RBRargo|2000 sensor and float experiment description

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0.0	19/08/2020	Simo-Matti Siiriä	First version to be circulated with partners
0.1	01/10/2020	Andre X., Amice M.	Main contribution from float/sensor description and qualification process and results
0.2	18/12/2020	Maze G.	Completed open ocean experiments and first data collected
0.3	19/12/2020	Maze G.	Final version submitted to the project coordination

EXECUTIVE SUMMARY

This deliverable describes the experiments performed and further testing plans in order to make a new RBRArgo[3] (formerly named RBRArgo|2000 OEM) Conductivity/Temperature/Depth (CTD) sensor available for the core Argo mission. The tests are performed with nke instrumentation Arvor-I floats and the integration is managed by IFREMER. At the start of the Euro-Argo RISE project this sensor model is still considered to be on "*Stage II: Global Argo Pilot*" by the Argo Steering Team (see here for a description). The testing and developments described here aim to determine if the sensor setup is matured to be approved by the Argo community.

FMI and IFREMER have prepared at-sea tests for four floats equipped with the RBRArgo[3] CTD. Two floats have been deployed in the open ocean (2020, IFREMER) and two will be in the marginal Baltic Sea (2021, FMI). These floats and sensor performances will be monitored, and later further analysed.

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1. Introduction

The objective of this task is to contribute to make available a new Conductivity/Temperature/Depth (CTD) sensor to the core Argo mission. This new sensor is the RBRArgo³ CTD. It is considered by international Argo to be in a "Stage II: Global Argo Pilot" phase. This means that the sensor has shown good performances on preliminary tests and that now, as many as possible floats equipped with this new CTD are to be deployed, in as many ocean conditions as possible, in order to assess the effective new sensor accuracy and stability in real operational conditions. This may result in ultimately making this new sensor "approved" by the Argo community.

Currently Arvor floats are available only with one CTD sensor model (the SBE41CP). This report describes the RBRArgo³ CTD integration design on the ARVOR float's type, first tests, and next tests in real conditions. Design and integration specifications for Arvor floats were managed by IFREMER. The floats were manufactured by subcontractor NKE. ARVOR, although the 2nd largest float model of the global Argo array today (2019), is the only float not yet available with the RBR sensor. Working on the ARVOR will maximize the impact of this task onto the strengthening of competitiveness of the European industry.

FMI and IFREMER have prepared at-sea tests for four floats equipped with the RBRArgo³ CTD. Two floats have been deployed in the open ocean (2020, IFREMER) and two will be in the marginal Baltic Sea (2021, FMI). These floats and sensor performances will be monitored, and later further analysed.

2. Float and sensor description

To embed the RBRArgo³ CTD on the Arvor-I, the design and industrial choice has been made to keep the same upper-end cap as the standard Arvor-I (with SBE41CP CTD), with a mechanical adaptor part. This allows us to benefit from the same standard price, and its reliability, as several hundred of these devices have already been deployed at sea.

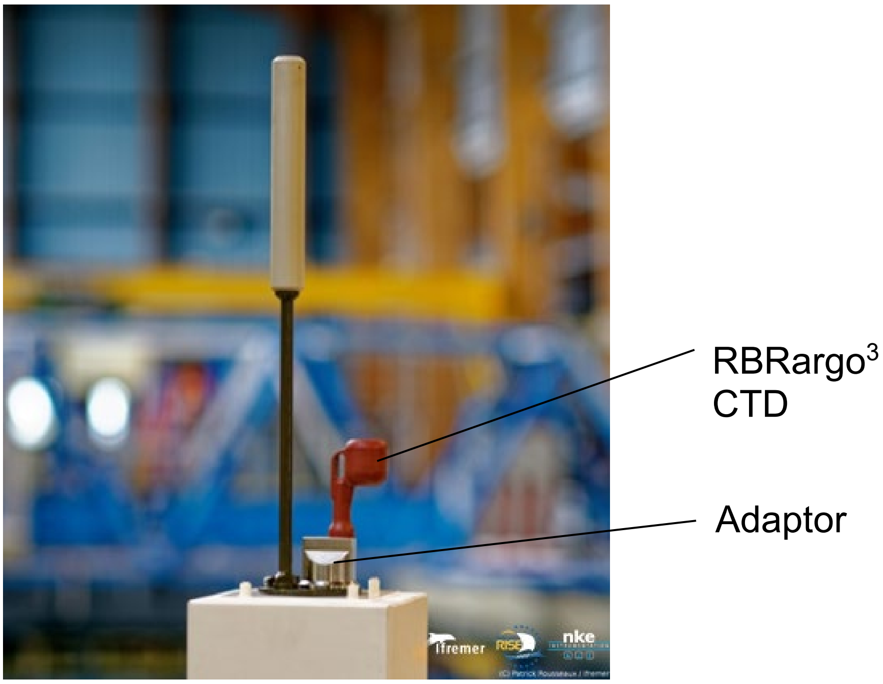


Figure 1: New Arvor-I RBR upper-end cap including an adaptor

This modification of the upper-end cap (figure 1), as well as the embedded sensor's electronics and the development of a new software driver for CTD management, are the only differences with the standard Arvor-I.

Figure 2: Arvor-I RBR float

The RBRArgo[3] CTD main specifications are :

Conductivity	
Range	0-85mS/cm
Initial accuracy	±0.003mS/cm
Typical stability	0.010mS/cm per year
Resolution	0.001mS/cm
Temperature	
Range	-5°C to 35°C
Initial accuracy	±0.002°C
Resolution	<0.00005°C
Time constant	~700ms
Typical stability	0.002°C/year
Pressure (Depth)	
Range	2000 dbar
Initial accuracy	±0.05% full scale (FS)
Resolution	0.001% FS
Time constant	<0.01s
Typical stability	0.05% FS

3. Qualification process and results

The Arvor-I profiling floats have been deployed at sea for more than 10 years now. The standard version is equipped with an SBE41CP. In the frame of the Euro-Argo RISE project, IFREMER and nke instrumentation integrated the RBRArgo[3] CTD. The so called "Arvor-I RBR" profiling float has thus undergone a qualification process, which is summarized here.

<u>Qualification of the adaptor part in hyperbaric tank</u>

The Arvor-I RBR upper-end cap is the same as the standard Arvor, except for the addition of an adaptor part between the cap and the CTD. This new assembly therefore had to be qualified as a hyperbaric chamber (Figure 3).

Figure 3: Qualification of the Arvor-I RBR adaptor part

Qualification of the new software driver

The software driver of the RBRArgo[3] CTD has been qualified by NKE in its lab, during unitary tests and simulations of operation on a test bench.

Qualification in seawater test pool

Then, five Arvor-I RBR profiling float (serial numbers AI3500-FR001 & AI3500-FR002 for the Euro-Argo RISE project, and 3 others for a third party customer) have been deployed in the seawater pool at IFREMER, where they completed 6 profiles at 20 m (Figure 4).

Figure 4: Qualification with 5 Arvor-I RBR in the seawater tank at IFREMER

Qualification of the Arvor-I RBR in hyperbaric tank

Finally, one Arvor-I RBR float has been deployed in operational conditions in an hyperbaric tank at IFREMER (Figure 5), which allows us to qualify the overall behavior of all subassemblies of the profiling float (CTD, hydraulic system, transmissions, etc.). In this test, the instrument behaves as if it were at sea, giving the hydraulic actions necessary to carry out its mission, and carrying out CTD acquisitions in accordance with its configuration. The displacement of the float is simulated by the manual variation of the pressure in the hyperbaric chamber by the operator.

Figure 5: Qualification of an Arvor-I RBR in hyperbaric tank at IFREMER

Conclusion

All stages of qualification went according to our expectations, and the Arvor-I RBR profiling float was therefore declared operational for deployment at sea.

4. At-sea experiments

4.1. Unitary tests

Unitary tests consist of a multi-cycle test in the seawater pool at IFREMER, by 20 m depth. It allows to verify the overall functionalities of the profiling float (hydraulic system, CTD acquisitions, transmission, etc.). Each float is tested this way before any deployment at sea.

Serial number	Date of test in seawater pool at IFREMER	Result	Deployment campaign
AI3500-20FR001	6 to 9 March 2020	OK	Open Ocean experiments
AI3500-20FR002	6 to 9 March 2020	OK	
?	to be done	?	Baltic Sea experiments
?	to be done	?	

4.2. Open Ocean experiments

Two ARVOR-I RBR floats, equipped with an RBRargo[3] CTD, have been deployed on Dec. 11st during the IEO cruise RAPROCAN2012 in the Canary Basin (see figure 6 below). During this campaign, two 3-headed Deep-Arvor, equipped with SBE41CP, SBE61CP and RBRconcerto[3] CTDs, have also been deployed, which could be helpful for inter-comparison of the results.

The deployment was the following:

- The two Arvor-I RBR deployed in station 24, where we have a long time series, and along one Arvor-I SBE41 and the two 3-headed floats (from WP3) ;
- The backup plan in case of bad weather, was to deploy the three Arvor-I floats south of El hierro (27.30ºN, 18ºW). But this did not happen.

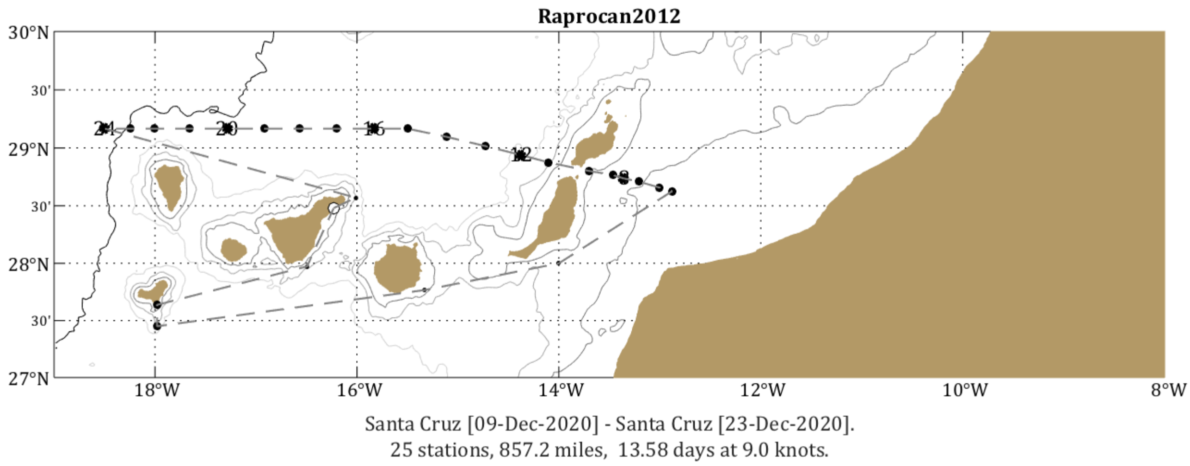


Figure 6: Map of the planned deployment in the Canary Basin during Raprocan2012 cruise in December 2020

Deployments will be made after a CTD cast using a SBE911+ with dual CT sensors. The deployment has been carried out using a crane, ensuring the floats were deployed smoothly and safely (Figure 7). Although the departing port is Santa Cruz de Tenerife, the floats were received on 16th November 2020 in IEO Cádiz and put onboard the ship, in order to avoid issues with the local customs authorities, the Canary Islands being in a different custom regime than the rest of Europe.

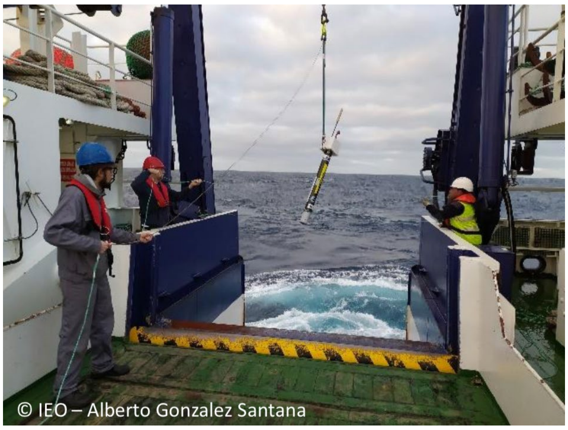


Figure 7: Arvor-I/RBR float deployment on the morning of Dec. 11st 2020.

Coordinates of deployments of the 3 core Argo floats:

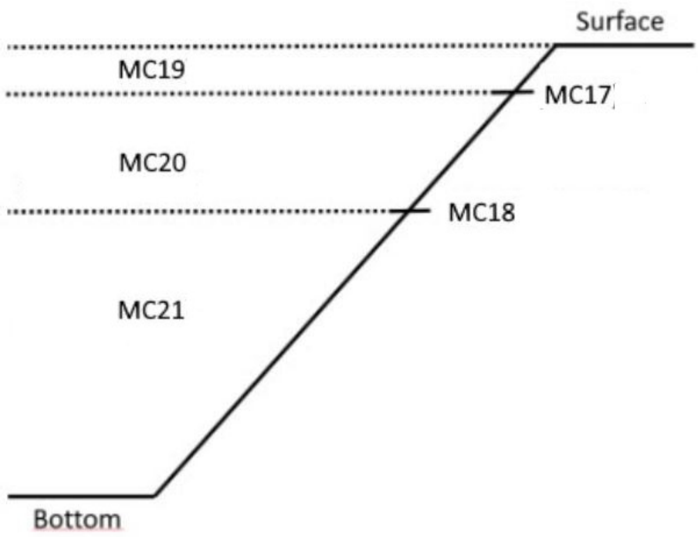
	AI3500-20FR001 Arvor-I/RBR	AI3500-20FR002 Arvor-I/RBR	AI2600-19FR105 Arvor-I/SBE
Date time	11/12/2020 8:45	11/12/2020 8:19	10/12/2020 16:29
Latitude	29°09.9928N	29°09.9928N	29°09.975N
Longitude	18°59.8373W	19°00.1417W	19°00.252W

Floats references

S/N	IMEI	email associated to IMEI	WMO	RBR S/N
AI3500-20FR001	300534060228320	laboelec@ifremer.fr co_iridium@ifremer.fr nke.iridium.sbd@gmail.com	6903075	203793
AI3500-20FR002	300534060226330	laboelec@ifremer.fr co_iridium@ifremer.fr nke.iridium.sbd@gmail.com	6903076	203794

Floats configuration

The sampling strategy of the profiling float is as follows :



The configuration of the float is the following:

Missions Parameters (Software 5900A06)				
#	Description	Default value	Choice	Unit
MC 0	Total number of cycles	*300*	500	-
MC 1	Number of cycles with cycle period 1	*300*	500	-
MC 2	Cycle period 1	*240*	240 (i.e. 10 days)	h
MC 3	Cycle period 2	*240*	240	h
MC 4	Reference day	*2*	2	days
MC 5	Expected time at the surface	*6*	6	h

MC 6	Delay before mission	*0*	30	min
MC 7	CTD sensor acquisition mode 1 : continuous 2 : économy 3 : mixt 4 : spot-sampling	*1*	1	-
MC 8	Descent sampling period	*0*	0	s
MC 9	Drift sampling period	*12*	3	h
MC 10	Ascent sampling period	*10*	10	s
MC 11	Drift depth (for "MC1" first cycles)	*1000*	1000	dBars
MC 12	Profile depth (for "MC1" first cycles)	*2000*	2000	dBars
MC 13	Drift depth (after "MC1" cycles are done)	*1000*	1000	dBars
MC 14	Profile depth (after "MC1" cycles are done)	*2000*	2000	dBars
MC 15	Alternated profile period (if = 1, no alternance)	*1*	1	-
MC 16	Profile pressure of alternated profile	*2000*	2000	dBars
MC 17	Threshold surface/Intermediate Pressure	*10*	400	dBars
MC 18	Threshold Intermediate /Bottom Pressure	*200*	1400	dBars

MC 19	Thickness of the surface slices	*1*	1	dBars
MC 20	Thickness of the intermediate slices	*10*	2	dBars
MC 21	Thickness of the bottom slices	*25*	5	dBars
MC 22	Iridium End of Life transmission period	*60*	180	min
MC 23	2nd iridium session wait period	*0*	20	min
MC 24	Grounding mode (0: shift, 1: stay grounded)	*0*	0	
MC 25	Grounding switch pressure	*100*	100	dBars
MC 26	Delay after grounding at surface	*10*	10	min
MC 27	Optode type (0: none, 1: 4330, 2: 3830)	*0 = aucune* *1 = 4330* *2 = 3830* *3 = externe*	0	-
MC 28	CTD sensor Cut-Off pressure (Pump stop)	*5*	2	dBars
MC 29	"In Air" acquisition cycle periodicity 0 : no acquisition 1 : acquisition at each cycle x: acquisition 1/x cycle	*SBE41 : 0* *CTD RBR : 1 (in air acquisition mandatory for the RBR CTD self calibration)*	1	-
MC 30	"In Air" acquisition sampling period	*30*	30	sec
MC 31	"In Air" acquisition total duration	*5*	5	min

Technical parameters (software 5900A06)				
#	Description	Default value	Choice	Unit
TC 0	Max eV activation on Surface (P< TC7)	800	800	cs
TC 1	Max volume eV during descent and repositioning	11	11	cm3
TC 2	Max duration pump during repositioning	290	290	cs
TC 3	Duration pump during ascent	720	720	cs
TC 4	Duration Pump during for surfacing	CTD SBE41 : 28000 (without optode) / 30000 (with optode) CTD RBR : 20000 (without optode) / 25000 (with optode)	22 000 when MC29=1 (mandatory for RBR), this value is not used, it's TC22	cs
TC 5	Pressure Delta for positioning (+/-)	30	30	dBar
TC 6	Max pressure before emergency ascent	2100	2100	dBar
TC 7	1st threshold for buoyancy reduction	1	1	dBar
TC 8	2nd threshold for buoyancy reduction	7	7	dBar
TC 9	Repositioning threshold	2	2	
TC 10	Max volume before detecting grounding	36 (55 if ICE option)	36	cm3
TC 11	Grounding pressure	200	200	dBar
TC 12	Pressure delta during drift (+/-)	50	50	dBar
TC 13	Average descent speed	25	25	mm/s
TC 14	Pressure increment	0	0	dBar
TC 15	Ascent End Pressure	10	10	dBar
TC 16	Average ascent speed	90	90	mm/s
TC 17	Float ascent speed control period	2	2	min

TC 18	Pressure ascent speed control pressure	10	10	dBar
TC 19	GPS timeout	45	45	min
TC 20	Hydraulic message transmission (0 : no, 1 ; yes)	1	1	
TC 21	Time before resetoffset	0	0	min
TC 22	Pump activation duration before "In Air" acquisition phase	CTD SBE41 : 33000 CTD RBR : 22000 (without optode) / 28000 (with optode)	22 000	cs
TC 23	Iridium timeout	120	120	min
TC 24	Float descent speed control period	5	5	min
TC 25	Pressure descent speed control pressure	3	3	dBar
TC 26	Offset added to internal vacuum threshold during self-test	50	50	mBar
TC 27	User options (BIT0 : Transmission of salinity correction for RBR CTD)	0 (bit0=1: if RBR CTD)	1	-
TC 28	Coef A	-	depending on serial number	-
TC 29	Coef B	-	depending on serial number	-

<u>TC28 & TC29 parameters (value is specific to each unit):</u>

Arvor-I serial number	TC 28	TC 29
AI3500-20FR001	1.454	-140.56
AI3500-20FR002	1.438	-169.46

First data collected

Figure 8 below shows the first profiles of temperature and salinity collected by the 3 floats.

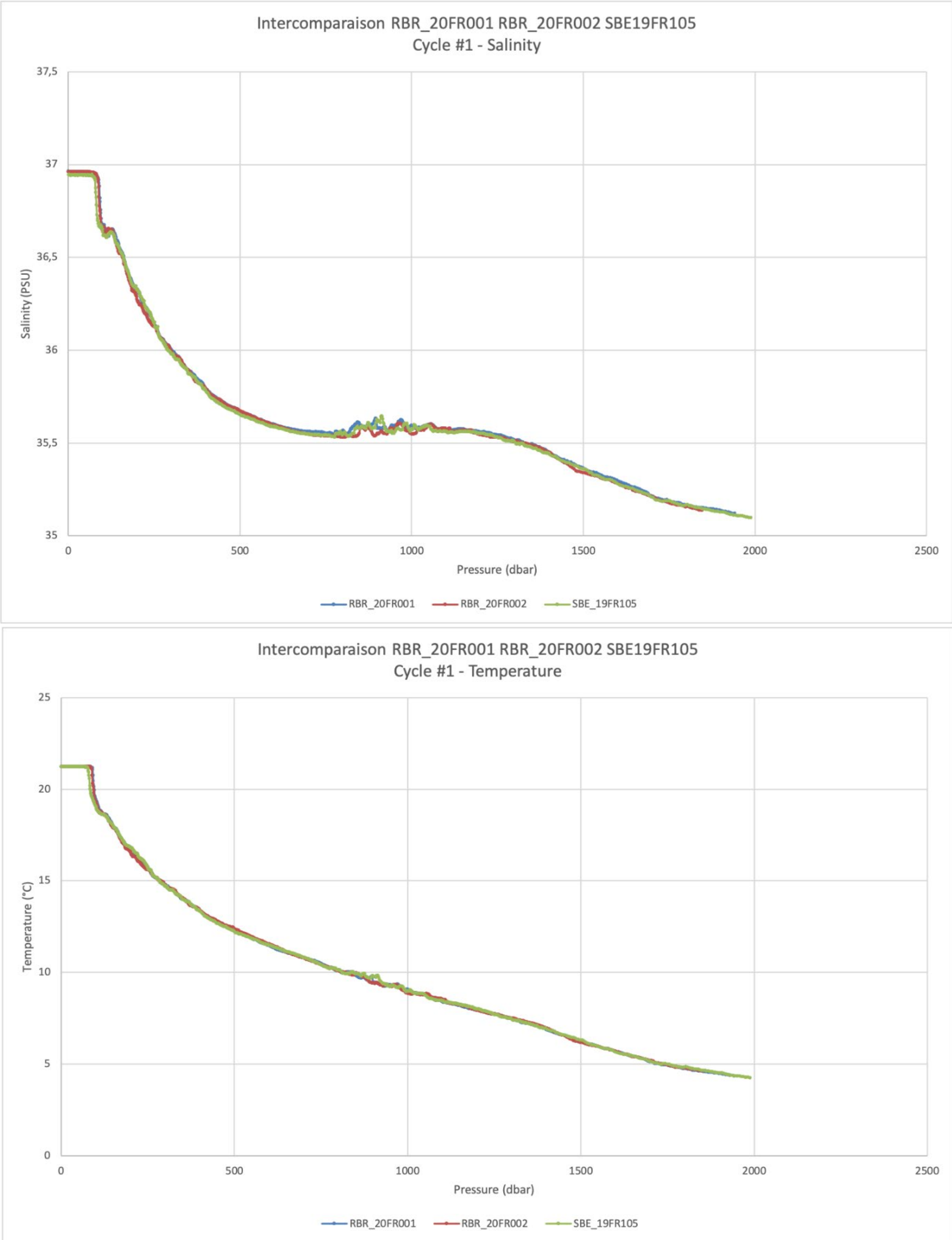


Figure 8: First profiles of salinity (up) and temperature (bottom) of the 3 deployed floats (RBR floats in blue and red, SBE float in green)

Figure 8 shows that none of the profiles provide perfectly similar data. These measurements are being analysed at the time of writing.

4.3. Baltic Sea experiments

For the Baltic Sea experiments, two ARVOR-I RBR floats (equipped with the RBRArgo[3] CTD) deployments are planned. One will be deployed on the Baltic Proper, Gotland deep in a Arandas Eurofleet cruise 22.3.-26.3.2021 Another will be deployed in Bothnian Sea during a planned Aranda cruise around 24.5. – 28.5.2021. Figure 9 below shows the planned deployment areas, and tracks of some earlier similar deployments. Operations in the Baltic Sea often require parameter changes during the missions. For these requirements a more detailed analysis is in the deliverable 6.4 (WP6).

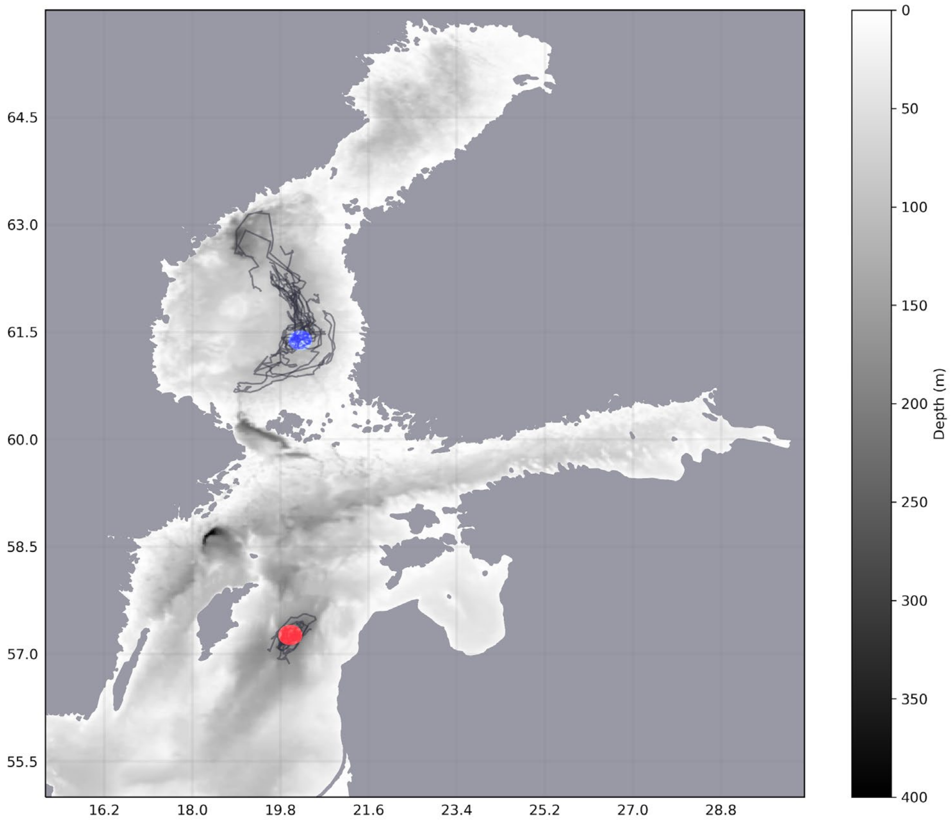


Figure 9: Bathymetry and the planned deployment locations on Baltic Sea. Red dot shows the Baltic Proper Gotlands deep. Blue one Bothnian Sea location. Paths of some earlier missions with similar deployments are illustrated in gray, to give an idea of expected mission area.

Of these planned areas, Baltic Proper's Gotland deep is deeper, largely over 200 meters, with stronger salinity gradient from surfaces ~7 units to bottom 12-13 units. As an Argo operating area, it is more stable, so the expected movement of the float is more constrained. The measurement frequency will be put higher at start to ensure everything works as expected, and then set to a 5-7 days interval for most of the mission time. Diving depths will vary depending a bit where the float ends, but will most likely be around 200 meters.

Bothnian Sea is shallower, expected measuring area varying around 100 meter depths. The salinity differences are smaller here, typically 4-6 units on surface, 6-7 at bottom. The measurement area is more dynamic, so the float is expected to drift in a larger area. Also as it is more north, there is a possibility to encounter ice during the mission. With timing the deployment in May it is likely for the area to be ice free when the mission starts. Initial measuring frequency will be higher here too, and depending on the drifting behavior will settle to 4-7 days cycles for most of the mission.

For both of the floats a reference CTD profile (SBE911+) will be taken with Aranda during the deployments. Also we aim to do other reference measurements later during the measurement cruises, provided the timing and location of the floats will allow it.

The battery status will be monitored throughout the missions, and the recovery of the floats planned accordingly.

5. Conclusion

This document summarises the steps carried out by IFREMER and FMI to undertake at-sea deployments with Arvor floats fitted with the RBRargo[3] sensor.

Design and integration specifications for Arvor floats were managed by IFREMER: 2 Euro-Argo RISE floats were successfully qualified in March 2020, which enabled partners to prepare for at-sea deployments.

At the moment of the writing, IFREMER deployed floats in the Canary Basin in December 2020 during an IEO cruise. 2 Arvor-I RBR along with one Arvor-I SBE41 were deployed in the same area that has a long time series. This strategy will assess the behavior of the sensors (accuracy and stability) in real operational conditions and allow a comparison with SBE41 sensor. This deployment will be a valuable contribution to the Stage II: Global Argo Pilot for the development of new sensors.

FMI is preparing unitary tests in collaboration with IFREMER as well as the deployment of their floats for 2021 in the Baltic Sea. Areas of deployment have been selected (Baltic Proper Gotland deep and Bothnian Sea) according to the experience of the past years as well as the deployment done in WP6.