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Report on the Italian Argo Program for 2023

1. The status of implementation of the new global, full-depth, multidisciplinary Argo array (major achievements and problems in 2023)

a. Floats deployed and their performance

A total of 18 Italian floats were deployed in 2023 (see Tables 1 and 2 for details). These floats were Arvor-I, Arvor-Ice, Provor CTS4, Provor CTS5, and Deep-Arvor designs manufactured by NKE (France). All floats transmit data via Iridium telemetry.

Mediterranean and Black Sea deployments

Ten units were released in the Mediterranean (Table 1). The Core-Argo floats have a park pressure at 350 dbar and maximal profiling depth at 2000 dbar. Bio-Argo floats have a park pressure at 1000 dbar and the maximal profiling pressure was set to 2000 dbar. One Arvor-I float (WMO 4903680) was deployed in the Sicily Channel and parked on the sea bottom to limit horizontal displacement and to sample that shallow area: the cycle time was set to 5 days and the parking depth was adjusted in order to be always greater than the maximum bathymetry. The Provor V Jumbo float was deployed in the Ionian Sea in November hosting 4 key BGC variables plus the UVP6 - underwater vision profiler to acquire particle size distribution and zooplankton taxonomy.

Most floats were deployed from research vessels of opportunity (i.e., R/V Atalante, R/V Aegaeo, R/V Gaia Blu, Speedboat (Malta), fishing vessel (Cyprus) and R/V Laura Bassi for the Mediterranean and R/V Agulhas II and Laura Bassi for the South Atlantic and Southern Ocean with the help of colleagues from France, Greece, Malta, Italy and Cyprus.

Model	WMO	Depl. Date	Lat	Lon	Cycles	Last Date	Lat	Lon	Status*	Cyc.**
Arvor- T/S Diss. Oxy	7901019	02-Mar-2023 10:07	33.90	33.00	2	08-Mar-2023 07:44	33.84	33.29	D	5
Arvor - T/S Diss. Oxy	2903795	24-Apr-2023 17:08	40.94	4.26	195	04-Feb-2024 22:09	41.31	03.61	A	5
PROVOR CTS4	1902605	28-Apr-2023 22:04	42.14	07.48	152	05-Feb-2024 12:05	42.17	07.27	A	5
Arvor - T/S Diss. Oxy	3902500	05-May-2023 04:08	40.84	04.95	152	04-Feb-2024 07:44	41.58	08.23	A	5
Arvor - T/S Core	4903680	08-Jul-2023 08:50	35.70	14.41	33	18-Dec-2023 22:09	36.34	14.04	D	5
Arvor – I DEEP	3902483	25-Oct-2023 14:46	36.50	21.58	16	02-Feb-2024 06:11	36.53	21.48	A	5
PROVOR V Jumbo	2903797	20-Nov-2023 14:40	35.86	17.80	33	03-Feb-2024 10:00	36.26	17.46	A	5
Arvor - T/S Diss. Oxy	4903679	25-Nov-2023 22:47	38.99	15.20	15	05-Feb-2024 09:49	39.19	14.54	A	5
Arvor – I DEEP	5906993	26-Nov-2023 12:56	37.06	17.88	8	30-Jan-2024 23:04	37.03	17.44	A	10
PROVOR CTS4	5907088	26-Nov-2023 13:16	37.06	17.89	16	02-Feb-2024 11:26	36.11	17.15	A	5

**Status in early February 2024: A = active, D = dead*

***Cycle: Length of cycle in days*

Table 1. Status information for the 10 Italian floats deployed in the Mediterranean Sea during 2023.

South Atlantic, South Pacific and Southern Ocean

With the help of Italian colleagues onboard the R/V Laura Bassi: a total of 5 Arvor-I equipped with ice-detection software were deployed, three along the Ross Ice Shelf (6903831, failed due to the lack of communication with the SBE41 probe, 6903832, and 6903833 re-deployed as WMO 6903810), two during the crossing the Circumpolar Current (6903829, 6903830). The adopted configuration in the Ross Ice Shelf Polynya consisted of a cycle time of 7 days and a park and maximum profile pressure of 1000 dbar (i.e. a park pressure at the seafloor). One float (6903794) was recovered for maintenance purposes.

In collaboration with the *Parthenope* University, three Arvor-I with ice detection were deployed in the southern Atlantic sector (5906980, 5906979, 4903650).

Model	WMO	Depl. Date	Lat	Lon	Cycles	Last Date	Lat	Lon	Status*	Cyc.**
Arvor-T/S ICE	6903829	09-Jan-2023 20:00	-63.02	172.73	40	05-Feb-2024 01:44	-63.98	-169.51	A	10
Arvor-T/S ICE	6903830	10-Jan-2023 13:02	-65.03	176.15	39	29-Jan-2024 03:22	-64.83	164.59	A	10
Arvor-T/S ICE	**6903831**	**26-Jan-2023 15:05**	**-77.16**	**168.90**	**2**	**03-Feb-2023 05:45**	**-77.04**	**168.93**	**D**	**7**
Arvor-T/S ICE	**6903832**	**27-Jan-2023 08:16**	**-77.41**	**174.38**	**56**	**04-Feb-2024 05:46**	**-76.67**	**173.84**	**A**	**7**
Arvor-T/S ICE	**6903833**	**29-Jan-2023 17:15**	**-77.96**	**-160.23**	**60**	**31-Jan-2024 16:42**	**-77.47**	**-163.21**	**recovered**	**7**
Arvor-T/S ICE	5906980	08-Feb-2023 03:07	-50.37	-0.29	-	08-Feb-2023 03:07	-50.37	-0.29	D	10
Arvor-T/S ICE	5906979	08-Feb-2023 16:52	-48.04	-0.98	37	05-Feb-2024 23:35	-53.93	36.39	A	10
Arvor-T/S ICE	4903650	08-Feb-2023 16:52	-48.05	-0.98	37	05-Feb-2024 23:51	-53.16	38.00	A	10

**Status in early February 2024: A = active, D = dead*

***Cycle: Length of cycle in days*

Table 2. Status information for the 8 Italian floats deployed in the Southern Ocean, South Atlantic and South Pacific during 2023.

Overall status at the end of 2023

In summary, at the end of 2023, the Argo-Italy program had a total of 86 active floats, including 35 in the Mediterranean Sea, 1 in the Atlantic Ocean (it left the Mediterranean Sea through the Strait of Gibraltar), 2 in the Black Sea (Figure 1), and 48 in the South Pacific, South Atlantic, and Southern Oceans (south of 60°S, see Figure 2).

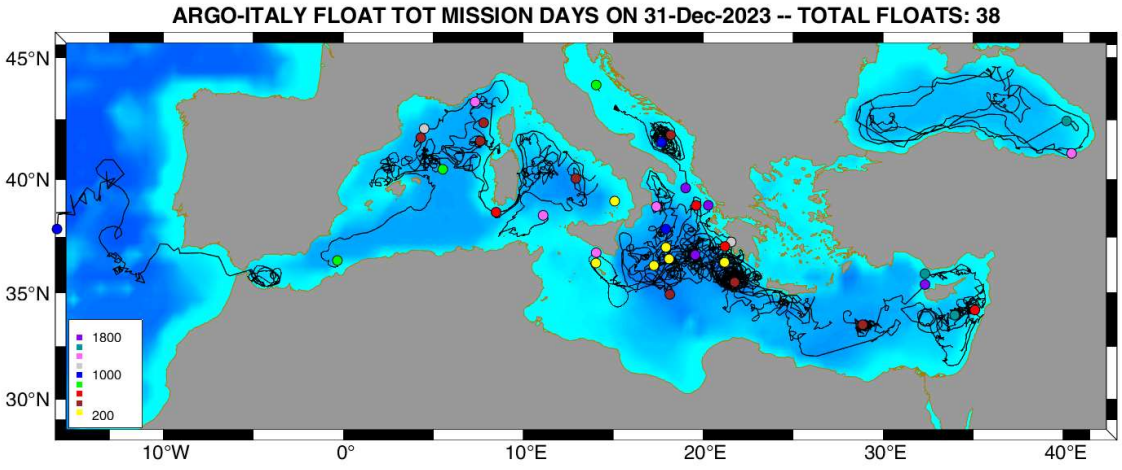

Figure 1. Trajectories and positions (circle symbols) on 31 December 2023 of the 38 Argo-Italy floats active in the Mediterranean and Black Sea (one float escaped in the Atlantic Ocean). Circles are color coded as a function of float age in days.

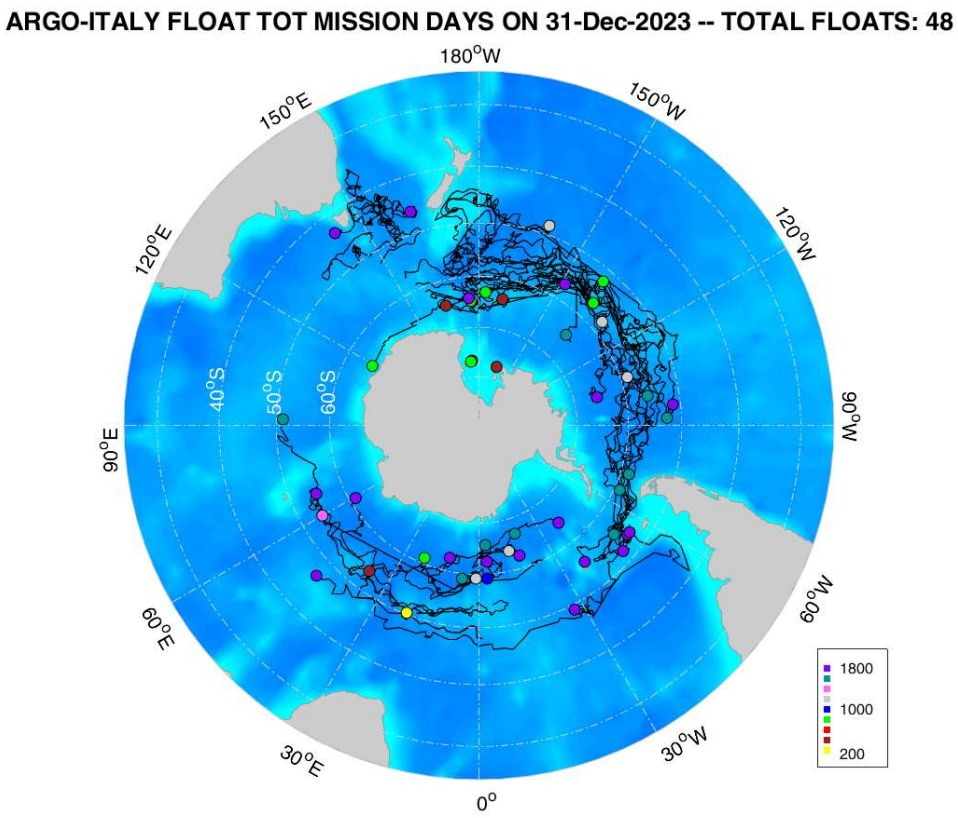

Figure 2. Trajectories and positions (circle symbols) on 31 December 2023 of the 48 Argo-Italy floats in the South Pacific, South Atlantic and Southern Oceans. Circles are color coded as a function of float age in days.

The temporal evolution of the number of active floats is shown in Figure 3 with weekly resolution, along with the annual numbers of float deployments and float deaths for the period 2012-2023. The float population in 2023 is in the range 80-90 active instruments. In 2023, the number of dead floats is well balanced by new deployments.

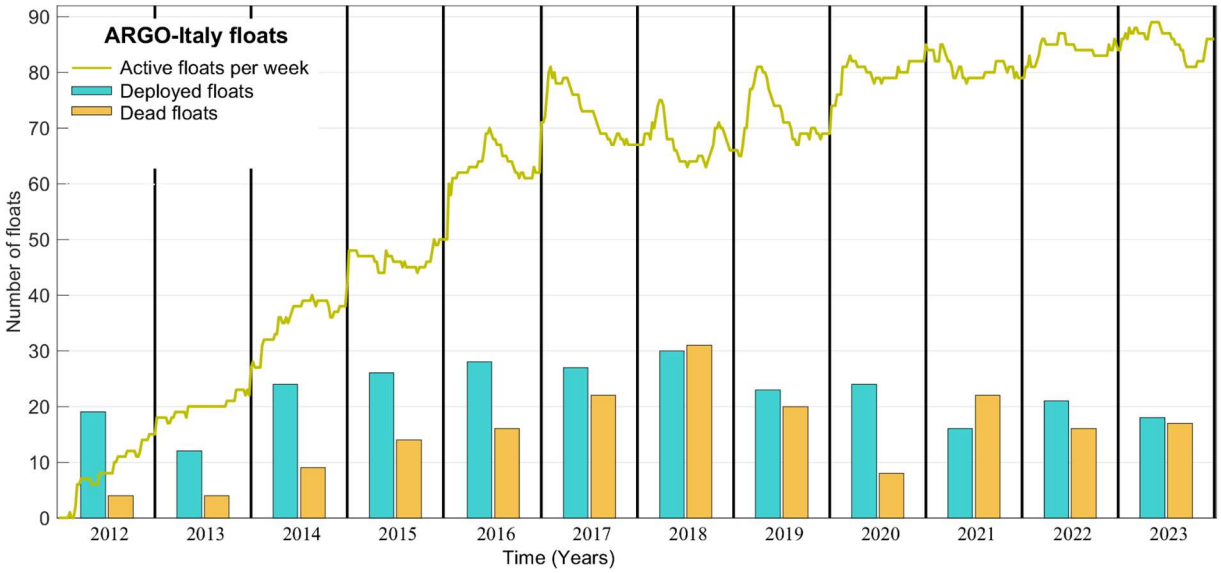

Figure 3. Temporal evolution of the number of Argo-Italy active floats with weekly resolution and histogram of the annual float deployments and losses.

Since 18 February 2012, a total of 268 Argo-Italy floats have been deployed, 157 in the Mediterranean and Black Seas and 111 in the Southern Hemisphere oceans. Over a 12 year period, they have provided about 43000 CTD profiles. The histogram of the number of floats in selected CTD profile classes is shown in Figure 4. The number of float profiles sorted by the main floats types shows the evolution in time of the Italian fleet (Figure 5). In this diagram, Core and Core DO floats are grouped; Bio floats are intended as floats equipped with sensors for measuring 2 to 6 BGC parameters. The spatial coverage provided is quite uniform (Figure 6) in the Mediterranean Sea with the exception of a small region in the Balearic sub-basin where a more intensive sampling took place as planned in the BIOSWOT Project.

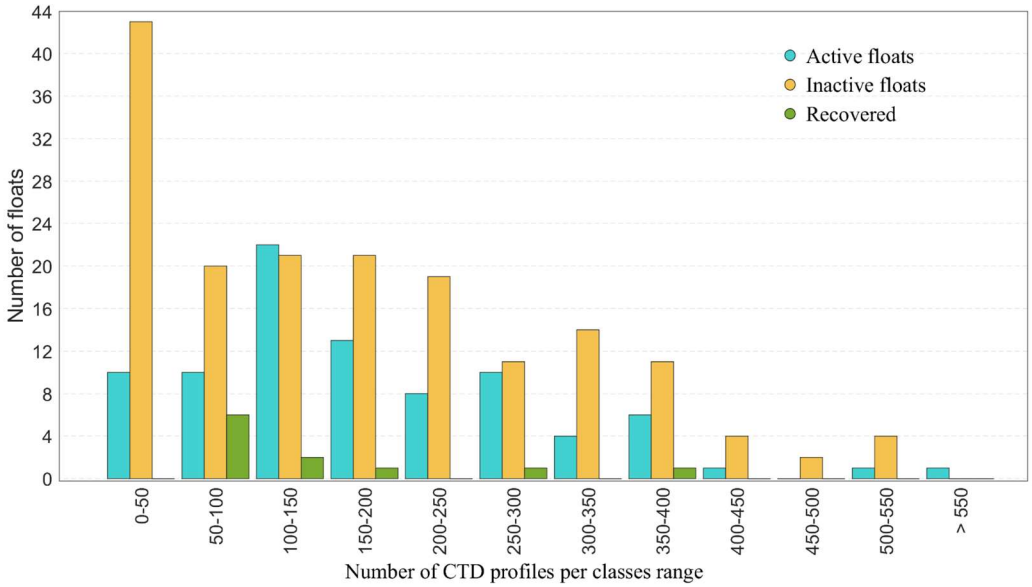

Figure 4. Histogram of the number of floats in selected CTD profile classes at the end of 2023 (orange: dead float, cyan: alive at the end of 2023, green: recovered).

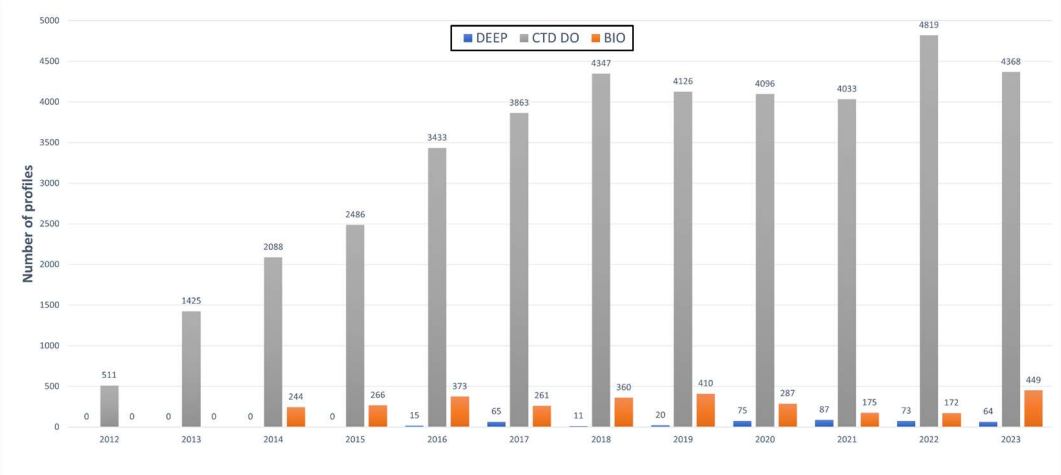

Figure 5. Number of float profiles from 2012 to 2023 sorted by main float types (orange: Bio floats, blue: Deep floats, grey: core and core DO floats).

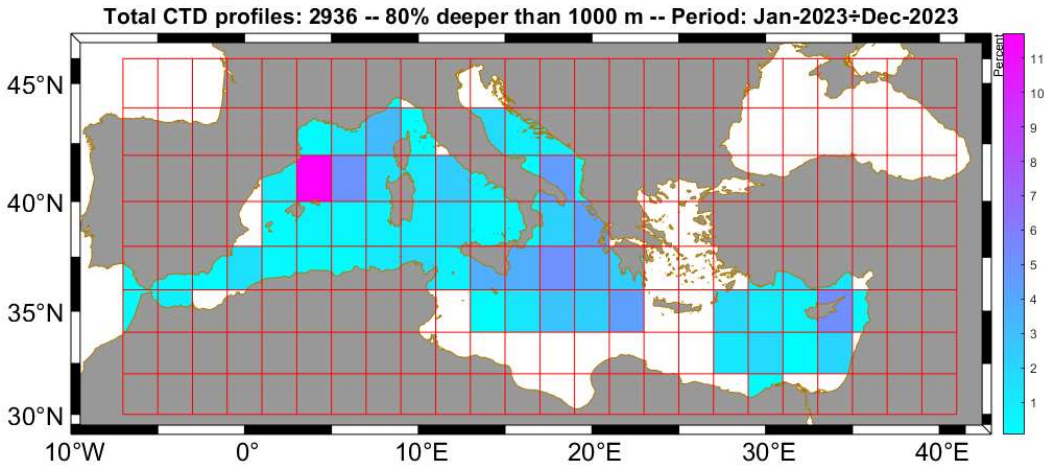

Figure 6. Density map of CTD profiles in 2023.

b. Technical problems encountered and solved

Mediterranean Sea

The Arvor DO 7901019 failed after 2 cycles due to a lack of communication with SBE41.

The Provor V Jumbo 2903797 stopped transmitting UVP data after the first few profiles. Anyway, it is still acquiring data. This will be investigated once the float will be recovered.

Global Ocean

The Core Arvor 5906980 failed after deployment for unknown cause.

Southern Ocean

The Core Arvor 6903831 failed after 2 cycles due to a lack of communication with the SBE41 probe.

c. Status of contributions to Argo data management (including status of high salinity drift floats, decoding difficulties, ramping up to include BGC or Deep floats, etc)

The data management for the Italian float is mostly done by the Coriolis GDAC. Metadata and data are available through the Coriolis web site in near real-time. The status of high salinity drift is regularly updated on the dedicated share file available at

https://docs.google.com/spreadsheets/d/1TA7SAnTiUvCK7AyGtSTUq3gu9QFbVdONj9M9zAq8CJU/edit#gid=1096144849

d. Status of delayed mode quality control process

The delayed mode quality control (DMQC) of the physical data (pressure, temperature and salinity) provided by the Italian floats was done for approximately 76,4% of eligible floats (191 out of 250 eligible floats) deployed between 2010 and 2022 in the Mediterranean and Black Seas, and Southern Ocean (all information and statistics to create the D-files have been sent to Coriolis). Physical data were quality controlled in delayed-mode following the standard Argo procedure. In particular, the OWC method in conjunction with other procedures is adopted to check and adjust the salinity data. The OWC is a statistical method based on the comparison between float salinity profiles and an accurate historical reference dataset. The high-quality ship-based CTD reference data from the near-surface to depths more than 2000 m, for QC purposes of Core and Deep-Argo float data in the Mediterranean and Black seas, was reviewed and improved. OGS collected CTD data from several research institutes at regional level and from the main European Marine Services in order to complement the official reference dataset. The reference dataset was quality controlled to obtain a good spatial distribution with more recent/contemporaneous data to reduce the effects of both the inter-annual and the seasonal variability of the Mediterranean Sea, mostly in the upper and intermediate layers of the water column. In order to obtain an even more accurate reference dataset, the procedure developed at BSH is being adapted to marginal seas to find errors, suspicious data, large time gaps, etc. Due to the high natural variability in the water column of the Mediterranean Sea, additional qualitative checks (i.e., a comparison between nearby floats and analysis of the deepest portion of the temperature-salinity diagram) are used in conjunction with the OWC method to better interpret results and hence provide an improved quality control analysis. OGS continuously implements these procedures to solve some problems (i.e. when different vertical sampling is used) and to better adapt them to marginal seas in order to obtain data of increasingly high quality. Furthermore, we started to implement the PCM (Profile Classification Model) method in the Mediterranean Sea. This approach allows a selection of reference data belonging to a similar water mass regime even though data are older with respect to the float profile. For some sub basins, the reference data are quite old and this method should be useful to solve this problem. The DMQC analysis was also conducted on the shallow-coastal floats deployed in the Mediterranean Sea, in the framework of the European H2020 Euro-Argo RISE project. In addition to the qualitative analyses, as comparisons between floats profiles and CTD at deployment or nearest CTD in space, the procedure developed for the Baltic sea has been adapted to the Adriatic Sea in order to improve the qualitative analysis. This analysis is under development and no D-files are produced at the moment.

OGS is committed to carrying out DMQC on all the Core-Argo floats of the Mediterranean and Black seas, and on some core floats in the World Ocean, as part of the Euro-Argo RISE, MOCCA project and other European projects over the coming years.

2. **Present level of and future prospects for national funding for Argo including a summary of the level of human resources devoted to Argo, and funding for sustaining the OneArgo mission: Core, BGC, Deep, Spatial (Polar, equator, WBCs)**

The Italian Ministry of Research has provided funding to buy 27 floats in 2023, including 15 Core-Argo with dissolved oxygen sensors, 2 Deep-Argo with dissolved oxygen sensors, 9 Core-Argo with dissolved oxygen sensors and with Ice Detection Algorithm implemented, and 1 Core-Argo equipped with the RBR CTD. In addition, the Italian human resources per year devoted to Argo-Italy was about 50 man-months for technical, administrative and scientific personnel involved in the project in 2023. It is expected that the same level will be maintained in 2024, including the procurement of about 8 additional Core-Argo with dissolved oxygen sensors. The Italian Ministry of Research has committed to provide funds in order to sustain the Italian contribution to Argo beyond 2024 (when a new five-years plan will start) as a founding member of the Euro-Argo Research Infrastructure Consortium. In addition to Italian national funding, in 2023 OGS received funding from the Italian PNRA (Programma Nazionale di Ricerche in Antartide) for personnel (about 6 man months) dedicated to activities related to Argo. CNR-ISMAR has purchased one BGC-Argo float that has been deployed in the Mediterranean Sea in late 2023.

In 2022, the Italian Ministry of Research has funded a 2.5-year grant (ITINERIS project) to purchase Bio/BGC/Deep floats (34 units by OGS and 9 units by CNR) to be deployed mainly in the Mediterranean and in key regions of our open seas. The scientific aims span from biogeochemical to bio-optical issues related to climate change as well as a modelling component. Furthermore, the deep data will be used to study the heat storage in the deepest layers of the water column particularly in the Mediterranean Sea. Our overall strategy will be to explore the key areas of the Mediterranean with BGC floats and also equipped with bio-optical sensors to characterise and provide new information to both experimental and modelling scientists. These new floats, together with previous ones, will provide the opportunity to quantitatively assess the importance of these measurements and better calibrate future funding in BGC, bio-optical, and Deep Argo in the Mediterranean Sea and in areas of multi-year interest. In doing so, we aspire to secure sustained, long-term funding for the BGC and Deep extensions of the Argo array. To realise this strategy, we are strengthening the interactions between the Italian observational Argo teams (OGS and CNR), the national and the European satellite community, and the biogeochemical modelling group at OGS. The ITINERIS floats are expected to be deployed in 2024-2026.

3. **Summary of deployment plans: please see the separate documents explaining the longer term outlook this year as a response to G7 requests. This spreadsheet is to be returned separately ASAP to help prepare for the meeting. It can be sent to Megan or dropped in the folder link containing the instructions.**

Here is a link to the commitments table at OceanOPS (if the link isn't working, visit OceanOPS and choose 'commitments' from the farthest right icon at the top of the page). If you cannot edit the online table, please send a list of deployment plans for each of the columns in the table as needed.

The Italian deployment plans from 2024 to 2028 have been provided as a separate contribution at https://drive.google.com/drive/folders/1a_hOVSpGMKajxd91Lv_fmP4IsmMnouNM, as requested. The main areas of interest are the Mediterranean and the Southern Oceans. Since 2023 it's been decided to equip the entire Core-Argo fleet with the dissolved oxygen sensor given the importance of this variable in water mass characterization.

Over a longer time frame, Italy is primarily interested in maintaining mainly its contributions to the Core mission and supporting the Bio/BGC and Deep Argo missions as long as funds are available for these extensions.

4. Summary of national research and operational uses of Argo data as well as contributions to Argo Regional Centers. Please also include any links to national program Argo web pages to update links on the AST and AIC websites.

Operational ocean forecasting

Data from core- and Bio/BGC-Argo floats in the Mediterranean Sea are routinely used for assimilation and forecast validation into the operational Mediterranean marine forecasting center (Med-MFC) run by the Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC) and the National Institute of Oceanography and Applied Geophysics (OGS). Med-MFC provides 3D daily physical and biogeochemical fields of the Mediterranean that are available on the Copernicus Marine Service at https://data.marine.copernicus.eu/products?facets=areas%7EMediterranean+Sea. Assessments done by the Med-MFC have clearly demonstrated the positive impact of Argo data on ocean analyses and predictions.

Specifically for the biogeochemical operational component, work done by OGS during 2023 included: (i) the inclusion of the assimilation of O2 profiles in the biogeochemical component of the Med-MFC (Amadio et al., 2023), (ii) the development of novel Neural Network applications for the reconstruction of synthetic biogeochemical profiles using Argo and BGC-Argo data (Pietropolli et al., 2023a and 2023b), and (iii) the development of novel ensemble data assimilation schemes for BGC-Argo profiles in the Mediterranean biogeochemical model (SEAMLESS H2020 project Cossarini et al., 2023) to foster the exploitation of BGC-Argo information with a focus on carbon sequestration, oxygen dynamics, eutrophication and plankton dynamics.

Additionally, new skill performance metrics of the Med-MFC biogeochemical predictions have been implemented using BGC-Argo data and are published regularly in the OGS webpage of the operational results (medeaf.ogs.it).

Ocean science
Argo data are being used by several researchers in Italy to improve the understanding of marine properties (e.g. circulation, heat storage and budget, and mixing) in both the Mediterranean Sea and the Southern Ocean. Biogeochemical-Argo data are being used to explore carbon fluxes and analyse the impact of extreme events on marine ecosystem structure and functioning , as well as to develop and validate new satellite products .

Web pages
The websites for the Italian contribution to Argo (Argo-Italy) are http://argo.ogs.it/#/. The link to the Mediterranean & Black Sea Argo Centre (MedArgo) is http://argo.ogs.it/medargo/.

5. **Issues that your country wishes to be considered and resolved by the Argo Steering Team regarding the international operation of Argo. These might include tasks performed by OceanOPS, the coordination of activities at an international level and the performance of the Argo data system. If you have specific comments, please include them in your national report. Also, during the AST-25 plenary, each national program will be asked to mention a single highlight or issue via a very brief oral report.**

   N/A

6. **To continue improving the quality and quantity of CTD cruise data being added to the reference database by Argo PIs, it is requested that you include any CTD station data that was taken at the time of float deployments this year. Additionally, please list CTD data (calibrated with bottle data) taken by your country in the past year that may be added to the reference database. These cruises could be ones designated for Argo calibration purposes only or could be cruises that are open to the public. To help CCHDO track down this data, please list the dates of the cruise and the PI to contact about the data.**

   OGS is committed to keeping the Mediterranean and Black Sea reference dataset up-to-date. For this purpose, OGS collects CTD data from different sources (Mediterranean and Black Sea riparian countries, national and European repositories) on a yearly basis. All non-restricted data are sent to the Coriolis GDAC for quality control, as some data policies do not allow the use of those data for scientific purpose and publication.

7. **Keeping the Argo bibliography (Bibliography | Argo (ucsd.edu)) up to date and accurate is an important part of the Argo website. This document helps demonstrate the value of Argo and can possibly help countries when applying for continued Argo funding. To help me with this effort, please include a list of all papers published by scientists within your country in the past year using Argo data, including non-English publications.**
   There is also the thesis citation list (Thesis Citations | Argo (ucsd.edu)). If you know of any doctorate theses published in your country that are missing from the list, please let me know. Finally, if you haven't already sent me a list of Argo PIs in your country, please do so to help improve the statistics on how many papers are published including an Argo PI vs no Argo PIs.

Argo PIs: Elena Mauri and Giorgio Dall'Olmo (OGS), Emanuele Organelli (CNR-ISMAR)

Bibliography (2023):

- Amadio, C., Teruzzi, A., Pietropolli, G., Manzoni, L., Coidessa, G., Cossarini, G., 2023. Combining Neural Networks and Data Assimilation to enhance the spatial impact of Argo floats in the Copernicus Mediterranean biogeochemical model. EGUsphere 1–28. https://doi.org/10.5194/egusphere-2023-1588

- Cossarini, G., Skakala, J., Wakamatsu, T., Teruzzi, A., Spada, S., & Yumruktepe, C. (2023). Guidelines on space-in situ data assimilation (D5.1). Deliverable report of project H2020 SEAMLESS. Zenodo. https://doi.org/10.5281/zenodo.7684591

- Gonzalez-Santana A., Oosterbaan M., Clavelle T., Maze G., Notarstefano G., Poffa N. and Velez-Belchi P., (2023). Analysis of the global shipping traffic for the feasibility of a structural recovery program of Argo floats. Front. Mar. Sci. 10:1161580. doi:10.3389/fmars.2023.1161580

- Kubin E., Menna M., Mauri E., Notarstefano G., Mieruch S. and Poulain P.-M. (2023). Heat content and temperature trends in the Mediterranean Sea as derived from Argo float data. Front. Mar. Sci. 10:1271638. doi:10.3389/fmars.2023.1271638

- Menna, M., Martellucci, R., Reale, M. et al. A case study of impacts of an extreme weather system on the Mediterranean Sea circulation features: Medicane Apollo (2021). Sci Rep 13, 3870 (2023). https://doi.org/10.1038/s41598-023-29942-w

- Pietropolli, G., Manzoni, L., Cossarini, G., 2023a. PPCon 1.0: Biogeochemical Argo Profile Prediction with 1D Convolutional Networks. EGUsphere 1–23. https://doi.org/10.5194/egusphere-2023-1876

- Pietropolli, G., Manzoni, L., Cossarini, G., 2023b. Multivariate Relationship in Big Data Collection of Ocean Observing System. Applied Sciences 13, 5634. https://doi.org/10.3390/app13095634

- Uitz, J., Roesler, C., Organelli, E., Claustre, H., Penkerc'h, C., Drapeau, S., et al. (2023). Characterization of bio-optical anomalies in the Kerguelen region, Southern Indian Ocean: A study

based on shipborne sampling and BioGeoChemical-Argo profiling floats. Journal of Geophysical Research: Oceans, 128, e2023JC019671. https://doi.org/10.1029/2023JC019671

- Stoer, A.C., Takeshita, Y., Maurer, T.L., Begouen Demeaux, C., Bittig, H.C., Boss, E., Claustre, H., Dall'Olmo, G., Gordon, C., Greenan, B.J.W, Johnson, K.S., Organelli, E., Sauzède, R., Schmechtig, C.M., and Fennel, K. (2023) A census of quality-controlled Biogeochemical-Argo float measurements. Front. Mar. Sci. 10:1233289. doi: 10.3389/fmars.2023.1233289

- Li M., Organelli E., Bellacicco M., Landolfi A., Serva F., Pisano A., Marullo S., Santoleri R. (2023). BGC-Argo floats and Earth Observation to assess the impact of Marine Heat Waves on phytoplankton communities in the NW Mediterranean Sea (The CAREHeat project). EC-ESA Joint Earth System Science Initiative, 22-24 November, Frascati (Italy). Poster.

8. **How has COVID-19 impacted your National Program's ability to implement Argo in the past year? This can include impacts on deployments, procurements, data processing, budgets, etc.**

   N/A

9. **Does your National Program have any deployment plans for RBR floats in the next couple years? If so, please indicate how many floats will you be buying in 2024 and 2025 (if known) and where they might be deployed.**

   OGS bought one Arvor I equipped with the RBR sensor in April 2023 and the float will probably be deployed in the Southern Adriatic in 2024.

References

- Cossarini, G., Mariotti, L., Feudale, L., Mignot, A., Salon, S., Taillandier, V., Teruzzi, A., d'Ortenzio, F. (2019). Towards operational 3D-Var assimilation of chlorophyll Biogeochemical-Argo float data into a biogeochemical model of the Mediterranean Sea. Ocean Modelling, 133, 112-128

- Cossarini, G., Feudale, L., Teruzzi, A., Bolzon, G., Coidessa, G., Solidoro, C.,Di Biagio V., Amadio C., Lazzari, P., Brosich Al., Salon, S. (2021). High-resolution reanalysis of the Mediterranean Sea biogeochemistry (1999–2019). Frontiers in Marine Science, 8, 1537.

- Salon, S., Cossarini, G., Bolzon, G., Feudale, L., Lazzari, P., Teruzzi, A., Solidoro, C., Crise, A. (2019). Novel metrics based on Biogeochemical Argo data to improve the model uncertainty

evaluation of the CMEMS Mediterranean marine ecosystem forecasts. Ocean Science, 15(4), 997-1022.

- Terzić, E., Lazzari, P., Organelli, E., Solidoro, C., Salon, S., d'Ortenzio, F., & Conan, P. (2019). Merging bio-optical data from Biogeochemical-Argo floats and models in marine biogeochemistry. Biogeosciences, 16(12), 2527-2542.

- Teruzzi, A., Bolzon, G., Feudale, L., & Cossarini, G. (2021). Deep chlorophyll maximum and nutricline in the Mediterranean Sea: emerging properties from a multi-platform assimilated biogeochemical model experiment. Biogeosciences, 18(23), 6147-6166.