Preliminary results of shallow coastal float operations in the Mediterranean Sea

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Work Package title	**Extension to marginal seas**
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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 open-ocean 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 four (4) float deployments in specific coastal areas of the Mediterranean Sea is presented. The technical and scientific outcomes are discussed and recommendations are provided regarding the expansion of such operations in the near future.

TABLE OF CONTENT

1 Introduction – General framework

During the last two decades, the monitoring array of Argo floats has evolved to an essential component of the global ocean observing system, providing an unprecedented amount of cost effective and high spatiotemporal resolution data (Riser et al. 2016). Being the major contributor to the physical oceanography basic research, the Argo Program is nowadays essential also for climate assessment studies, and ocean state analysis and forecasting. Furthermore, Argo provides an *in-situ* complement to the satellite ocean-observing system, enhancing long-term reanalyses and predictions of the ocean's state (Le Traon, 2013).

Currently, one of the ongoing activities of the Argo program is its enhancement and extension into regions that were previously under sampled such as the ice-covered regions and the marginal seas (Jayne et al., 2017). Such an extension largely relies on the combined efforts of national and international Argo initiatives. 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 EMS. 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. With regards to the Mediterranean Sea, the systematic use of Argo floats takes place for more than a decade and has initiated a new era of oceanographic monitoring (Kassis and Korres, 2020) however, such expansion has been lately proven to be advantageous even in especially shallow areas such as the Baltic Sea (Siiriä et al., 2019), or enclosed sea regions such as the Black Sea (Grayek et al., 2015). Nevertheless, certain topographic features of the marginal seas, and especially of the Mediterranean, such as the combination of intrigue coastlines, and complex bathymetry in relatively shallow water environments, raises concerns and questions whether Argo platform, that has been originally designed to perform in the open ocean environment, can adequately perform in coastal regions. The latter is being investigated under the framework of Euro-Argo RISE project and more specifically under its WP6 activities where targeted deployments have been planned in specific shallow coastal areas of the EMS.

The Mediterranean Sea is a basin of dense populated coastal zone with intense socio-economic activity. It also integrates different sub-basins with important hydrological features, and strongly variable climatic signals (Kassis and Korres, 2020). Studies of the oceanographic processes that dominate in such areas largely rely on the expansion of the availability of the observational tools and methods. Thus, the systematic use of Argo is particularly important since it allows more enhanced monitoring, research, analyses, and forecasting by the oceanographic community. For the Mediterranean Sea, this expansion is expressed with the significantly higher Argo float coverage with the target, set by Euro-Argo, of 60 active floats at any given time. During the recent years this number exceeds 75 active floats, (Figure 1) that corresponds to more than twice the standard global Argo density. This fact, combined with the floats' configuration to perform five-day drifting/profiling cycles according to the MedArgo (http://nettuno.ogs.trieste.it/sire/medargo/active/index.php) specifications (Poulain et al., 2007), results in a significantly increased spatiotemporal resolution and provides a better understanding of the short-scaled variability in the Mediterranean's sub-basins. In addition, apart from the implementation of increased floats density, Mediterranean basin has been used as a test case for the BGC Argo extension, which is also one of the targets of Euro-Argo ERIC (Euro-Argo ERIC, 2017). The latest experience of BGC floats deployments in the Mediterranean has shown that this so-called "bioregionalization" approach, can be considered a possible option in the global

BGC-Argo implementation plan (D'Ortenzio et al., 2020). However, either for standard, or BGC floats, the question remains whether these can adequately perform in specific Mediterranean sub-basins, which may be scientifically important but present challenging topographic characteristics.

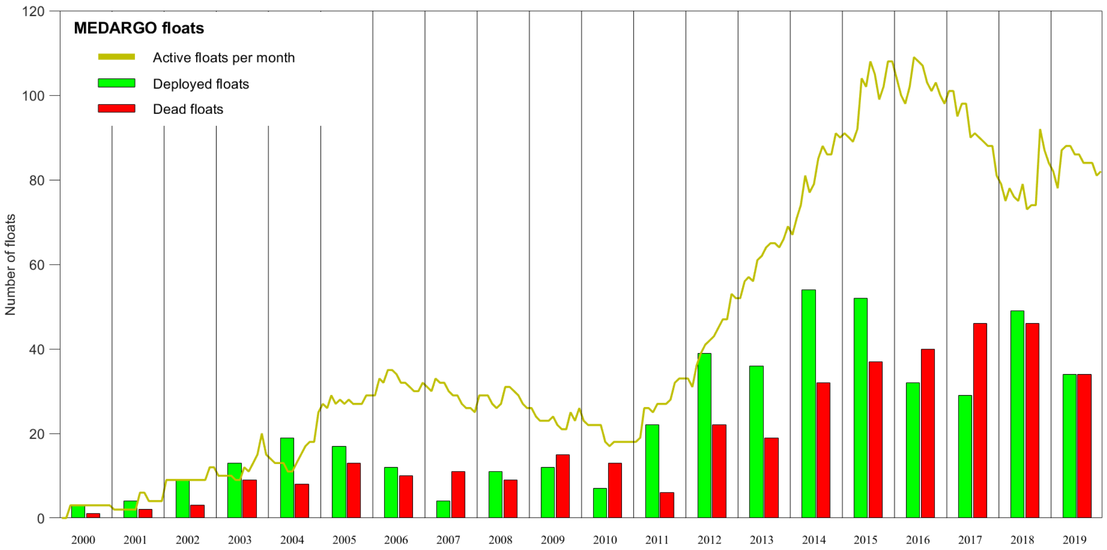

Figure 1. Interannual variability of float population in the Mediterranean Sea related to the number of yearly deployments and dead floats.

Under this aspect, this document provides preliminary results of targeted Argo missions in the Mediterranean Sea that are designed to explore Argo floats capability to monitor the shallow coastal shelf. The aim is the improvement of the floats' operations in such areas, increase their life expectancy and sampling efficiency, and provide feedback to WP 2, and in particular to task 2.1 that will analyse how the recommendations of this task are applicable to EMS. Thus, in chapters 2-5 the Euro-Argo RISE task 6.1 partners present the experience gained from these test case deployments. More specifically, in chapter 2, the mission of an Argo float deployed in a relatively deep coastal area of the North Aegean Sea by HCMR is presented. In chapter 3 a similar float mission in the North Adriatic, a source of one of the densest waters of the Mediterranean Sea, is described by OGS. Chapter 4 presents a mission of a float deployed by SU in the Gulf of Lions, where pre-deployment mission designs are proposed and several scenarios performed within the MOOSE observing system. The outcomes of a float deployed at a shallow shelf region near Palma Bay in the Balearic archipelago are presented by SOCIB in chapter 5. Finally, in chapter 6, the four floats' performance is summarized, in conjunction with the various configuration schemes used in each case. Additionally, the operators' assessment of the available operational monitoring tools, along with recommendations on similar future activities, are discussed.

2 Preliminary results of float operation in the North Aegean Sea

2.1 Introduction

The North Aegean sub-basin is a plateau characterized by a weaving coastline and an irregular bottom topography that incorporates shallow sills and deep troughs (Figure 2) (Kassis 2017). The characteristic water mass of North Aegean is the Black Sea originated cold and fresh water outflowing from the Dardanelles Straits. This water mass, the so-called Black Sea Water (BSW), enters the North Aegean and creates a strong low salinity - low temperature signal in the upper layers with salinities ranging between 29 - 31 psu and temperatures not exceeding 16 ^{o}C. BSW gradually becomes saltier during its southward course and recirculation in the area, by mixing with Aegean surface waters (Kassis 2017). Such mixing results in strong permanent thermohaline fronts that have been observed in the area as BSW encounters the relatively warm and high salinity Levantine originated water masses (Zervakis and Georgopoulos, 2002). These are namely the Levantine Surface Water (LSW) and the Levantine Intermediate Water (LIW). The intermediate layers of the north Aegean are mainly occupied by the LIW whose core extends until depths of 400 m, whilst below this layer, locally formed very dense water has also been identified ($\sigma\theta > 29.50$ kg m^{-3}) (Zervakis et al., 2000). Due to such high densities observed in the North Aegean, the sub-basin is identified as one of the principal Dense Water Formation (DWF) regions of the Mediterranean (Theocharis et al., 1999; Zervakis et al., 2000). The DWF in the north Aegean appears to be modulated by the intensity and frequency of the high salinity intrusions from the south, combined with the intensity of the BSW inflow through the Dardanelles. According to this, an increased BSW inflow in the area could insulate the deeper layers from the atmosphere, absorbing a large part of the heat and salt exchange. On the other hand, reduced BSW inflow combined with increased LSW intrusion could trigger DWF events especially during cold winters (Zervakis et al., 2000).

The monitoring of the North Aegean with Argo floats was introduced with the operational action plan of the Greek Argo infrastructure that included the purchase and deployment of 25 new floats for the period 2014 - 2020, covering the medium-term monitoring needs of the wider Eastern Mediterranean area. In this plan, many factors were taken into account in order to achieve the best monitoring results. The deployments aimed to cover understudied basins of the region such as Aegean, eastern Ionian and western Levantine. This effort, in combination with other national initiatives operating in the area, and the Euro-Argo ERIC activities, resulted in a significant rise of the float coverage in the Eastern Mediterranean (Figure 3). Apart from the spatial gaps, the complex topography of each area and their general circulation features, that are the main factors of float losses, were taken into account for the deployment strategy. According to this, a survey has been done on the deployments and float loss rate in the whole Mediterranean for the period 2010 - 2013. An interesting statistical outcome from this survey, that was included in the Greek Argo strategic planning, was that the lifetime expectancy of the floats for the wider region of the Eastern Mediterranean Sea appeared to be approximately 20% less than of those in the Western part. A fact that is mainly attributed to the complex bathymetry and topography of the region. During the following years and especially with regards to the North Aegean, the floats' lifetime appeared significantly reduced in comparison to other sub-basin reaching an average of 82 cycles per float. Thus, the combination of the area's scientific importance along with its challenging topography, was the main reason the North Aegean sub-basin was indicated as one of the targeted areas for the investigation of the potential of Argo profiling floats to operate in shelf areas.

Under the Euro-Argo RISE project task 6.1 activities, a standard CTD Argo float was purchased and deployed by HCMR in a relatively deep but coastal trench of the North Aegean. Information and data regarding this test mission is hereby presented, assessed, and further discussed under the context of the potential of Argo to contribute on the monitoring of such coastal areas.

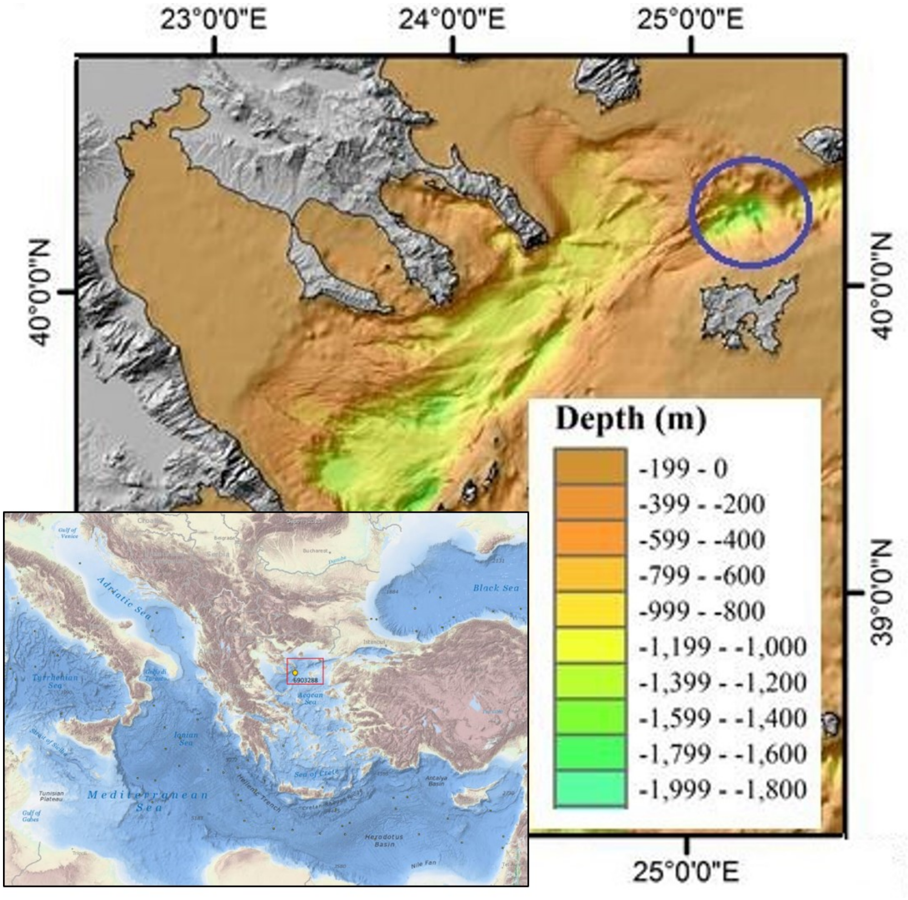

Figure 2. Topography of the North Aegean plateau (Kassis 2017), the blue circle indicate the deep trench where the float 6903288 was deployed.

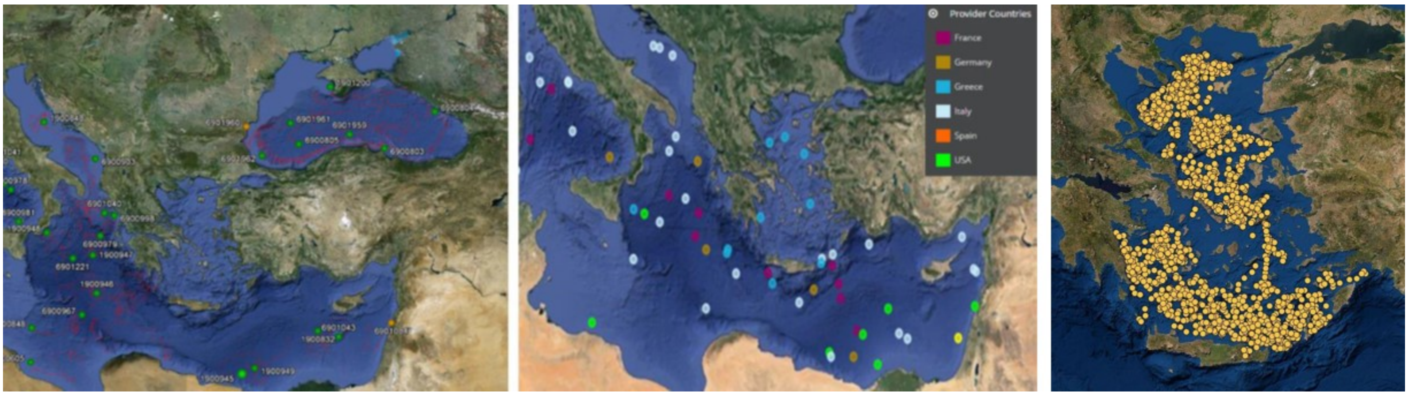

Figure 3. Active floats (green dots) and their trajectories (red lines) in the Eastern Mediterranean at the end of 2012 (left) (http://www.jcommops.org/board?t=Argo). Active floats per country in the Eastern Mediterranean in the mid-2015 (blue dots represent the Greek floats positions) (middle) (www.greekargo.gr) (Kassis 2017), distribution of the Argo profiles in the Aegean Sea (https://cloud.ifremer.fr).

2.2 Methodology

2.2.1 Float configuration and deployment

The float, purchased in December 2019 by HCMR under the framework of Euro-Argo RISE project, was an APEX 11 standard Conductivity - Temperature - Depth (CTD) float manufactured by Teledyne Webb Research (http://www.teledynemarine.com/apex-argo?ProductLineID=61) with Iridium SBD telemetry and the Sea-Bird SBE-41 integrated CTD sensor (https://www.seabird.com/sbe-41-argo-ctd/product?id=54627907875).

The float was tested in the HCMR laboratory and was configured to perform 2-day cycles, drift at 800 m depth and perform profiles from the same depth. The high frequency sampling and the deep drifting depth was chosen in order the float to remain in the relatively trench after the shelf break north of Limnos Isl. 6 nm off the coast (Figure 2), perform deep profiles close to the coast and monitor the intermediate layers circulation and the Black Sea water input. Further information of the float’s configuration parameters is hereby presented (Table 1).

Table 1: Mission and configuration parameters of the WMO 6903288 float

Mission Parameters	Mission Parameters	Mission Parameters	Mission Parameters	Sample Configuration
|ActivateRecoveryMode on	|DownTime 2683	|MActivationCount 262	|PnPCycleLen 1	|sample_cfg|<PARK>
|AscentRate 0.08	|EmergencyTimerInterval 3600	|MActivationPressure 25.00	|PreludeSelfTest on	|sample_cfg|SAMPLE PT 2500 4 0 DBAR 1
|AscentStartTimes -1 -1 -1 -1	|HyperRetractCount 0	|MinBuoyancyCount 147	|PreludeTime 120	|sample_cfg|<ASCENT>
|AscentTimeout 208	|HyperRetractPressure 850.00	|MinVacuum 9.00	|SurfacePressure 4.00	|sample_cfg|SAMPLE PTS 800 400 20 DBAR 1
|AscentTimerInterval 120	|IceMonths 0000	|ParkBuoyancyNudge 16	|TelemetryDays 0 0	|sample_cfg|SAMPLE PTS 400 20 10 DBAR 1
|BuoyancyNudge 50	|IdleTimerInterval 3600	|ParkDeadBand 25.00	|TelemetryInterval 900	|sample_cfg|SAMPLE PTS 20 5 5 DBAR 1
|DeepDescentCount 321	|InitialBuoyancyNudge 300	|ParkDescentCount 321	|TelemetryTimeout 120	
|DeepDescentPressure 800.00	|LeakDetect on	|ParkDescentTimeout 267	|UpTime 328	
|DeepDescentTimeout 1	|LogVerbosity 5	|ParkDescentTimerInterval 900	|VitalsMask 0007	
|DeepDescentTimerInterval 5		|ParkPressure 800.00	|Checksum A0F8	
|DeepProfileFirst off		|ParkTimerInterval 3600		

The deployment of the 6903288 float took place in early February 2020 during a research cruise with the R/V Aegaeo in the central and northern Aegean sub-basins. The float was registered in Argo Information Centre (AIC), re-tested on board, achieved satellite communication and transmitted GPS position. A part of the communication with the float during the pre-deployment testing is presented below:

```
Battery Voltage:    14.16 V

Float Current:      65.6292 mA

Coulomb Count:      868.2891 mAh

Bladder Pressure:   7.7 dbar

Internal Vacuum:    7.8 dbar

Piston Position:    254 counts

*******************************************************************************

Float Test Completed @ 2020-02-09 10:50:19 :          <<PASS>>

*******************************************************************************
```

The float was deployed on the 9th of February at 13:30 in a narrow deep trench of the North Aegean, 6 nm north of Limnos Isl. (Figures 2, 4, Table 2). Along with the deployment, a CTD reference profile cast was performed.

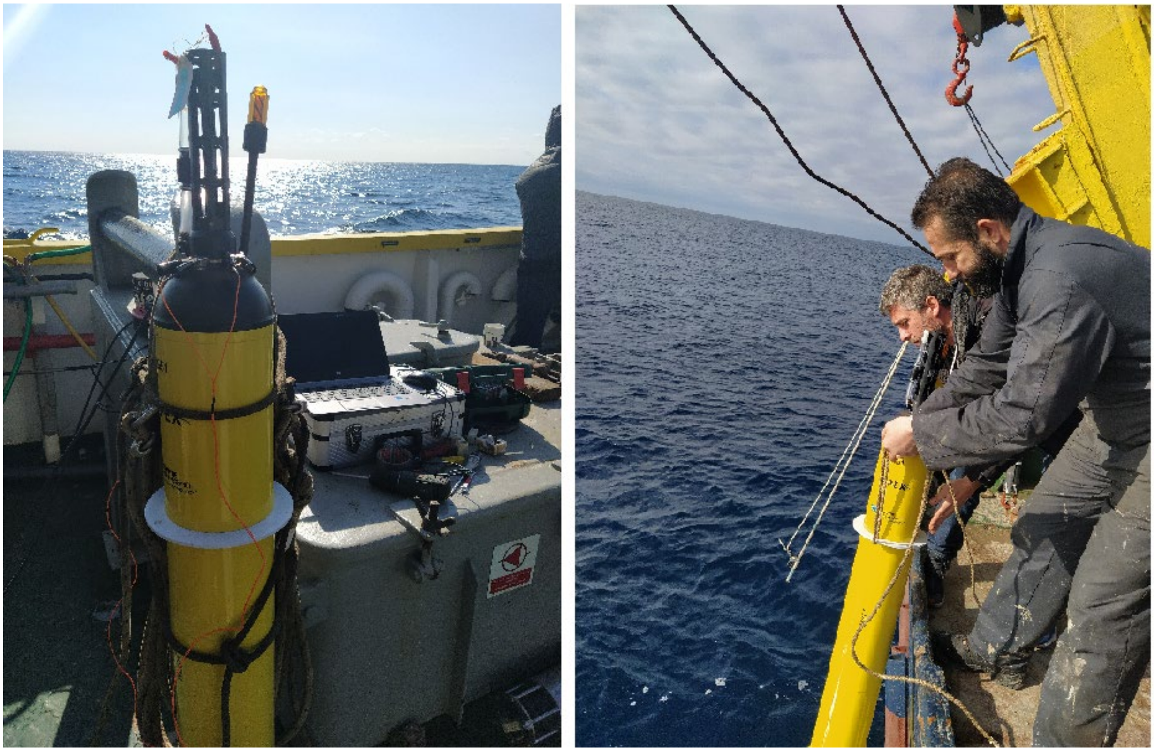

Figure 4. Photographs on the R/V AEGAEO during the pre-deployment testing and the deployment of the APEX float (WMO 6903288) by HCMR in the North Aegean in February 2020.

Table 2: Information regarding the WMO 6903288 float mission

Type	WMO	IMEI	Serial Number	Deployment Date/Time	Deployment Latitude	Deployment Longitude	Total Cycles	Date of Last Cycle	Location of Last Cycle
APEX 11	6903288	881600005135	021-3219	09/02/2020 13:30	40.42 N	25.42 E	120	05/10/2020	39.97 N 24.37 E

2.2.2 Monitoring of the float's performance

Through the updated Euro-Argo monitoring tool (available at https://fleetmonitoring.euro-argo.eu/dashboard), a variety of parameters were made available regarding the float's mission (https://fleetmonitoring.euro-argo.eu/float/6903288.) This generic tool, developed under the framework of the EU Monitoring the Ocean Climate Change with Argo (MOCCA) project (*D3.3.1* and *D3.3.2* https://www.euro-argo.eu/EU-Projects/MOCCA-2015-2020/Deliverables), provides enhanced information regarding technical and functional parameters of the floats' performance. During the 6903288 float's mission, graphical representations of the float's metadata, along with technical parameters and alerts for malfunction and detection of early failures were supervised with the help of this tool.

Furthermore, based on previous experience on platform monitoring systems, HCMR has been utilizing an automatic alerting system (http://poseidonsystem.gr/alerts/?m=2) for the monitor of basic parameters of the platforms' location and data transmission. This system has been partially updated to enhance the operational monitoring needs of the 6903288 float. More specifically, the automatic alerting system incorporated additional features for the real-time monitoring of crucial parameters that described the float's operation. Such are the bathymetry and the distance from the coastline since the float was deployed at a relatively deep but near the coast plateau, where the bathymetry and coastline are specifically complex. Additionally, the maximal depth reached by the float and the grounding events were being monitored. The alerting system is based in pre-defined thresholds and an alert message is transmitted in cases the monitored parameters overcome these thresholds. Thus, similar to the alerting messages whether there are delays or major differences in the transmission time, alert messages were sent to the PI when profiling or parking pressure was recorded to be less than 155.0 dbar. Additional parameters and control criteria can be added on the alerting transmission messages such as the distance from the deployment point. Further details on the monitoring/alerting systems during the operation of floats in coastal areas can be found in the Deliverable of Euro-Argo RISE project D6.1 “Tailoring of the controlling and monitoring tools for operations in shallow coastal waters”.

2.3 Results

2.3.1 Technical and mission data

The float did not transmit its first descending profile thus, its first profile was transmitted on the 11th of February 2020. The sensors' performance was assessed by the testing of the temperature and salinity profile data against the CTD cast acquired from the R/V Aegaeo during the deployment. The results showed good agreement between the deck CTD and the Argo float's SBE 41 sensors. More specifically, for depths greater than 400 m, the average temperature difference was found less than 0.001 °C with a STD of approximately 0.0004 °C (Figure 5). For salinity, the average difference was less than 0.0018 psu with an STD of approximately 0.0006 psu (Figure 6).

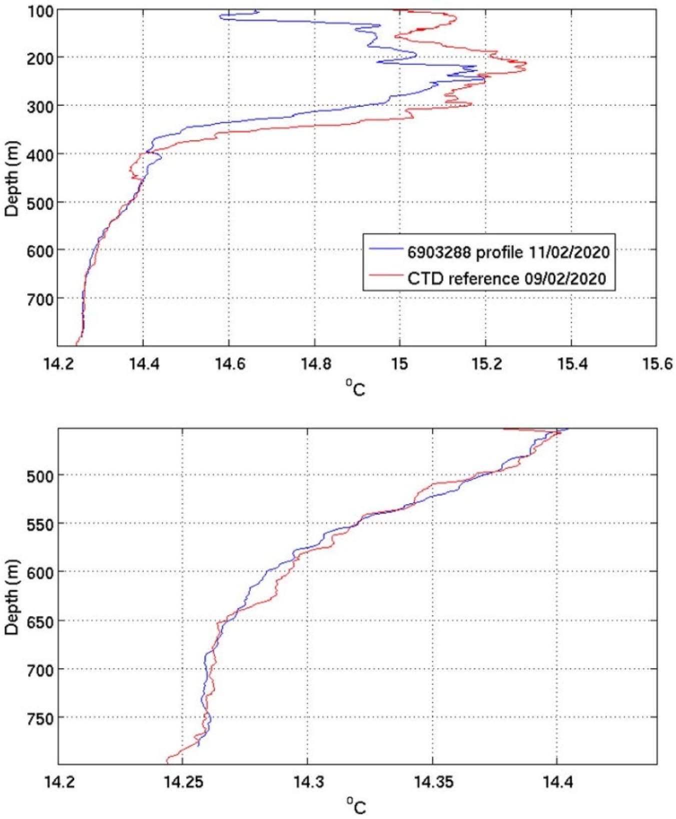

Figure 5. Comparison of temperature profiles acquired by CTD of R/V AEGAEO during the deployment of 6903288 float (red line) and the first profile the float transmitted (blue line).

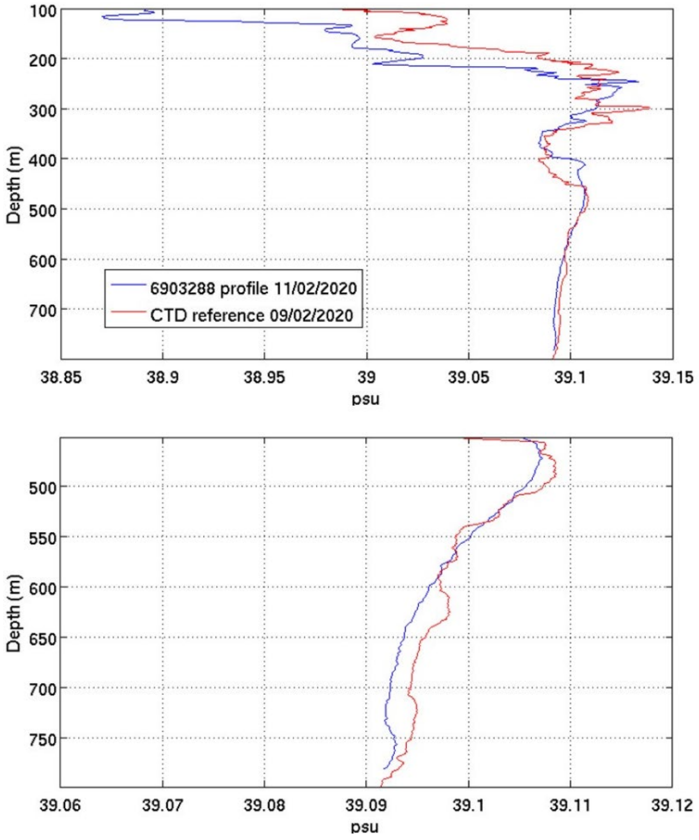

Figure 6. Comparison of practical salinity profiles acquired by CTD of R/V AEGAEO during the deployment of 6903288 float (red line) and the first profile the float transmitted (blue line).

The float remained in the area of deployment performing profiles under a cyclonic drift for almost 2 months (Figure 7 A). After the 30th cycle the float started to slowly drift westwards through a shallow passage (Figure 7 B, 8), and in mid-May (49th cycle) the float entered a second deep plateau 60 km approximately southwest of the deployment location (Figure 7 C, 8). The majority of the acquired profiles reached the 800 m target especially during the first and last phases of the mission. In the period between the 20th and 40th cycle, the float touched several times the seabed and its profiles were significantly shallower since it drifted over the shallow passage that separate the two plateaus (Figure 8). On the 5th of October 2020 the float transmitted for the last time. The checking of the technical parameters transmitted by the float during this last cycle did not indicate any problem or malfunction. Furthermore, the fact that the float's position was relatively far from the coast (> 15 km) rejects the hypothesis that the platform was beached somewhere near the coast. The most possible scenario to explain the float's loss is the assumption that probably it remained trapped on the seabed while drifting for its 121st cycle since a few kilometres southern or eastern from its last transmission the bathymetry changes to shallow depths. This hypothesis is strengthened from the fact that the substrate in this area is soft and muddy due to increased sediment deposition (Lykousis et al., 2002) however, other reasons of the float's loss might be its entrapment in fishing nets.

The total number of cycles performed by the float was 120 during which all technical data transmitted were normal apart from a slight drift on the platform's clock. Regarding the scientific data, the vast majority (99 %) are qualified as good for both temperature and salinity by the automatic quality control check. A visual inspection of the 120 temperature and salinity profiles (Figure 9) is in agreement with the near-real time quality assessment.

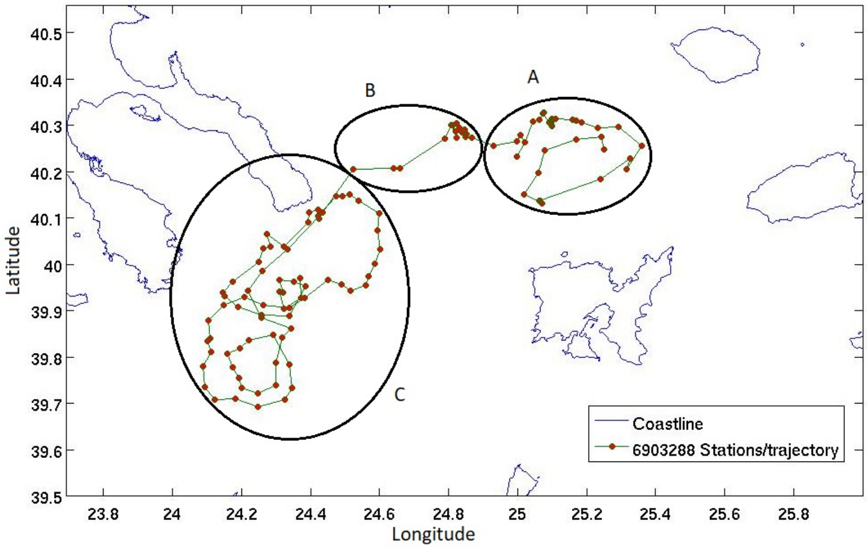

Figure 7. Trajectory and profile locations transmitted by the 6903288 float during its lifetime from the 11/02/2020 until 05/10/2020. The three areas covered by the float (A, B, C) are indicated by black circles.

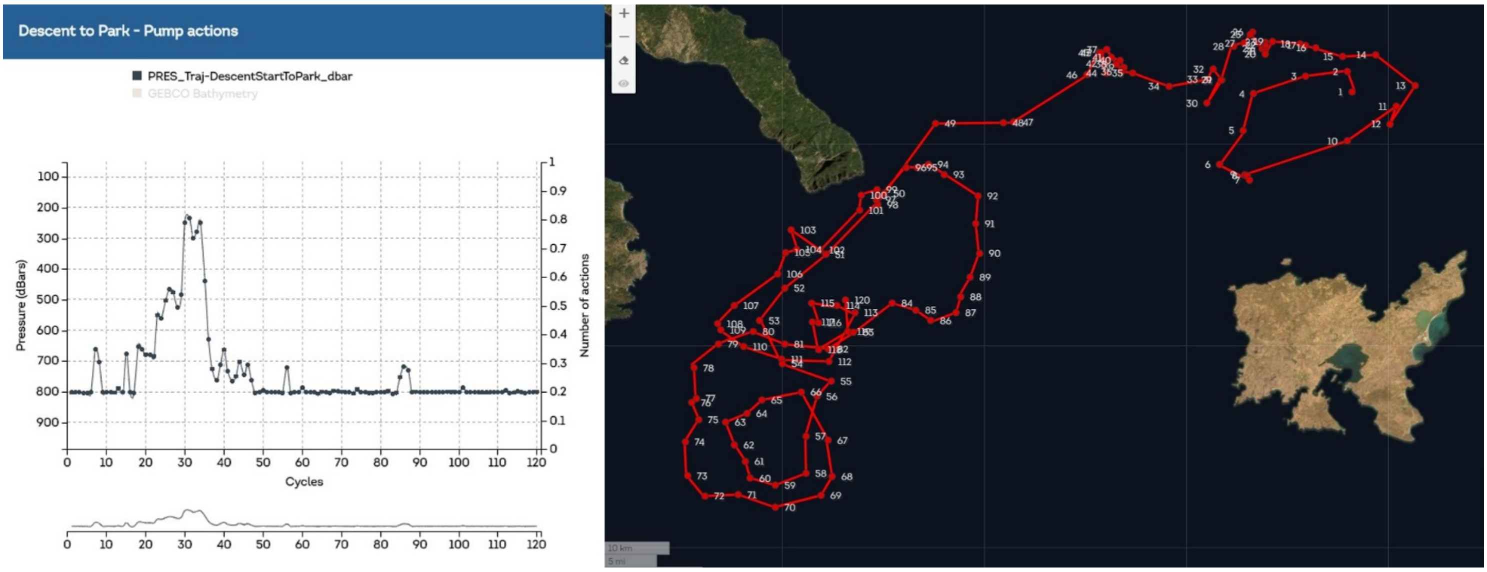

Figure 8. Maximum pressure reached by the 6903288 float during descent (left), the float's trajectory and the 120 profile locations transmitted (right) https://fleetmonitoring.euro-argo.eu/float/6903288).

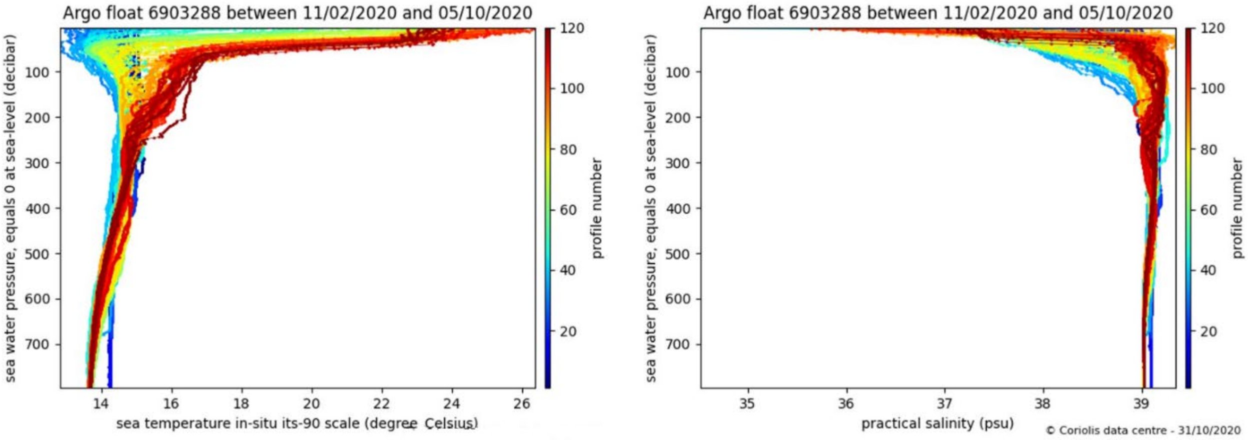

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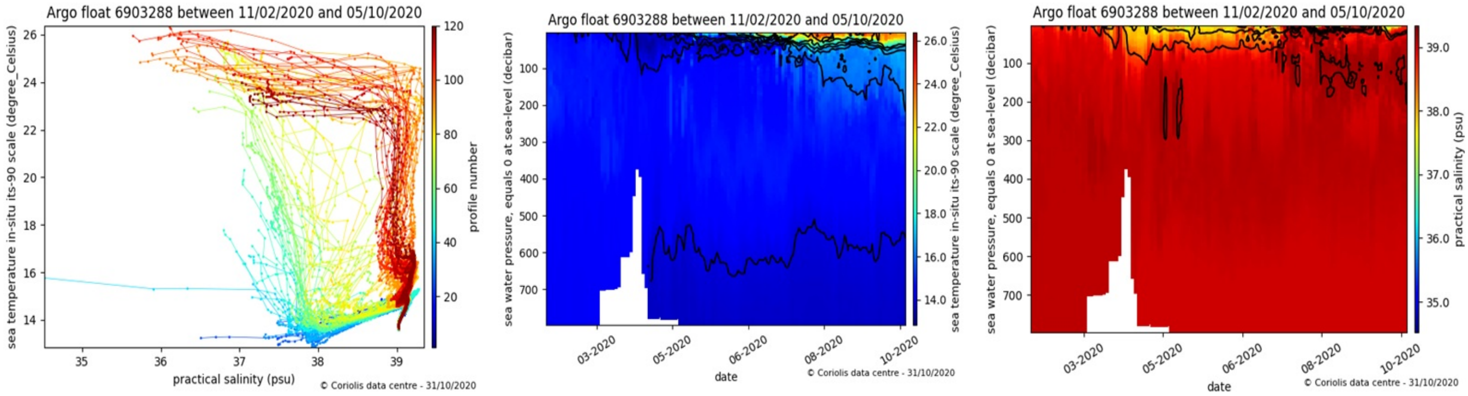
Figure 9. Profiles of temperature (left) and practical salinity (right) transmitted by the 6903288 float during its lifetime from the 11/02/2020 until 05/10/2020 (https://fleetmonitoring.euro-argo.eu/float/6903288).

2.3.2 Scientific data

The preliminary data analysis on the temperature and salinity profiles has indicated interesting information regarding the physical parameters variability in the area of study. A wide span has been observed for both temperature and salinity within the water column. Especially at the surface layers, temperature variability reflected the intense seasonal cooling and warming and was recorded well-below the 13 °C during the late March – early April period whilst, it exceeded 26.2 °C in September (Figures 9, 10, 11). For the same layers, the practical salinity range was recorded between 35.65 psu – 39.24 psu with both higher and lower values mainly observed during the summer – early autumn period (Figures 9, 10, 12). For the deeper layers (> 500 m depth), an interesting feature depicted is the drop of temperature for approximately 0.5 °C, which coincided with the float's exit from the initial deployment plateau (Figure 7, 10, 11). This happened after the 34th cycle in mid-April (Figure 11) and highlights the different deep-intermediate water masses at the eastern (Figure 7 A) and the western (Figure 7 B, C) sub-basins of the North Aegean. The former, seems to host relatively warm and of high salinity waters (14.25 °C, 39.09 psu) which reflects the LSW and LIW strong influence, whilst the latter, presents colder and fresher water masses (13.65 °C, 39.02 psu) (Figures 11, 12).

Another interesting result is the absence of strong BSW signals in the areas where the float operated. The investigation of the salinity profiles for the upper layers (5 – 50 m) where the BSW is observed, revealed only few salinity records (during September 2020) which are below the 36 psu (Figure 12, left panel). On the contrary, high salinity is recorded in both surface and intermediate layers, indicative of LSW and LIW strong presence (Figure 12).



Argo float 6903288 between 11/02/2020 and 05/10/2020

Argo float 6903288 between 11/02/2020 and 05/10/2020

Argo float 6903288 between 11/02/2020 and 05/10/2020

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Figure 10. T/S diagram (left), Hovmöller diagrams of temperature (middle), and practical salinity (right) from the profiles transmitted by the 6903288 float during its lifetime from the 11/02/2020 until 05/10/2020 (https://fleetmonitoring.euro-argo.eu/float/6903288).

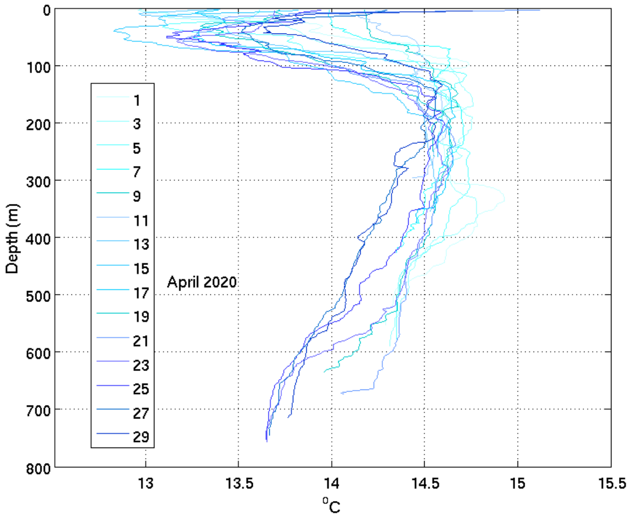

Figure 11. Temperature profiles transmitted by the 6903288 float during April 2020

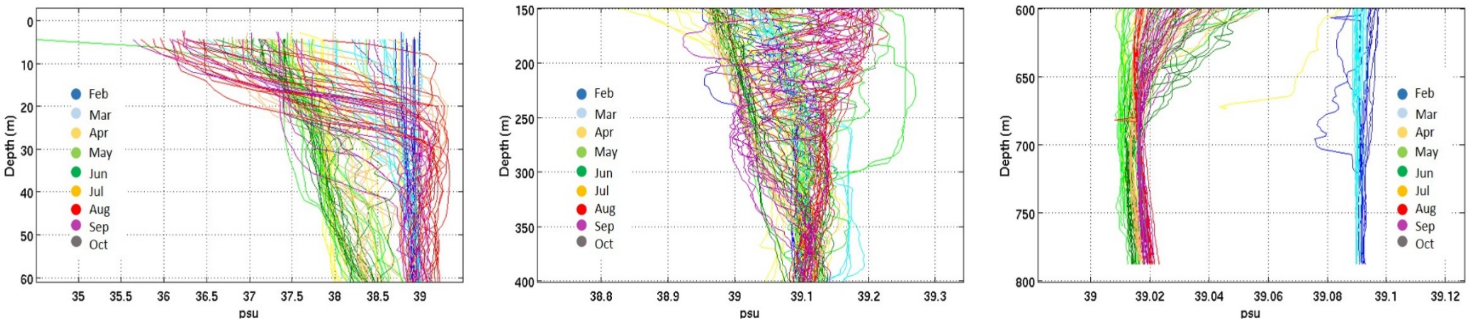

Figure 12. Practical salinity profiles per month transmitted by the 6903288 float during its lifetime from the 11/02/2020 until 05/10/2020 in the surface layer (left), intermediate layer (middle), and deep layer (right)

2.4 Discussion - Conclusions

The test mission in the North Aegean has been in general successful since the float managed to sample in high frequency for 8 months providing a large number of good quality profiles for the first time in this area. The total number of 120 profiles acquired by the float largely exceeds the average profile number per float in the area which was until now approximately 90. This fact can be assigned to two principal reasons. The first is the high sampling frequency (2-days cycle), and the second is the relatively deep parking depth that prevented the float from drifting along the coastline. With regards to the latter, it shown that the combination of a well-planned mission configuration set up, with enhanced operational monitoring tools, can lead to significant improvements of similar missions in the near future. This is particularly important in areas of challenging topography where the float loss rate is significantly increased. Thus, a combination of low-cost shallow-depth-rated floats, with the increase of the floats' potential to gather more profiles, can lead to a cost effective Argo monitoring plan in such areas. The experience gained from the 6903288 float showed that, although its early loss, the data gathered is a valuable source of information regarding the hydrography of the North Aegean basin. It has revealed important aspects regarding the area's physical parameters spatiotemporal variability. Such are the absence of BSW in the winter-spring period followed by its weak appearance at the western part during the late summer-autumn period. At the same time, strong signals of both LSW and LIW are apparent whilst, a longitudinal gradient of both temperature and salinity at the deep layers is observed between the eastern and the western part of the sub-basin. This is expressed by colder and fresher deep water masses towards the west and may reflect the result of variable DWF mechanisms in the area. The latest profile data from 6903288 Argo float highlight that an increase of the monitoring coverage in the following years can lead to conclusive results regarding the spatiotemporal variability and trends of the basin's physical properties.

3 Preliminary results of float operation in the North Adriatic Sea

3.1 Introduction

The North Adriatic (NA) is the northernmost, semi-enclosed region of the Mediterranean Sea with a depth that not exceed 100 meters. Its maximal width is about 200 km (Figure 13). The general circulation of NA is cyclonic and it is sustained by the Western Adriatic Current (WAC) that flows along the western coast and by the Eastern Adriatic Current (EAC) on the eastern side of the basin. The northernmost part of the NA is the site of the densest water mass formation in the Mediterranean Sea: once formed, this water mass flows southward at sea bottom level (Poulain et al., 2001).

Figure 13. Location of the North Adriatic Sea

A standard core-Argo float has been deployed in the NA Sea for the first time, in the framework of the European Euro-Argo RISE project. The aim of this experiment is to test an Argo platform in such shallow coastal areas and see the feasibility from different points of view: technical, instrumental, human resources. Argo is designed for operations in open ocean and the challenge is to try to use this monitoring system in regions characterized by complex geography and bathymetry such as the NA. Eventually, the goal is also to optimize the float set up and to increase the life expectancy in this test area.

3.2 Methodology

The target of the Euro-Argo RISE experiment in the NA is to keep the float in a limited area and to operate it as a virtual mooring in order it stays in shallow waters and far from the coast.

Such kind of operations with Argo platforms requires avoiding stranding events and maritime traffic and hence there is a need of good monitoring and controlling tools such as the one of Euro-Argo. The monitoring tool provides a lot of technical information, graphs, alerts that allow the float operator to take decision and quickly send new settings to the platform if needed. In addition to this system, some home-made tools have been tested, such has an automatic email alert system that gives you the float position and the depth of the sea at the float location almost in real time (see Deliverable D6.1 for details).

Before the Euro-Argo RISE float deployment, an Argo-Italy float was deployed in the Middle Adriatic Sea (Figure 14). It served as a test-case and the float was configured with a specific mission setting in order to start acquiring the know-how needed for this kind of operations in shallow coastal areas.

Figure 14. Locations and trajectories of the Argo-Italy float (WMO 6903263, red line) and the Euro-Argo RISE float (WMO 6903783, grey line) in the Middle Adriatic Sea and in the North Adriatic Sea, respectively.

The Argo-Italy profiler is an Arvor-I model manufactured by NKE and its WMO number is 6903263 (Table 3). It was deployed the 23rd of March 2019 in the Middle Adriatic Sea and the target was to keep the float in the Pomo Pit (a depression in that region, where the maximal depth is about 270 meters). In order to reach this target, the float was configured with a cycle length of 5 days and a parking depth close to the bottom.

Table 3: Main information of the Argo-Italy float WMO 6903263

Float type	WMO	Deployment date	Deployment latitude	Deployment longitude	Last station date	Cycle
Arvor-I	6903263	23 March 2019	43.013 N	15.106 E	3 November 2020	119

The main mission commands and set up values are:

MC0= 500, number of total cycles

MC2= 120, cycling period

MC11= 300, parking depth

MC12= 300, maximal profile depth

MC17= 100, threshold zones 1/2

MC18= 700, threshold zones 2/3

MC19= 1, vertical resolution in zone 1

MC20= 2, vertical resolution in zone 2

MC21= 25, vertical resolution in zone 3

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

MC25= 10, shifting upward amount

The platform did not move off the Pomo Pit and it is still there after nineteen months and 119 profiles as of 3rd of November 2020 (Figure 15). The maximal radius of displacement from the deployment point is about 20 km and we were able to limit the float drift at such level thanks to an accurate work done in term of adjusting the float configuration according to the needs.

Figure 15. Trajectory of the Argo-Italy float (WMO 6903263) in the Pomo Pit (Middle Adriatic Sea). Number of cycles are also reported in white.

In figure 16 the temperature and salinity profiles in the Pomo Pit area are shown, whilst the grounding events are highlighted in the Hovmöller diagram (red boxes in figure 17). The float was programmed to hit the bottom at every cycle and to be parked at the seabed for the entire cycle length in order to stay in a confined area, within the Pomo Pit.

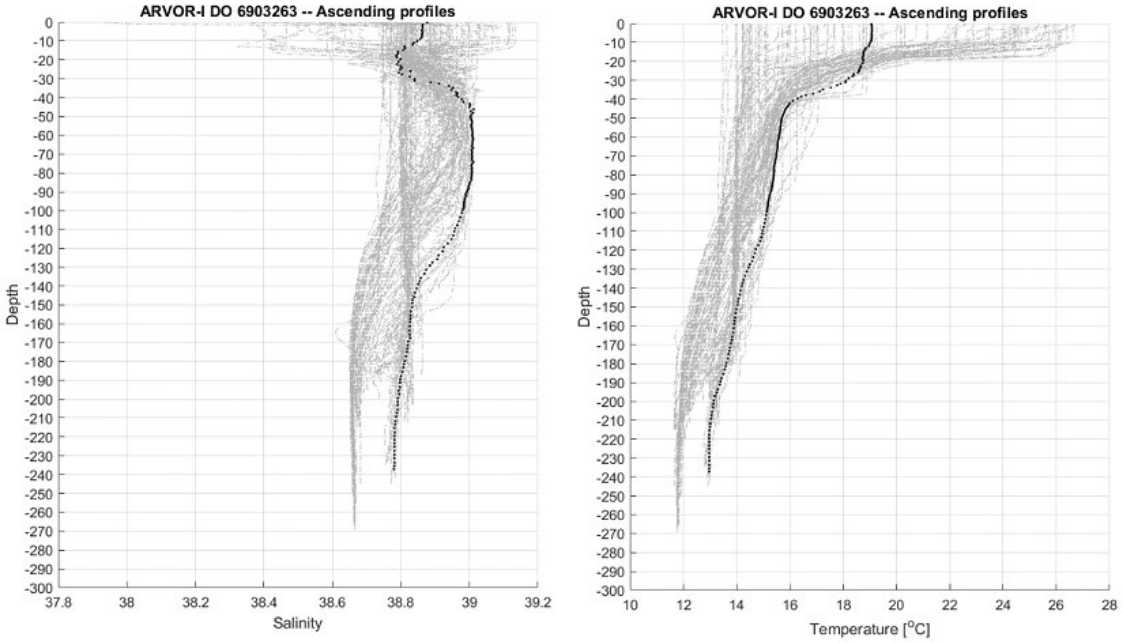

Figure 16. Salinity (left) and temperature (right) profiles of the Argo-Italy float (WMO 6903263). The last available profile is coloured in black.

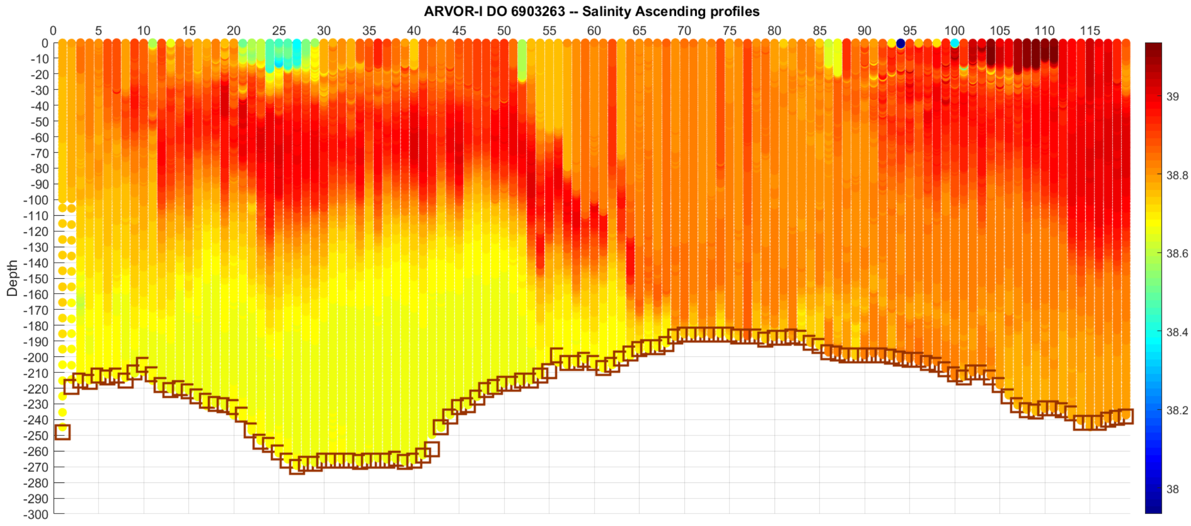

Figure 17. Hovmöller diagram of salinity for the Argo-Italy float 6903263. Grounding events are highlighted as red boxes.

The Euro-Argo RISE float is manufactured by the French NKE and it is an Arvor-I model (Table 4). Its WMO number is 6903783 and it was deployed off the Italian coast of the North Adriatic Sea the 31st of July 2020, by the Italian CNR R/V Dallaporta (Figure 18). The float is equipped with the

Iridium bi-directional telemetry system that allows a two-way communication system: float can send data and can receive new mission configuration commands.

Table 4: Main information of the Argo-Italy float WMO 6903783

Float type	WMO	Deployment date	Deployment latitude	Deployment longitude	Last station date	Cycle
Arvor I	6903783	31 July 2020	44.049 N	13.698 E	3 November 2020	21

The main mission commands and set up values are:

MC0= 500, number of total cycles

MC2= 48 (cycles 1 to 3); 120 (from cycle 4), cycling period

MC11= 200, parking depth

MC12= 200, maximal profile depth

MC17= 100, threshold zones 1/2

MC18= 500, threshold zones 2/3

MC19= 1, vertical resolution in zone 1

MC20= 1, vertical resolution in zone 2

MC21= 5, vertical resolution in zone 3

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

MC25= 5, shifting upward amount

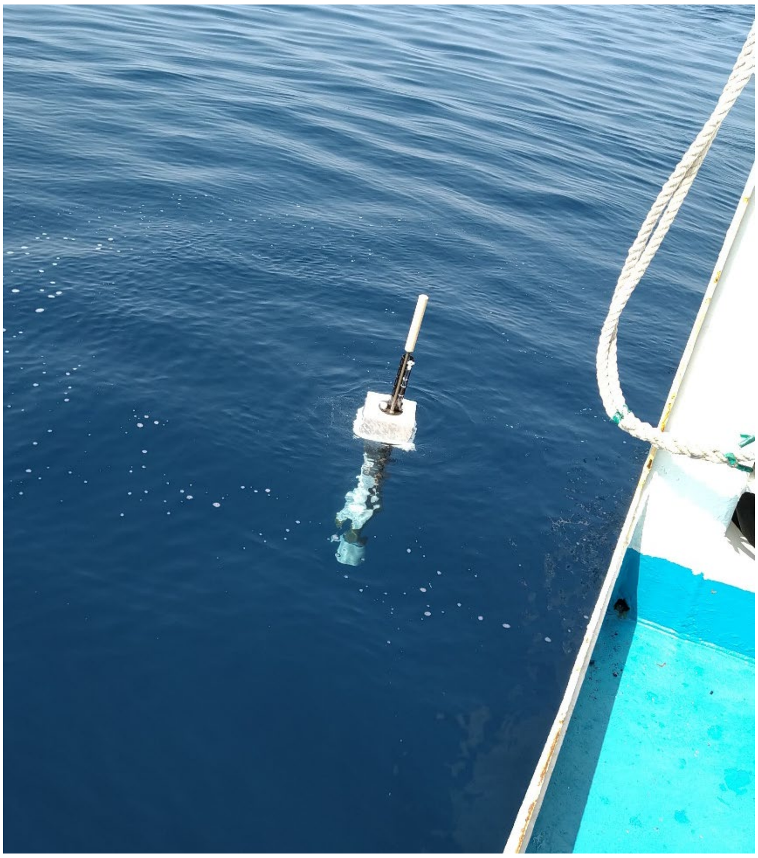

Figure 18. Deployment of the Euro-Argo RISE float (WMO 6903783) in the North Adriatic Sea by the Italian R/V Dallaporta, the 31st of July 2020.

The Argo float parameter MC 0 was unexpectedly changed to 0 by the software (firmware 5900A05) because an auto-test error was detected by the float itself. This parameter was immediately changed to 500 (normal working value), to prevent the float to stay in end of mission status and drifting at surface for a long time.

The target of the mission is to keep the float on the shelf and use it as a virtual mooring, limiting the drift. For this purpose, the float was configured with a parking depth at the sea bottom (MC 11 and MC 12 = 200) and it was forced to stay grounded for the entire length of the cycle. The cycle length was initially set to 2 days. The drifting extent was carefully checked during the first three profiles. CMEMS models of the daily mean sea water velocity near the float's parking depth were used (see Deliverable D6.1 for details) and the displacement between consecutive profiles was about within 1 km. Since cycle 4, the cycle length was set to 5 days.

3.3 Results

The Euro-Argo RISE float slowly drifted northwest up to cycle 13 and then suddenly moved southward (Figure 19). The current at the sea bottom level seems to be very weak (as by CMEMS model) and hence, the greatest part of the drift is more likely to be during the Argo float ascent and descent phases. However, given the low dynamic at depth, the float is still in shallow waters (less than 70 meters) of the NA and profiles locations are very close: the maximal displacement from the deployment point is about 10 km and the last location is about 8 km west.

Figure 19. Trajectory of the Euro-Argo RISE float (WMO 6903783) in the North Adriatic Sea). Number of cycles are also reported in white.

The first salinity and temperature profiles are presented in figure 20. The bottom impacts at about 70 meters are shown in figure 21 and they were performed at every cycle, as scheduled, to try to keep the float in the target area.

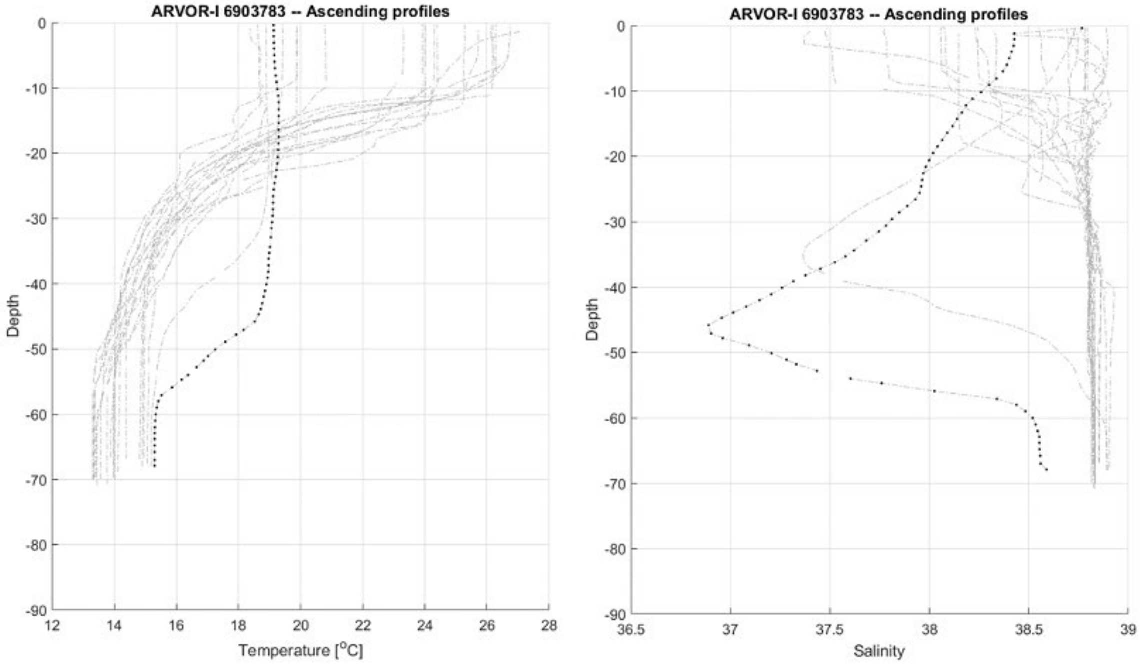

Figure 20. Salinity (left) and temperature (right) profiles of the Euro-Argo RISE float (WMO 6903783). The last available profile is coloured in black.

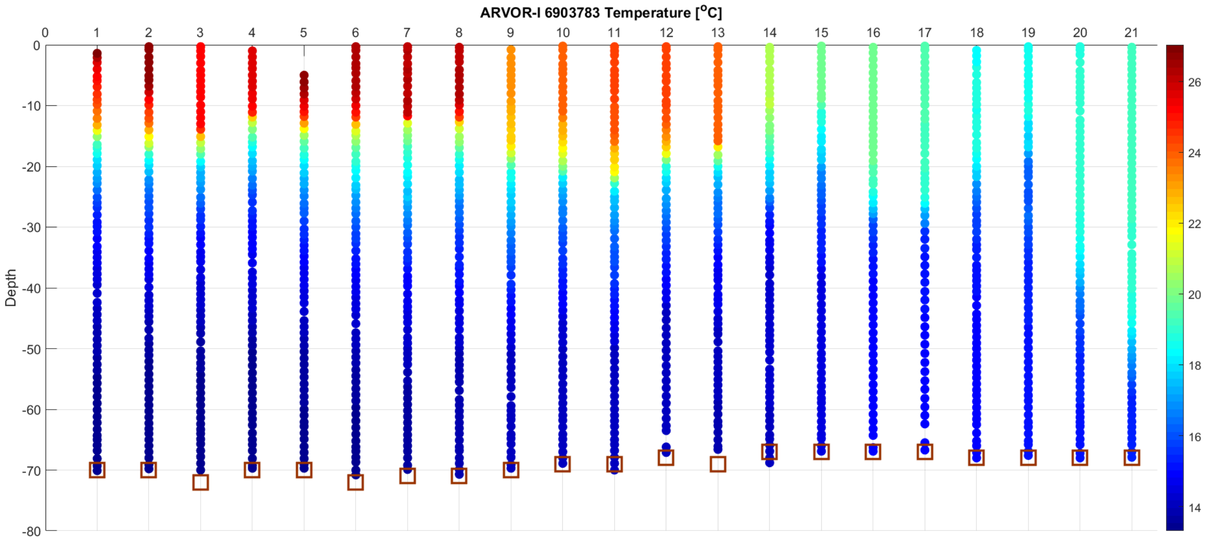

Figure 21. Hovmöller diagram of temperature for the Euro-Argo RISE float (WMO 6903783). Grounding events are highlighted as red boxes

3.4 Discussion – Conclusions

The test performed with the Italian Argo float in the Pomo Pit (Middle Adriatic Sea) was successful and provided the basis for the Euro-Argo RISE float experiment in the NA, a restricted and shallow area. We are still in a preliminary phase since just few cycles were acquired by the Euro-Argo RISE float but it seems that the test is promising. Anyway, this kind of operations require a higher level of interactivity between the operator and float. Monitoring tools are crucial to control the platform and float data and information have to be processed and received as soon as possible by the operator since he might have to change quickly the mission parameters. The latter was possible thanks to the automatic procedure developed at OGS that processed the float SBD files and send the needed information by email to the operator. The mission configuration used seems adequate to explore this shallow and small-sized sea and we were able to control the float drift by limiting the displacements in a small area around the deployment location. At the time of writing this report the mission target is reached: the float is still on the shallow shelf and far away from the coast. The programmed grounding at every cycle seems not to have any impact on the float behaviour.

4 Preliminary results of float operation in the northwestern Mediterranean Sea

4.1 Introduction

The global Argo observing system operates arrays of profiling floats, collects high frequency records of the upper ocean state, and provides measurements of essential variables (temperature, salinity) for operational users and ocean science researchers.

Associated to the evolutions of Argo network since more than a decade, the Laboratoire d’Océanographie de Villefranche has set up and tested biogeochemical floats in the Ligurian Sea, a deep basin of the northwestern Mediterranean bordered by a steep continental shelf. There, the embedding large-scale circulation is dominated by a cyclonic flow parallel to the coasts. This geostrophic current enters from the north-west of Corsica, flows around the high densities of the central basin which form a dome, and exits towards the south-west along the Provençal coast. Thanks to these characteristics, the Ligurian Sea is a relevant place to investigate the potential of profiling floats in shelf areas, in the aim to close the gap between open-ocean and shallow waters. The observation site Moose/Dyfamed, visited monthly since 1991, is another asset of this place, as it provides field logistics and reference measurements of essential variables.

4.2 Methodology

The deployment of the Euro-Argo RISE float (Table 5, WMO 6902899, note that cycle 115 is not missing, sent on November 17 11:47) occurred on December 11th 2019, at the Dyfamed site from the R/V Tethys-2 (Figure 22). This float was programmed to drift at a parking depth of 1000 m and to profile every 3 days. Deeper parking depths (down to 2000 m) could be planned for further deployments in the Liguro-Provençal Current. The objectives of the mission were to sample the Ligurian Current and participate to the sampling effort of the MOOSE network (https://www.moose-network.fr).

Table 5: Main information of the float WMO 6902899

Platform type	WMO	IMEI number	Serial number	Deployment date	Deployment latitude	Deployment longitude
PROVOR III	6902899	300125010116590	OIN13-S4-06	11/12/2019	43°21	7°54

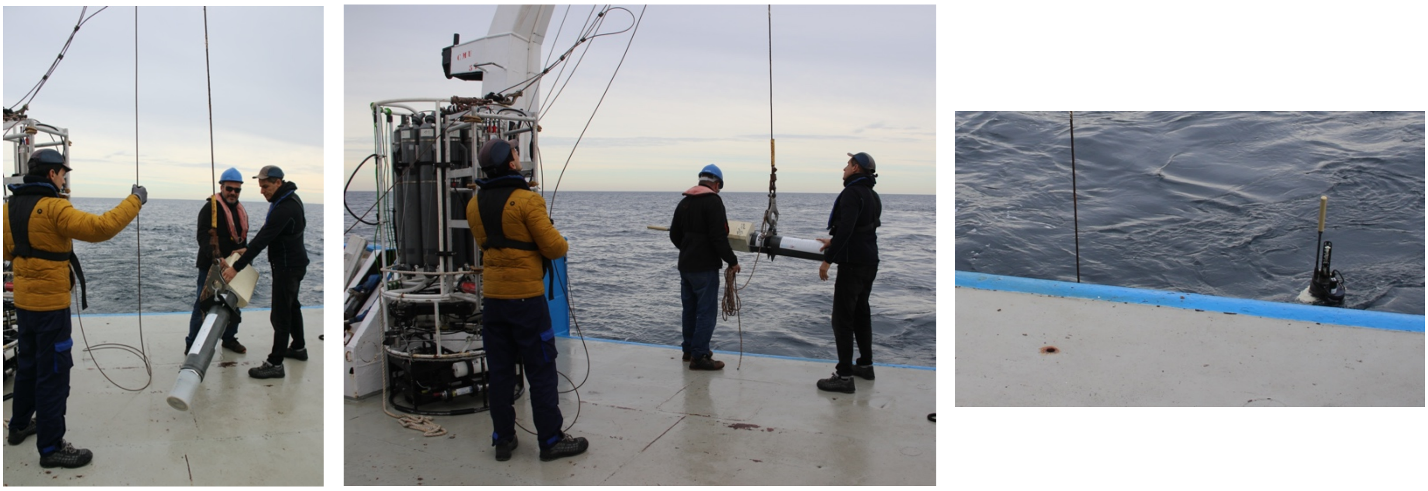

Figure 22. Deployment of the Euro-Argo RISE float (WMO 6902899) in the Ligurian Sea by the R/V Thetys 2, on the 11th of December 2019.

4.3 Results

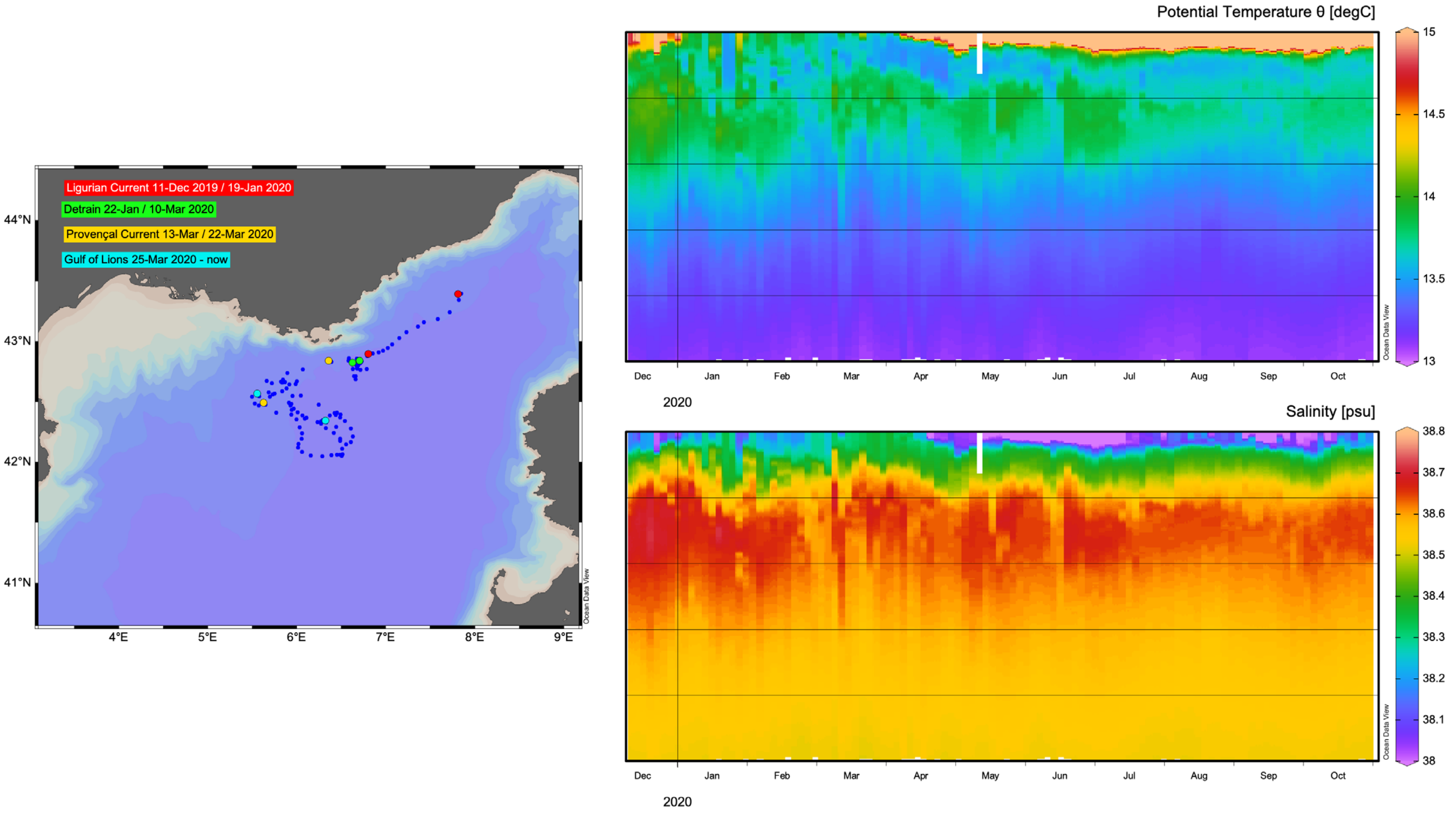

Figure 23. Trajectory and Hovmöller diagrams of temperature and salinity for the Euro-Argo RISE float (WMO 6902899)

Following its deployment, the Euro-Argo RISE float crossed 140 km in the sector south-south west at an average speed of 3 km per day. It drifted in the cyclonic edge of the geostrophic jet until the 19 January 2020, sampling the Levantine intermediate waters core (Figure 23).

At the entrance of the Gulf of Lions, the float was stopped and detrained from the geostrophic jet until 10 March 2020, recirculating there under the retention of meandering activity at this point.

Then the float went on sampling the cyclonic circulation along the shelf of the Gulf of Lions, until 22 March 2020. It definitely escaped from the current at the meridian 5°30’E, and remained offshore in the northwestern Mediterranean Basin (Figure 23).

The initial plan was to recover the float during the annual cruise MOOSE-GE in that region, but due to the COVID-19 pandemic restrictions this operation has been cancelled. However, the float has not drifted away from the MOOSE areal extension (that covers the North-West Mediterranean north 40°N) after about 100 cycles, so the collected dataset still represents this marine observatory (Figure 23).

The initial plan is still pending with one year of delay: we hope to recover the float during the next MOOSE-GE cruise in spring 2021, and redeploy it at Dyfamed in autumn 2021 to sample the Ligurian Current.

4.4 Discussion – Conclusions

The initial strategy of drifting at depth deeper than the core of the current, and the relatively high cycling frequency provided a characterization of the Liguro-Provençal current during the winter 2019-2020 from the 19-December 2019 until the 22-March-2020. Before drifting away from the marginal zone, the trajectory showed straight portions of the flow and retention point at the meridian 6°40’ E. This first attempt of float programing proposes a first compromise between monitoring the current in a pure Lagrangian point of view (following the flow) and increasing the residence time in this dynamically intense circulation feature.

Field operations in the Ligurian Sea will likely follow on next year. We hope the recovery of this float in June 2021 during the cruise MOOSE-GE and its redeployment at the Dyfamed site in autumn 2021. Such sequences of deployments and recoveries give access to technical parameters that control float life expectancy (e.g. power consumption), and provide metrological verification of the sensors (in particular, the evolution of their accuracy). By sticking close to the Argo best practices, the potential of maintaining an Argo component among the MOOSE observing system will be assessed, in complement to other platforms such as gliders or instrumented moorings.

5 Preliminary results of float operation in the South Palma

5.1 Introduction

The initial plan was to launch the Euro-Argo RISE T/S ARVOR-I float on the shallow shelf region near Cabrera Island (National Park) in the Balearic archipelago (Figure 24) and maintain a continuous change of configuration parameters in order to start operating the float in the coastal area. It was however, later decided to change the launching area to the South of Palma, figure 25, to better focus on the particular issues under this task (risk of collision with ships, being lost or touching the sea bottom).

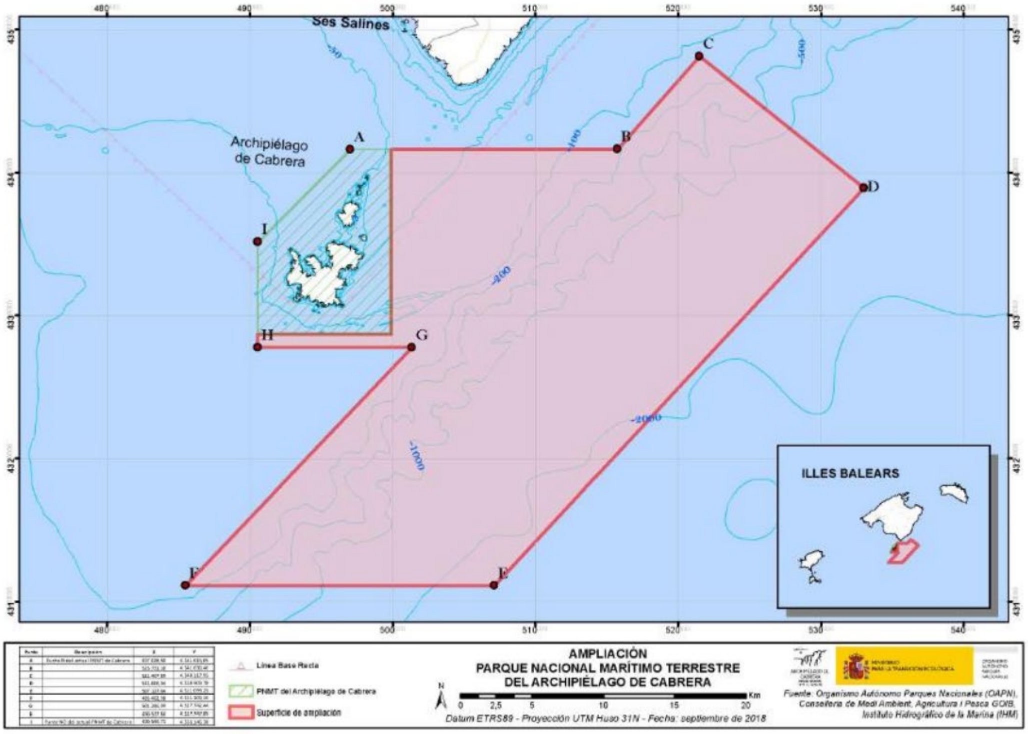

Figure 24. First area selected for the experiment.

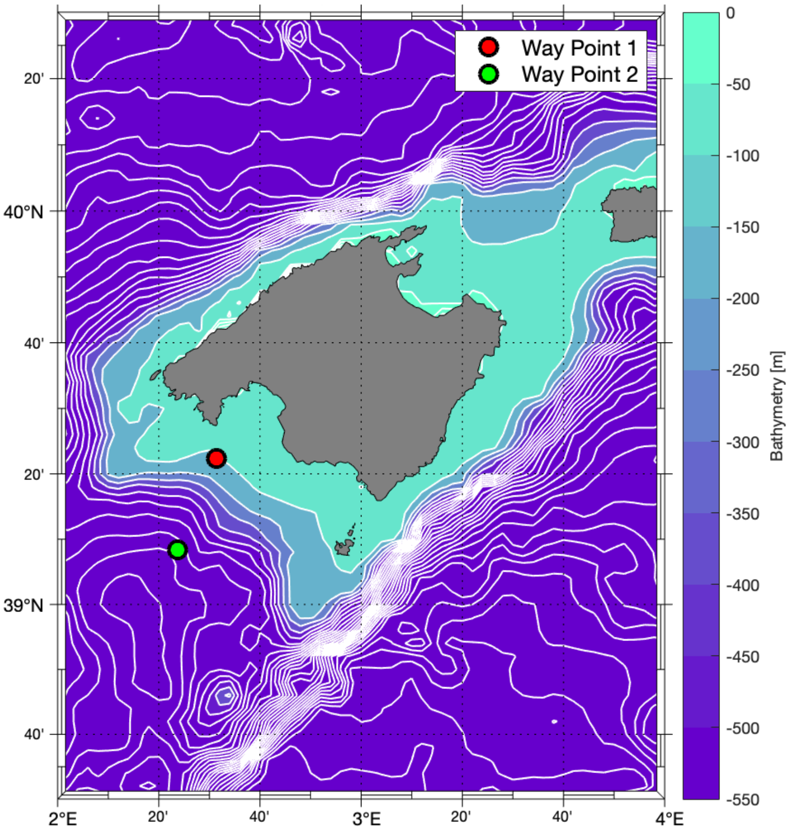

Figure 25. Experimental design.

The Bay of Palma has an extension of around 32 km from the coast to a bathymetric line of 200 m depth. The historical time series of the surface salinity registered in the Bay of Palma Buoy varies between 36.5 - 38.5 psu. The location is strategic, since it is centered in the Western Mediterranean. This is an important transition area between Atlantic and Mediterranean waters. This is a key area in the regional circulation of water masses because their topography controls the exchanges between the sub-basins of Algeria and the Balearic Islands (Pinot et al., 2002). The area has a big impact because Balearic current recirculates cyclonically over the northern islands slope (Pascual et al, 2002). Due to the current fields in the area, the profiling float could drift several kilometers far from the launching point.

The importance of local dependence on marine activities (maritime traffic, fishing, tourism) is very strong. Marine reserves and other vulnerable marine ecosystems are particularly important.

SOCIB Lagrangian Facility (Tintoré et al., 2013, 2019) has contributed since 2011 to the Argo program in the Mediterranean, launching several profiling floats from different manufacturers (Apex, Arvor and Provor), with Argos and Iridium transmission (Figure 26). The Canales SOCIB seasonal research vessel sampling programs, across the Balearic Channels (Figure 27), are normally used as a ship of opportunity to launch the profilers.

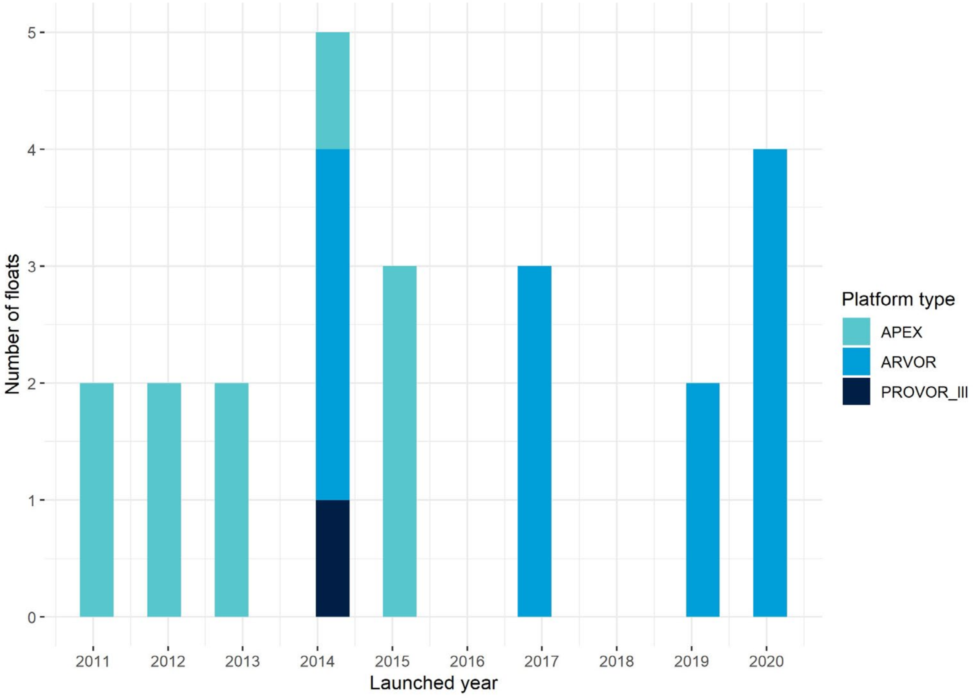

Figure 26. Different types of profiling floats deployed by SOCIB.

Figure 27. Sampling points in the SOCIB seasonal research programs across the Balearic Channels

To investigate the potential of floats in coastal areas (Euro-Argo RISE WP6, Task 6.1), a T/S Arvor I was launched on the 12nd of March 2020.

A lagrangian experiment was organized using the RV SOCIB and the float (6901278) was launched in the south of the Bay of Palma as shown in figure 25 (Waypoint 1). This float had a 24-hours profiling frequency and a parking depth of 100 m. One CTD cast was done to compare with the data obtained from the first cycle of the float and check possible sensor drifts and offsets in salinity and temperature.

At the Waypoint 2 in figure 25, the following platforms were launched:

- 1 T/S ARVOR-I (6901279) under Euro Argo Program to enhance the SOCIB profilers database + Argo Spain as to be part of the Euro Argo Program. This float had the typical Mediterranean configuration (The maximum profiling depth is 2000 dbar. Floats are programmed to dive to a ‘parking depth’ of 1000 m and to drift for approximately five days).
- 2 SVP-B’s launched (under Global Drifter Program) to enhance the SOCIB drifters database to maintain an active float of 12 SVP-B per year.

Another CTD cast was also done at the same point.

Ongoing weather forecasts and the results in 3D surface currents from a numerical model working in real-time at SOCIB (Western Mediterranean OPerational forecasting system, WMOP) were used to adjust the float’s settings, enabling it to drift away from the shore.

5.2 Methodology

5.2.1 Float characteristics

Platform information: Arvor I model manufactured by the French NKE (WMO number: 6901278) with a lithium battery and a battery pack 2 WILPA1621A.

Sensors: Pressure sensor manufactured by DRUCK (model DRUCK_2900PSIA) and temperature and conductivity sensor manufactured by SBE (model SBE41CP_V7.2.5) with their specific physical parameters (Table 6).

Table 6: Physical parameters

PARAMETER	SENSOR	UNITS	ACCURACY	RESOLUTION
PRES	CTD_PRES	dbar	2.4 dbar	0.1 dbar
TEMP	CTD_TEMP	degC	0.002 degC	0.001 degC
PSAL	CTD_CNDC	psu	0.005 psu	0.001 psu

5.2.2 Configuration

5.2.2.1 Cycle mission commands

MC0 = 500

MC1 = 500

MC2 = 24

MC3 = 24

MC11 = 100

MC12 = 100

MC13 = 100

MC14 = 100

MC22 = 60

MC23 = 0

MC24 = 1

MC25 = 30

MC4 = 1

MC5 = 6

MC6 = 15

MC7 = 1

MC8 = 0

MC9 = 1

MC10 = 10

MC15 = 1

MC16 = 2000

MC17 = 10

MC18 = 500

MC19 = 1

MC20 = 1

MC21 = 1

MC26 = 10

MC27 = 0

MC28 = 2

MC29 = 0

MC30 = 30

MC31 = 5

5.2.2.2 Cycle technical parameters

TC0 = 800

TC1 = 11

TC2 = 290

TC3 = 720

TC4 = 27000

TC5 = 30

TC6 = 2100

TC7 = 1

TC8 = 7

TC9 = 2

TC10 = 36

TC11 = 200

TC12 = 50

TC13 = 25

TC14 = 0

TC15 = 10

TC16 = 90

TC17 = 2

TC18 = 10

TC19 = 36

TC20 = 1

TC21 = 0

TC22 = 33000

TC23 = 120

TC24 =

TC25 =

5.2.3 Deployment and monitoring methodology

The float (6901278) was launched in Waypoint 1 (39º22.291' N, 2º30.991' E) as shown in figures 25 and 28. The bathymetry at this point was 94.4 m (research vessel sonda), the ship velocity was 0.7 kn (drifting velocity). The weather conditions: 3.1 kn wind speed, 111º wind direction, water temperature 14.5 ºC.

Figure 28. Euro-Argo RISE mission launching point. Deployment of Arvor-I as part of Euro-Argo RISE Project.

The monitoring procedure to follow the float was:

- To decode the float raw data: parse of sbd files while the Coriolis decoding chain is not yet initiated.
- To check the Western Mediterranean OPerational forecasting system (WMOP) that runs operationally on a daily basis, producing forecasts at different depths of currents. It is useful for understanding if the profiler is going to move away from coastal water and allowing to change mission configuration parameters in advance.
- To check the last GPS position delivered by the profiler using the SOCIB Deployments web client application. Also, the Argo fleet monitoring tool is used, superimposing the sea currents provided by the latest AVISO satellite derived data.
- In order to detect the different water masses in the area, potential temperature versus salinity (θ/S) diagrams were done continuously.

5.3 Results

The first cycle (downcast) of the float (WMO 6901278) was compared with the downcast data from ship observations at the same location and the 2nd cycle (up-cast). Figure 29 shows significant deviations between the instruments, in particular in the upper 40 m for both T and S that we are presently studying and try to understand.

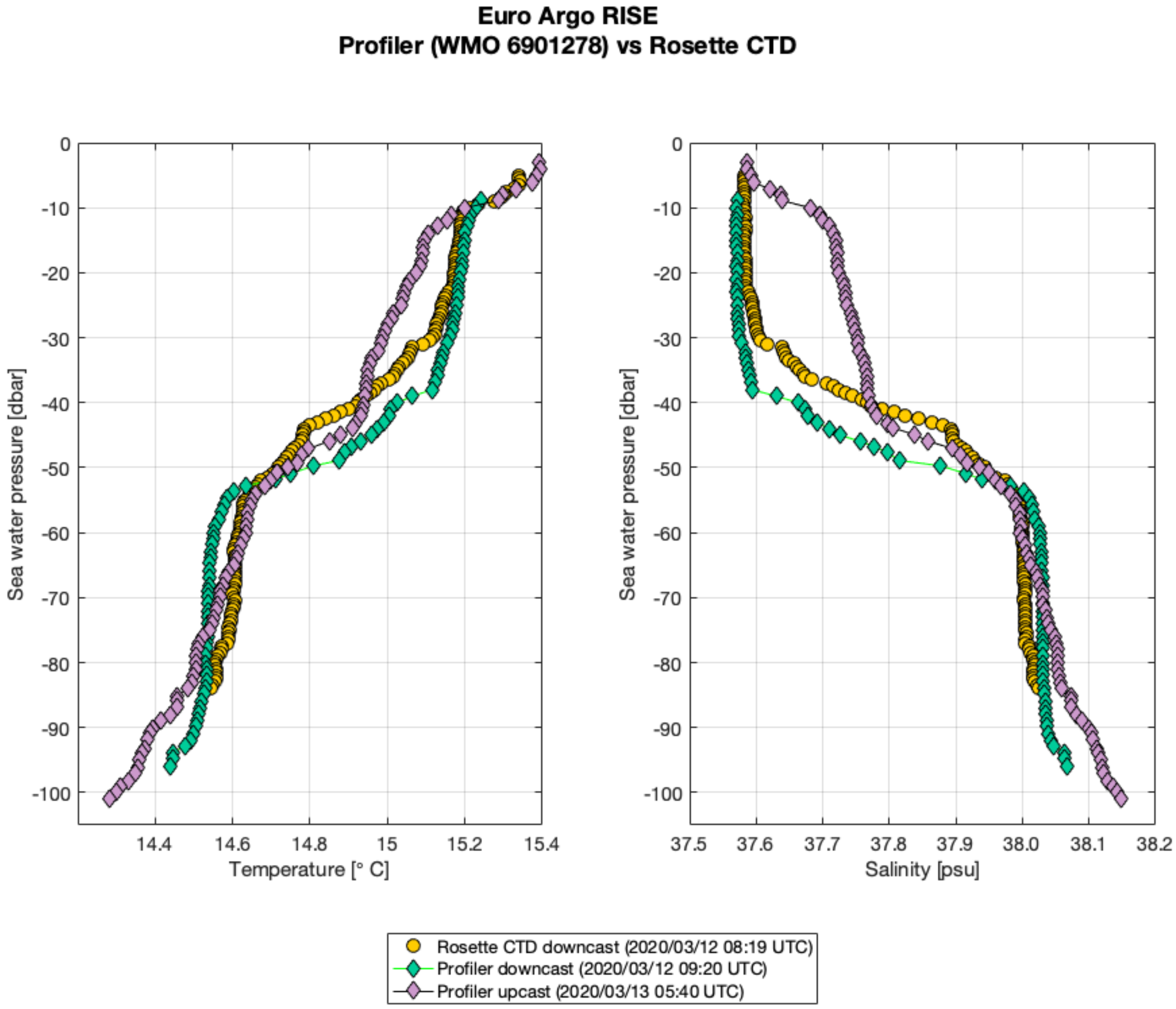

Figure 29. Temperature (a) and salinity (b) comparison from ship rosette CTD and profiling float

The float was staying in shallow waters from 12/03/2020 until 05/08/2020 (cycle 78). This means that the float was in shallow waters around 5 months. The float was drifting along the Balearic Current (over the Balearic continental shelf, Figure 30).

The float sampled the Atlantic Water (AW), Resident AW and Levantine Intermediate Water (LIW), according to López-Jurado et al, 2008 and Juza et al, 2019 (Figure 31).

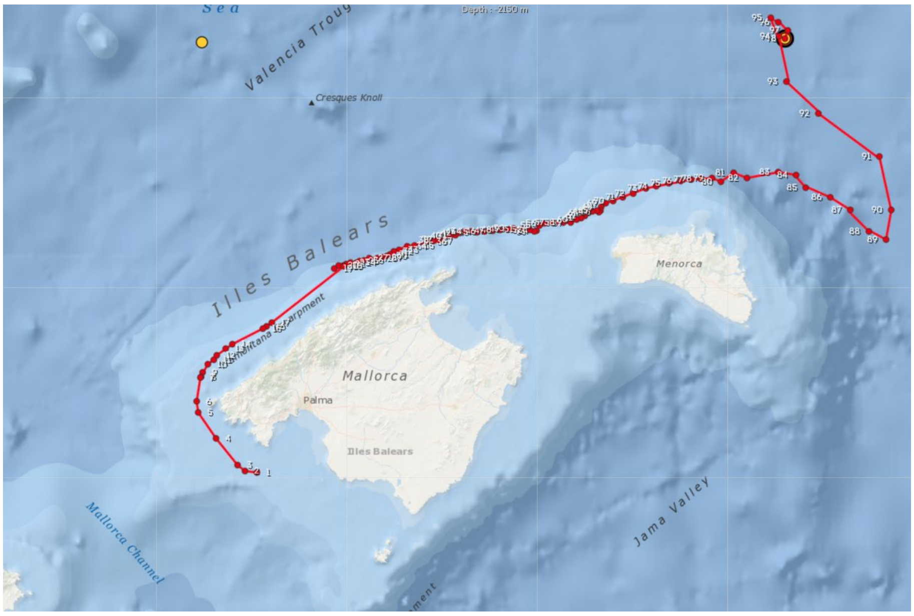

Figure 30. Trajectory of the Euro-Argo RISE Argo float (source: Fleet monitoring).

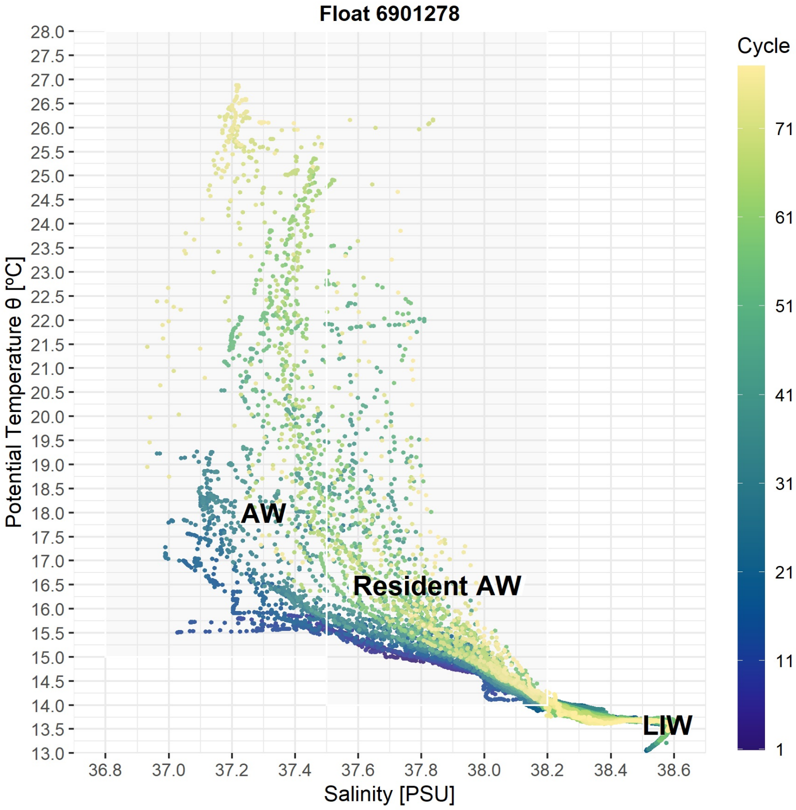

Figure 31. Potential temperature versus salinity (θ/S) diagram.

While the float was in shallow waters, the maximum pressure registered was 1000 dbar. In this time period some mission commands were changed four times (Table 7). On the 12nd August 2020, the float configuration was changed to "Med 5 days".

Table 7: Summary of mission commands changed during the shallow waters mission

DATE	19/03/2020	31/03/2020	22/04/2020	09/05/2020
MISSION COMMANDS	MC 2 48	MC 2 96	MC 2 24	MC 2 48
	MC 11 300		MC 11 1000	
	MC 12 300		MC 12 1000	

5.4 Discussion – Conclusions

Strong surface currents could make the float drift on the surface farther than intended (Figure 32). Such conditions were revised from the weather forecasts and the numerical models beforehand in order to make the surfacing time shorter trying to avoid the surface drift or to make the float drift to the desired direction at the surface. The experiment showed that if the float is maintained deeper, it will be kept in the area of interest.

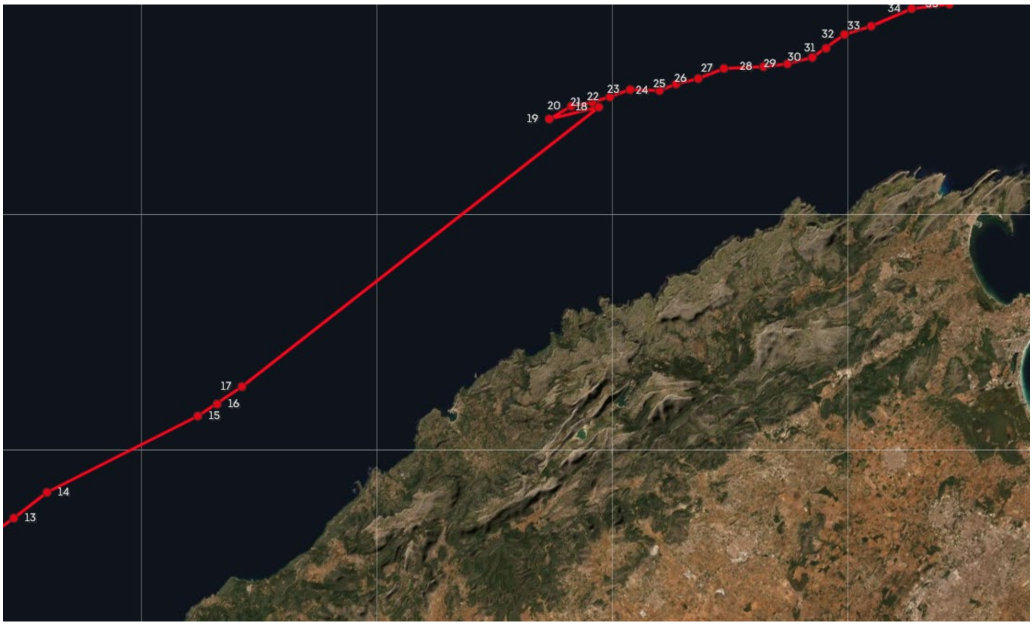

Figure 32. The float drifted around 15 miles in 4 days (4 miles per day) between cycles 17 and 18 (source: Fleet monitoring).

Maybe due to the COVID-19 lockdown, the collision with ships was under control. In a normal situation with high marine traffic, another way of operation should be investigated.

The use of several sources of data, such as floats, cruises and surface drifters, can provide extra data for better monitoring.

6 Summary and main outcomes

6.1 Floats' configuration and performance

The experience gained from the four Argo float missions has been proved very useful and highlights the importance of Argo expansion in the shallow coastal areas of the Mediterranean Sea. However, it also highlights the constraints of the Argo platform to operate in such areas. For sure, it seems that there is a need for alternative configuration settings and specially designed operations with the help of advanced monitoring tools.

A common aspect of the previously described operations relevant to the floats' configuration settings is the parking depth parameter. In all cases it is shown that the setting of a relatively "deep" parking depth, in the sense that the latter is either close or even identical to the profiling depth parameter, has been proved advantageous to the mission. The main reason for such configuration was to prevent the float from drifting away from the targeted area. More specifically, in the operations of South Palma and Ligurian Sea, deep parking was chosen since the strong surface and sub-surface currents are identified as the main factor for the float's drift. In the North and Central Adriatic and North Aegean cases, the parking depth was set close to the sea-bed or deep enough so as the float to remain "trapped" in depression plateaus and deep trenches. Moreover, the fact that the floats often grounded on the bottom did not seem to have any particular impact on their behaviour.

Another common strategy followed was the high frequency sampling. The PIs' choice to set profiling cycles that varied between 1 to 5 days was also proven advantageous. It has provided large number of profiles in important and highly variable areas, but also acted as a preventing factor for the floats to drift in long distances between two consequent profiles especially in areas where strong deep currents prevail. Furthermore, the high sampling frequency provided trajectory data of valuable information regarding the near bottom current activity.

Regarding the floats' life expectancy, the up-today data are promising. With the exception of the float deployed in the North Aegean, where the communication of the float is lost after 8 months of operation and 120 profiles transmitted, the rest 3 floats are still operating. The float deployed in the Ligurian Sea has already performed 123 cycles after a year of operation whilst, for the South Palma case 105 cycles are performed in almost 8 months period. For the Adriatic case, although it is still early since the float operates for only 4 months and has performed 28 cycles, the mission seems to reach its targets.

6.2 Operational monitoring and interactivity

As shown from the reports, the configuration of the floats should be properly planned in conjunction with the utilization of advanced operational monitoring tools. The existing and updated tool provided by Euro-Argo (https://fleetmonitoring.euro-argo.eu/dashboard) has been proven extremely valuable for the near real-time monitoring of the floats' performance for both technical and scientific data. Operating Argo floats in coastal areas require more interactivity than deployments in the open ocean, as the float operator needs to decide whether they should change certain configuration settings. Moreover, it has been shown that coastal operations require increased real–time information so as the interaction between the operator and float takes place in short time scales. Under this aspect, the implementation of additional monitoring/controlling tools are under development in link with the Euro-Argo RISE WP2 and will be tailored in Marginal Seas Argo floats operations. Preliminary examples of such statistical information that can be provided through automated real-time scripts are presented in figure 33. According to this figure, for the 4 missions described previously, the grounding events are mapped whilst the changes in the cycle time and parking pressure are statistically presented. Such tools can be utilized for large fleets/groups of floats, and provide valuable information to the operators.

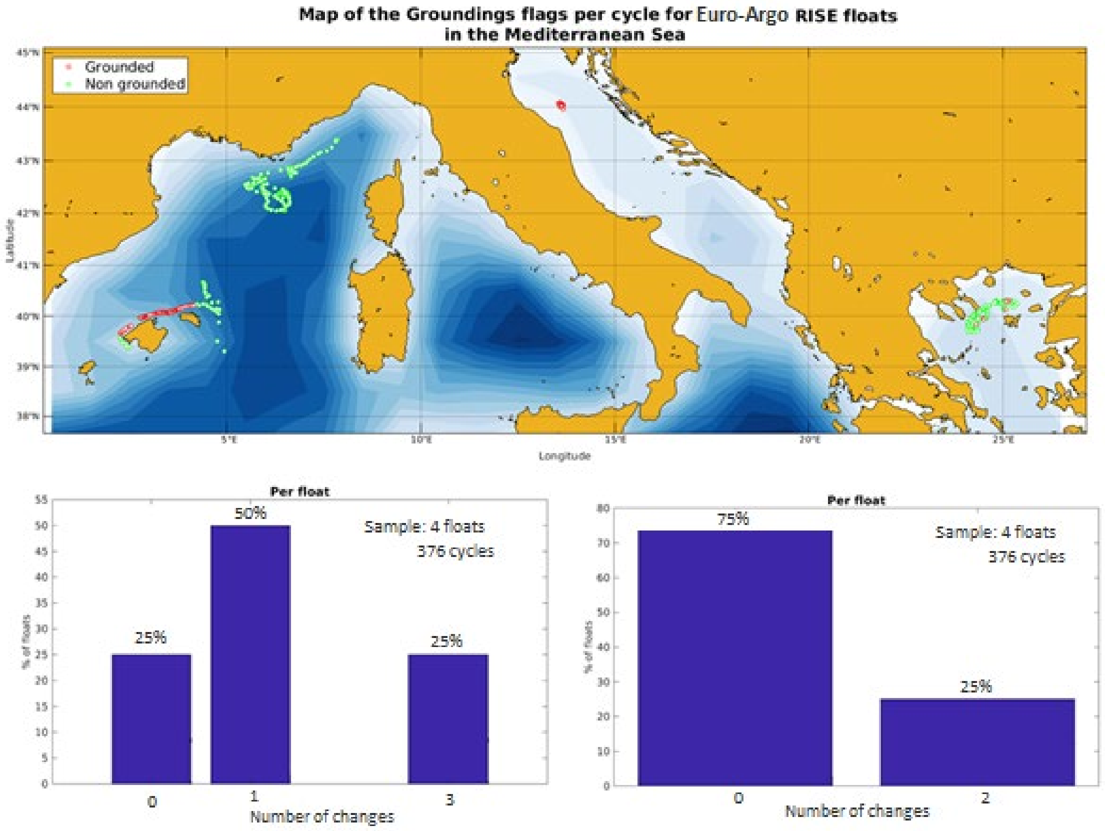

Figure 33. Mapping and statistical outputs provided by WP2 (D2.1 script "config_fleet_status") regarding the status of the 4 Euro-Argo RISE missions in the Mediterranean Sea. Top: Mapping of grounding events, bottom left: Changes in cycle time, bottom right: Changes in parking depth

However, apart from the monitoring tools, additional information have been reported to be crucial for the float operators such as estimations of the currents activity, weather conditions and forecasts, hydrodynamic data from numerical models.

6.3 Recommendations on future activities

Although being still in a preliminary phase, the operational use of Argo floats in shallow coastal areas seems to be a potential part of an integrated oceanographic monitoring system in the Mediterranean Sea. This will rely in the ability of the float operators to control the floats and alternate their missions in near real-time, based on more advanced monitoring tools, which can lead to significant improvements of similar missions in the near future. Furthermore, given the special characteristics of such missions, the possibilities of early recoveries and redeployments should also be explored in order to minimize the cost of early float losses. A best-practices handbook for coastal Argo missions might help operators to plan and execute missions that will act complementary to other monitoring platforms of the coastal sea zone such as gliders and moorings. The experience from the test deployments in targeted areas highlights the added value that Argo can provide through high quality, and spatiotemporally dense datasets. Furthermore, the potential use of floats with additional biogeochemical sensors raises this value. However, the cost effectiveness might be a preventing factor for the Argo expansion in such shallow coastal areas. Thus, along with a float recovery planning, the possibility of special designed floats for shallow water use should also be enforced.

Summarizing, the increased float coverage in specific sub-basins of the Mediterranean will lead to enhanced monitoring and investigation of variable and transitional areas and will be a valuable source of information regarding the hydrography and ecosystem functioning. Such evolution will also strengthen the contribution of Argo to both the description of the Good Environmental Status (GES) and to the European Ocean Observing System (EOOS). Furthermore, with regards to climatic variability studies, enhanced Argo coverage into sub-basins of marginal seas will help the investigation of extreme events over the coastal zone and the description of their possible impacts on the marine system (Kassis and Varlas, 2020). Particularly, this information can be used for the description of short scale events enhancing coupled met-ocean forecasts, whilst, it can also be potentially important for fisheries, aquaculture, and agencies (e.g. national meteorological and oceanographic offices and the national oceanographic monitoring services) related to ecosystem preservation and tourism.

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