INVESTIGATING THE CAPABILITY OF ARGO FLOATS TO MONITOR SHALLOW COASTAL AREAS OF THE MEDITERRANEAN SEA

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Dimitris Kassis (1), Giulio Notarstefano (2), Inmaculada Ruiz-Parrado (3), Vincent Taillandier (4), Lara Díaz-Barroso (3), Esterine Evrard (5), Romain Cancouët (5) and Luca Arduini Plaisant (5)

(1) Institute of Oceanography, Hellenic Centre for Marine Research, PO Box 712 Anavyssos, Attica GR-190 13, Greece, dkassis@hcmr.gr

(2) National Institute of Oceanography and Applied Geophysics - OGS, Borgo Grotta Gigante 42/C 34010 - Sgonico (TS), Italy, gnotarstefano@inogs.it

(3) Balearic Islands Coastal Observing and Forecasting System - SOCIB, Parc Bit, 07121 Palma, Spain, inmaruizparrado@gmail.com, ldiaz@socib.es

(4) Sorbonne Université, CNRS, UMR 7093, Laboratoire d'Océanographie de Villefranche, Villefranche/mer, France, taillandier@obs-vlfr.fr

(5) Euro-Argo ERIC, Campus Ifremer - Technopole Brest Iroise 1625 Route de Sainte-Anne 29280 Plouzané – France, esterine.evrard@euro-argo.eu, romain.cancouet@euro-argo.eu, Luca.Arduini.Plaisant@euro-argo.eu

Abstract

The extension of Argo float coverage to the European marginal seas is one of the strategic targets of the Euro-Argo European Research Infrastructure Consortium (ERIC). Under this general framework, the Argo capability to monitor the shallow coastal shelf remains an open question. In the Euro-Argo RISE H2020 project, targeted deployments have been undertaken to investigate this potential. In this study, we present the experience and outcomes from 4 such deployments in areas of the Mediterranean Sea with intrigue coastlines and complex bathymetry (north Aegean, north Adriatic, south Palma, and Gulf of Lions). We focus on the floats' configuration settings and the monitoring tools/software that have been utilized to follow the floats' performance. Our results show that certain configuration parameters such as the drifting depth, and the sampling frequency, play a significant role in the floats' performance. Technological advances both on the floats' characteristics and on the monitoring-controlling tools can lead to significant improvements of similar missions in the near future. The fact that all floats achieved successful missions and acquired data showing important hydrographic features, highlights the importance of Argo expansion in targeted shallow coastal areas where Argo can be a complementary part of an integrated oceanographic monitoring system for the Mediterranean Sea.

Keywords: Drifting Profilers, Argo Profiles, Argo Trajectories, Coastal Monitoring, Marginal Seas

1. Introduction

The operational oceanographic monitoring of the coastal waters of the European Marginal Seas (EMS) has lately been a top priority because of the anthropogenic pressures and climatic variability that affect their hydrography and ecosystems with important socio-economic impacts. However, the establishment of an adequate and cost-effective integrated observation system remains a challenging task which will require international cooperation and synergies between different oceanographic platforms. For the global Argo system, which during the last two decades has been providing unprecedented amounts of cost effective and high spatiotemporal resolution data from the global ocean (Riser *et al.*, 2016), the extension into regions that were previously under sampled, such as the ice-covered regions and the marginal seas, is ongoing (Jayne *et al.*, 2017). Regarding the EMS, the Euro-Argo European Research Infrastructure Consortium (Euro-Argo ERIC) has timely adopted a plan for Argo expansion which is described in its strategic targets (Euro-Argo ERIC, 2017). This has resulted in an increasing number of float coverage in the Nordic, Baltic, Mediterranean, and Black Seas that has produced enhanced datasets and allowed better oceanographic monitoring during the last years. During the last decade, the systematic use of Argo floats has initiated a new era of oceanographic monitoring in the Mediterranean's different sub-basins (Figure 1) revealing important hydrological features, and strongly variable climatic signals (Kassis and Korres, 2020).

Under the Euro-Argo RISE H2020 project, the further extension of Argo deployments along the Mediterranean's coastal sub-basins is investigated. In this study we focus on the preliminary results from four standard CTD Argo float deployments in specific targeted areas (Kassis *et al.*, 2021 D6.2). We present a summary of the floats' performance in conjunction with the various configuration schemes used in each test case. We attempt to assess the available operational monitoring tools used by the floats' operators in order to provide recommendations on similar future activities. The outcomes of the missions are promising and highlight the important complementary role Argo floats have on the integrated monitoring system of the Mediterranean's coastal zone.

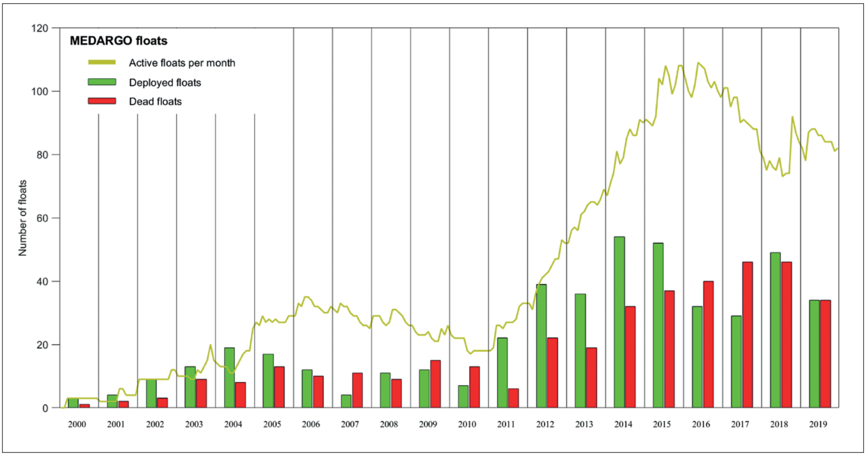

Fig. 1. Interannual variability of float population in the Mediterranean Sea.

2. Methods and tools

2.1 Floats' configuration and deployment

All floats were deployed between late-2019 and mid-2020 at specific targeted locations identified by the operators (Table I). The floats integrated the standard CTD sensors and were equipped with the Iridium bi-directional telemetry system. Operators pre-configured them with slightly different mission parameters according to the characteristics of each area and the target of each mission. More specifically, the float deployed in the North Aegean by HCMR was configured to perform 2-day cycles, drift and perform profiles at 800 m depth. The high frequency sampling and the deep drifting depth were chosen in order for the float to remain in the relatively deep trench after the shelf-break. A similar configuration albeit modified for a shallower plateau, was used for the float deployed by OGS in the North Adriatic where both parking and profiling depths were set to 200 m. The cycling period in that case was initially set to 2 days and changed early to 5 days. For the Ligurian Sea experiment (SU), the parking and profiling depths were set deeper (1000 m) and the cycling period was set to 3 days. For the Palma Bay case the float deployed by SOCIB was set to drift at 100 m and profile at 1000 m depth at a cycle period of 24 hours, changed to 5 days some months later.

Table I: Floats' deployment information

FLOAT TYPE	WMO	DEPLOYMENT DATE	DEPLOYMENT LOCATION	LAST STATION DATE	CYCLES PERFORMED
APEX 11	6903288	9 February 2020	North Aegean Lat: 40.42 N, Lon: 25.42 E	5 October 2020	120
ARVOR I	6903783	31 July 2020	North Adriatic Lat: 44.05 N, Lon: 13.7 E	6 February 2021	40
PROVOR III	6902899	12 November 2019	Ligurian Sea Lat: 43.35 N, Lon 7.90 E	13 April 2021	165
ARVOR I	6901278	12 March 2020	Palma Bay Lat: 39.38 N, Lon: 2.52 E	10 April 2021	130

2.2 Monitoring of the floats' performance

Through the recently updated Euro-Argo monitoring tool (https://fleetmonitoring.euro-argo.eu/dashboard), a variety of parameters were made available regarding the floats' mission (Figure 2). This generic tool provides information regarding technical and functional parameters of the floats' performance allowing the float operator to make timely decisions for new configuration settings if needed. In addition to this system, customized tools have been tested, such as automatic email alert systems that provide the float position and the depth of the sea at the float location almost in real time (Notarstefano *et al.*, 2020 D6.1). Thus, with the combination of such tools the float operator was provided with graphical representations of the floats' metadata, along with technical parameters and alerts for malfunction and detection of early failures.

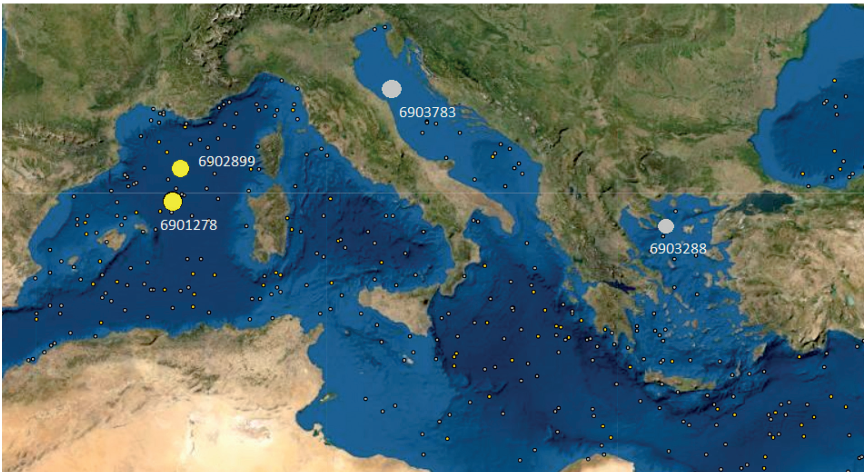

Fig. 2. Latest location of Euro-Argo RISE floats (yellow – active, grey – inactive) provided by the Euro-Argo monitoring tool (https://fleetmonitoring.euro-argo.eu/dashboard).

3. Results

The floats' missions were successful since floats managed to operate for a long time in the targeted areas (2 of the floats are still operational), providing an adequate number (Table I) of good quality profiles. In the North Aegean, 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 the high sampling frequency and to the relatively deep parking depth that prevented the float from drifting along the coastline. Regarding the North Adriatic case, the configuration used seemed adequate for the float to explore this shallow plateau. The operators were able to control the float's drift by limiting the displacements in a small area around the deployment location whilst the programmed grounding at every cycle did not have any particular impact on the float's behaviour. Regarding the Ligurian Sea mission, the initial strategy of setting the drifting depth deeper than the core of the Liguro-Provençal current along with the relatively high cycling frequency, provided a characterization of the current during the winter period of 2019 – 2020. This first attempt of float programming proposes a compromise between monitoring the current in a pure Lagrangian point of view and increasing the residence time in this dynamically intense circulation feature. For the Palma Bay mission, it was shown that strong surface currents could make the float drift on the surface farther than intended. 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 would be kept in the area of interest.

Apart from the mission assessment under a technical point of view, the floats' operations provided interesting oceanographic information based on both the acquired profiles and performed trajectories. Such an example is the longitudinal gradient of both temperature and salinity at the deep layers of the North Aegean (Figure 3) 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 dense water formation mechanisms in the area.

4. Discussion and future recommendations

Certain configuration settings seem to have played a significant role in the previously described operations. The 'deep' parking depth, in the sense that this is either close or even identical to the profiling depth parameter, has been proved advantageous to the missions. In all cases it is shown that this setting prevented 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 subsurface currents are identified as the main factor for the float's drift. In the North and Central Adriatic

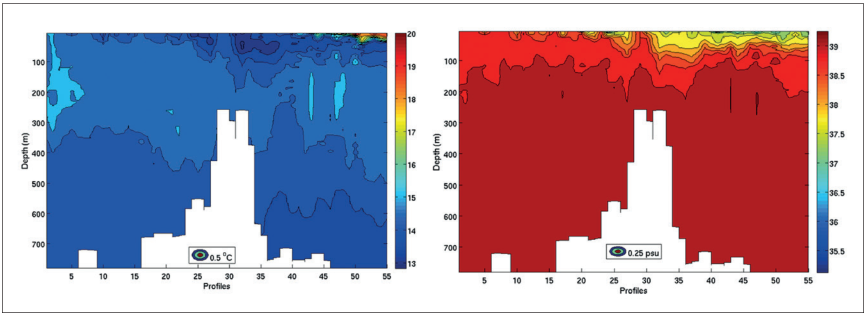

Fig. 3. Hovmöller diagrams of temperature (left), and practical salinity (right) from the first 55 profiles transmitted by the 6903288 in the North Aegean Sea.

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 operators' choice to set profiling cycles that varied between 1 and 5 days was also proven advantageous. It has provided a 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.

Although still in a preliminary phase, the operational use of Argo floats in shallow coastal areas can potentially be an important part of an integrated oceanographic monitoring system in the Mediterranean Sea. The experience we gained from the presented deployments highlights the added value of Argo through the provision of high quality, and spatiotemporally dense datasets in areas that were previously under-sampled. Either being autonomous, or acting complementary to other monitoring platforms such as gliders and moorings, coastal Argo missions can lead to enhanced monitoring and investigation of variable and transitional areas being a valuable source of information regarding the hydrography and ecosystem functioning. This will however require a well-planned monitoring strategy and will rely on the ability of the float operators to control the floats and alternate their missions in near real-time. Operational tools (Figure 4) and additional information such as estimations of the currents activity, weather conditions and forecasts, hydrodynamic data from numerical models, will be crucial for the float operators. Such advanced monitoring tools can lead to significantly improved missions in the near future whilst, 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.

This would be particularly important especially for coastal missions with floats that carry biogeochemical sensors (BGC Argo) and cost significantly higher than standard CTD floats. 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).

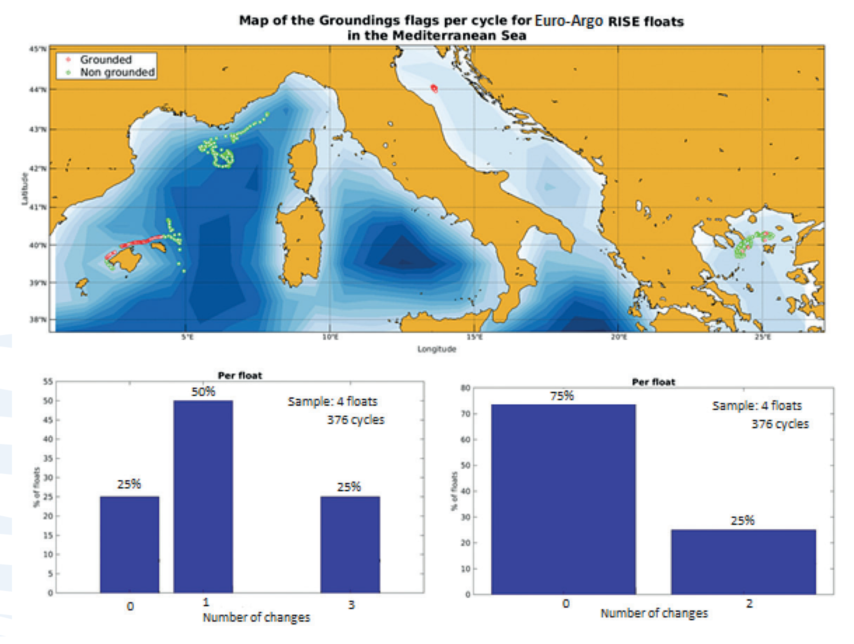

Fig. 4. Mapping and statistical outputs provided by Euro-Argo RISE WP2 team regarding the status of the 4 float missions in the Mediterranean Sea. Top: Mapping of grounding events, bottom left: Changes in cycle time, bottom right: Changes in parking depth.

Acknowledgements

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References

D'Ortenzio, F., Taillandier, V., Claustre, H., Prieur, L. M., Leymarie, E., Mignot, A., ..., and **Schmechtig, C. M.** (2020). Biogeochemical Argo: the test case of the NAOS Mediterranean array. *Frontiers in Marine Science*, 7, 120.

Euro-Argo ERIC, 2017: Strategy for evolution of Argo in Europe. *EA-2016-ERIC STRAT*. https://doi.org/10.13155/48526

Notarstefano, G., Pacciaroni, M., Kassis, D., Palazov, A., Slabakova, V., Tuomi, L.,

Siiriä, S., Walczowski, W., Merchel, M., Allen, J., Ruiz, I., Diaz, L., Taillandier, V., Arduini-Plaisant, L., and Cancouët, R. (2021) Tailoring of the controlling and monitoring tools for operations in shallow coastal waters, Euro-Argo RISE H2020 project Deliverable 6.1, under EC review.

Jayne, S. R., Roemmich, D., Zilberman, N., Riser, S. C., Johnson, K. S., Johnson, G. C., and Piotrowicz, S. R. (2017). The Argo program: present and future. *Oceanography*, 30(2), 18-28.

Kassis, D., and Korres, G. (2020). Hydrography of the Eastern Mediterranean basin derived from argo floats profile data. *Deep Sea Research Part II: Topical Studies in Oceanography*, 171, 104712.

Kassis, D., Notarstefano, G., Taillandier, V., Ruiz, I., Diaz, L., Cancouet, R., Evrard, E., and Arduini Plaisant, L. (2021). Preliminary results of shallow coastal float operations in the Mediterranean Sea Euro-Argo RISE H2020 project Deliverable 6.2, under EC review.

Riser, S. C., Freeland, H. J., Roemmich, D., Wijffels, S., Troisi, A., Belbéoch, M., ... and Jayne, S. R. (2016). Fifteen years of ocean observations with the global Argo array. *Nature Climate Change*, 6(2), 145-153.