Submitted by: G. Notarstefano (OGS), E. Mauri (OGS), Giorgio Dall'Olmo (OGS), Massimo Pacciaroni (OGS), Antonella Gallo (OGS) and Emanuele Organelli (CNR-ISMAR)

Report on the Italian Argo Program for 2022

Note that in this report we use the AST terminology as reported in the table hereafter. BGC is also used, in a general manner, to indicate the Argo extension towards the biogeochemistry

T/S Core	Temperature and Salinity sensors
T/S/O2	Temperature, Salinity and Dissolved Oxygen sensors
BGC	Full Biogeochemical sensors suite (AST definition: oxygen, pH, nitrate, chlorophyll fluorescence, suspended particles, downwelling irradiance)
Bio	Other Bio like floats (carrying some of the BGC sensors)
Deep	Deep float
Southern Ocean	Below 60°S (AST definition)

1. The status of implementation of the new global, full-depth, multidisciplinary Argo array (major achievements and problems in 2022)

a. Floats deployed and their performance

A total of 21 Italian floats were deployed in 2022 (see Tables 1 and 2 for details). These floats were Apex, Arvor-I, Arvor-Ice, Provor CTS4 and Deep-Arvor designs manufactured by Teledyne Marine (USA) and NKE (France). All floats transmit data via Iridium telemetry.

Mediterranean and Black Sea deployments

Fourteen units were released in the Mediterranean (Table 1). The Core-Argo floats have a park pressure at 350 dbar and maximal profiling depths alternating between 700 and 2000 dbar. Bio-Argo floats have a park pressure at 1000 dbar and the maximal profiling pressure was set to 1000 dbar for one platform and to 2000 dbar for two platforms. To measure high-frequency processes in the Sicily Channel, all of these floats have cycles of 5 days during most of their initial operating life, except for one Arvor-I float (WMO 6903821) which had short cycles of 3 hours. One Italian float was deployed in the shallow northern Adriatic (WMO 6903815) to complement the Euro-Argo RISE (EU H2020 project) fleet. The platform was used in a targeted shallow mission close to the coast. The cycle

time was set to 5 days and the parking depth equal to the maximum bathymetry (less than 80 m).

Most floats were deployed from research vessels of opportunity (i.e., R/V Dallaporta, R/V Pourquoi Pas?, R/V Belgica II, R/V Aegaeo, R/V Ammochostos, M/Y ROE, Malta Guard Coast for the Mediterranean and R/V Agulhas II and Laura Bassi for South Atlantic, South Pacific and Southern Ocean) with the help of colleagues from Greece, Malta, Italy and Cyprus.

South Pacific and Southern Ocean

With the help of Italian colleagues onboard the R/V Laura Bassi: a total of 7 Arvor-I equipped with ice-detection software were deployed: two of them, while crossing the circumpolar current (6903808, 6903809), two along the Ross Ice Shelf polynya (6903810, 6903811), one at Terra Nova Bay (6903812, as recovered and re-deployed float) and two (6903813, 6903814) in the Somov sea. 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).

Model	WMO	Depl. Date	Lat	Lon	Cycles	Last Date	Lat	Lon	Status*	Cyc.**
Apex APF9	6903816	23-Feb-2022 16:20	40.56	2.62	107	26-Mar-2022 23:17	38.92	-0.05	D	-
Arvor - T/S Diss. Oxy	6903818	03-Mar-2022 13:53	40.73	2.67	220	21-Feb-2023 16:52	38.81	3.78	A	5
Arvor - T/S Core	6903817	04-Mar-2022 09:33	40.89	2.78	214	21-Feb-2023 09:58	40.61	2.63	A	5
Arvor - T/S Core	6903815	17-Mar-2022 10:17	43.68	14.27	69	22-Feb-2023 04:29	43.89	14.07	A	5
Arvor - T/S Core	6903819	19-May-2022 21:02	40.51	11.00	56	20-Feb-2023 07:54	41.09	11.33	A	5
Arvor - T/S Core	6903820	21-May-2022 18:49	38.89	13.29	56	22-Feb-2023 05:51	40.52	12.68	A	5
Arvor- T/S Core	6903821	25-May-2022 07:57	35.90	14.10	388	18-Feb-2023 12:58	36.13	15.63	A	5
Arvor - T/S Diss. Oxy	6903822	01-Jun-2022 11:41	36.26	20.52	53	17-Feb-2023 03:54	35.33	21.34	A	5
PROVOR CTS4	6903823	21-Nov-2022 08:42	34.31	33.08	25	18-Feb-2023 11:23	33.43	33.59	A	5
Arvor - T/S Diss. Oxy	6903824	25-Nov-2022 17:18	33.94	28.11	18	20-Feb-2023 14:22	33.26	28.56	A	5
PROVOR CTS4	6903825	14-Dec-2022 08:13	41.50	18.12	18	22-Feb-2023 11:46	42.02	18.08	A	5
Arvor - T/S Diss. Oxy	6903826	15-Dec-2022 13:20	34.90	23.50	15	19-Feb-2023 05:44	35.50	20.80	A	5
Arvor – I DEEP	6903827	16-Dec-2022 21:10	35.60	22.47	-	-	-	-	D	-
PROVOR CTS4	6903828	18-Dec-2022 05:18	35.77	22.30	15	19-Feb-2023 11:28	35.43	21.35	A	5

**Status in early February 2023: A = active, D = dead; **Cycle: Length of cycle in days*

Table 1. Status information for the 14 Italian floats deployed in the Mediterranean Sea during 2022.

Model	WMO	Depl. Date	Lat	Lon	Cycles	Last Date	Lat	Lon	Status*	Cyc.**
Arvor-T/S ICE	6903808	11-Jan-2022 16:42	-61.01	175.36	41	16-Feb-2023 15:12	-59.85	-162.59	A	10
Arvor-T/S ICE	6903809	12-Jan-2022 06:47	-63.03	176.69	41	17-Feb-2023 05:33	-59.12	-163.93	A	10
Arvor-T/S ICE	**6903810**	**27-Jan-2022 11:53**	**-77.16**	**168.93**	**66**	**26-Jan-2023 08:51**	**-77.31**	**168.42**	**recovered**	7
Arvor-T/S ICE	**6903811**	**27-Jan-2022 21:41**	**-77.42**	**174.34**	**71**	**18-Feb-2023 05:37**	**-76.74**	**173.26**	**A**	7
Arvor-T/S ICE	**6903812**	**01-Feb-2022 08:56**	**-75.28**	**164.12**	**52**	**25-Jan-2023 06:45**	**-75.18**	**164.05**	**A**	7
Arvor-T/S ICE	6903813	08-Mar-2022 12:28	-66.00	148.05	67	18-Feb-2023 01:29	-64.52	130.64	A	10
Arvor-T/S ICE	6903814	11-Mar-2022 08:46	-65.53	146.90	67	23-Feb-2023 01:25	-64.68	160.37	A	10

**Status in early February 2023: A = active, D = dead; **Cycle: Length of cycle in days*

Table 2. Status information for the 7 Italian floats deployed in the Southern Ocean, South Atlantic and South Pacific during 2022.

Overall status at the end of 2022

In summary, at the end of 2022, the Argo-Italy program had a total of 85 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 47 in the South Pacific, South Atlantic, and Southern Oceans (south of 60°S, see Figure 2).

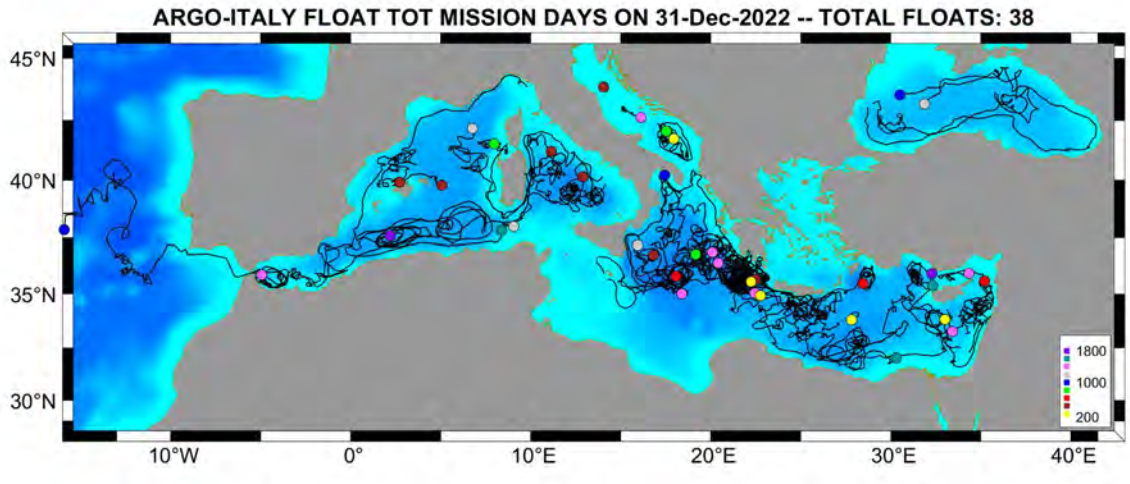

Figure 1. Trajectories and positions (circle symbols) on 31 December 2022 of the 38 Argo-Italy floats active in the Mediterranean and Black Sea. Circles are color coded as a function of float age in days.

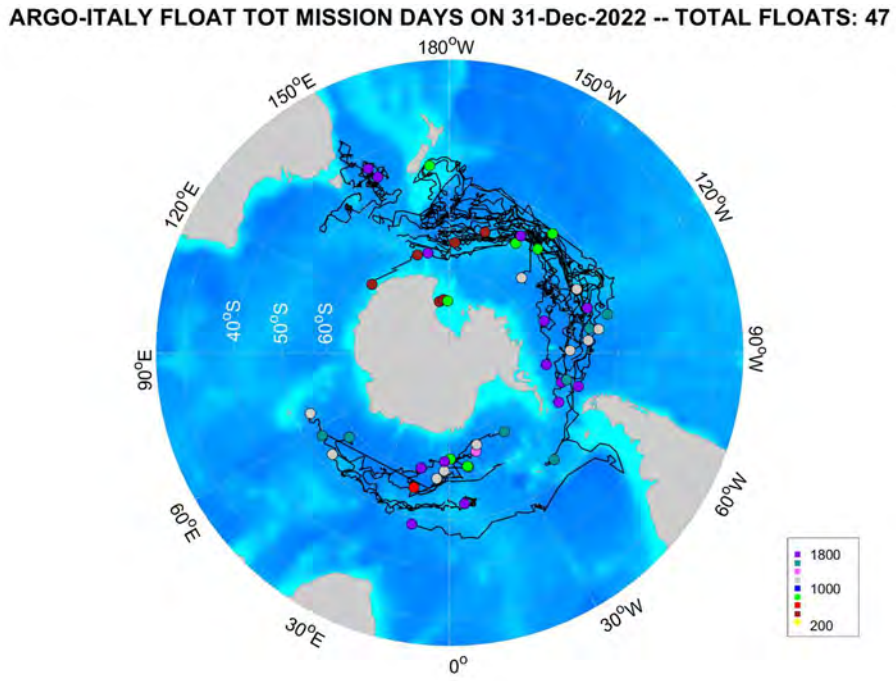

Figure 2. Trajectories and positions (circle symbols) on 31 December 2022 of the 47 Argo-Italy floats in the South Pacific, South Atlantic and Southern Oceans. Circles are color coded as a function of float age in days.

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 2012-2022. The float population in 2022 is quite stable at about 85 active instruments. In 2022, the number of deployments exceeded the number of dead floats.

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 250 Argo-Italy floats have been deployed, 147 in the Mediterranean and Black Seas and 103 in the Southern Hemisphere oceans. Over a 10 year period, they have provided about 38000 CTD profiles. The histogram of the number of CTD profiles per float is shown in Figures 4a and 4b. One hundred and seven floats, about 43% of the total deployments, have collected more than 180 profiles. Overall (during 2012-2022), ~6% of floats failed shortly after deployment.

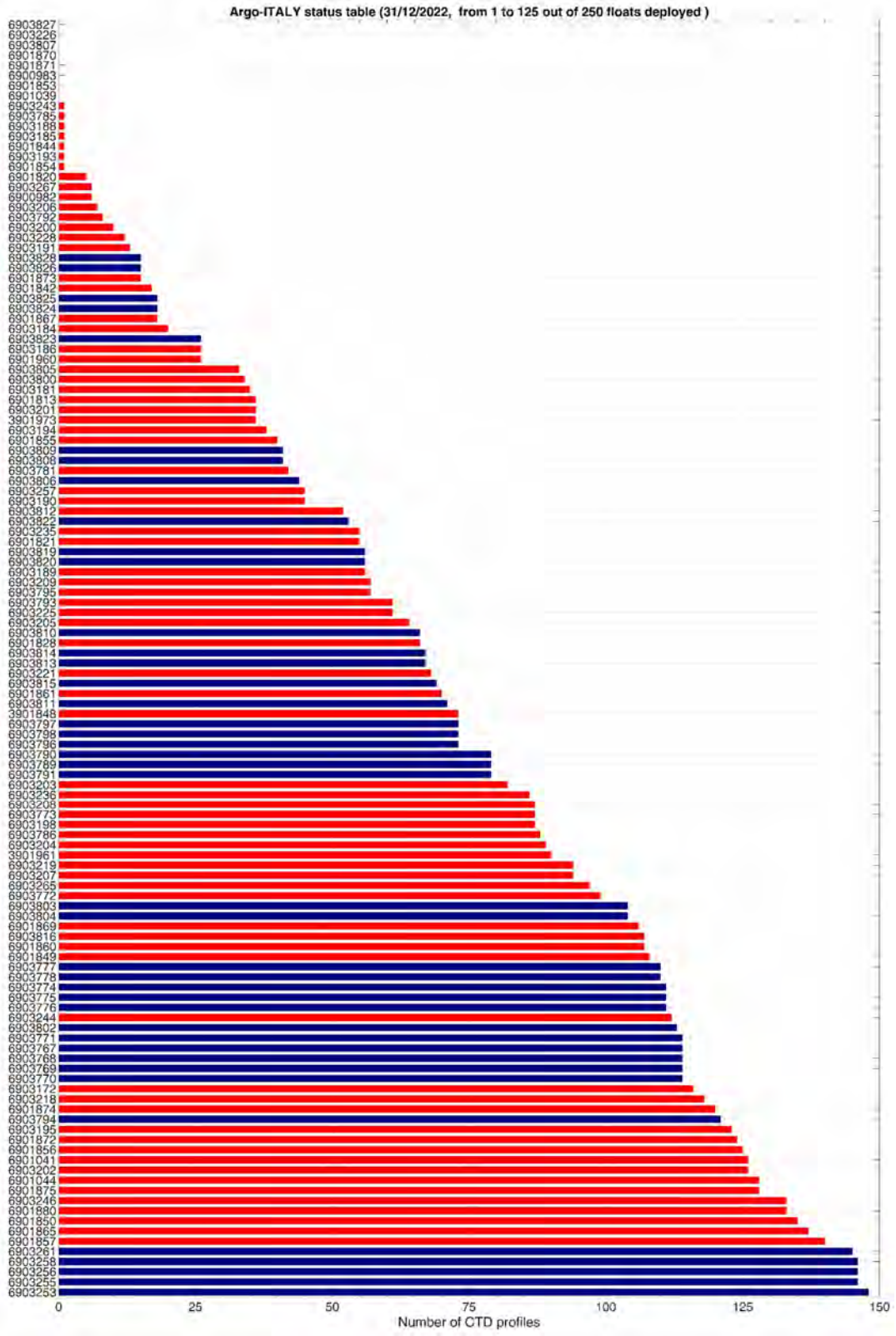

Figure 4a. Histogram of the number of CTD profiles per float (red: dead float, blue: alive at the end of 2022). Panel A from 1 to 125 floats.

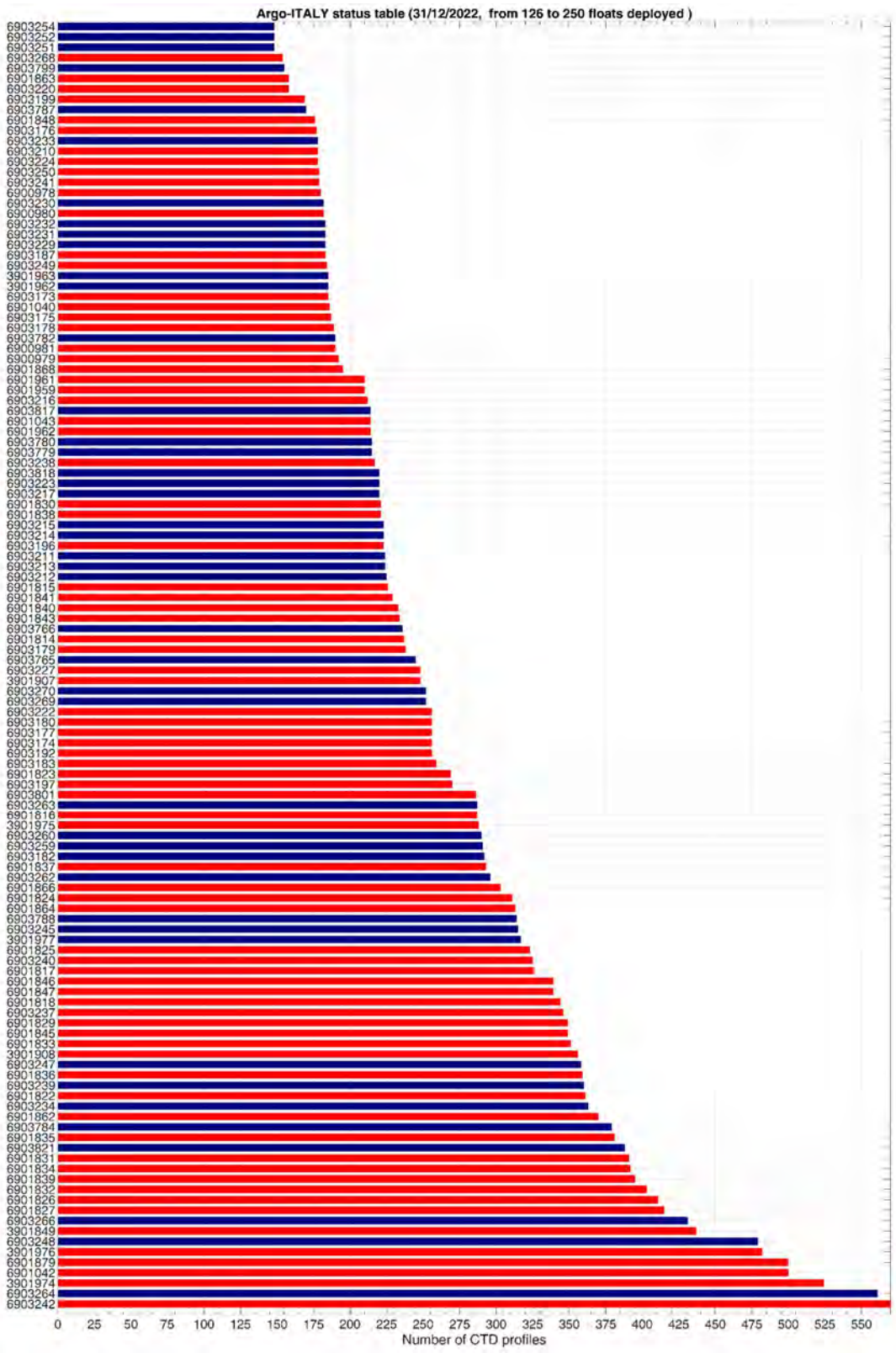

Figure 4b. Histogram of the number of CTD profiles per float (red: dead float, blue: alive at the end of 2022). Panel B from 126 to 250 floats.

b. Technical problems encountered and solved

Mediterranean Sea

The BGC-Argo 6903805 equipped with sensors to measure the 6 EOVs was deployed in the Southern Adriatic Pit in November 2021. The float stopped transmitting data after 33 cycles (end of January 2022) and the cause is unknown.

The Deep-Argo 6903827 was deployed in the eastern Ionian Sea in mid December 2022 and it failed at launch (it did not surface after the deployment). According to NKE a possible cause of failure could be the fact that the float stayed in the crate too long before the deployment. In such a case, a battery failure can happen and they suggested running an autotest next time to check the float. Unfortunately, due to logistical problems with the ship's time and plans, this float was not deployed soon (within a few months after its manufacture).

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 in the Mediterranean and Black seas was done for approximately 70% of eligible floats (161 out of 229 eligible floats) deployed between 2010 and 2021 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 . The DMQC analysis has been conducted also on the deep floats deployed in the Mediterranean Sea. This analysis requires a different approach with respect to Core-Argo floats, due to the pressure-dependent salinity bias. Hence, the correction for pressure effects on conductivity, called CPcor correction, is necessary before applying the OWC procedure for checking any sensor drift and offset in salinity. The DMQC was applied to 5 out of 7 eligible floats. Of these, only two D-files were sent to Coriolis because the floats only have between 1 and 10 cycles and need no correction. For the other three that show potential drift and need correction, the procedure is under development.

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 16 floats in 2022, including 2 with dissolved oxygen sensors, 4 standard T/S floats, 7 standard T/S floats with Ice Detection Algorithm implemented, 2 Deep floats and 1 Bio float. 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 2022. It is expected that the same level will be maintained in 2023, including the procurement of about 25 additional standard floats all equipped also with dissolved oxygen sensors, and 4 Deep floats. The Italian Ministry of Research has committed to provide funds in order to sustain the Italian contribution to Argo beyond 2023 as a founding member of the Euro-Argo Research Infrastructure Consortium. In addition to Italian national funding, in 2022 OGS received funding from EC projects (e.g. Euro-Argo RISE) for several activities related to Argo. CNR has purchased one Bio-Argo float that will be 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 floats (16 units by OGS and 9 units by CNR) to be deployed mainly in the Mediterranean but not only. The scientific aims span from bio-optical to biogeochemical issues related to climate change as well as a modelling component. The project involves both OGS and CNR. Our overall strategy will be to exploit the data from these new floats, together with those from previous floats, to further demonstrate to funders the value of BGC Argo in the Mediterranean Sea (but not only). In doing so, we aspire to secure sustained, long-term funding

for the BGC extension of the Argo array. To realise this strategy, we are strengthening the interactions between the Italian observational BGC-Argo teams (OGS and CNR), the national and the European satellite community, and the biogeochemical modelling group at OGS.

3. **Summary of deployment plans (level of commitment, areas of float deployment, Argo missions and extensions) and other commitments to Argo (data management) for the upcoming year and beyond where possible.**
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 for 2023 and 2024 are detailed in Table 3 (note that 2024 plans are only an estimate). The main areas of interest are the Mediterranean and the oceans of the South Hemisphere. 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.

Year	T/S floats (some of them with DO)		BGC/BIO floats		Deep floats		Total
	Quantity	Area	Quantity	Area	Quantity	Area	
2023	6-7 0 3 5	Mediterranean Black Sea South. Ocean Global	2 0	Mediterranean Black Sea	1-2	Mediterranean	**18-19**
2024	6 0 2 4	Mediterranean Black Sea South. Ocean Global	6-8 0	Mediterranean Black Sea	2	Mediterranean	**20-22**

Table 3. Italian float deployment plans for 2023 and an estimate for 2024.

Over a longer time frame, Italy is primarily interested in maintaining its contributions to the Core mission and supporting the BGC and Deep Argo missions as long as funds are available for these extensions. Float deployments in the next few years will be similar to those listed in Table 3.

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.

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 assimilated into the Mediterranean Forecasting System (MFS) operational forecasting system run by the Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC) and OGS, respectively. 3D daily maps of Mediterranean ocean forecasting systems are produced and available on the Copernicus Marine Environment Monitoring Service (CMEMS) at https://data.marine.copernicus.eu/products?facets=areas%7EMediterranean+Sea. Assessments have clearly demonstrated the positive impact of Argo data on ocean analyses and predictions. In particular, studies on the optimization of float sampling and cycling characteristics for the Mediterranean have been performed, and a methodology has been developed to assimilate Argo sub-surface velocities into numerical models.

Within the Marine Copernicus Service, BGC-Argo is an important asset (complementary to ocean colour) of the biogeochemical-model component of the Mediterranean Sea managed by OGS. BGC-Argo data are used for model development (Terzic et al.,2019), data assimilation (Cossarini et al., 2019, Teruzzi et al., 2021) and validation of operational and reanalysis Copernicus products (Salon et al., 2019; Cossarini et al., 2021). Novel artificial intelligence (Pietropolli et al., 2022) and ensemble data assimilation (SEAMLESS H2020 project) methods are ongoing activities to foster the exploitation of BGC-Argo information with a focus on carbon sequestration, oxygen dynamics, eutrophication and plankton dynamics.

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 (Organelli et al., 2022), as well as to develop and validate new satellite products (Dionisi et al., 2022).

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/.

Contribution at regional and international level
CNR organized and contributed to the joint floating school between EURO-Argo and EUROFLEETS+ carried out in September 2022 in Italy on board of the CNR's R/V Dallaporta.

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-24 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)

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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.**

   We experienced some delays related to float procurements and deployments but the impact was not too strong. The situation has now returned back to normal.

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 2023 and 2024 (if known) and where they might be deployed.**

   OGS will buy one Arvor I equipped with the RBR sensor in April 2023. The float will be deployed at the end of 2023 or in 2024.

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