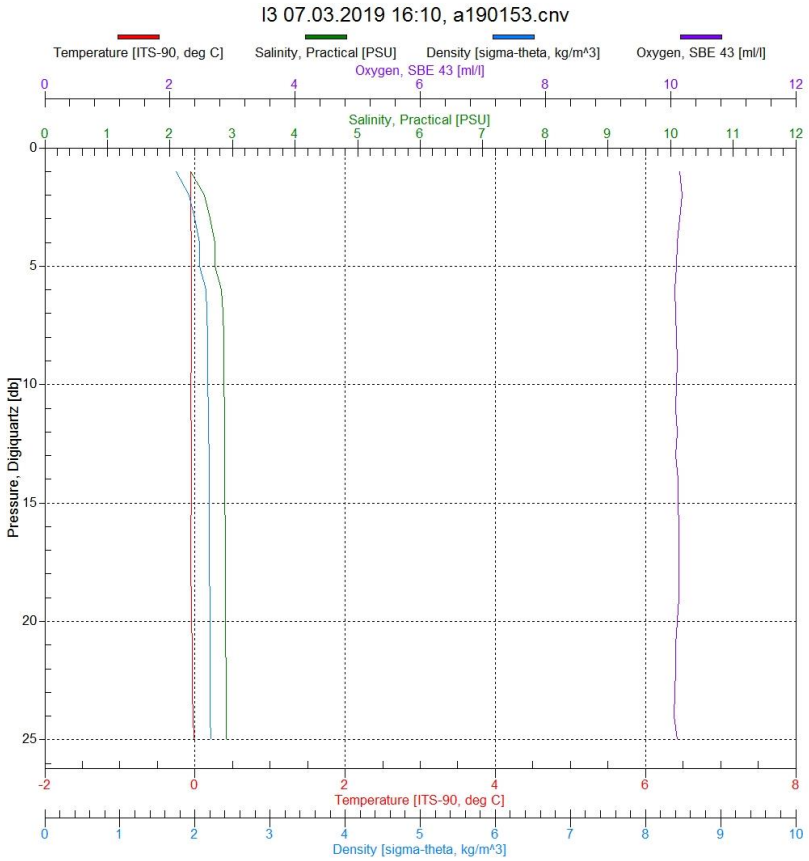

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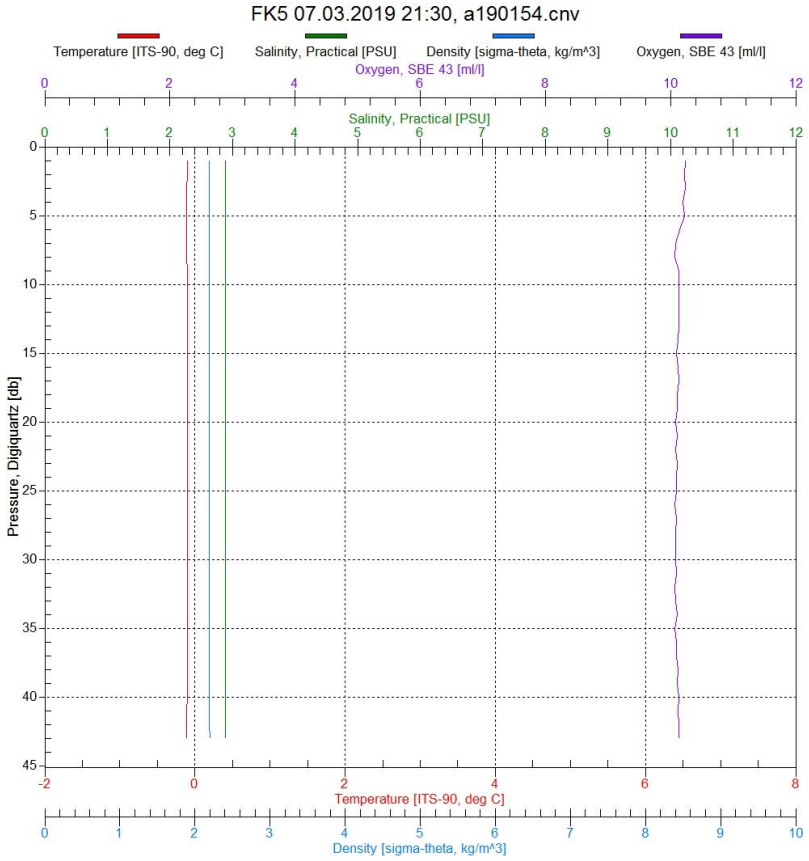

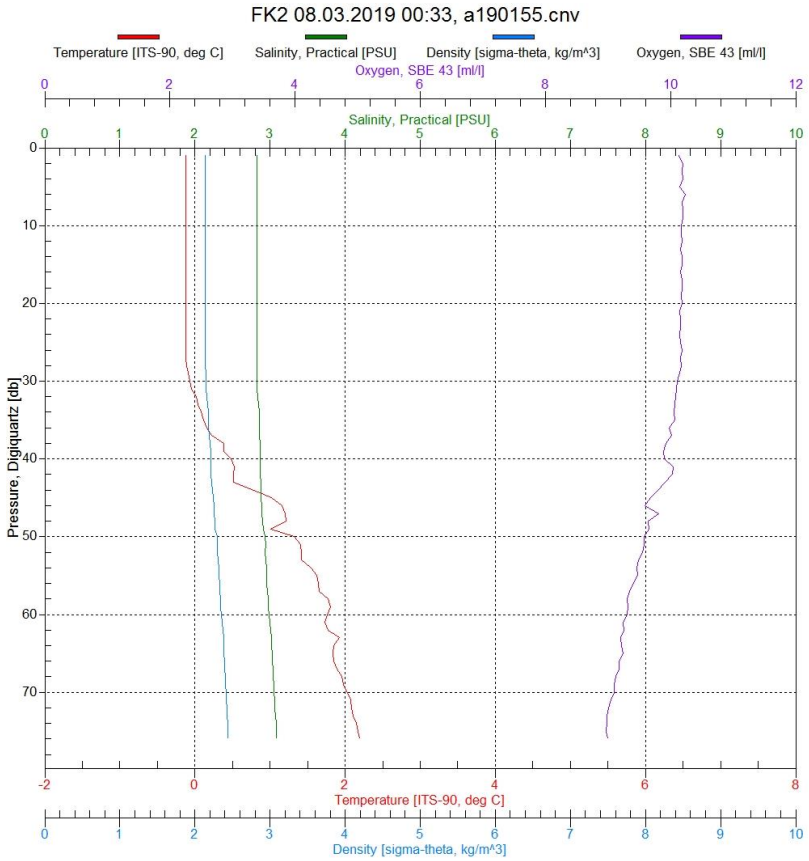

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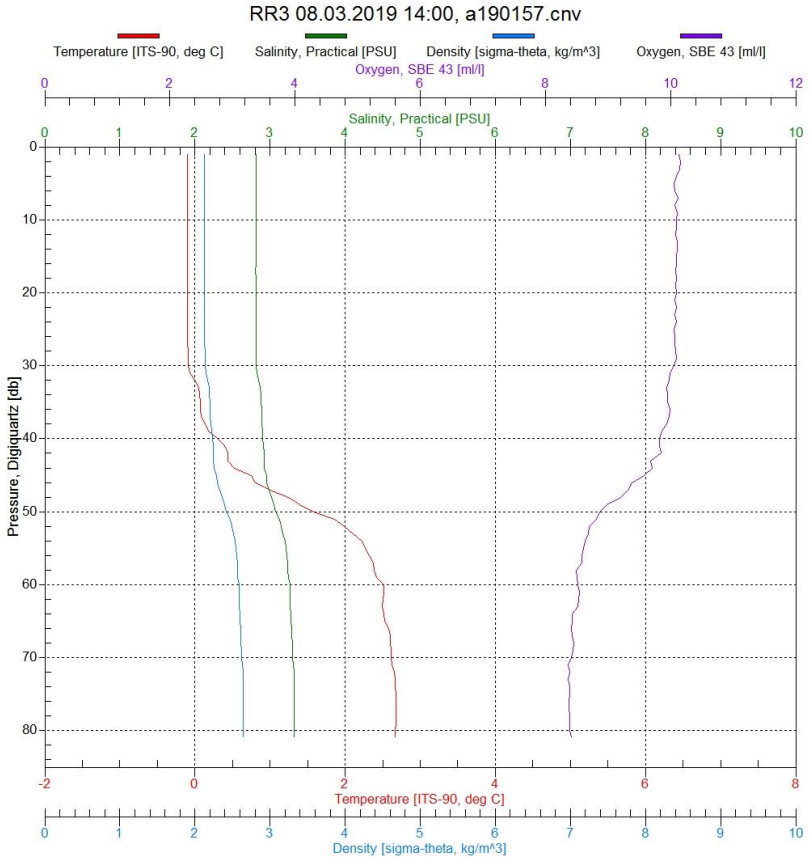

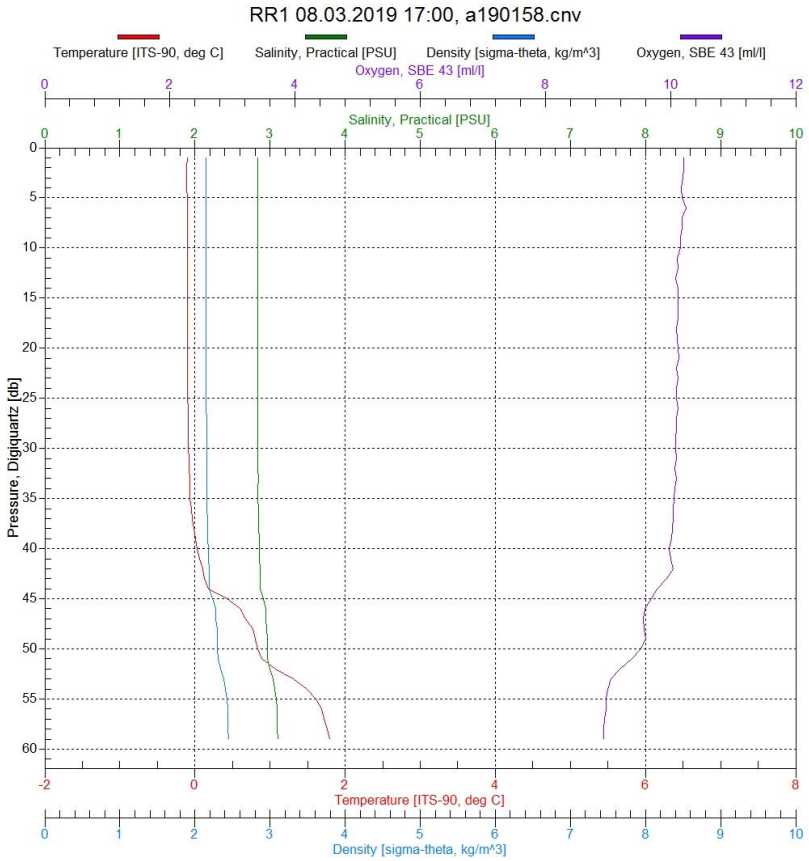

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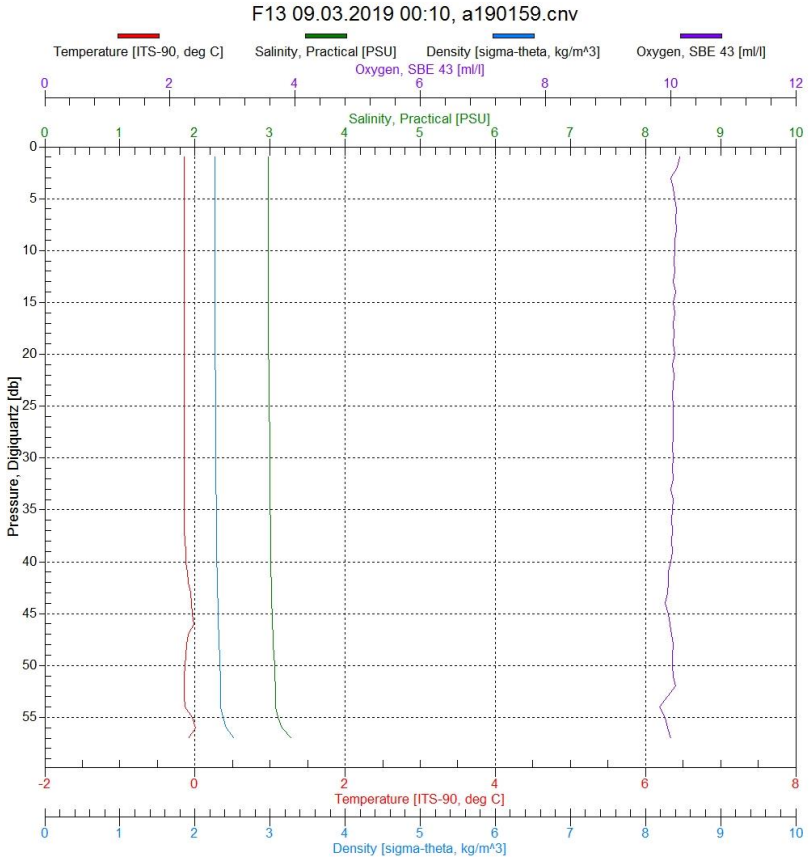

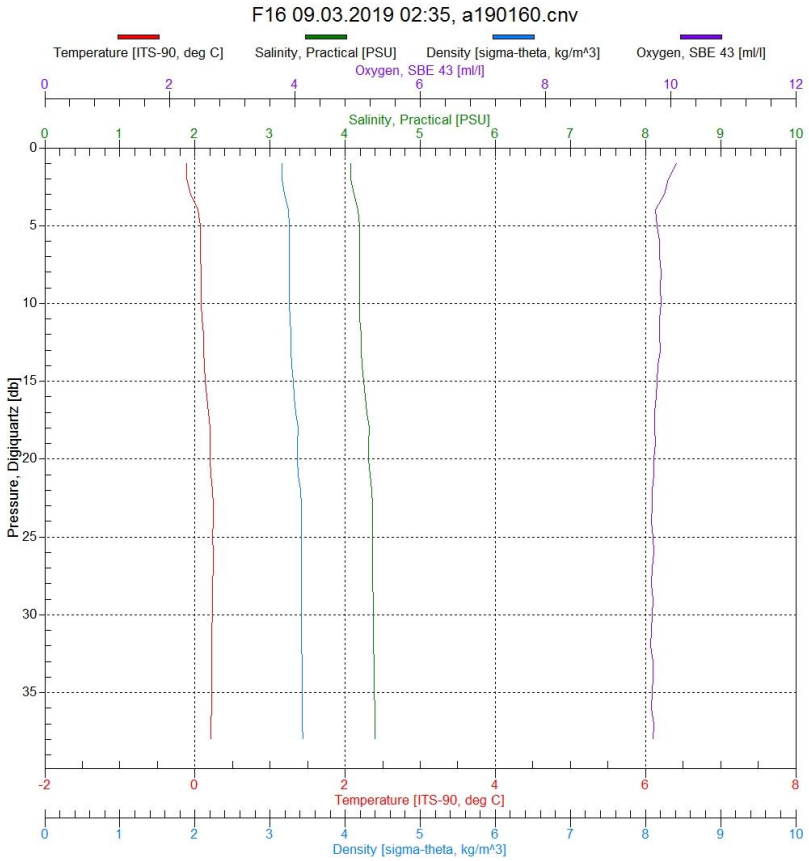

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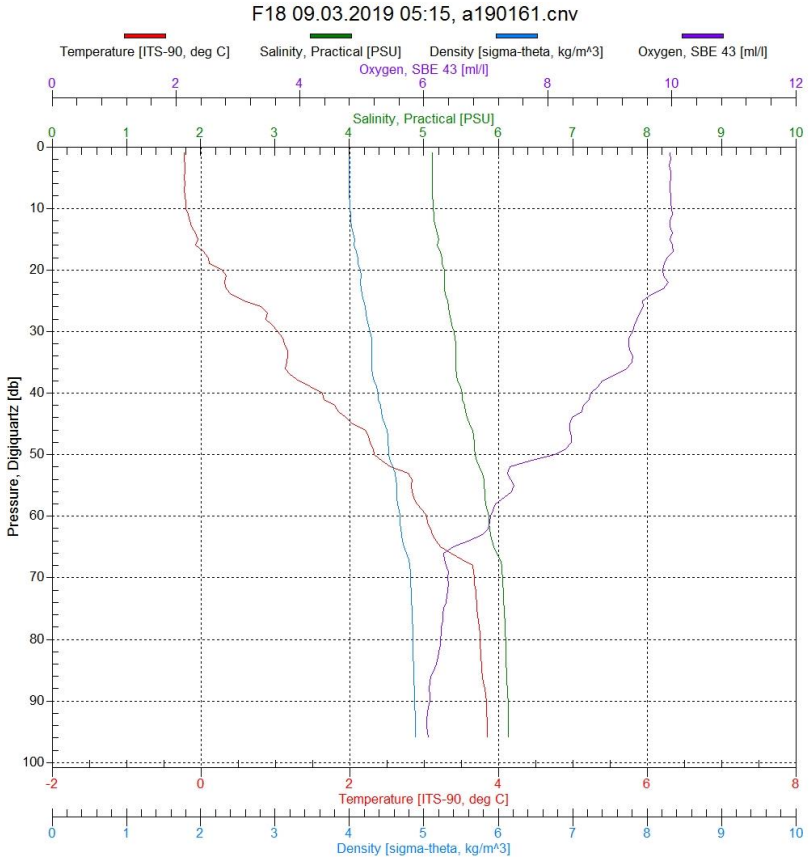

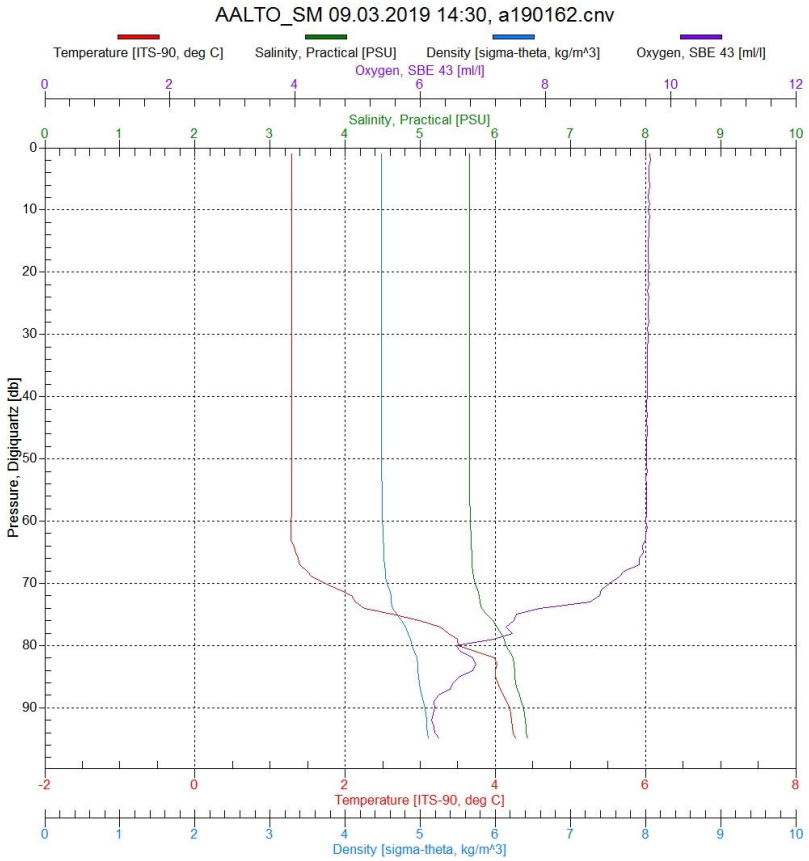

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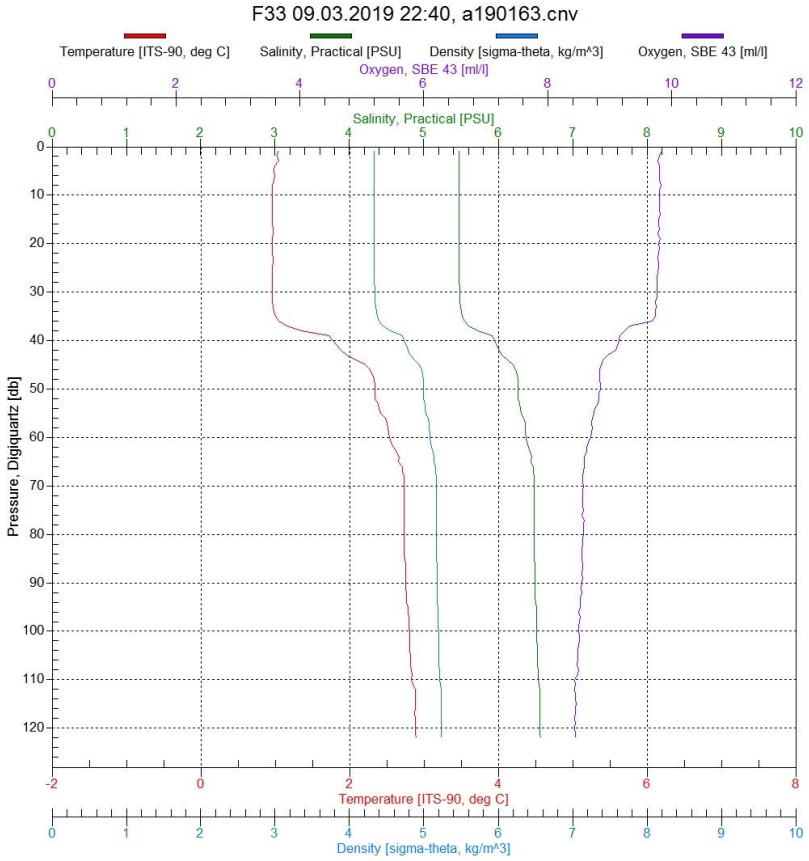

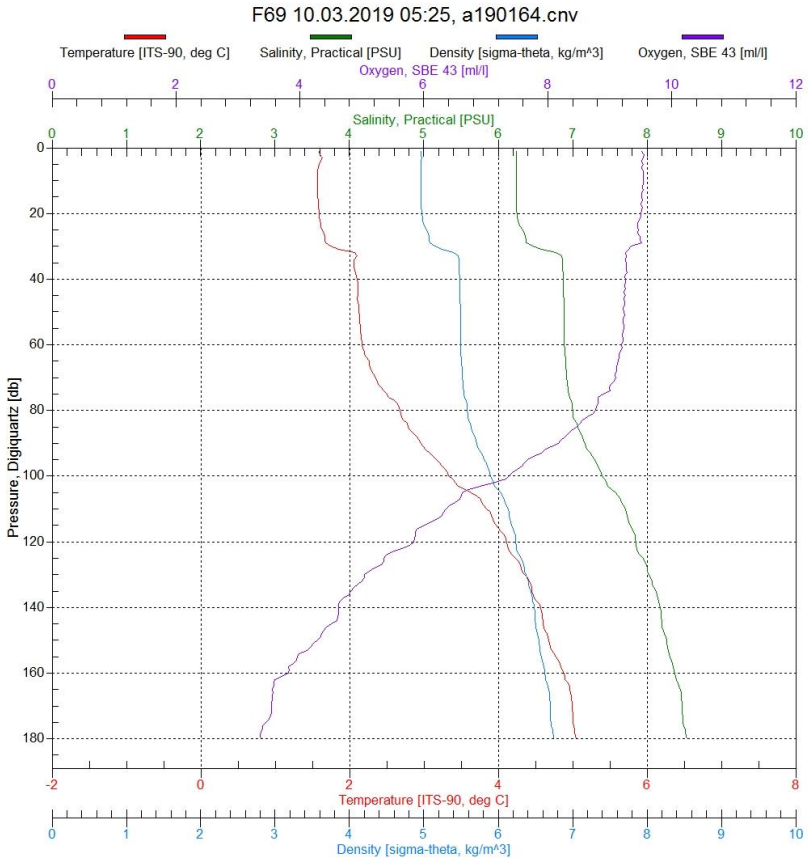

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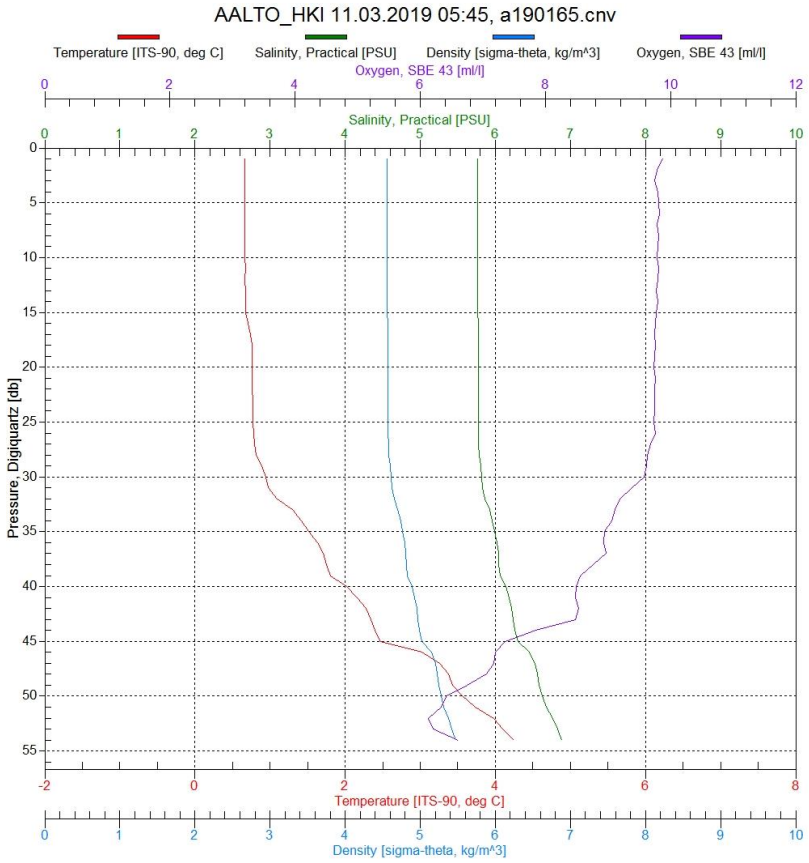

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