Report on the Italian Argo Program for 2021

1. **The status of implementation of the new global, full-depth, multidisciplinary Argo array (major achievements and problems in 2021)**

   a. floats deployed and their performance

   In total, **16 Italian floats** were deployed in 2021 (see Tables 1 and 2 for details). These floats were Arvor-I, Arvor-Ice, Provor CTS4 and Deep-Arvor designs manufactured by NKE (France). All floats transmit data via Iridium telemetry.

   Mediterranean and Black Sea deployments

   Seven units were released in the Mediterranean (Table 1). Most floats have a parking depth at 350 dbar and maximal profiling depths alternating at 700 and 2000 dbar. They all have cycles of 5 days except for one Arvor-I float (WMO 6903801) which had short cycles of 3 h during most of their initial operating life to measure high-frequency processes in the Sicily Channel. One Italian float was deployed in the shallow northern Adriatic (WMO 6903800) as a complement of the Euro-Argo RISE (EU H2020 project) fleet. The platform was used in a targeted shallow mission close to the coast. The cycle length was set to 5 days and the parking depth equal to the maximal bathymetry (about 70 m).
   Most floats were deployed from research vessels of opportunity (i.e., R/V Dallaporta, R/V Bat-Galim, R/V Aegaeo, 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 Israel.

   South Atlantic, South Pacific and Southern Ocean

   Four Italian floats were deployed in the Ross Sea polynya with the help of Italian colleagues onboard the R/V Laura Bassi. Two of them (6903794 and 6903795) were recovered after the previous mission and redeployed (Table 2). All floats are ice detection. The Arvor-Ice uses an Ice Sensing Algorithm (ISA) based on temperature readings to abort surfacing when sea ice is present at the sea surface. The adopted configuration in the area of the polynya was a drifting and profiling depth of 1000 dbar with a cycling period of 7 days. Two floats were recovered in early 2022 (6903793 was redeployed and 6903795 sent to maintenance) and two died in 2021.
   Five Italian floats were deployed in the South Atlantic Ocean in 2021 (Table 2) with the help of Italian colleagues onboard the R/V Agulhas II. Three out of five floats are Arvor-Ice model. All the floats were programmed to cycle between the surface and 2000 dbar every 10 days and to drift at the parking depth of 1000 dbar. They were all still active in early 2022.

Five Italian floats were deployed in the South Atlantic Ocean in February 2020 (Table 2) with the help of Italian colleagues onboard the R/V Agulhas II. Three out of 5 floats are Arvor-Ice model. All the floats were programmed to cycle between the surface and 2000 dbar every 10 days and to drift at the parking depth of 1000 dbar. They were all still active in early 2020.

Model	WMO	Depl. Date	Lat	Lon	Cycles	Last Date	Lat	Lon	Status*	Cyc.**
Arvor - T/S Diss. Oxy	6903799	25-Apr-2021 13:30	41.65	17.22	79	14-Feb-2022 00:50	41.85	17.06	A	5
Arvor - T/S Core	6903800	04-May-2021 10:58	44.05	13.62	33	12-Ott-2021 06:18	43.96	13.63	D	5
Arvor - T/S Core	6903801	10-Jun-2021 09:56	35.96	14.09	263	13-Feb-2022 05:48	35.23	19.23	A	5
Arvor - T/S Diss. Oxy	6903802	10-Aug-2021 23:02	33.15	34.16	38	12/-Feb-2022 05:48	33.82	33.98	A	5
Arvor - T/S Diss. Oxy	6903803	20-Sep-2021 04:18	34.81	26.16	30	13-Feb-2022 05:52	35.32	22.66	A	5
Arvor-I DEEP	6903804	20-Sep-2021 23:55	36.02	28.63	29	09-Feb-2022 06:05	35.76	28.58	A	5
Provor CTS4	6903805	11-Nov-2021 09:43	41.53	18.06	33	28-Jan-2022 11:34	41.14	17.59	A	5

*Status in early February 2022: A = active, D = dead
**Cycle: Length of cycle in days

Table 1. Status information for the 7 Italian floats deployed in the Mediterranean Sea during 2021.

Model	WMO	Depl. Date	Lat	Lon	Cycles	Last Date	Lat	Lon	Status*	Cyc.**
Arvor-T/S Core	6903806	10-Dec-2021 08:43	-60.04	-0.05	7	09-Feb-2022 05:57	-59.27	3.34	A	10
Arvor-T/S Core	6903807	11-Dec-2021 11:12	-63.99	1.48	-	11-Dec-2021 11:12	-63.99	1.48	-	10
Arvor-T/S ICE	6903792	18-Jan-2021 05:48	-77.16	168.93	8	02-Mar-2021 06:12	-77.28	168.68	D	7
Arvor-T/S ICE	6903793	19-Jan-2021 03:08	-77.42	174.34	61	26-Jan-2022 06:08	-76.27	173.94	recovered	7
Arvor-T/S ICE	6903794	21-Jan-2021 20:36	-77.73	-178.52	49	25-Dec-2021 05:57	-77.69	-179.92	D	7
Arvor-T/S ICE	6903795	30-Jan-2021 03:56	-75.28	164.01	57	23-Jan-2022 05:54	-74.97	164.63	recovered	7
Arvor-T/S ICE	6903798	24-Feb-2021 00:15	-64.00	0.43	36	10-Feb-2022 05:55	-61.55	-8.73	A	10
Arvor-T/S ICE	6903796	24-Feb-2021 14:25	-63.00	-2.44	36	10-Feb-2022 05:53	-62.75	-9.75	A	10
Arvor-T/S ICE	6903797	24-Feb-2021 20:30	-62.07	0.13	36	10-Feb-2022 05:51	-61.47	-9.00	A	10

*Status in early February 2022: A = active, D = dead
**Cycle: Length of cycle in days

Table 2. Status information for the 9 Italian floats deployed in the Southern Ocean, South Atlantic and South Pacific during 2021.

Overall status at the end of 2021

In summary, at the end of 2021, the Argo-Italy program had a total of 77 active floats, including 29 instruments in the Mediterranean Sea, 1 in the Atlantic Ocean (it escaped from the Mediterranean through the Strait of Gibraltar), 3 in the Black Sea (Figure 1) and 44 in the South Pacific, South Atlantic and Southern Oceans (southern of 60 °S, see Figure 2).
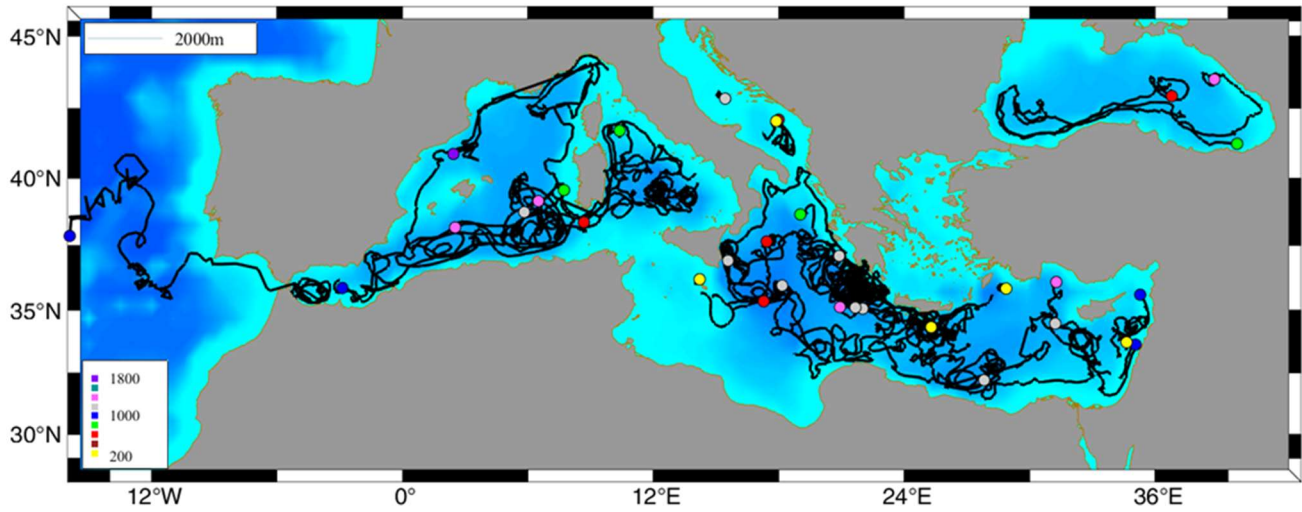
Figure 1. Trajectories and positions (circle symbols) on 31 December 2021 of the 33 Argo-Italy floats active in the Mediterranean and Black Sea. The circle symbols are color-coded as a function of float age in days.
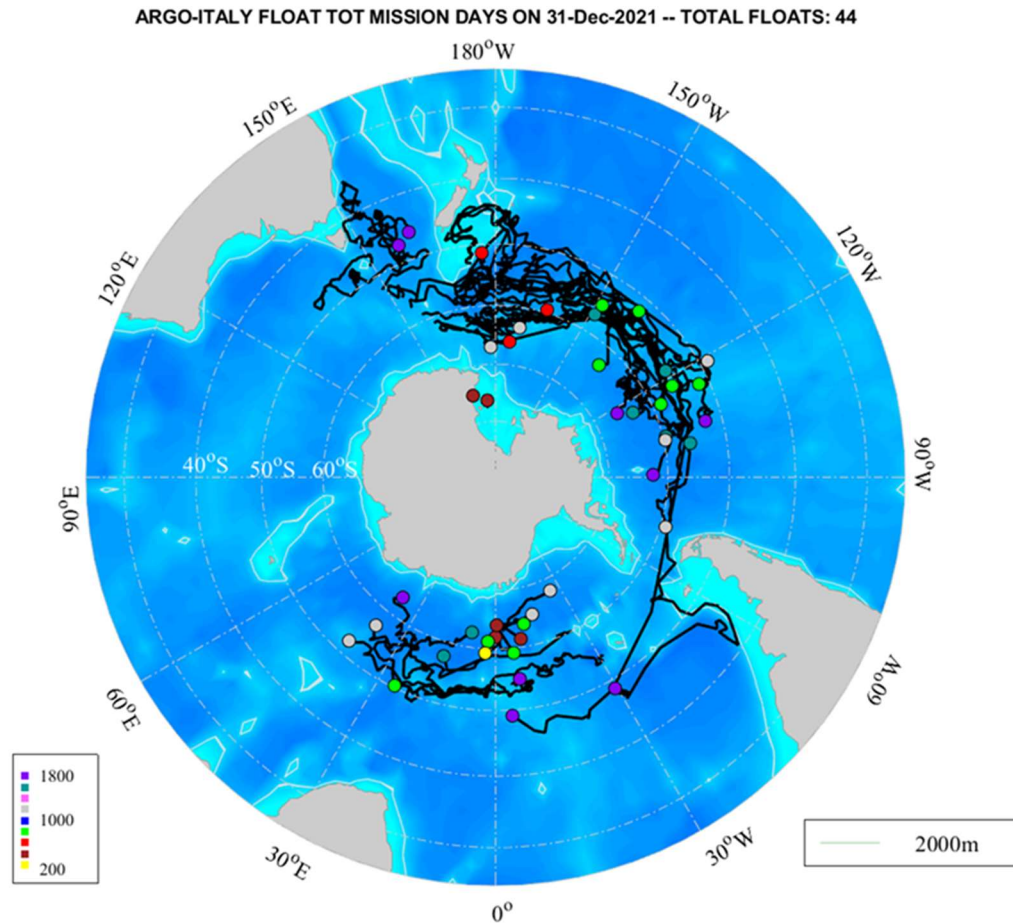
Figure 2. Trajectories and positions (circle symbols) on 31 December 2021 of the 44 Argo-Italy floats in the South Pacific, South Atlantic and Southern Oceans. The circle symbols are color-coded as a function of float age in days.

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 2012-2021. The float population in 2012-2021 is quite stable at about 77 active instruments in 2021. In 2021, the number of dead floats exceeded the number of deployments.
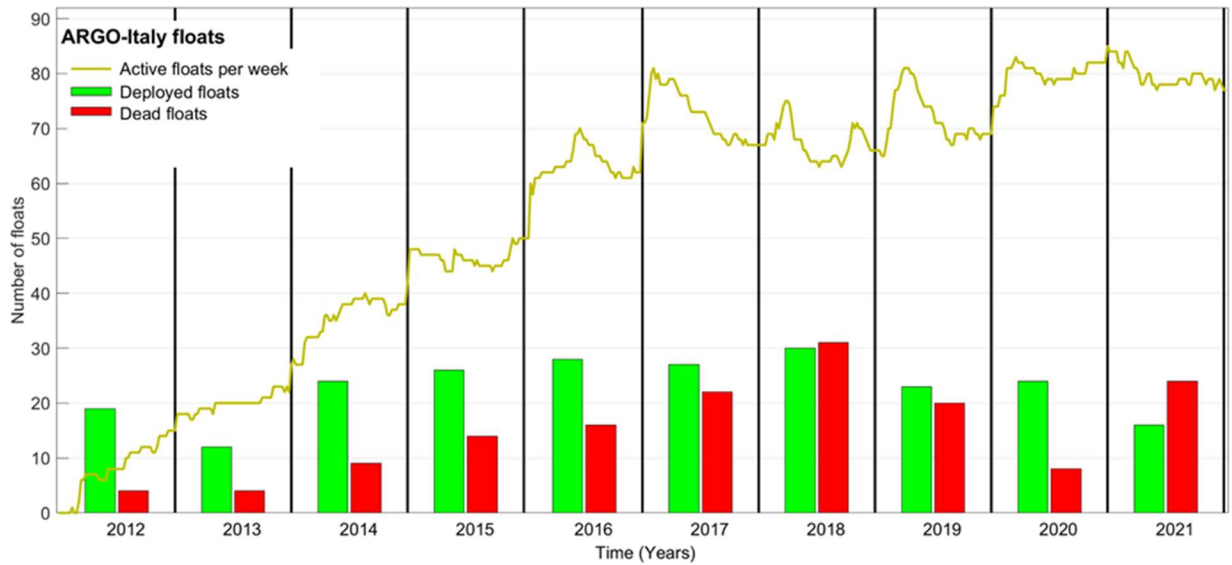
Figure 3. Temporal evolution of the number of Argo-Italy active floats with weekly resolution and histogram of the annual float deployments and losses.

Since 18 February 2012, a total of 229 Argo-Italy floats have been deployed, 133 in the Mediterranean and Black seas, and 96 in the oceans of the Southern Hemisphere. In less than 10 years, they have provided about 33060 CTD profiles. The histogram of the number of CTD profiles per float is shown in Figure 4. Ninetythree floats, about 40 % of the total deployments, have done more than 180 profiles. In total (during 2012-2021), ~6 % of the floats have failed just after deployment.
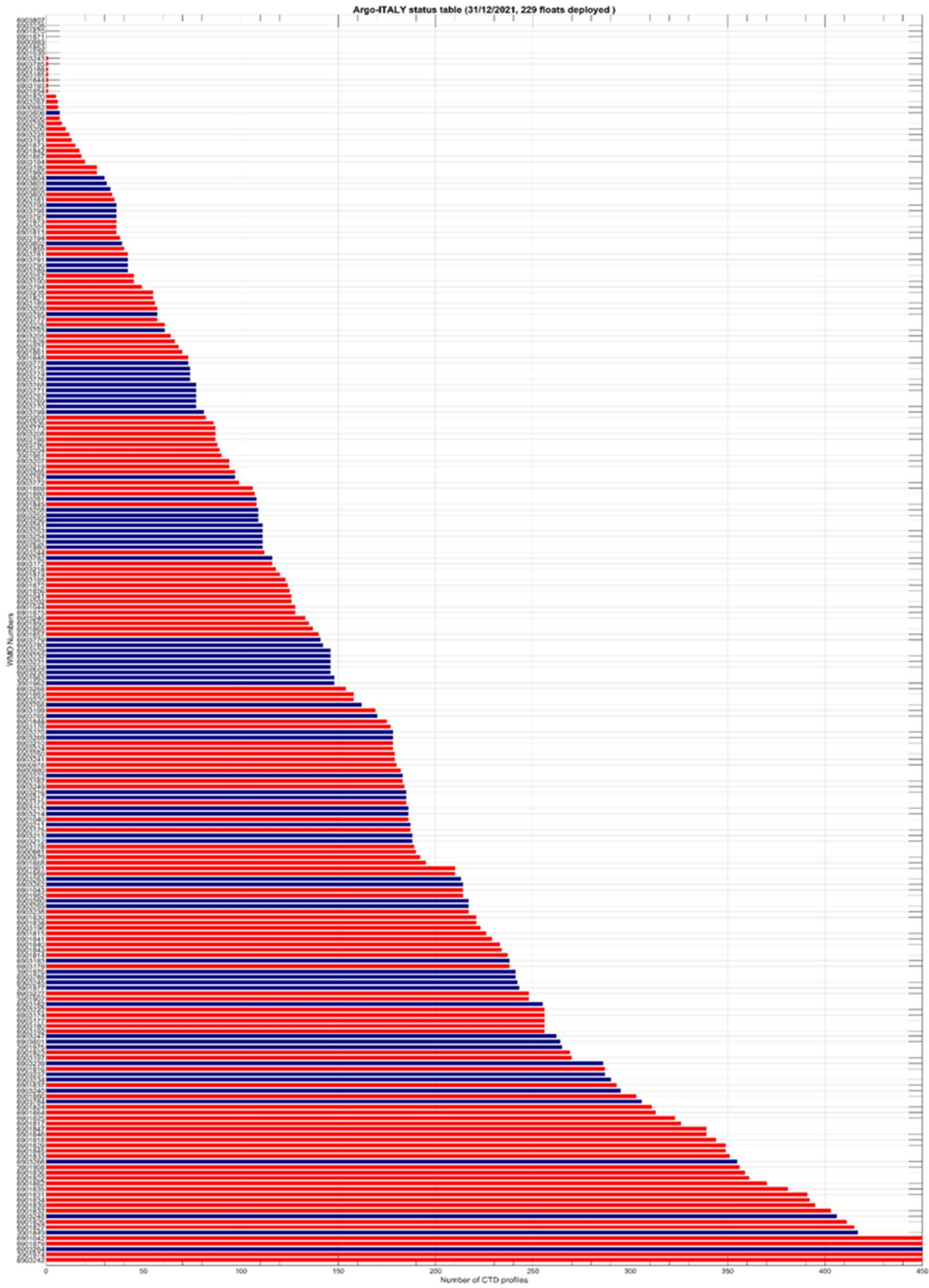
Figure 4. Histogram of the number of CTD profiles per float (red: dead float, blue: alive at the end of 2021).

b.   technical problems encountered and solved

Mediterranean Sea

In total, one float stopped functioning before the end of the year 2021. The Arvor-I float 6903800 deployed in the northern Adriatic Sea in May 2021 stopped transmitting after cycle 33 and the cause is still unknown

c. <u>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)</u>

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://app.activecollab.com/186315/projects/45?modal=Task-4086-45

d. <u>status of delayed mode quality control process</u>

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 about 95 out of about 134 eligible floats (all information and statistics to create the D-files sent to Coriolis). The temperature and salinity data of those floats were quality controlled following the standard Argo procedure, covering the period 2010-2020. The OWC procedure is used to check and adjust salinity data. It is a statistical method, based on reference datasets. The accuracies of the float data are assessed by comparison of Argo salinity profiles with calibrated reference measurements. An accurate reference dataset plays an important role in the quality control analysis and these data have to be quite close in time and space to the float measurements. The latter is necessary, in order to reduce the effects both of the inter-annual and the seasonal variability of the Mediterranean Sea, mostly in the upper and intermediate layers of the water column. For these reasons, OGS collected CTD data in complement of the official reference dataset using two approaches: personal contacts and regional data services. The standard statistical method adopted by the Argo community for the salinity correction is strictly affected by the natural changes in the water column of the Mediterranean Sea and hence a careful interpretation of the method results is necessary. For this reason, we adopted other qualitative checks (i.e., the comparison between nearby floats and analysis of the deepest portion of the temperature-salinity diagram) in order to increase reliability of the analysis. The DMQC of the Italian floats deployed in the Southern Ocean (and South Pacific and Atlantic oceans) started in 2019 and was applied to 70 out of about 85 eligible floats.

OGS started the DMQC of the Deep-Argo physical data and updated the "deep" reference dataset in the Mediterranean Sea used for the quality control procedure.
One OGS expert was included in the BGC working group for the DMQC strategy in Europe.

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 core mission and the enhancements: BGC, Deep, Spatial (Polar, equator, WBCs)**

The Italian Ministry of Research has provided funding to buy 19 floats in 2021, including 4 instruments with dissolved oxygen sensors, 5 standard T/S floats, 7 standard T/S floats with Ice Detection Algorithm implemented and 3 Bio floats. 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 2021. It is expected that the same level will be maintained in 2022, including the procurement of 13 additional standard floats, 2 Bio floats and 2 Deep floats. The Italian Ministry of Research is committed to provide funding in order to sustain the Italian contribution to Argo beyond 2022 as a founding member of the Euro-Argo Research Infrastructure Consortium. In addition to the Italian national funding, OGS has funding from EC projects (e.g. Euro-Argo RISE) for several activities related to Argo.

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.**

The Italian deployment plans for 2022 and 2023 are detailed in Table 3. The main areas of interest are the Mediterranean and the oceans of the South Hemisphere.

Year	T/S floats (some of them with DO)		BGC floats		Deep floats		Total
	Quantity	Area	Quantity	Area	Quantity	Area	
2022	10	Mediterranean	2	Mediterranean	1	Mediterranean	**23**
	1	Black Sea	1	Black Sea			
	8	South Hemisphere					
2023	10	Mediterranean	2	Mediterranean	1	Mediterranean	**22**
	1	Black Sea	0	Black Sea			
	8	South Hemisphere					

Table 3. Italian float deployment plans for 2012-2023.

On the longer time frame, Italy is interested to maintain contributions to the Argo Core mission and the BGC and Deep Argo Extension with numbers similar to those listed in Table 9. OGS is committed to carry out DMQC on all the Argo floats of the Mediterranean and Black seas, and on some floats in the World Ocean, as part of the Euro-Argo RISE, MOCCA project and other European projects over the coming years.

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/.

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.

Physical and Biogeochemical Argo float data in the Mediterranean (along with other in-situ and remotely sensed data) are routinely assimilated into the Mediterranean Forecasting System (MFS) operational forecasting system run by the Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC) and OGS. 3D daily maps of Mediterranean ocean forecasting systems are produced and available on the Copernicus Marine Environment Monitoring Service (CMEMS). 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, as well as the development of methodology for the assimilation of Argo float sub-surface velocities into numerical models.

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.

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 the AIC, 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.**

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.**

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.

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

9. **Argo is still interested in piloting the RBR CTD. 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 2022 and 2023 (if known) and where they might be deployed.**

   Planned in 2023