Preliminary results of shallow coastal float operations in the Black Sea

Ref.: D6.3_V1.1

Date: 26/03/2021

Under EC review

Euro-Argo Research Infrastructure Sustainability and
Enhancement Project (EA RISE Project) - 824131

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement no 824131.
Call INFRADEV-03-2018-2019: Individual support to ESFRI
and other world-class research infrastructures

Document Reference

Project	**Euro-Argo RISE - 824131**
Deliverable number	**D6.3**
Deliverable title	**Preliminary results of shallow coastal float operations in the Black Sea**
Description	**Report that details the preliminary results of Argo float operations in shallow coastal areas of the Black Sea.**
Work Package number	**6**
Work Package title	**Extension to Marginal Seas**
Lead Institute	**IO-BAS**
Lead authors	**Atanas Palazov**
Contributors	**Giulio Notarstefano, Violeta Slabakova, Romain Cancouët**
Submission date	**26/03/3021**
Due date	**[M18] 30 June 2020**
Comments	**This deliverable was postponed due to Covid-19 pandemic (Article 51 claimed)**
Accepted by	**Giulio Notarstefano**

Document History

Version	Issue Date	Authors	Comments
V0.0	08/12/2020	Atanas Palazov	Preliminary draft version
V0.1	05/02/2021	Atanas Palazov, Violeta Slabakova, Giulio Notarstefano, Romain Cancouët	Completed draft version
V1.0	26/02/2021	Atanas Palazov, Violeta Slabakova, Giulio Notarstefano, Romain Cancouët	Updated version after comments from Estérine Evrard and Antoine Poteau.
V1.1	26/03/2021	Atanas Palazov, Violeta Slabakova, Giulio Notarstefano	Proofreading and final editing

EXECUTIVE SUMMARY

The extension of Argo float coverage to the European marginal seas is described as one of the strategic targets of the Euro-Argo European Research Infrastructure Consortium (ERIC). Under the framework of Euro-Argo RISE H2020 project and more specifically under WP6 “Extension to marginal seas”, regional extensions and implementation of the Argo array activities have been undertaken to serve the extension of Argo into targeted shallow coastal waters of European Marginal Seas (EMS) that have important socio-economic impact. Furthermore, a main scope under this WP is the investigation of the potential of Argo profiling floats to operate in shelf areas and fill the monitoring gap between offshore and shallow waters. Under this framework, targeted deployments of Argo floats in coastal areas of the EMS have been undertaken, mainly focusing on the technical aspects and the configuration of the floats. Furthermore, the Principal Investigators focus on the optimization of the sampling characteristics, being in strong link with the project’s task 2.1, and the utilization of existing and new controlling and monitoring tools that will be tailored for operations in EMS (see D2.1). These main targets will be pursued by the three tasks of WP6, dedicated to different marginal seas: task 6.1 for the Mediterranean Sea, task 6.2 for the Black Sea and task 6.3 for the Baltic Sea. In this document, the experience from two (2) float deployments in the coastal areas of the western Black Sea is presented.

TABLE OF CONTENT

Introduction

Black Sea is a region of particular interest in terms of its past and present level of ecological degradation by anthropogenic influences among the European Seas and highly dynamic and complex eddy-driven circulation system. The Black Sea receives drainage from almost one-third of the continental Europe (five times its surface area) which includes 17 countries with about 160 million inhabitants. It is virtually isolated from the rest of the European Seas except a limited exchange through the Turkish Straits System, and hence extremely vulnerable to external environmental stresses. Besides, its resources have become unsustainable and its ecological state has deteriorated dramatically. Natural and man-made impacts are widely recognized to be the key ecological drivers in the regions under the direct influence of the rivers input and land based pollution, which is the case of the northwestern (NW) Black Sea area. The three large rivers Danube, Dnipro and Dniester pour into the NW Black Sea, carrying vast amount of nutrients, organic and inorganic matter, which induces a significant impact on the hydrodynamic regime and ecological processes in the region, modulated strongly by large scale climatic and atmospheric teleconnection patterns.

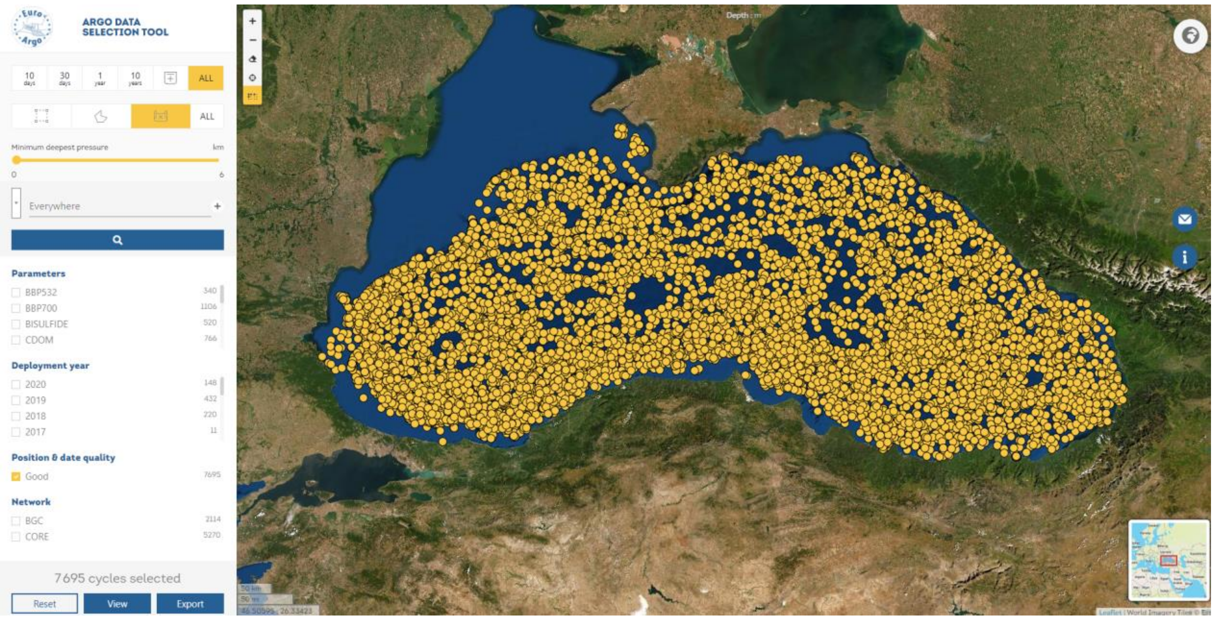
Several changes in the Black Sea ecosystem have been documented over the last four decades, especially its NW part as the most sensitive to external forcing, including a shift from a relatively pristine phase around 70-ies to a phase of ecosystem degradation till early 90-ies, (Zaitsev & Alexandrov 1997, Mee 1992, Yunev et al. 2002, Yunev et al. 2005), substantial modification of the phytoplankton community structure (Bodeanu et al. 1998, Moncheva 1995, Moncheva et al. 2001,) as well as increase in the magnitude, duration and frequency of phytoplankton blooms leading to anoxia/hypoxia and loss of benthic community (Friedrich et al. 2010). Overfishing, biodiversity changes, exotic species introduction and eutrophication (Daskalov 2002, Oguz and Gilbert 2007, Yunev et al. 2007, Capet et al. 2013, Shiganova 2008) have been identified as major ecological concerns.

Comprehensive knowledge and understanding of the physical and biogeochemical processes are essential to increase the scientific capability to assess the recent stage of evolution and the controlling mechanisms of the ecosystem and to enhance the forecasting capacity in order sustainably manage the coastal and offshore waters of the Black Sea basin. This calls for regular physical and biogeochemical observations of both spatial and temporal variability. The majority of *in situ* observations that are commonly used for monitoring of the Black Sea are generally based on near-shore monitoring programmes or irregular oceanographic cruises that provide either non-synoptic, coarse resolution realizations of large scale processes or detailed, but time and site specific snapshots of local features and processes. These gaps can be successfully filled in by Argo floats which provide cost effective and excellent space/time resolution data.

The Euro-Argo European Research Infrastructure Consortium (ERIC) has timely adopted a plan for the expansion of Argo into marginal seas and has included it in its strategic targets (Euro-Argo ERIC, 2017) aiming to provide high quality in-situ datasets in the European marginal seas. This has resulted in an increasing number of float coverage in sea regions such as the Nordic, Baltic, Mediterranean, and Black Seas allowing better oceanographic monitoring and producing enhanced datasets during the last years.

Since 2002 to the present, 45 Argo floats have been deployed in the Black Sea during different international, regional and national scientific initiatives. The northwestern shelf part of the Black Sea is not visited by the Argo floats (Figure 1) because of its shallow depths and the specifics of sea currents.

This fact raises a question whether the Argo platform, that has been originally designed to perform in the open ocean environment, can adequately perform in coastal and shelf regions of the Black Sea.



Parameters
☐ BBP532 340
☐ BBP700 1106
☐ BISULFIDE 520
☐ CDOM 766

Deployment year
☐ 2020 148
☐ 2019 432
☐ 2018 220
☐ 2017 11

Position & date quality
☑ Good 7695

Network
☐ BGC 2114
☐ CORE 5270

7695 cycles selected

Figure 1. Profiles of the Black Sea Argo floats

This document provides preliminary results of targeted Argo missions in the Black Sea that are designed to explore Argo floats capability to monitor the shallow coastal and shelf waters. The aim is the improvement of the floats' operations in such areas, increase their sampling efficiency, and provide feedback to WP 2 (improvement of the core Argo mission).

The regional expansion of Argo into shallow areas is addressed by the partners (IO-BAS and OGS). Two floats were deployed in the North-Western and Western shelf of the Black Sea in front of Danube delta (OGS with the collaboration of Romanian institute GeoEcoMar) and Kamchia river delta (IO-BAS) Figure 2. Floats were controlled using specific available monitoring tools and home-made tools.

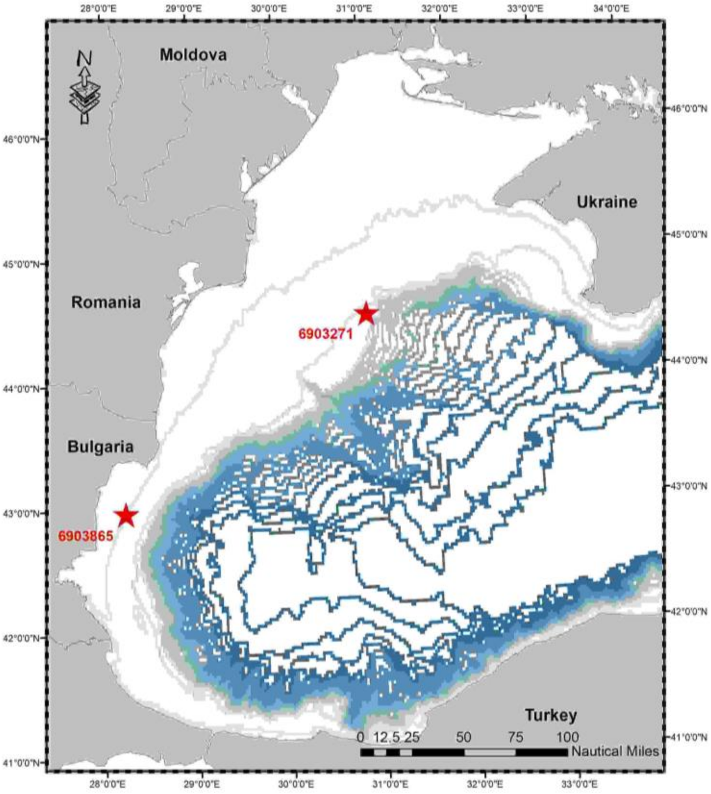


Figure 2. Euro-Argo RISE floats (WMO 6903271 and WMO 6903865) deployment locations

The two floats used different approaches to be kept in operation in shallow waters.

The first one (in front of Danube delta) was set to step on the seabed when parking at a depth of about 100 m. The second (in front of Kamchia) was anchored at a depth of 50 m.

IO BAS float

It was decided to test possibilities to moor an ARGO float in order to fix it in shallow waters and prevent fast movement to deep waters. This would allow collection of ARGO data in shallow waters never visited before by ARGO floats. We decided to moor the ARGO in 50m depth which will allow easy recovery in case of problems with mooring.

In order to design buoy mooring systems such as the structure arrangement to be able to translate data under harsh sea conditions it is recommended to take into account the criteria formulated in terms of Ultimate Limit State. In the standards it is suggested to consider at least 3 types of mooring line and current profiles.

It is suggested to provide further research on the misalignment effects of the mooring system necessary for design checks, including co-directional current and waves where the largest short-term mooring system base fatigue damage could be determined.

The applied methodology follows the DNV standards for domain simulations (DNV-OS-J103, 2013) and for mooring systems (DNVGL-OS-E301, 2015). Accomplished steps are as follow:

- Mean up-crossing analysis to extrapolate the maximum mooring line tensions and buoy position;
- The global maximum is modeled by Weibull distribution;

- Mooring line length and diameter are defined.

The motion responses of the float are examined through a time domain analysis of the displacements and motion tensions to support the comparison of the results among the provided environmental conditions.

The Arvor-I float is considered as reference for the numerical simulations. It features 24 kg shallow water anchored cylindrical buoy with one catenary mooring line. After consultations with NKE, the buoyancy is considered to be 1 kg. In the present study it is assumed that the mooring system is connected by tuning pin with the same characteristic as the mooring line – mass, density and stiffness.

The numerical application AQWA included in the software package ANSYS is used for current study. It is based on numerical panel method and as an addition captures mooring line stiffness and damping forces in axial direction, buoyancy effects, seabed contact forces and hydrodynamic loads from mooring motion using Morison's equations.

The environmental conditions refer to a deployment location off the Bulgarian coast where the water depth is around 50 m were investigated. To extract the extreme environmental conditions, extrapolated conditions according to DNV and Bureau Veritas recommendations were applied.

In order to increase probability of considering the maximum buoy displacement, 3-hour sea state simulation is recommended. Statistical reliability was ensured by running 20 different simulations for each case.

The work is focused on conditions with different current profiles which show important effects of current misalignment. The achieved results involved analysis of three cases. Motion responses were obtained by using of AQWA simulation tool as in addition variation in the mooring dynamics due to changes in environmental conditions. The dynamic mechanisms of the mooring lines are provided by meaningful frequency and time analysis.

In order to provide the buoy mooring line design the results of line tension force are examined in terms of Weibull parameters to enable comparison of possible loads.

Time domain buoy response dynamic analysis is conducted in order to examine behaviour of the buoy under the selected extreme environmental conditions.

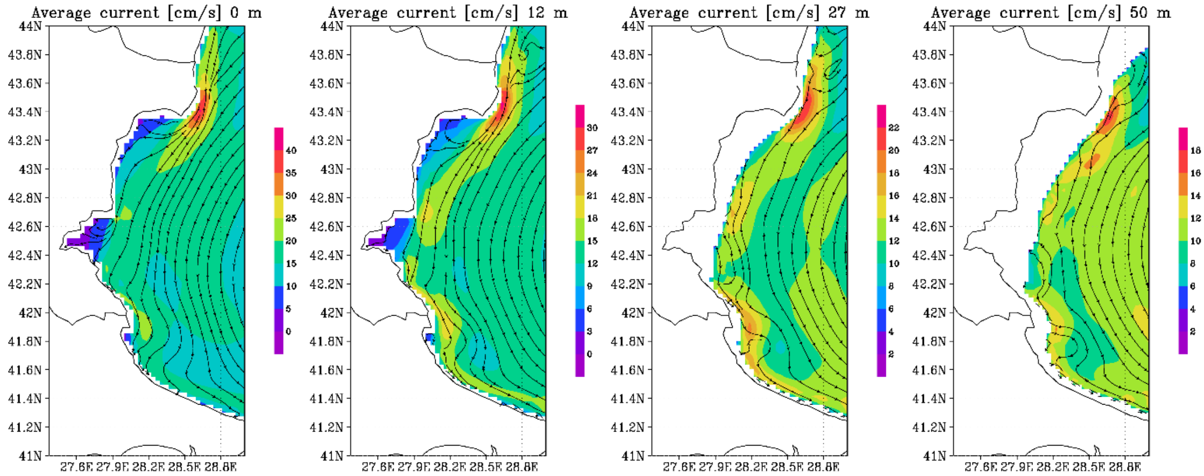


Figure 3. Velocity contour lines at several water depth in the Black Sea refer to the offshore site of Bulgaria's coast

In order to define a set of environmental conditions and to take into account velocity profiles with reference to water depth three cases are prepared and examined by using data from Figure 3. Table 1 shows the boundary conditions' cases.

Table 1: Current velocity characteristics used by simulated cases

Water depth [m]	0	12	27	50
Case 1 Velocity[m/s]	0.3	0.15	0.1	0
Case 2 Velocity[m/s]	0.5	0.25	0.15	0
Case 3 Velocity[m/s]	0.7	0.3	0.2	0

In order to identify the vertical position of the buoy and to define the increment/decrement of heave displacement as a function of current profile, the simulation of case 3 with higher velocity shows that the vertical position remains applicable for data translation. We can see that the dock line stays tight even when unstretched condition is achieved which gives the case that the line will remain operational when there is lack of sea current.

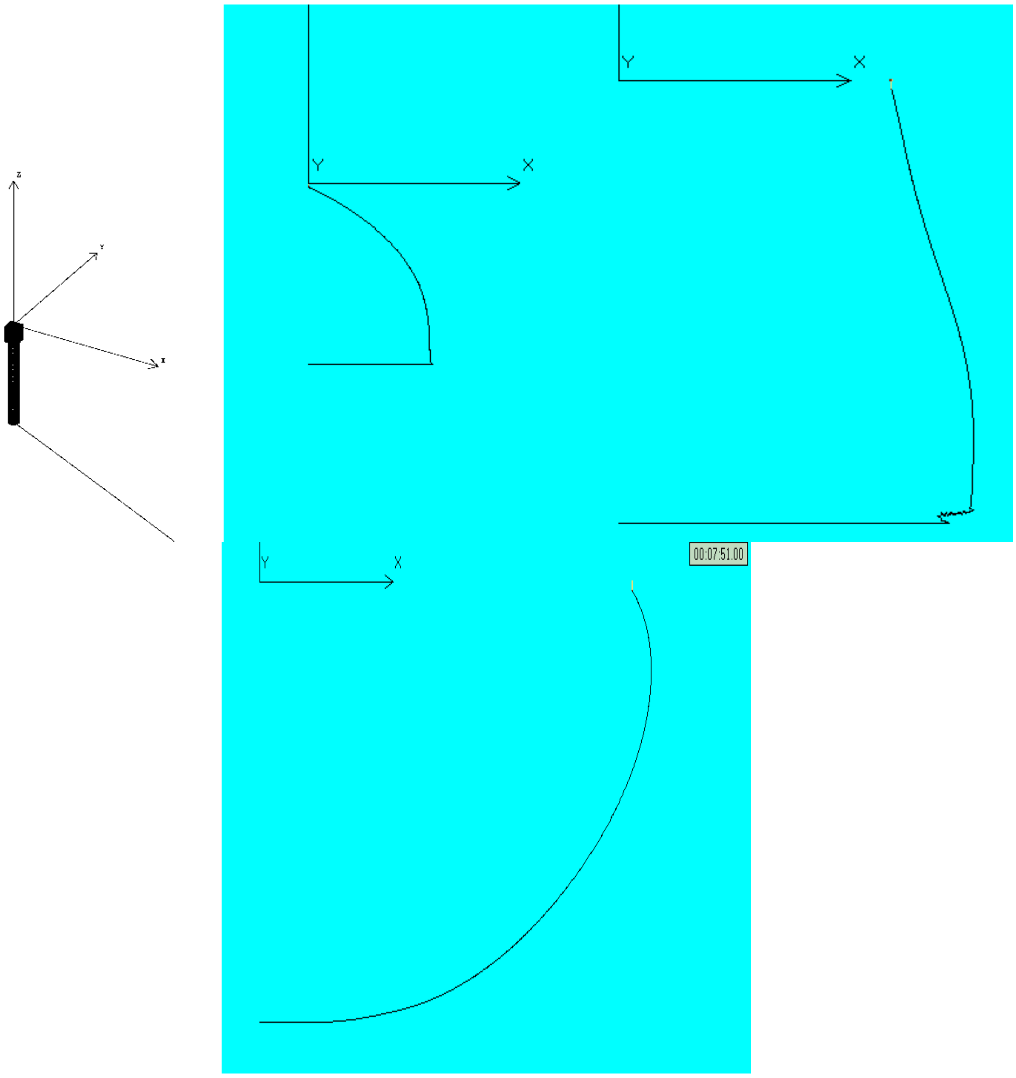


Figure 4. Buoy position at different instances of time for Case 3

The distribution of Weibull is fitted on the obtained mooring line tension for environmental Case 3. Figure 4 shows that the distribution fits well to the extreme mooring line loads.

The results from Weibull distribution are taken into account by mooring line selection Figure 5.

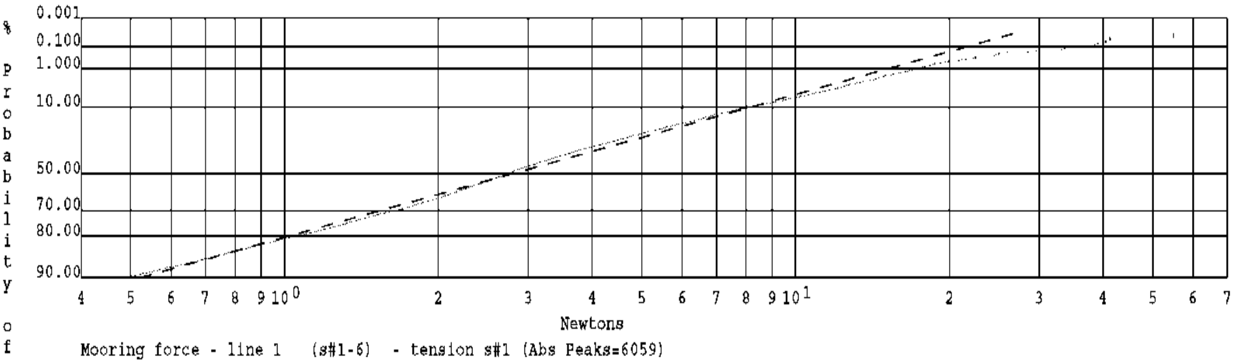


Figure 5. Mooring line axial force [N] Weibull peak distribution

Since the buoy has to float to be able to transfer data, the heave motion time history is presented in Figure 6. It shows COG position which is situated 0.8 m from the topside of the buoy.

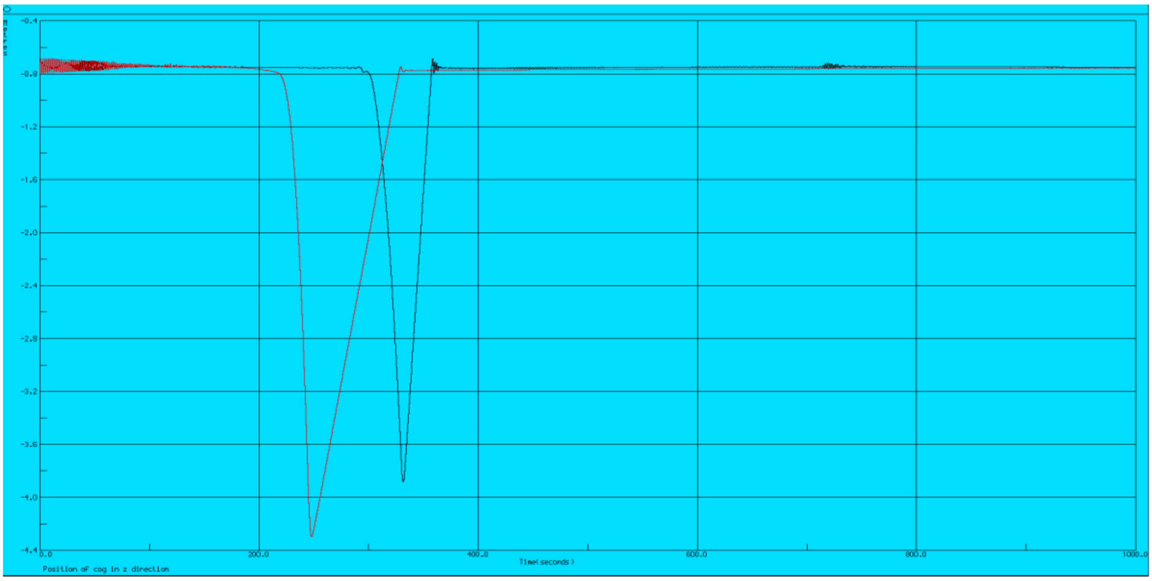


Figure 6. Structure COG position in z direction for case 1 and 3

Even by Case 3 with higher current velocity it follows the trajectory as by Case 1 and 2 which gives the opportunity to make a conclusion that the chosen mooring line properties will be able to perform the float main task and namely to collect and transmit environmental data.

IO-BAS deployed one Euro-Argo RISE Argo float (WMO 6903865) on 24th of July 2020 off the Bulgarian Black Sea shelf at 50 m depth to test its potential as a virtual mooring using a fishing line with almost neutral buoyancy (Figure 7). The length and the diameter of the fishing line attached to the float and anchor were 100 m and 2 mm, respectively. Its density was 1150 kg/m3 and the calculated weight in the water is 42,4 gr.

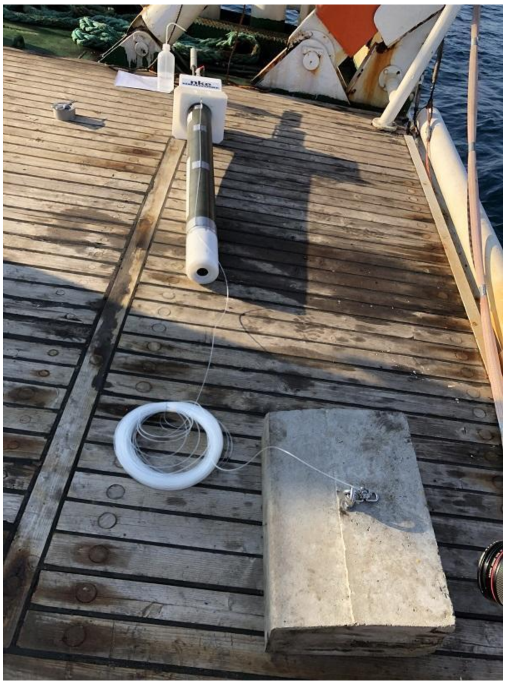


Figure7. Mooring arrangement.

The float is manufactured by the French NKE and it is an Arvor-I model. The main platform information is summarized in Table 2. The float is equipped with the Iridium bi-directional telemetry system that allows a two-way communication between the platform and the control center.

Table 2: Main information of the Argo float WMO 6903865

Float type	WMO	Deployment date	Deployment latitude	Deployment longitude	Last station date	Cycle
Arvor-I	6903865	24 July 2020	42.9813N	28.2338 E	15 November 2020	94

The IO–BAS float was programmed to drift at 30 meters depth and to profile to 50m. The mission cycle was set up to 24 hours. The mission settings just after deployment are described in Table. 3.

Table 3. Platform mission settings

Mission parameters			
Abbr.	**NAME**	**VALUE**	**UNIT**
MC0	MC0 – Number of cycles	300	-

MC1	MC1 – Number of cycles with « Cycle Period 1 »	300	-
MC2	MC2 – Cycle Period 1	24	Hours
MC3	MC3 – Cycle Period 2	24	Hours
MC4	MC4 – Reference Day	1	Mission day
MC5	MC5 - Estimated hour on surface	4	Hour in the day
MC6	MC6 – Delay Before Mission	0	Minutes
MC7	MC7 – CTD acquisition mode	1	-
MC8	MC8 – Descent Sampling Period	0	Seconds
MC9	MC9 – Drift Sampling Period	12	Hours
MC10	MC10 – Ascent Sampling Period	10	Seconds
MC11	MC11 – Drift Depth during MC1 cycles	40	dBar
MC12	MC12 – Profile Depth during MC1 cycles	50	dBar
MC13	MC13 – Drift Depth after MC1 cycles, up to MC0 cycles	40	dBar
MC14	MC14 – Profile Depth after MC1 cycles, up to MC0 cycles	50	dBar
MC15	MC15 – Alternate profile period	1	-
MC16	MC16 - Alternate Profile pressure	2000	dBar
MC17	MC17 - Threshold Middle/Surface Pressure	10	dBar
MC18	MC18 - Threshold Middle/Bottom Pressure	200	dBar
MC19	MC19 - Thickness of the surface layers	1	dBar
MC20	MC20 - Thickness of the middle layers	10	dBar
MC21	MC21 - Thickness of the bottom layers	25	dBar

MC22	MC22 - End of life Iridium period (Iridium Only)	60	Minutes
MC23	MC23 – Iridium 2nd session wait period (Iridium only)	0	Minutes
MC24	MC24 - Grounding mode (0 = Shift, 1 = Stay grounded)	0	Minutes
MC25	MC25 – Grounding switch pressure (Minus Pressure profile)	50	dBar
MC26	MC26 – Wait at surface in case of grounding at surface	10	Minutes
MC27	MC27 – Optode Type (0 = none, 1 = 4330, 2 = 3830)	0	-
MC28	MC28 – CTD Sensor Cut-Off pressure	5	dBar
MC29	MC29 – In air Acquisition Period	0	-
MC30	MC30 – In air acquisition sampling period	30	Seconds
MC31	MC31 – In Air acquisition duration	5	Minutes

The Euro-Argo (https://fleetmonitoring.euro-argo.eu/) and Ocean-OPS (https://www.ocean-ops.org/) tools were used to monitor the technical details and alerts linked to the float mission.

OGS float

One Argo platform (Euro-Argo RISE float WMO 6903271) is tested in shelf areas of the north-western side of the Black Sea with the aim of keeping the float in shallow waters, far from the coast and avoiding the high marine traffic (Figure 8). Since Argo floats usually operate in open ocean, the goal is also to try to optimize the float setting for this kind of operation and to explore any technical and instrumental limits that can prevent the use of Argo on shelf areas of the Black Sea.

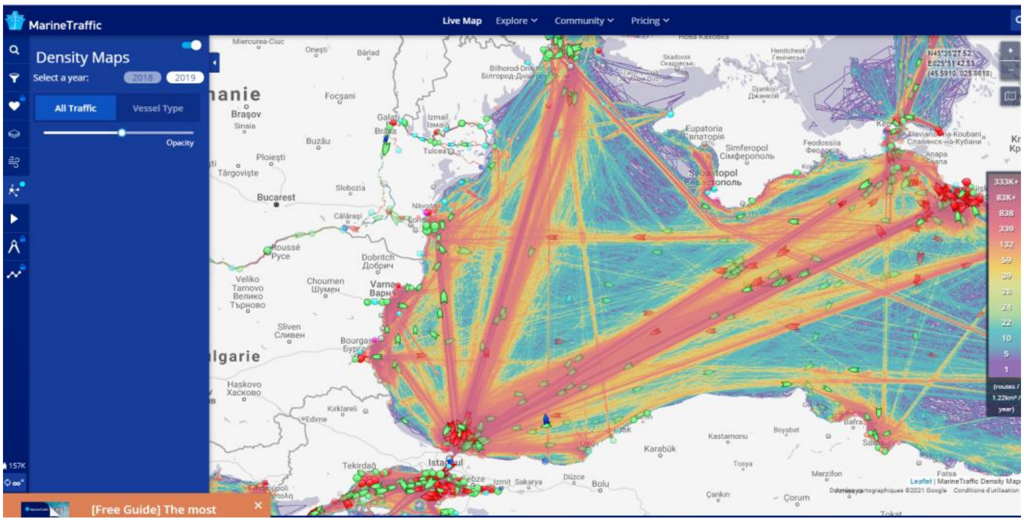


Figure 8. Black Sea marine traffic density map (source https://www.marinetraffic.com)

The Black Sea coastal areas are characterized by intense maritime traffic. Hence, to avoid collision with ships and to prevent stranding events of the platform, a set of monitoring and controlling tools has been used. The Euro-Argo (https://fleetmonitoring.euro-argo.eu/) and Ocean-OPS (https://www.ocean-ops.org/) monitoring tools provide users with a friendly and useful interface that allows them to check technical details, graphs, alerts linked to the Argo mission. In addition, some home-made tools have been developed, like an automatic email alert system to have the float position and the depth of the sea at the float location almost in real time. These systems are crucial when the operator has to send new settings to the platform in order to modify the mission (see Deliverable D6.1 for details).

The float is manufactured by the French NKE and it is an Arvor-I model. The main platform information is summarized in Table 4. The float is equipped with the Iridium bi-directional telemetry system that allows a two-way communication between the platform and the control center.

Table 4: Main information of the Argo-Italy float WMO 6903271

Float type	WMO	Deployment date	Deployment latitude	Deployment longitude	Last station date	Cycle
Arvor-I	6903271	1 October 2019	44.539 N	30.971 E	16 January 2021	240

Since the planned mission target is to keep the float on the shelf, the float was initially configured with a parking depth at the sea bottom in order to limit its displacement due to the sea currents (MC 11 and MC 12 = 150); moreover, the float was placed at the seabed for the entire length of the cycle. The cycle length (MC 2) was gradually increased from 1 to 5 days in order to carefully check the float behaviour at the first stage of the mission. The platform and mission settings just after deployment are described in Table 5.

Table 5: Platform and mission settings at the in the first part of operations

First cycle mission commands			First cycle technical parameters		
MC0= 500	MC11=150	MC22= 60	TC0= 800	TC10= 36	TC20= 1
MC1= 500	MC12=150	MC23= 0	TC1= 11	TC11=200	TC21= 0
MC2= 24	MC13=150	MC24= 1	TC2=290	TC12= 50	TC22= 33000

MC3=24	MC14=150	MC25= 5	TC3= 720	TC13=25	TC23= 120
MC4= 1	MC15=1	MC26=30	TC4=27000	TC14=0	TC24= 5
MC5=6	MC16=2000	MC27=0	TC5=30	TC15= 10	TC25= 189
MC6= 15	MC17=100	MC28= 2	TC6=2100	TC16=90	TC26= 0
MC7=1	MC18=500	MC29= 0	TC7= 2	TC17= 2	TC27=36096
MC8= 0	MC19=1	MC30=30	TC8= 7	TC18=10	TC28=-17761
MC9= 3	MC20= 1	MC31= 5	TC9= 2	TC19= 36	
MC10= 10	MC21= 5				

The main mission commands (listed in Table 5) description is provided hereafter:

MC0 = number of total cycles

MC2 = cycling period (in hours)

MC11 = parking depth

MC12 = maximal profile depth

MC17 = threshold zones 1/2

MC18 = threshold zones 2/3

MC19 = vertical resolution in zone 1

MC20 = vertical resolution in zone 2

MC21 = vertical resolution in zone 3

MC24 = grounding mode (0 shift upward, 1 stay grounded)

MC25= shifting upward amount

Results

IO BAS float

After the deployment, the float uncounted difficulty to dive and ascend in the water column compared to normal. For some cycles the float was not able to ascent and reaches the surface (Figure 9) which affected its regular transmissions (Figure 10). Most of the CTD profiles were with low quality. The pressure offset correction of the float was 12 dbar for some cycles between cycles 3 and 20 (Figure 11). No valid GPS position could be determined which caused a serious problem for monitoring of the float.

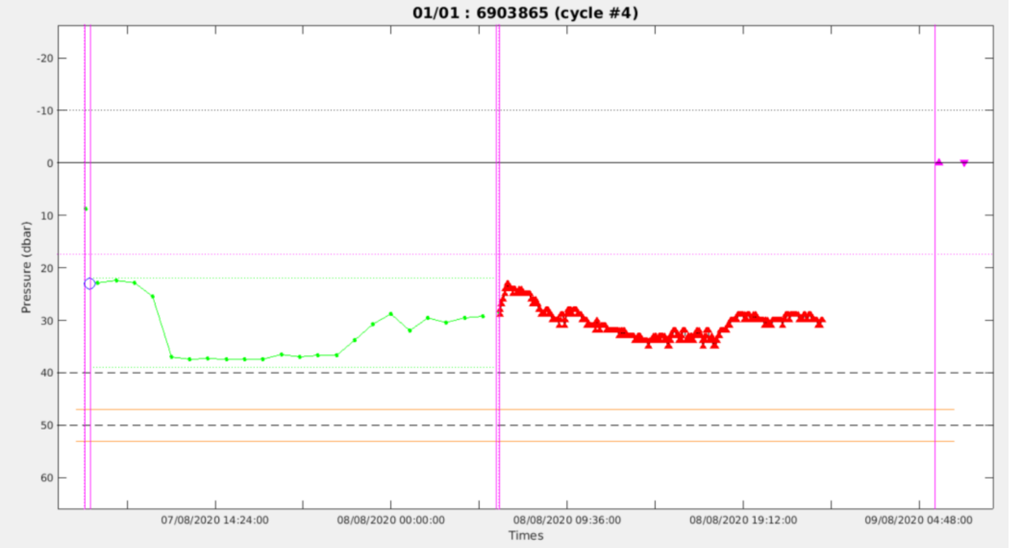
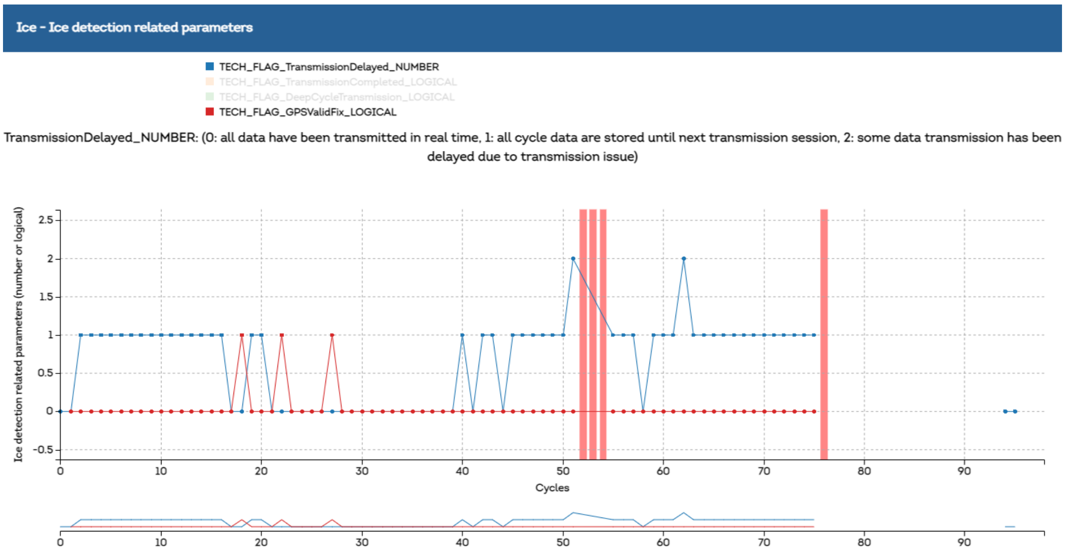


Figure 9.Underwater trajectory (time versus pressure figure) of the float WMO 6903865 for cycle 4 (https://fleetmonitoring.euro-argo.eu/float/6903865)



TransmissionDelayed_NUMBER: (0: all data have been transmitted in real time, 1: all cycle data are stored until next transmission session, 2: some data transmission has been delayed due to transmission issue)

Figure 10. Transmission (0) or absence of transmission (1) of the float WMO 6903865 as a function of cycle number. The float did not transmit on cycles 2 to 16, then 19 and 20, etc. (https://fleetmonitoring.euro-argo.eu/float/6903865)

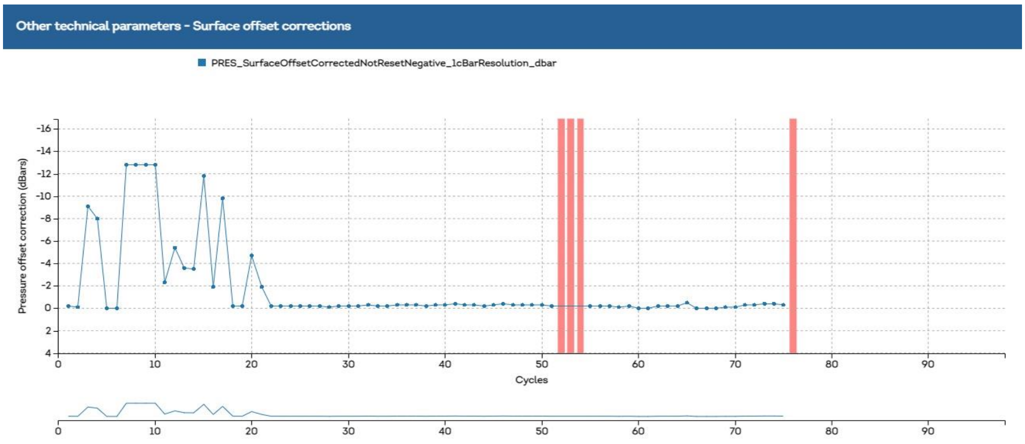


Figure 11. Pressure offset correction (https://fleetmonitoring.euro-argo.eu/float/6903865)

In order to understand the reason for its abnormal behaviour several options were considered:

1. Problem with the mooring line and/or the way the float was attached on the line which affected its freedom of movement (float had difficulties to emerged from the water and to made a good GPS fix and to transmit the data);
2. Insufficient buoyancy due to relatively fresh surface water in the Black Sea which don't allow the float antenna to rise enough above the sea surface to communicate stable with the satellite.
3. Weather and sea state conditions (waves, currents, winds) which affected its regular transmissions.
4. Technical problem with the float's communication hardware.

During cycle 21 on 25 August the float suddenly increased its drifting depth from 20dbar to 45 dbar in a few hours (Figure 12) and the float started to transmit profiles with positions significantly different from the position where the float was fixed possibly due to the broken mooring line. Despite the float starting to drift freely it continued to transmit profiles irregularly and almost all GPS positions were not valid which challenged the monitoring of the float and made impossibility for its recovery. According to the Euro-Argo fleet monitoring tool only 3 (cycles 18, 22 and 27) out of 94 GPS positions were valid (Figure 13).

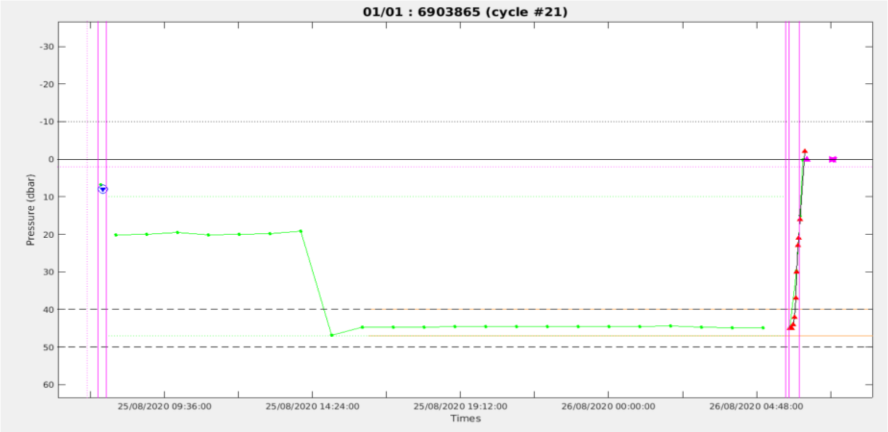


Figure 12. Underwater trajectory (time versus pressure figure) of the float WMO 6903865 for cycle 21 (https://fleetmonitoring.euro-argo.eu/float/6903865)

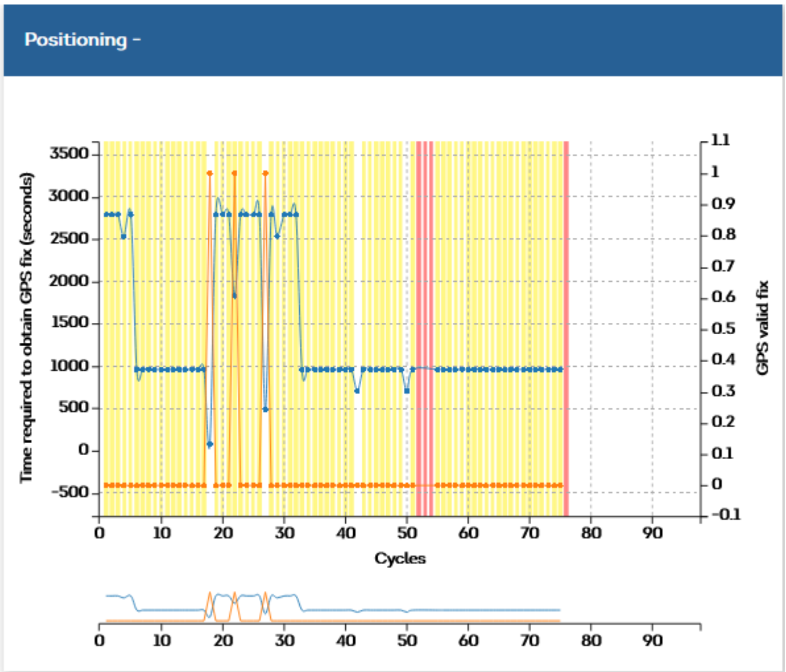


Figure 13. Valid GPS positions of Euro-Argo RISE Argo float WMO 6903865 (source https://fleetmonitoring.euro-argo.eu/float/6903865).

In the period from 25th September 2020 to 15th of November the float stopped to transmit the data. On 15th November the float sent a series of messages with IRIDIUM positions located in the middle of the Bosporus Strait (09:48) and close to Bağırkanlı Limanı port (17: 24) - Figure 14. On 16th November the location of the float was in Bağırkanlı Limanı port. Immediately the IO-BAS team contacted its Turkish colleague and asked them to help to recover the float. Turkish colleagues visited the place but the float was not found. Unreliable GPS data of the position of the float did not allow us to attempt to recover it.

Figure 14. Last locations of the Euro-Argo RISE Argo float WMO 6903865

OGS float

OGS deployed one Euro-Argo RISE Argo float the 1st of October 2019 off the Danube River delta (Figure 15 and 16), just before the shelf break. A joint collaboration between OGS (Italy), GeoEcoMar (Romania) and IO-BAS (Bulgaria) has been established for the deployment operations. The float was deployed in the framework of the Anemone project.

The target of the mission is to keep the float on the shelf and use it as a virtual mooring. Different values of cycle length and parking depth were tested and the float is on 18th of January 2021 operating in the south-western Black Sea (Figure 17).

Figure 15. Deployment of the float WMO 6903271 in the north-west shelf of the Black Sea, the 1st of October 2019.

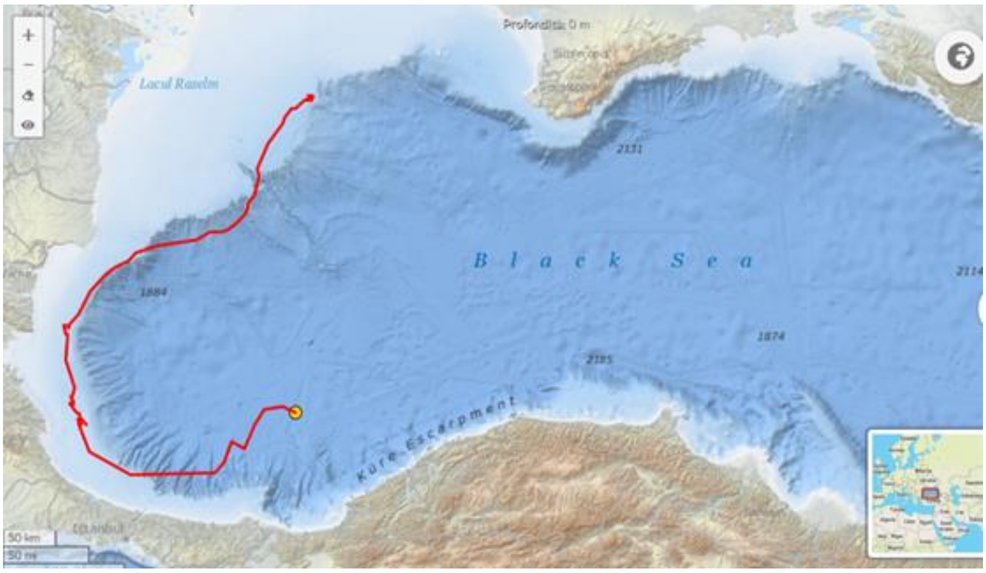


Figure 16. Trajectory of float WMO 6903271 from 1st of October 2019 to 16th January 2021. Deployment (red dot) and last available (yellow dot) locations are shown.

The radius of displacement from the deployment location was about 6 km in the first two months (Figure 17) and we were able to reach such a result thanks to an accurate work done in term of adjusting the float configuration according to the needs (the cycle length was gradually increase to 2 days: MC 2 = 48. The parking depth was confirmed at the sea bottom). The Hovmoller diagram and the profiles of potential temperature are shown in Figure 18: the potential temperature drop in the top 30 meters is evident and impacts on the density of this surface layer (Figure 18, right panel).

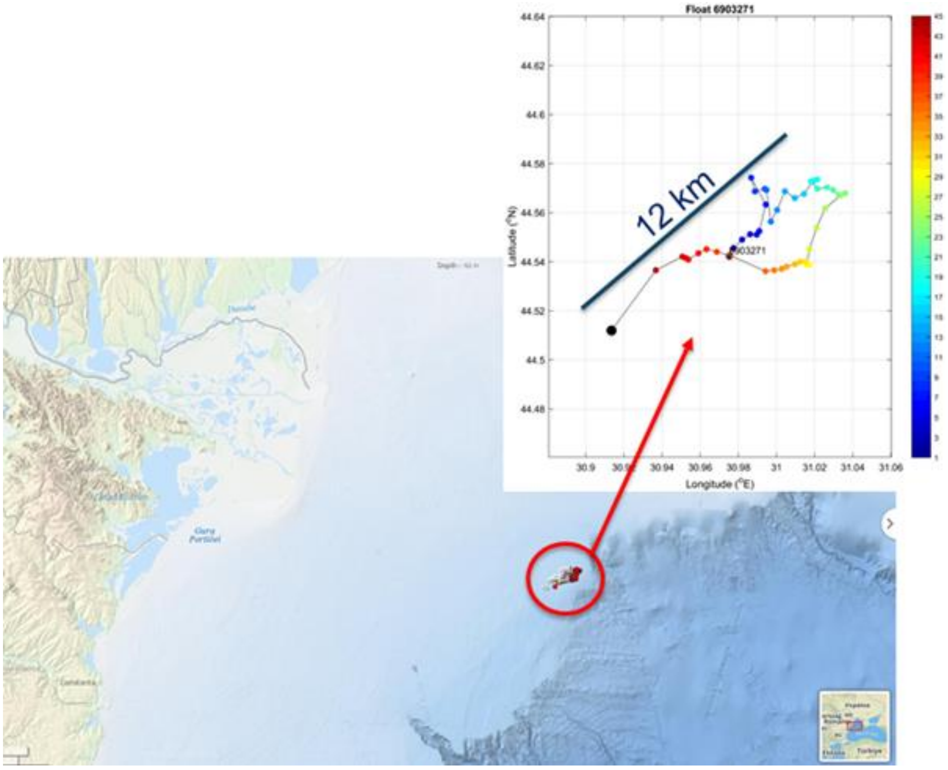


Figure 17. Trajectory of float WMO 6903271 (October and November 2019), color-coded per cycle number.

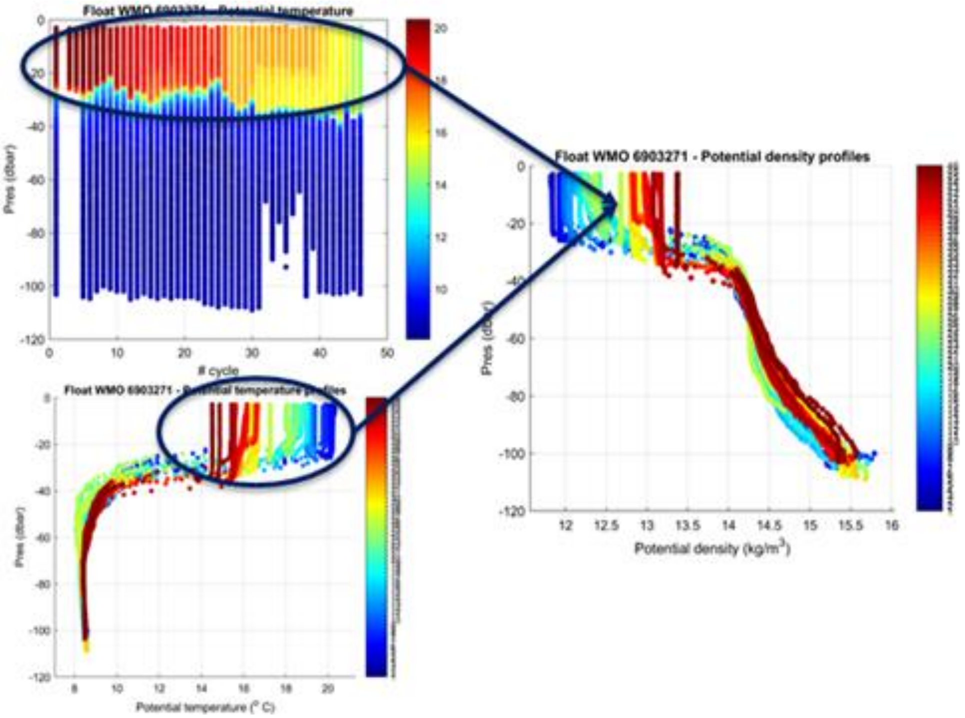


Figure 18. Hovmoller diagram of potential temperature (top right); profiles of potential temperature (bottom right) and potential density (right panel) color-coded per cycle number.

The float started moving south quite fast toward the shelf break in November 2019. As soon as we noticed the float drifted west (away from the break) we changed the cycle length to 2 hours (MC 2 = 2) that means the platform can continuously perform profiles down to about 75 m, without touching the bottom. In this way, the float was advected westward by the near surface current. The float eventually reached the deployment location on the 12th of November 2019 where the mission parameters were changed again (2-day cycle and parking depth at the sea bottom).

The float rapidly moved toward the South, about 3 km from 24 to 26 of November (cycles 45 and 46). MC 2 was set to 96 hours to keep the Arvor parked longer at the sea bottom.

The float drifted south-west very fast, approaching the shelf break in proximity of a canyon (February 2020). Cycle length was set to 1 hour in order to try to capture a cyclonic near surface current system. The float crossed the canyon at the beginning of March 2020; the configuration was changed to a 5 days cycle and parking depth to the bottom to avoid the float being captured by the main anticyclonic system (RIM current). After cycle 89 (end of March 2020) the float received the command to perform cycles every 2 hours. In this way it was expected to dive in the upper zone (0-50 dbar). The float was intentionally left in the near surface water to try to approach the shelf again; this was done taking into account the horizontal velocity field at surface (CMEMS product: https://resources.marine.copernicus.eu/?option=com_csw&task=viewer&record_id=b09312b0-1b4d-4cac-b585-eeb4089ba8a1) and the wind field in the area (the wind forecast on ventusky.com was about 20 kt toward SW on 1st of April at 9:00 AM). The cycling period was reduced to 1 hour forcing a parking depth and the maximal profile depth to 10 dbar the 1st of April. The parameter relative to the pressure tolerance at parking depth was changed from 30 dbar (generally used for deep water) to 5 dbar (TC 5 = 5). The float drifts as expected; it moves south-westward at few degrees clockwise from wind direction (see Figure 19).

About Float

WMO
6903271

Inst reference
AI2600-19EU003

Transmission system
IRIDIUM

Owner
EURO-Argo

Sensors
CTD_PRES, CTD_TEMP, CT

Figure 19. Trajectory of float 6903271 up to the beginning of April 2020.

We asked NKE about the mission parameters to perform very short profiles (about 10 dbar). As a result, the following TC parameters were adjusted:

TC 0 volume at each electrovalve action on surface, reduced

TC 5 pressure tolerance during repositioning, reduced

TC 8 2nd threshold for buoyancy reduction, reduced

TC 15 ascent end pressure, reduced

The float eventually reached again the shelf (western side of the Black Sea) in the middle of April 2020 and the cycle length was set to 5 days.

The vertically averaged (every 1 m) potential temperature, salinity and sigma-theta (Figures 20, 21 and 22) were computed at cycle 198 (20-June-2020). The bathymetry comes from ETOPO 1 Global Relief Model (doi:10.7289/V5C8276M) http://dx.doi.org/10.7289/V5C8276M.

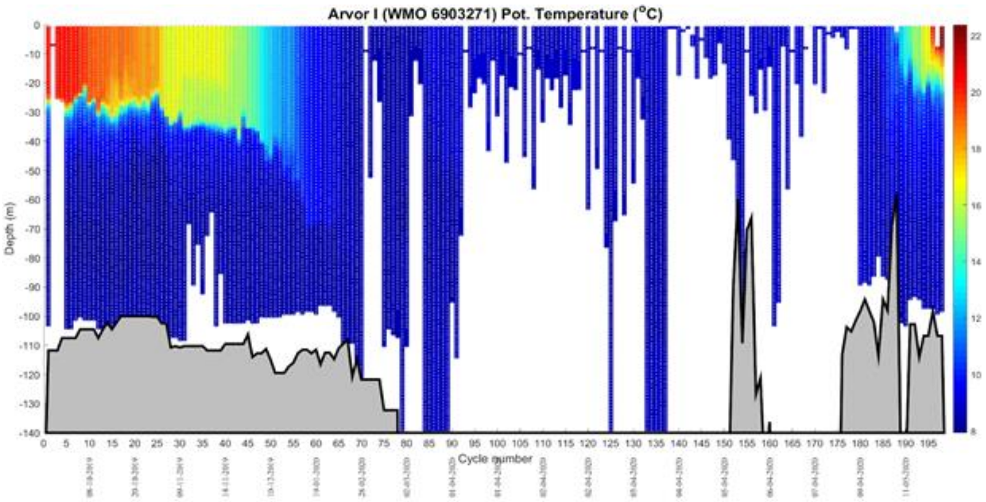


Figure 20. Hovmoller diagram of potential temperature and sea floor (in grey) up to 20th of June 2020.

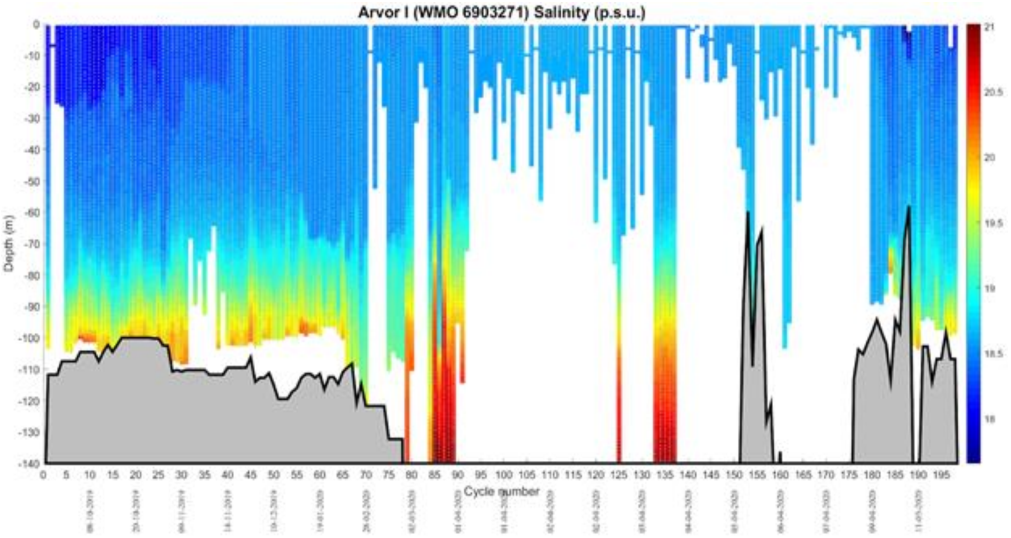


Figure 21. Hovmoller diagram of salinity and sea floor (in grey) up to 20th of June 2020.

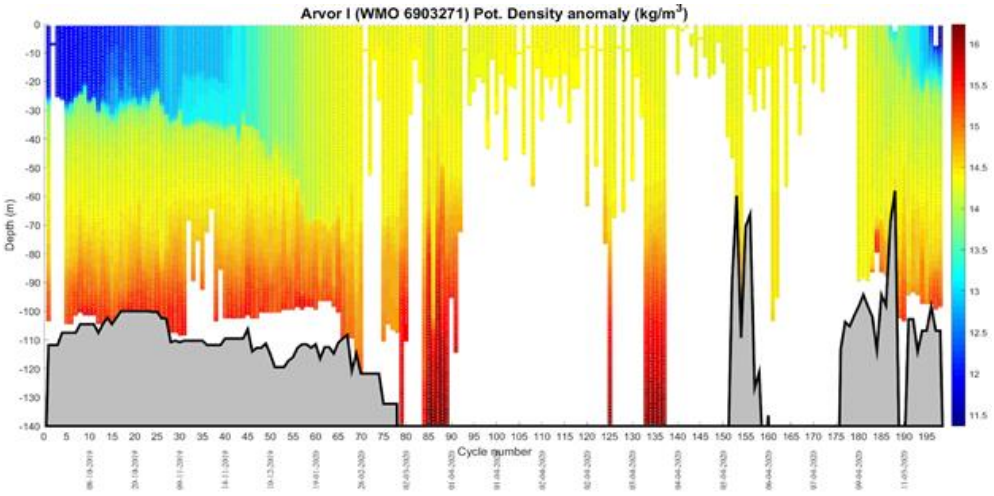


Figure 22. Hovmoller diagram of salinity and sea floor (in grey) up to 20th of June 2020.

The float then slowly drifted southward for 8 months and eventually exited the shelf in the southwestern part of the Black Sea, probably captured by the Rim Current, the 7th of December 2020 at cycle 232. The float settings were changed to the typical Black Sea configuration:

!MC 11 200

!MC 12 1500

!MC 18 700

!MC 19 2

!MC 20 10

!MC 21 25

!MC 24 0

!MC 25 100

Discussion – Conclusions

IO BAS float

This first attempt to use mooring in the Black Sea shallow waters raises more questions than gives any answers. We need to continue analysing the results, consider the possible reasons for the float behaviour and to try to solve technical problems and to reach a proven solution for the use of this technology.

OGS float

The first steps of the Argo operation on the western shelf of the Black Sea were successful and allowed us to gain a first know-how and expertise. Specific configurations, both on technical and on mission side, were tested. Home-made tools, CMEMS products, wind field products, Ocean-OPS and AIC tools were fundamental to achieve our targets and crucial to "pilot" the Argo platform in a difficult environment such as the shelf break of the western Black Sea. We were able to limit, to speed up the float displacement and to slightly drive the float according to our needs but the human resources used are much higher than the ones usually needed for standard Argo operations.

References

Bodeanu N., Moncheva S., Ruta G., Popa L,.1998. Long-term evolution of the algal blooms in Romanian and Bulgarian Black Sea waters. Cercetari Marine, INCDM Constanta, 31: 37-55

Capet A, J.-M. Beckers ,M. Gregoire, 2013. Drivers, mechanisms and long-term variability of seasonal hypoxia on the Black Sea northwestern shelf – is there any recovery after eutrophication. Biogeosciences, 10, 3943–3962, 2013, www.biogeosciences.net/10/3943/2013/doi:10.5194/bg-10-3943-2013

Daskalov G. M.2002 Overfishing drives a trophic cascade in the Black Sea. Mar. Ecol. Prog. Ser. 225, 53–639. Kideys, A. (2002). The comb jelly Mneniopsis leidyi in the Black Sea, in: Leppäkoski, E. et al. (Ed.) (2002). Invasive aquatic species of Europe: distribution, impacts and management. pp. 56-61.

DNV-OS-J103 (2013) "Design of Floating Wind Turbine Structures"

DNVGL-OS-E301 (2015) "Position mooring"

Friedrich, J., Cociasu, A., & Mee, L. D., 2010. Historical legacy of Danube River nutrient discharge and eutrophication in the North-Western Black Sea - Nutrient recycling in the shelf sediments. Danube News, 12(22), 7-9.

Mee, L.D. 1992. The Black Sea in Crisis: A need for concerted international action. Ambio 21:278-286.

Moncheva, S.1995. Phytoplankton under the influence of eutrophication - peculiarities and ecological significance. Proc. of the Symp."Ecological Problems and Economical Prospects of the Black sea", 16-18 Sept. 1991, Istanbul, Turkey, Published by the Black Sea Foundation, 271-279.

Moncheva S., V. Doncheva, and L. Kamburska, 2001.Phytoplankton blooms long-term history off the Bulgarian Black Sea coast in relation to environmental factors: do the 90's manifest a sign of ecosystem health improvement. Journal of Environmental Protection and Ecology, 2, 4, 997-989. ISSN 1311-5065.

Oguz, T. and Gilbert, D., 2007. Abrupt transitions of the top-down controlled Black Sea pelagic ecosystem during 1960-2000: Evidence for regime-shifts under strong fishery exploitation and nutrient enrichment modulated by climate-induced variations. Deep-Sea Research I: doi:10.1016/j.dsr.200609.200010.

Shiganova, T., 2008. Introduced Species, in Black Sea Environment, Kostyanoy, A.G. and Kosarev, A.N., Eds., Berlin: Springer–Verlag, 2008, vol. 5, part Q, pp. 375–406.

Yunev O A, Vedernikov V I, Basturk O., Yilmaz A, Kideys A E, Moncheva S, Konovalov SK,2002.Long-term variations in surface chlorophyll-a and primary production in the open Bla ck Sea: changes in the pelagic ecosystem over the last decades. Mar. Ecol. Prog. Series, vol. 230:11-28.

Yunev O., S.Moncheva, J. Carstensen, 2005 Long-term variability of vertical chlorophyll a and nitrate profiles in the open Black Sea: eutrophication and climate change. Marine Ecology-Progress Series vol. 294 p. 95 5.

Yunev, O.A., J. Carstensen, S. Moncheva, A. Khaliulin, G. Ertebjerg, S. Nixon, 2007. Nutrient and phytoplankton trends on the western Black Sea shelf in response to cultural eutrophication and climate changes.2007 Estuarine Coastal and Shelf Science 74(1):63-76, DOI: 10.1016/j.ecss.2007.03.030.

Zaitsev, Y. P. & B. G. Alexandrov, 1997. Recent man-made changes in the Black Sea ecosystem. In; Ozsoy, E., Mikaelyan, A. (Eds.), Sensitivity to Change: Black Sea, Baltic Sea and North Sea. Kluwer Academic Publishing, Dordrecht, The Netherlands, pp. 25-31