Tailoring of the controlling and monitoring tools for operations in shallow coastal waters

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EXECUTIVE SUMMARY

Argo is an in-situ network for the observation of the subsurface ocean at global level. Argo platforms were originally designed as oceanographic instruments for the open ocean, and eventually used into shallow coastal waters to provide observations for these under-sampled regions. The European H2020 Euro-Argo Research Infrastructure Sustainability and Enhancement (Euro-Argo RISE) project aims at investigating the potential of Argo profiling floats in shelf/coastal areas of European Marginal Seas.

Fleet monitoring activities are crucial to succeed in these kinds of operations where the level of interactivity between the operator and the platform is much higher with respect to the standard ones. Hence, appropriate tools and great expertise are needed. The main tools used by the European Argo community were developed by Euro-Argo, Ifremer and Ocean-OPS Argo Information Centre but they were never deeply tested in shallow/coastal operations. In the framework of the Euro-Argo RISE project, these monitoring tools are used together with other tools and home-made tools. Eventually, suggestions for improving the monitoring activity and for tailoring the existing tools were provided.

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Introduction

The Argo program

Argo is the most cost effective and lowest environmental impact in-situ network for the near real time observation of the subsurface ocean at global level. Argo platforms are designed to spend most of their lifetime below the sea surface at a predefined drifting depth. They can be equipped with sensors to measure a set of essential ocean variables (physical and biogeochemical parameters). Argo floats acquire profiles of the water column at selected temporal cycles from deep layers (2000 to 6000 meters) to the near surface and transmit data via telemetry systems (mainly Iridium and Argos) while they are at surface (figure 1). Originally designed as oceanographic instruments deployed in the open ocean, there is a need to investigate the possibility to use Argo floats into shallow coastal waters to provide observations for these under-sampled regions.

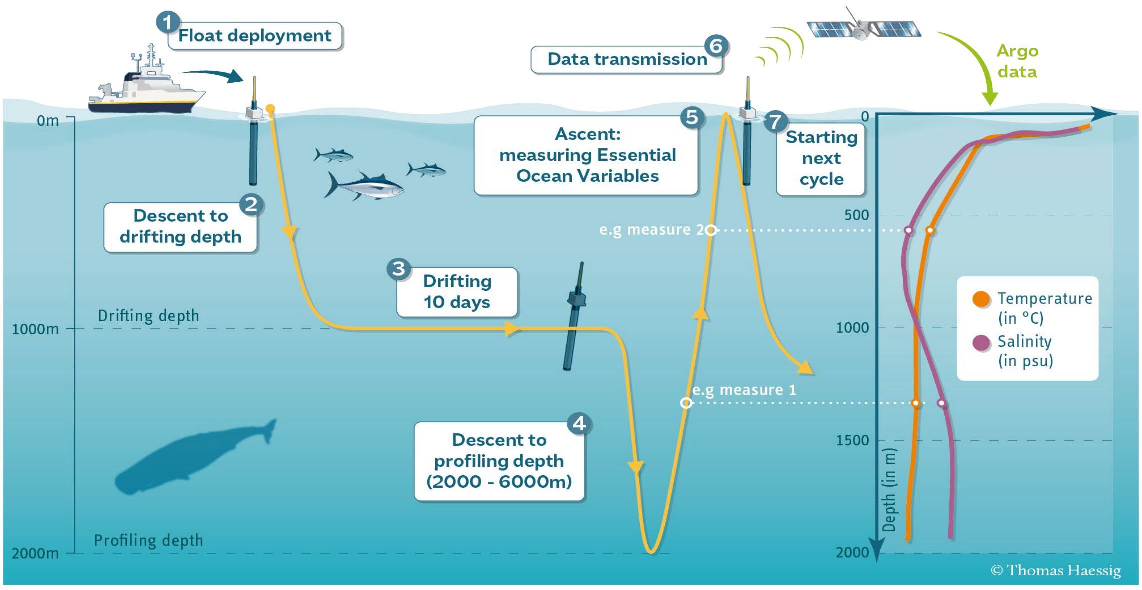

Figure 1: Scheme of a core Argo float typical deep ocean cycle.

The Euro-Argo European Research Infrastructure Consortium (ERIC) operates to sustain the Argo program at European level with a target of 25% in terms of contribution to the international network. In the framework of the European H2020 Euro-Argo Research Infrastructure Sustainability and Enhancement (Euro-Argo RISE) project there is a specific objective in Work Package (WP) 6: investigate the potential of Argo profiling floats in shelf areas to close the gap between open-ocean and shallow/coastal waters. With this work package, the ERIC aims to answer a European need and specificity: the Marginal Seas. This work is planned in specific areas of three European Marginal Seas (EMS) (Mediterranean, Black and Baltic Seas) with the target to test platforms, mission configurations, monitoring tools and required involvement of human resources. In particular, this deliverable describes the monitoring activities of Euro-Argo RISE Argo floats, considering experience of Europe for the Marginal Seas and providing suggestions to tailor the existing monitoring tools for operations in shallow/coastal waters of EMS.

Argo float monitoring activities in European Marginal Seas

Argo floats have been deployed in EMS since 2000, first in the Mediterranean Sea, then in the Black Sea (2002) and eventually in the Baltic Sea (2011). A summary of the EMS Argo activities is provided in the document *"Strategy for evolution of Argo in Europe"*, available at https://archimer.ifremer.fr/doc/00374/48526/51012.pdf. There has been a need to extend Argo in EMS since the European scientific community showed a strong interest in improving the climate change studies also at regional scales, in areas highly affected by anthropogenic activities. Years of experience were acquired in terms of sampling strategy, tailored platform configuration settings and design of monitoring tools. Each EMS is different and hence specific expertise was gained in the three regions.

At the beginning, EMS Argo operations were affected by telemetry types and inadequate monitoring tools. Indeed, the one-directional telemetry system like Argos did not allow any change of the float configuration parameters after the deployment and it needed the float to spend several hours at surface for transmitting data. Monitoring tools were mainly designed for operations in the open ocean and had a pre-defined set of maps, meta and technical information. These two elements limited the development of the Argo array in EMS. The arrival of the bi-directional telemetry system (Argos-3 and Iridium) was a big step forward because it reduced the surfacing time and allowed the change of the sampling characteristics (more details are provided in the dedicated reports and deliverables of the European E-AIMS project available at https://www.euro-argo.eu/EU-Projects/Completed-projects/E-AIMS-2013-2015). This consistently limited hazards of collisions, stranding events, theft by seafarers, etc.

Monitoring tools developed during the years as well. The main tools were originally developed by Euro-Argo, Ifremer and Ocean-OPS Argo Information Centre (AIC) and then they were strongly improved in the framework of Euro-Argo ERIC and dedicated EU project (MOCCA). More detailed maps, bathymetry, warning systems, meta and technical information, graphs were made available and allowed to better track the Argo fleet in EMS. In addition, home-made tools were developed (warning systems, visualization tools; more in section: "Monitoring activities in shallow coastal waters of European Marginal Seas") at national level and used as a complement of the Euro-Argo monitoring tool.

Regional expertise gained for operations in EMS, development of technology, improvement of monitoring systems significantly pushed the evolution of Argo in EMS where operating with freely drifting platforms is challenging due to high marine traffic, constrain areas, complex bathymetry and coastline. In the framework of the Euro-Argo RISE project, times were mature to go beyond and start exploring the remaining not sampled areas of EMS, characterized by higher levels of difficulties from the technical point of view. A combination of ad hoc mission configurations, advanced monitoring tools and warning systems will strongly help to achieve this new frontier of Argo in EMS.

Monitoring tools

A monitoring system is an essential tool to follow the Euro-Argo RISE fleet in EMS. It is useful to report about the status of the fleet, platform locations and trajectories, cases of early failures and the monitoring of critical technical parameters (i.e., battery voltage, last transmission date, grounding events, etc.) through a web interface with dashboards, status tables and graphs. The main tools used by the Argo community are presented hereafter.

The Euro-Argo and Ocean-OPS AIC monitoring tools

One way to control the Euro-Argo RISE float fleet is through the Euro-Argo monitoring tool that is available at https://fleetmonitoring.euro-argo.eu/dashboard. This tool has been developed in the framework of the EU Monitoring the Ocean Climate Change with Argo (MOCCA) project and a complete description is provided in two deliverables: *D3.3.1 Description of the at sea monitoring procedure* and *D3.3.2 Description of the at sea monitoring procedure (revised)*, available at https://www.euro-argo.eu/EU-Projects/MOCCA-2015-2020/Deliverables.

The Euro-Argo monitoring tool is an enhanced version of previous systems where the metadata, technical and functional monitoring of the floats has been significantly improved. Improvements were mainly done on the presentation of the float metadata and technical parameters together with a set of predefined alerts on the graphs. A notification system (alert system on a dashboard) for malfunction and detection of early failures was implemented. This is beneficial to report about the behaviour of the fleet.

The Euro-Argo tool consists of a dashboard that allows the monitoring of a group of floats (figure 2: the Euro-Argo RISE floats) and a platform webpage dedicated to single floats where metadata, data graphs, a map and plots of main technical parameters are shown (figure 3: main information for the Euro-Argo RISE float 6903783)

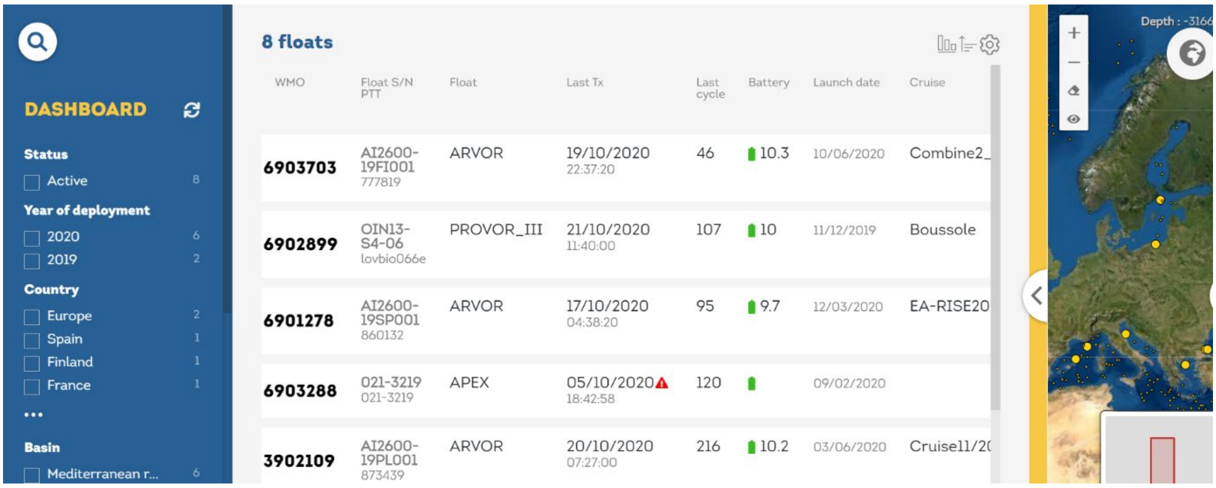

Figure 2: Dashboard of the Euro-Argo monitoring tool. The Euro-Argo RISE float group is shown.

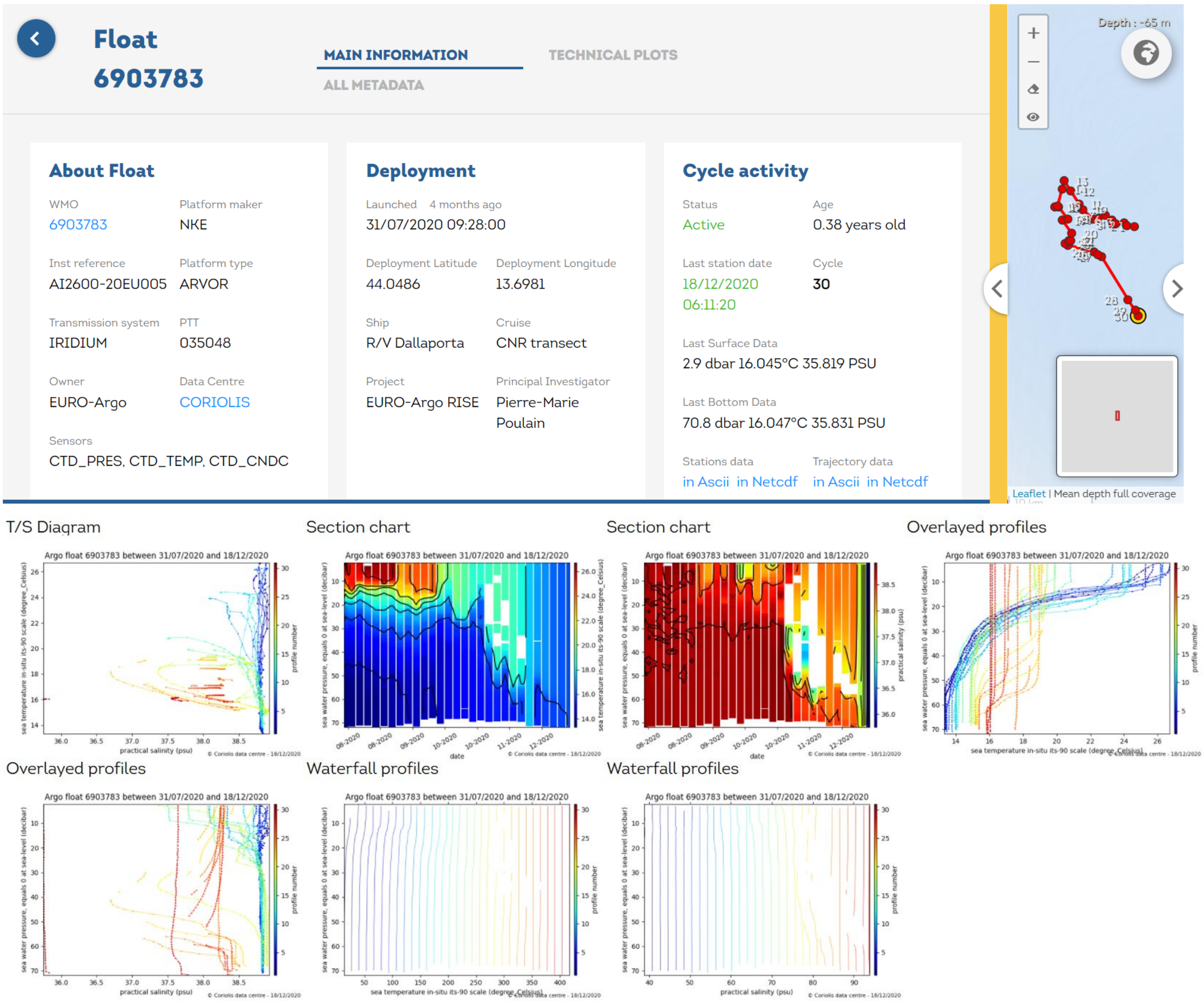

Figure 3: Platform webpage of the Euro-Argo monitoring tool. The Euro-Argo RISE float 6903783 is shown.

In the platform webpage, the user can visualize the metadata of the float. A useful information is the mission configuration used in the float lifetime (figure 4: mission configuration for the Euro-Argo RISE float 6903783), like the cycle length, the park pressure and the profile pressure. Nevertheless, many other information can be visualized such as the platform and deployment information, sensors on-board the float, the parameters acquired.

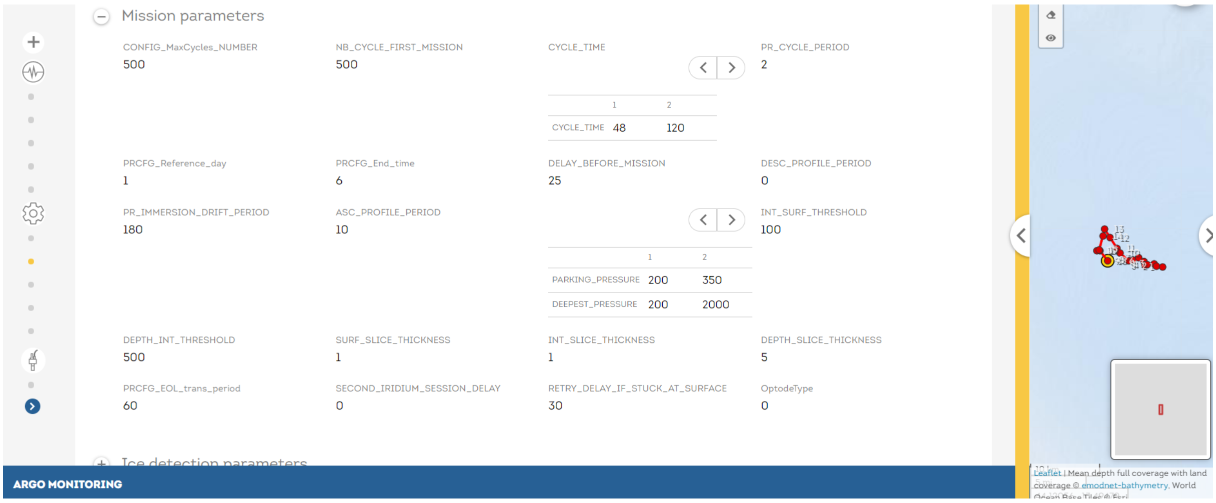

Figure 4: Metadata information in the platform webpage of the Euro-Argo monitoring tool (Euro-Argo RISE float 6903783).

The main technical parameters of a single float are available in the platform webpage and help the user to monitor the float behaviour through dedicated plots. Alternatively, all technical parameters can be plotted on the webpage. The maximum pressure values reached during the descent to the parking depth are plotted in figure 5 and the information on grounding events at each cycle is also reported. Other technical parameters available are related to data transmission, positioning, battery voltage.

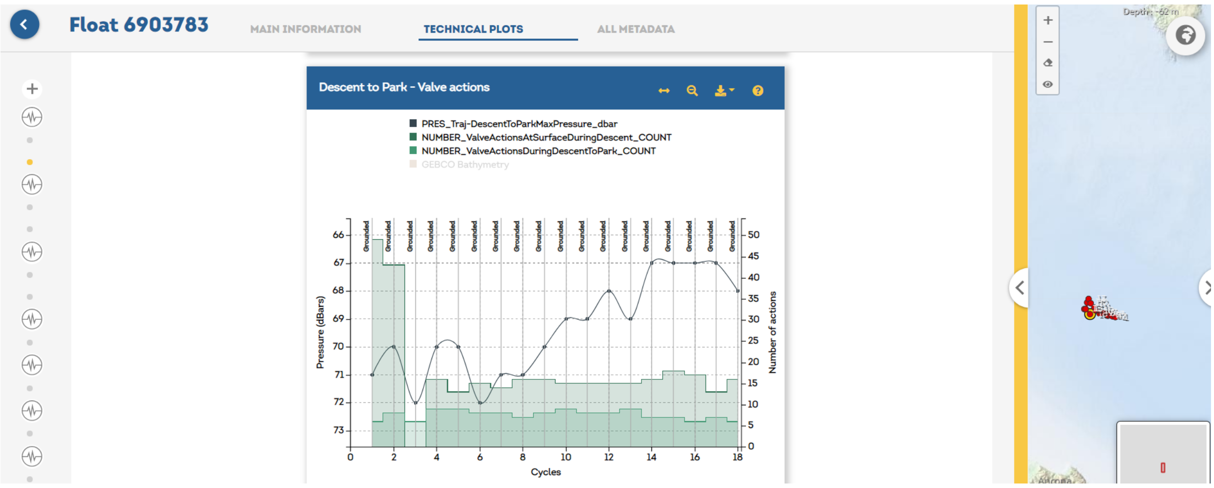

Figure 5: Technical parameter graphs (Descent to park – valve actions of the Euro-Argo RISE float 6903783) in the platform webpage of the E-A monitoring tool.

Alerts and warnings are set up and are based on thresholds and trends on one or combination of these technical parameters (example of an alert is shown in figure 6, where Euro-Argo RISE float 6903288 has an alert due to a delay in data transmission).

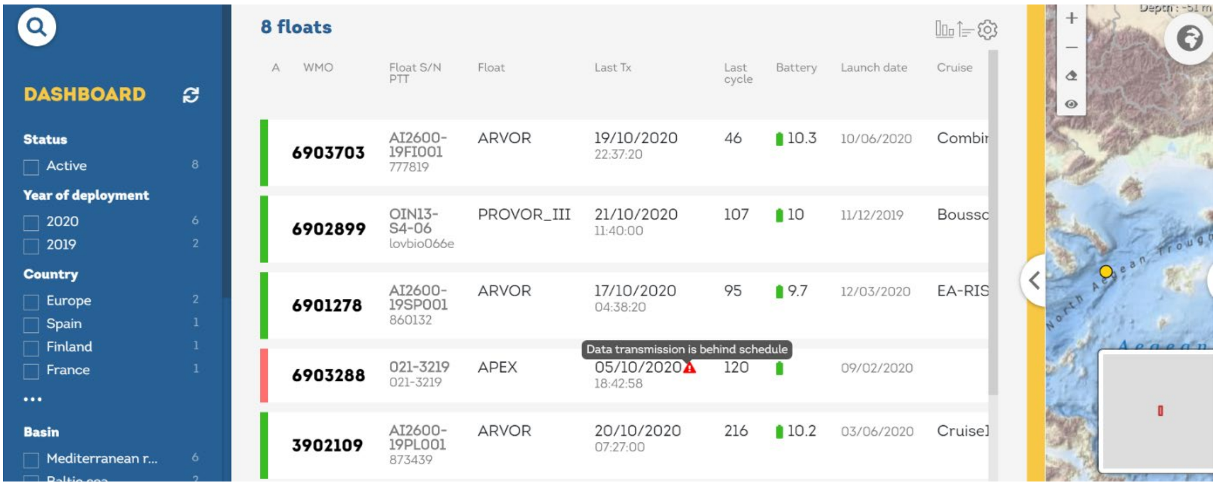

Figure 6: Example of an alert for float 6903288 in the dashboard of the Euro-Argo monitoring tool.

In addition to the Euro-Argo monitoring tool, the Ocean-OPS AIC https://www.ocean-ops.org/board?t=argo presents a large set of interesting tools increasing the possibility of float monitoring. Some statistics are presented in the Charts>Summary part permitting to have a better assessment of the fleet taken into account. It can be filtered by deployment network (Euro-Argo) or by deployment Sea Regions such as the Mediterranean region, the Black or Baltic Sea.

Other tools are in the window Charts>Instrumentation:

- **The age distribution** (figure 7) computes the lifetime of the floats and can be grouped either by floats model, telecommunication type, etc…

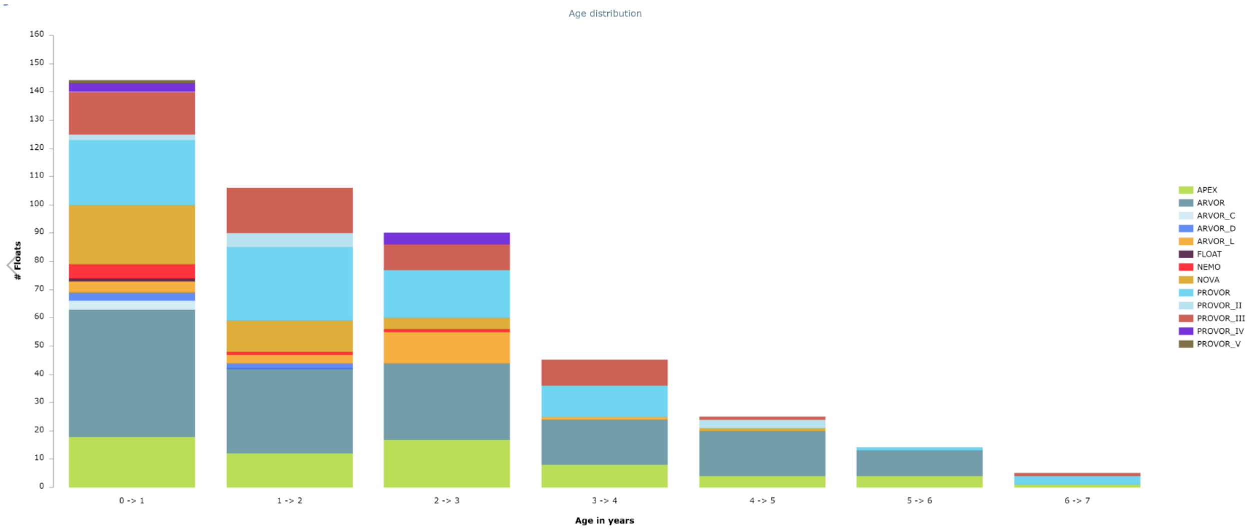

Figure 7: Age distribution per model type of the whole fleet in the Mediterranean region (active and inactive floats)

- **The Performance on target** (figure 8) calculates the percentage of floats grouped by generation, model type, telecommunication type, etc.) reaching a specific number of profiles.

Figure 8: Performance on target (100 profiles) per telecommunication type: blue=ARGOS, cyan= ARGOS3 and red=Iridium; in the Mediterranean region (inactive and active floats)

- **The survival rate** (figure 9) is computed in order to better assess the life expectancy of a certain population/generation of floats. It is calculated as such (in Ocean-OPS):

  Survival rate at age x = Survivors / (Survivors + Decreased); where **Survivors** = Platforms older than age x and **Decreased** = Platforms inactive or closed before age x. Different variables are available to permit a grouping of this computation.

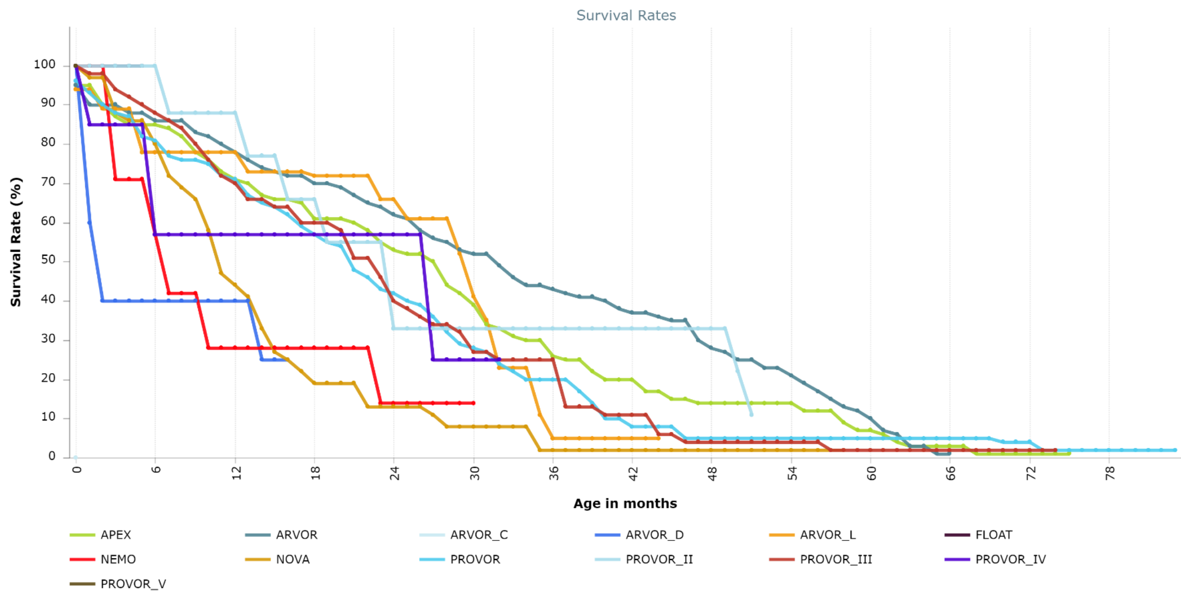

Figure 9: Survival rate calculations grouped by model type, in the Mediterranean region (inactive and active floats).

This tool is very powerful, however it comes with certain limitations. Some other time variables are investigated in the frame of the Task 2.1 (WP2), to be integrated in the OceanOps AIC, which is crucial when comparing life expectancy of floats. Some have a 10-day cycle period when others cycle every 2 days, it is obvious that they're going to last less time. In the frame of the Task 2.1 of the Euro-Argo RISE project, the Euro-Argo ERIC Office team is developing new tools in order to have a better assessment of the life expectancy of floats and possibly provide recommendations to improve lifetimes of floats in the future.

This work focuses on the impact of float sample selection in lifetime studies, in computing survival rates taking into account different units (age, number of cycles, vertical distance), and investigating the impact of some configuration parameters that most impact battery consumption. Additionally, the ERIC Office developed some tools permitting to geographically plot the configuration and technical parameters values of a fleet of floats, and how they changed over time. All these tools are completing the set of tools available for a better and more precise monitoring of the floats and their configurations.

Monitoring activities in shallow coastal waters of European Marginal Seas

Argo floats in the framework of the Euro-Argo RISE project are used as test cases for future Argo operations in shallow/coastal waters of EMS. Working in these areas is difficult and can be critical due to the proximity to the coastline, shallow and complex bathymetry, small archipelagos, and narrow basins. Also, the scientific needs and mission configurations of the floats are different from open ocean: quicker cycle time periods, shallower drift parking depths, will to keep the floats in a targeted area, etc. Float operators must rely on accurate and trustable monitoring systems to track their floats and quickly act to provide new mission configurations if needed. Indeed, the aim is to prevent floats from stranding events, getting stuck at the sea bottom, and collision with ice/shore in some areas. In this way, the best float settings can be achieved together with an improved life expectancy.

Operations in shallow/coastal water of EMS requires a higher level of interactivity with the Argo platforms with respect of operations in open ocean since the operator has to check the float behaviour, the float location, the sea and atmospheric conditions on a basis mainly linked to the cycle period of the float (about 1 to 5 days). Hence, multiple levels of information are needed. However, such information could be available from different sources while it would be desirable to be accessible on one system only to facilitate the work of the float operator.

In this section, the Euro-Argo RISE monitoring activities in different geographical areas are described. The Euro-Argo monitoring tool is used in conjunction with other tools and systems by the Euro-Argo RISE WP6 partners.

Eight Euro-Argo RISE floats have been deployed in shallow/coastal waters of EMS by seven WP6 partners (Euro-Argo RISE Argo floats locations as of 16th October 2020 are shown in figure 10). Four Argo platforms in the Mediterranean Sea (see deliverable D6.2 "Preliminary results of shallow coastal float operations in the Mediterranean Sea" for details), two in the Black Sea (see deliverable D6.3 "Preliminary results of shallow coastal float operations in the Black Sea" for details), and two in the Baltic Sea (see deliverable D6.4 "Preliminary results of shallow coastal float operations in the Baltic Sea" for details). In addition, some WP6 partners are testing one of their own national Argo floats as a complement of the Euro-Argo RISE operations.

Figure 10: Euro-Argo RISE Argo float locations (big yellow and grey dots for active and inactive floats, respectively) as of 21th December 2020.

Monitoring activities in the Mediterranean Sea

a. OGS monitoring activity

The National Institute of Oceanography and Applied Geophysics (OGS) deployed one Euro-Argo RISE Argo float (Arvor-I model manufactured by the French NKE, WMO number: 6903783) in the shallow area of the north Adriatic Sea the 31st July 2020. The aim of the mission is to keep the float on the shelf and to use it as a virtual mooring (figure 11).

Figure 11: Trajectory of the Euro-Argo RISE Argo float WMO 6903783 managed by OGS, as of 16th October 2020. Profiles (red dots) and last profile (yellow dot) locations are also shown.

The Euro-Argo tool (https://fleetmonitoring.euro-argo.eu/float/6903783) and the Ocean-OPS/AIC tool are systematically used to check the float behaviour and status.

Since a requirement of this Argo mission is to be ready to promptly act in changing the mission parameters, the last float information has to be available as soon as possible. Hence, float SBD messages are decoded at OGS in order to have information quicker than DAC (Data Assembly Center) can provide. A controlling system has been developed at OGS and it is currently valid only for standard Arvor-I floats. The tool works in this way: the last GPS position is decoded by searching for the corresponding iridium SBD message (technical message ID=0); the positioning data is also used to estimate the bathymetry (interpolating the ETOPO 1, one Arc-Minute Global Relief Model) and the distance from the deployment point. The controlling system sends an email with all the information and the trajectory in attachment as a kml file. The program is called within a cron job.

An important tool that has been used in complement of the other tools is the daily mean of the horizontal sea water velocity at selected depth (figure 12). This product is provided by the European Marine Copernicus Service (CMEMS - Copernicus Marine Environment Monitoring System) and it is available at the dedicated webpage. These maps are used to try to predict the float displacements at the parking depth and during the ascent/descent phases. This is an important indication that helps the operator in taking decisions when the float approaches the coast or areas that should be avoided.

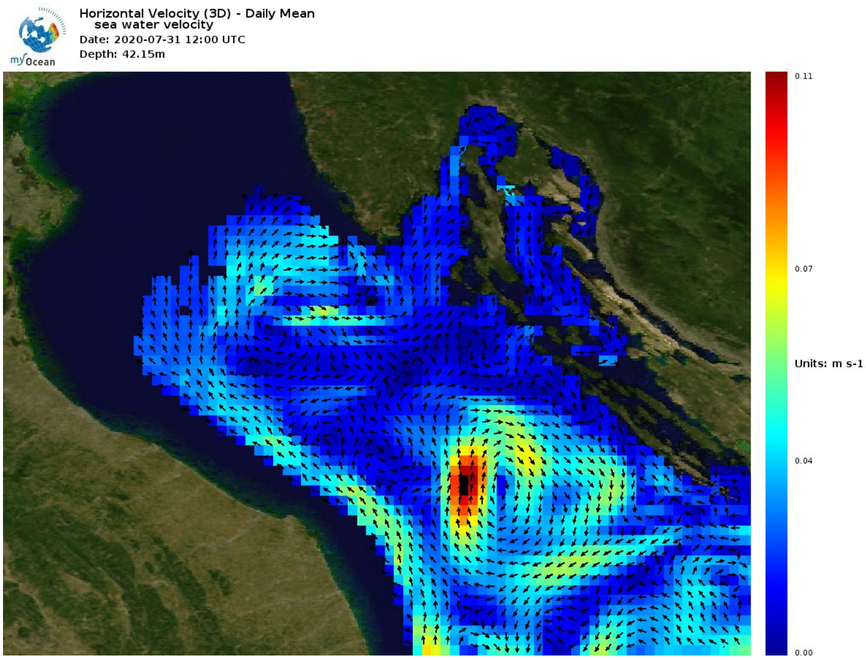

Figure 12: daily mean of the horizontal sea water velocity at 42.15 meters depth on 31st of July 2020. CMEMS product available at: https://view.marine.copernicus.eu/ViewService/?record_id=66fb61fa-c911-4f7e-aec1-959627bbf2b3

b. HCMR monitoring activity

The Hellenic Centre for Marine Research (HCMR) deployed one Argo float (Apex model manufactured by Teledyne Webb Research, USA, WMO number 6903288) the 9th February 2020 in the North Aegean at a relatively deep coastal plateau north of Limnos Island 6 nm off the coast (figure 13). The target of the mission is to keep the float after the shelf break in order to perform deep profiles close to the coast to monitor the intermediate layer circulation and the Black Sea water input.

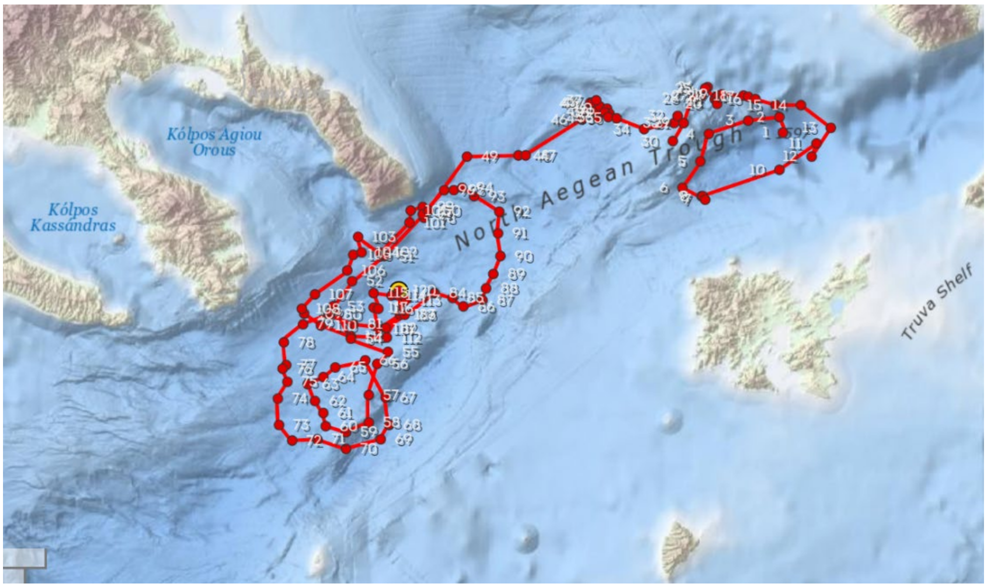

Figure 13: Trajectory of the Euro-Argo RISE Argo float WMO 6903288 managed by HCMR, as of 5th October 2020. Profiles (red dots) and last profile (yellow dot) locations are also shown.

Regarding 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. For the enhanced operational monitoring of the float deployed by HCMR (WMO number 6903288) this automatic alerting system has been updated and additional features were implemented in order to monitor in near-real time crucial parameters of the float's operation. Since the float was deployed at a relatively deep but near the coast plateau of the north Aegean, where the bathymetry and coastline are specifically complex, the maximal depth reached by the float, along with the distance from the coast were being monitored. These two parameters are essential for understanding whether the float is drifting away from the targeted plateau and near the coast. In cases when these two parameters overcome predefined thresholds (for depth this is set to less than 155.0 dbar pressure), alert messages are sent to the PI. Furthermore, the transmission time is monitored and an alert is transmitted in case there are delays or major differences in the transmission time. Finally, an Argo Delay Alert Message is set up for over 6 days delay. Additional parameters can be added on the alerting transmission messages. For example, in the following message several parameters are monitored:

|air_engine_task|Air engine destination reached: 12.06 >= 12.00

|sky_search|Found the sky

|SURFACE|Completing Mission No.: 14

|mission_state|cycle sleep count: 205, sleep time: 167922, awake time: 2848, elapsed time: 170770

|WatchDog|WatchDog Events: 0

|RMC|Set Clock: 03/06/2020 09:08:54

|GPS|GPS TimeToFix: 53 secs

|GPS|GPS Skew: 0 secs

|GPS|GPS Fix: 03/06/2020 09:08:01,40.24841,25.24945,7

|GPS|Time and location set

|Approximate depth (m)|: 830

|Approximate distance from shore (m)|: 13239

|Float 69032881 last position|: 39.7871 24.3070

On date (UTC) 01-06-2020 11:15:32 the float transmitted its location with estimated bathymetry 795 m as recorded by the automatic alerting system shown in the example below (table 1). In this example it is also possible to point to Google map and visualize the last position. Other control criteria will be added, such as the distance from the deployment point.

table 1: automatic alerting system developed at HCMR

Platform	**Last date received**	**Latitude**	**Longitude**	**Depth**
PR_PF_6903288	2020-06-01 11:15:32	39.7882	24.2986	795.19

c. SOCIB monitoring activity

The Balearic Islands Coastal Observing and forecasting System (SOCIB) deployed one Euro-Argo RISE Argo float (Arvor-I model manufactured by the French NKE, WMO number: 6901278) the 12th March 2020 off the Palma Bay (figure 14), to investigate the opportunities to keep the platform in shallow water and to try to use it as a virtual mooring.

Figure 14: Trajectory of the Euro-Argo RISE Argo float WMO 6901278 managed by SOCIB, as of 17th October 2020. Profiles (red dots) and last profile (yellow dot) locations are also shown.

To monitor the SOCIB float, the following activities were done periodically:

- Decode the float raw data: parsing sbd files while the Coriolis decoding chain is not yet initiated.
- Check the Western Mediterranean OPerational forecasting system (WMOP), that outputs forecasts operationally on a daily basis, producing forecasts of currents at different depths. This is useful for predicting if the profiler is going to move away from coastal water and allowing a change in mission configuration parameters in advance.
- Check the last GPS position delivered by the profiler using the SOCIB Deployments web client application. Also, the Argo fleet monitoring tool was used, superimposing the ocean surface 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 plotted and interpreted continuously.

d. SU monitoring activity

The Sorbonne University (SU) deployed one Euro-Argo RISE Argo float (Provor model manufactured by the French NKE, WMO number: 6902899) the 11th of December 2019 in the Ligurian Sea (figure 15). The target of the mission is to sample the Ligurian Current and participate in the sampling effort of the MOOSE network.

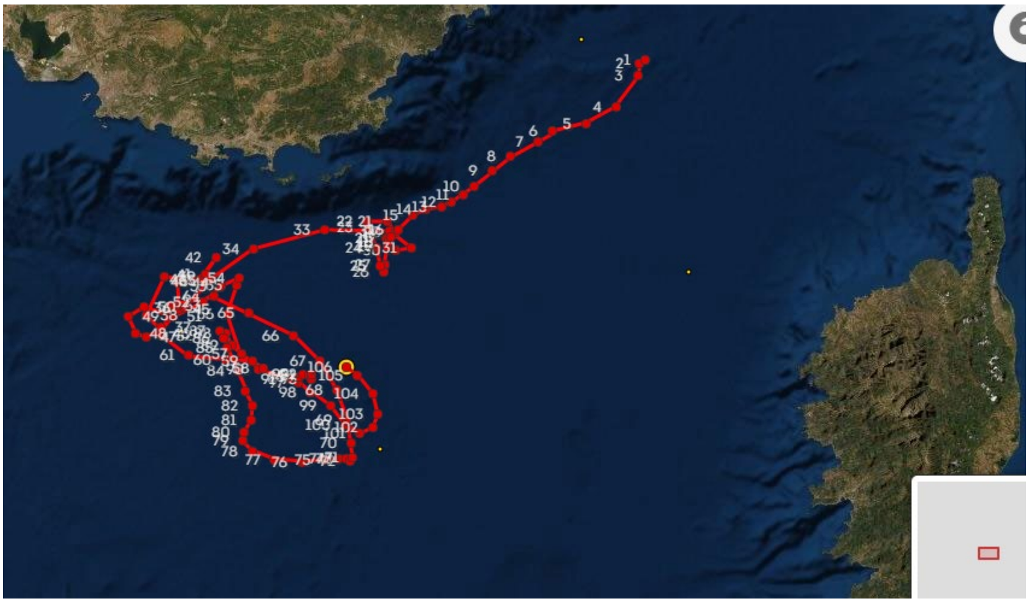

Figure 15: Trajectory of the Euro-Argo RISE Argo float WMO 6902899 managed by SU, as of 18th October 2020. Profiles (red dots) and last profile (yellow dot) locations are also shown.

The SU float has been programmed in the view of previous deployments from the Dyfamed observation site. The assessment of the historical dataset has been conducted over a set of 20 trajectories. The parking depth and the cycling frequency were the two relevant parameters that control the residence time of the float inside the Ligurian Sea. The choice of a drifting depth of 1000m and cycling frequency of 3 days was confirmed to be a fair compromise to enhance the observation window of the geostrophic jet (that reached one season) with a mesoscale resolution. The fleet monitoring tool could help to refine the choice of the two parameterisations given seasonal variations or even real time situation by regional simulation forecasts.

The float has been monitored periodically using the online tool "Argo fleet monitoring" to visualize the functioning of the platform and the evolution of the trajectory, however the initial programming was not modified in order to be comparable with a future redeployment. The RTQC profile data were downloaded from the Coriolis GDAC in order to assess the possible sensor drifts. In a first guessed analysis, water properties were singled out using temperature-salinity diagrams. The periodicity of this monitoring activity was daily during the first week of deployment, weekly during the phase of sampling inside the current, monthly since the float left the current.

Monitoring activities in the Black Sea

a. OGS monitoring activity

OGS deployed one Euro-Argo RISE Argo float (Arvor-I model manufactured by the French NKE, WMO number: 6903271) the 1st of October 2019 off the Danube River delta (figure 16), just before the shelf break in order to avoid the intense maritime traffic closer to the coast. The target of the mission is to keep the float on the shelf and use it as a virtual mooring.

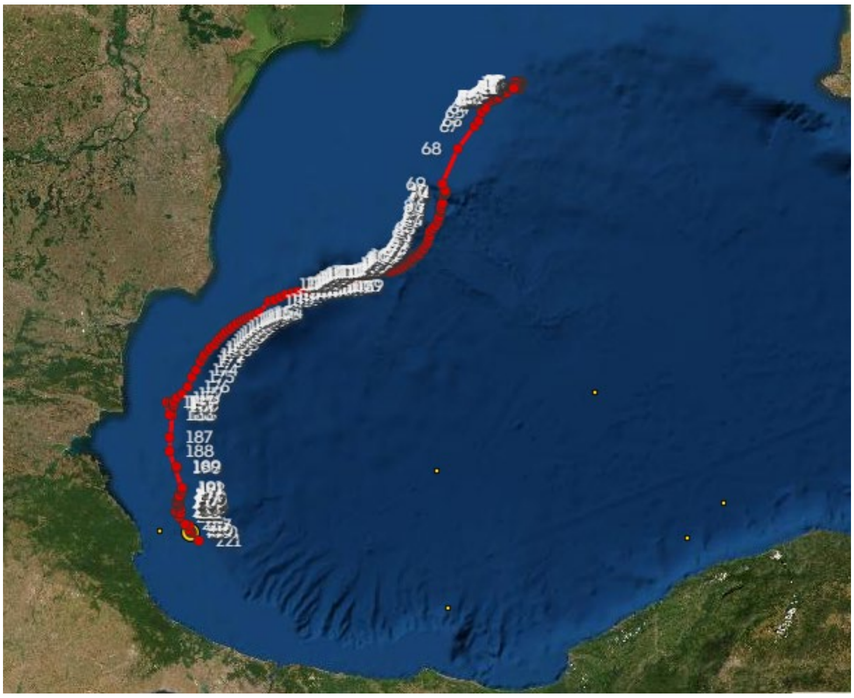

Figure 16: Trajectory of the Euro-Argo RISE Argo float WMO 6903271 managed by OGS, as of 18th October 2020. Profiles (red dots) and last profile (yellow dot) locations are also shown.

The Euro-Argo fleet monitoring tool (https://fleetmonitoring.euro-argo.eu/float/6903271) is used to check the float status. In addition, an automatic alerting system (described in the section dedicated to the OGS float in the Adriatic Sea) was implemented in order to quickly monitor the maximal depth reached by the float and its location, useful for understanding if it is moving away from the targeted area. The following type of message is sent by the system to the operator by email:

> Float 6903271 last position
>
> On date (UTC) 13-10-2020 06:41:28 http://maps.google.com/maps?q=loc:41.954+28.4963
>
> Estimated bathymetry -80.5 m

and a kml trajectory file is available. In this example it is also possible to point to Google map and visualize the last position. Other control criteria will be added, such as the distance from the deployment point.

We use, as we did for the float in the Adriatic Sea, the daily mean of the horizontal sea water velocity at selected depth, available at the Marine Copernicus website.

Another tool used is the Ventusky web application focused on weather prediction and meteorological data visualisation (https://www.ventusky.com/) that provided a fundamental support during the monitoring activity of this float. At some point the float was intentionally left in the near surface water to try to approach the shelf again; this was done taking into account the wind field in the area at 10 meters above ground (see figure 17) and the daily mean of the horizontal sea water velocity near the sea surface (figure 18).

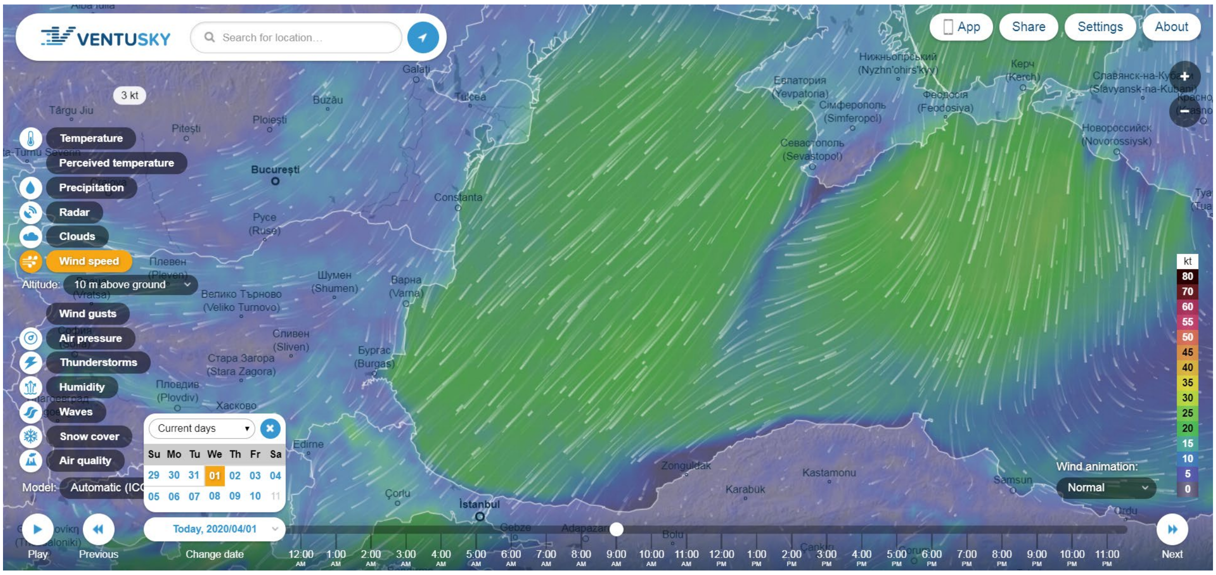

Figure 17: Wind field forecast at 10 meters above ground on 1st of April at 9:00 available at ventusky.com. Wind was about 20 kt SW in the Argo float operational area.

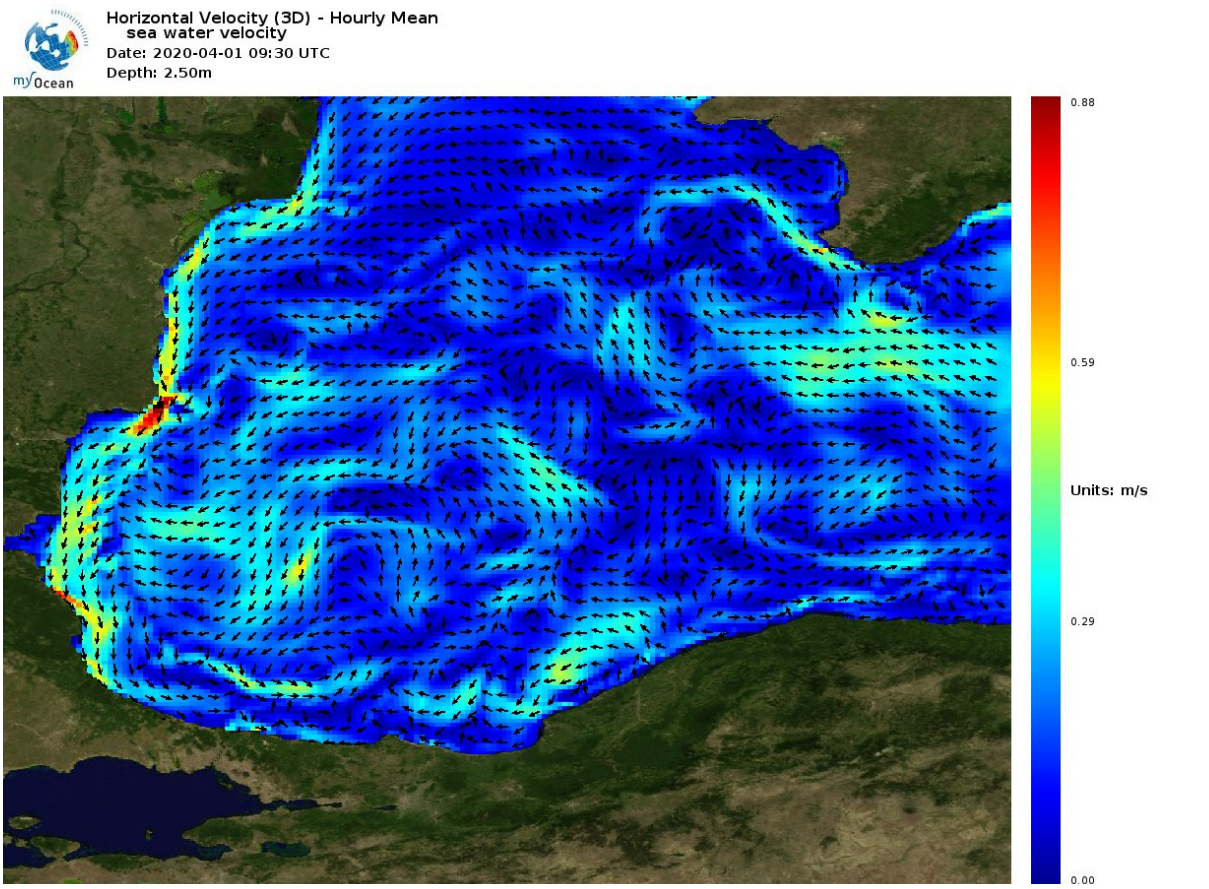

Figure 18: daily mean of the horizontal sea water velocity at 2.50 meters depth on 1st of April 2020. CMEMS product available at: https://resources.marine.copernicus.eu/?option=com_csw&task=viewer&record_id=b09312b0-1b4d-4cac-b585-eeb4089ba8a1

The float drifted as expected; it moved south-westward at a few degrees clockwise from wind direction (see figure 19) and it eventually reached the shelf at cycle 152 (5 April 2020).

Figure 19: South-westward drift of float 6903271 as a consequence of a modification of the configuration setting, to try to shift the float again on the Black Sea shelf.

We can also have an estimate of the displacement of the float from the area of deployment (or the targeted area) by plotting such distance against time. Another parameter that is important to monitor is the cycle period of the platform, since it significantly impacts on its lifetime (see figure20). These other two tools have been developed at OGS and used to have a more complete view of the monitoring analysis.

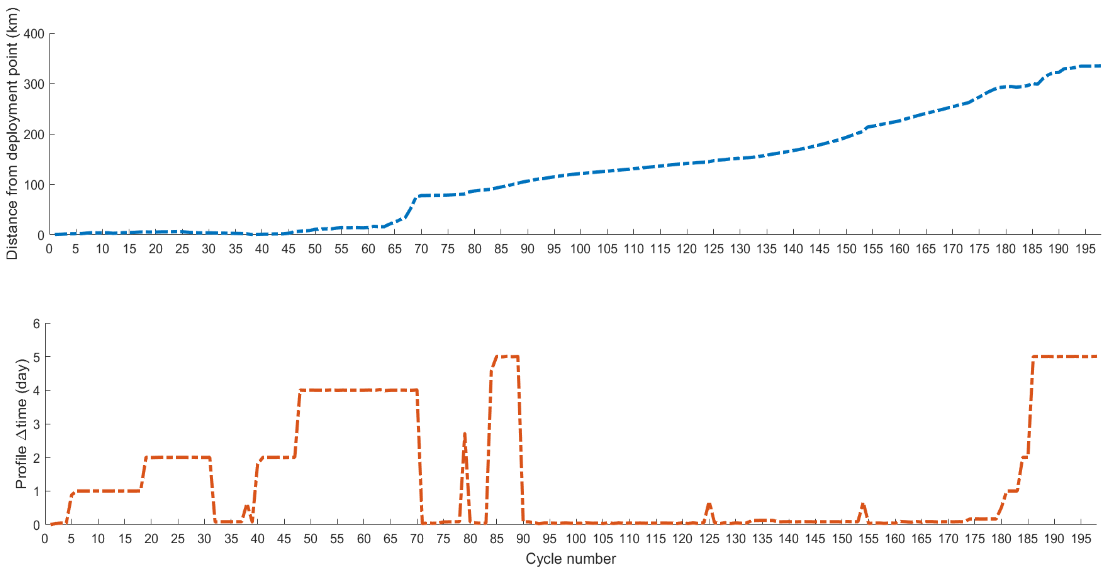

Figure 20: displacement (km) of the float from the area of deployment (top) and cycle period of the platform (bottom).

We were able to operate quickly, as needed, and to monitor almost in real-time the float thanks to the availability of several tools that provide us useful and critical information about the float status and the meteorological and sea conditions.

b. IO-BAS monitoring activity

IO-BAS deployed one Euro-Argo RISE Argo float (Arvor-I model manufactured by the French NKE, WMO number: 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 neutral buoyancy (figure 21).

Figure 21: Trajectory of the Euro-Argo RISE Argo float WMO 6903865 managed by IO-BAS, as of 25th September 2020. Profiles (red dots) and last profile (yellow dot) locations are also shown.

To monitor the IO-BAS float, the following activities were done:

- Visual check of the last GPS position delivered by the profiler using Google Earth API;
- Check the float status using Euro-Argo fleet monitoring tool (https://fleetmonitoring.euro-argo.eu/float/6903865) and JCOMMOPS/AIC tool;
- Check the weather forecast (https://www.windy.com/, https://www.passageweather.com/) to support monitoring activity of this float.

According to the decoded data at Coriolis data centre only 3 out of 94 GPS positions were valid (figure 22).

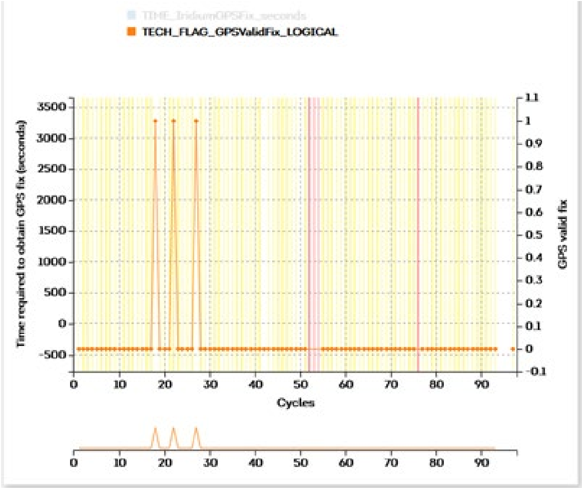

Figure 22. Valid GPS positions of Euro-Argo RISE Argo float WMO 6903865 (source https://fleetmonitoring.euro-argo.eu/float/6903865).

According to the Euro-Argo fleet monitoring tool and Ocean-OPS/AIC tool the updated trajectory of the float is a straight line in southeast direction (figure 23).

Figure 23. Trajectory of the Euro-Argo RISE Argo float WMO 6903865 managed by IO-BAS, as of 16th November 2020. Profiles (red dots) and profile on 25th September 2020 (yellow dot) locations are also shown.

Monitoring activities in the Baltic Sea

a. FMI monitoring activity

The Finnish Meteorological Institute (FMI) deployed one Euro-Argo RISE Argo float (Arvor-I model manufactured by the French NKE, WMO number: 6903703) on June 10th 2020 to the Northern Baltic Proper (NBP) close to the HELCOM monitoring site LL19 (figure 24). The target of the mission is to keep the floats in the Northern Baltic Proper, which is a very dynamic area.

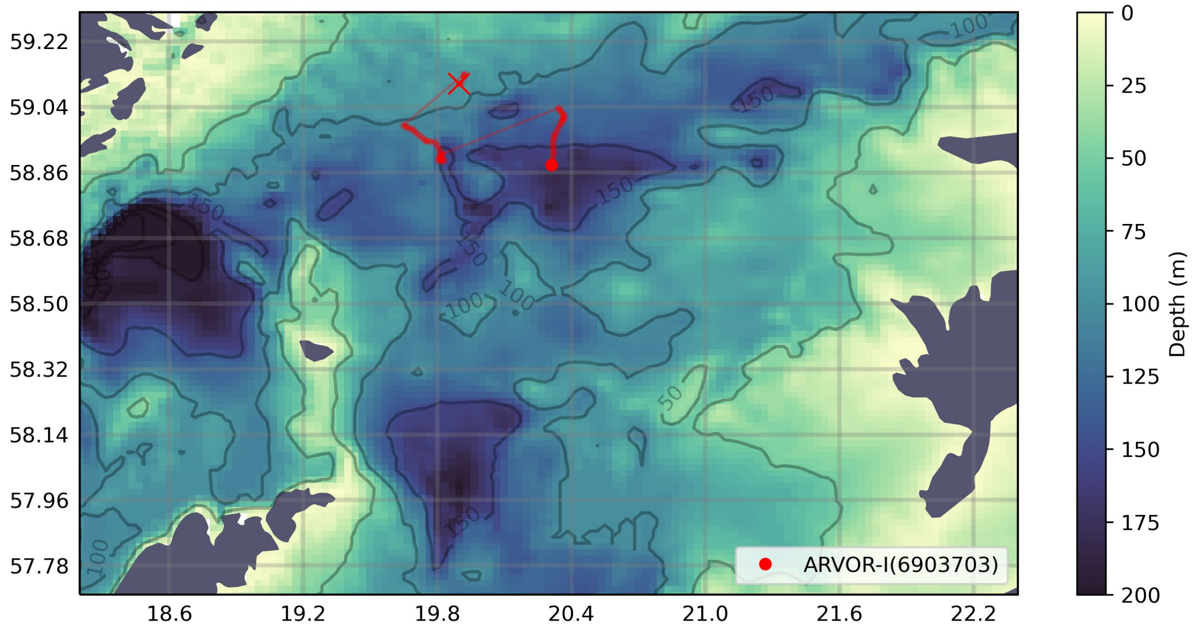

Figure 24: Trajectory of the Euro-Argo RISE Argo float WMO 6903703 managed by FMI, as of 16th November 2020. Red lines with small dots indicate the trajectory, large red dot the deployment location, and the red cross the latest profile.

Mission was started with a high profiling frequency of roughly six hours, then gradually lowered to once a week. This was done in order to quickly observe the float operation at start and adapt the parameters to required diving depths.

Baltic Sea floats have the risk of either getting stranded on shore, stuck on bottom or hit on ice, depending on the area of deployment. To avoid these occurrences FMI monitors the floats and tries to steer them away from such hazards. This is done by monitoring the locations of each float, and changing the profiling frequency and depth based on the situation. Diving depth is updated based on the location, so that it could measure as complete profiles as possible, while avoiding the collisions to the bottom.

For the constant risk of bottom contacts it is needed to know the locations, and location depths of the floats. Monitoring is required to detect the situations where mission parameter changes are needed. These include situations where the float ends up in much deeper or shallower areas than earlier, risk of ending up on shore, and generally make sure that the float is performing well with the parameters currently given. The weather conditions are monitored on the operating area so that if some scientifically interesting situation presents itself, the cycle frequency can be increased for added data, and occasionally suitable weather has been attempted to be used to prevent/reverse drifting to undesired areas. FMI recovers most of the floats at the end of their mission. This requires extra effort for monitoring, as we need to have a good estimate where to find the float before the cruise, and inform the ship of its exact location as well as possible at the time of the recovery.

In the northern parts of Baltic Sea, the collision with ice needs monitoring and controlling. Floats on such areas do apply ice avoiding algorithms. These can occasionally trigger too early, for this reason the algorithm is often turned on only after it starts to seem probable that the float may encounter ice. A separate report on ice avoiding practices as deliverable 5.1 in WP5 is under preparation.

The monitoring tools applied range from the Euro-Argo and Ocean-OPS AIC tools to local weather forecast to reviewing the direct measuring data files as they arrive to the servers. A quick list of the tools is presented in table 2.

Table 2: List of monitoring tools used and short explanation of the purposes

Monitoring tool/method	**General purpose**
Euro-Argo and Ocean-OPS AIC tools	Quick overview of fleet status, browsing float trajectories and data. Quick plots of status.
direct review of mission files from server/e-mail	real time monitoring of float location, battery status and operations when deciding changes for mission or during recovery.
robust analysis scripts made per-purpose	Throughout analysis of float operations, polished plots, bridge between monitoring and research/data analysis
Weather info, sea charts, ice charts, other bathymetry data	Together with above methods, used to decide diving depths, cycle periods, and the need for ISA activation.
(Experimental/further development) Review of model current data to estimate float trajectories	Exploring the options to use these for mission planning and faster reaction for potential complications, e.g. drifting to shores.

For reviewing the general situation of the fleet, and quick check-up for the trajectories the Euro-Argo and Ocean-OPS are usually the most straightforward procedure.

More detailed monitoring and analysis and reviewing of the floats missions is done offline by extracting mission data, and processing it with typically python scripts designated or built specifically for each task. An example of such a task is to review how deep areas the float has stayed during the mission (figure 24). The advantage here is having the plotting and data analysis tools on the same workflow.

When a float mission is in the state that constant decisions on floating depth or cycle frequency are made, the float status is often checked directly from the raw data files arriving to the server (Apex type), or e-mail (Arvor type). These are translated to readable ascii format. From these it is quick to see the floats last location, state of battery, whether the logs indicate problems with bottom contacts and whether the float has had any other problems receiving/completing its instructions. Transmitted files are also used during recovery, as they provide the latest known location in almost real time.

Decision making on the mission parameters requires knowledge of aspects such as local bathymetry and weather. For bathymetry the national marine charts are consulted where available, as well as IOW's bathymetry data for other areas. Weather information most often is reviewed from FMI's forecasts and ice conditions from the FMIs ice charts. When applying model data for estimating probable areas the floats are going is also in consideration, but so far mostly experimental.

Figure 24 shows the movement of the float until 2020-11-16. Considering the high dynamic of the area, in general it can be said that the float has managed to stay relatively well in the designated area.

b. IO PAN monitoring activity

The Institute of Oceanology of the Polish Academy of Sciences (IO PAN) deployed one Euro-Argo RISE Argo float (Arvor-I model manufactured by the French NKE, WMO number: 3902109) the 3rd June 2020 in Gdansk Bay (figure 25). The target of the mission is to keep the float on the shelf and use it as a virtual mooring.

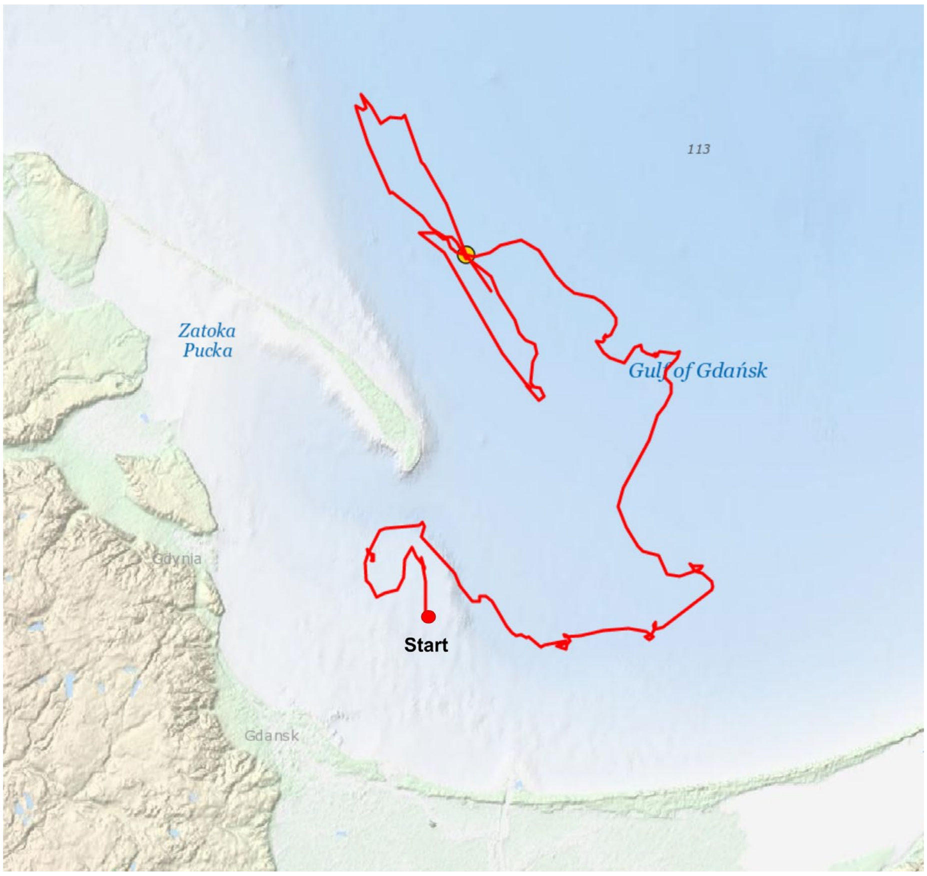

Figure 25: Trajectory of the Euro-Argo RISE Argo float WMO 3902109 managed by IO PAN, as of 10th December 2020. Start (red dot) and last profile (yellow dot) locations are also shown.

For the Baltic Sea monitoring, IOPAN utilise standard tools provided by Euro-Argo: https://fleetmonitoring.euro-argo.eu/dashboard

All our floats are visible at IOPAN webpage: https://www.iopan.pl/hydrodynamics/po/Argo/argo_balticfloats.html

In specific operations, like float recovery, special procedures are applied. One of them consists of reading SBD files, decoding the data and sending exact positions to the vessel. This greatly improves the ability to find the float, especially during the rough sea conditions. Meteorological conditions are usually checked in the marine zyGrib service: https://zygrib.org/. Good weather forecast helps in choosing the right time for recovery.

IO PAN also uses sea currents to predict the displacement of the float. During expected surface current from the shore (upwelling case) the float is forced to stay on the surface in order it drifts offshore. When wind induces downwelling events, the parking depth is set deeper, so that the float moves away from the shore. To proper select the float depth, the Polish Argo team collaborates with modellers and use a high-resolution model of the Baltic Sea (http://ebaltic.plgrid.pl/#). This method will be further developed and the virtual floats tracking in specific model layers will be introduced.

IO PAN also collaborates with the SatBaltic system (http://www.satbaltyk.pl/en/). Data from Argo floats are provided and assimilated in model. Model results are used for checking the Argo data and predicting the drift.

Suggestions for tailoring the monitoring tools for float operations in shallow coastal waters of European Marginal Seas

The Euro-Argo RISE Argo operations in shallow coastal waters of EMS started recently (end of 2019) and operators started to monitor their floats on the basis of the expertise gained in EMS activities in the previous years. It's been soon evident that a more careful monitoring of the fleet and more human-platform interactivity were needed. Hence, the WP6 partners developed some home-made monitoring tools, alert and warning systems. They also used other kinds of tools that provide additional and useful information for the monitoring of the fleet. After this first year of Argo operations in shallow coastal waters of EMS, the WP6 partners proposed a set of suggestions to try to improve the Euro-Argo and the Ocean-OPS monitoring systems and indications on other tools and systems that they believe useful to use as a complement of the monitoring activity. The description is provided hereafter:

1. anticipate (prepare float metadata, warn the DACs ahead of deployments, etc.) float decoding at the DAC if needed to access to float data quickly after deployment. The speed up of the decoding could be crucial in critical times of Argo operations in shallow/coastal areas of EMS.
2. implementation of notification/warning/alert systems to take into consideration the distance from the shore, critical bathymetry, distance from targeted areas and/or deployment location, malfunctioning sensors. This could be an email notification system with a link to the monitoring tool or attachments to visualize the float status.
3. tools for assessing the battery health in order to improve the estimate of the float life expectancy (counting the total length of the performed profiles and the pump actions)
4. add links to the Euro-Argo fleet monitoring tool to other existing tools to be used as a complement of the monitoring activities, like:
    a. sea water velocity, sea currents from the CMEMS 3D models, to check how the float could drift at various depths (https://resources.marine.copernicus.eu/)
    b. wind at surface (https://www.ventusky.com)
    c. marine traffic to obtain the shipping density that helps in avoiding collisions with vessels (https://www.emodnet-humanactivities.eu/view-data.php)
5. add layers to the Euro-Argo fleet monitoring tool, like:
    a. more options for bathymetry since it is a bit coarse in some regions.
6. suggestions to improve the Euro-Argo fleet monitoring tool:

a. high density messages of the float's location in cases it is drifting on surface and there is an ongoing operation for its recovery
b. In some cases, users want to quickly check through data from several floats with minimal clicks. When the floats WMO's were consequent this is convenient in the http://www.argodatamgt.org/Access-to-data/Argo-data-selection as you have buttons "Next" and "Previous", which takes you to WMO +1 or WMO -1 float with one click and directly shows it's data. Similar simple system to quickly browse the data of several floats would be useful.
c. As often the user wants to look at the same or similar set of floats with similar graph setups, a possibility to save these settings so that you would have instantly right float-filters and plotting types ready, when coming to the page would speed up the float check-up process.
d. include historical Argo trajectories with possibly parking depth/Lagrangian velocity, as a background information to help decision in changing float programming. The Lagrangian timescales are lower than Eulerian ones (@Argo profiling depths: some days for Lagrangian and few weeks of Eulerian). In consequence, predictability would be better assessed from trajectories than from sea currents (that are already available from ANDRO dataset). To do so, historical trajectories (over one 1 month) in a neighbourhood of the active float's location, including the parking depth in colour-scale, could be a precious decision tool.