National Strategy for Argo Global Network Profiling floats Deployments

Argo France Steering Committee

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1 Background and Objectives

1.1 Background

To ensure the maintenance of the international OneArgo network (Roemmich et al., 2019) of autonomous profiling float (https://argo.ucsd.edu/), France is committed to contribute to deploy a significant part of the global network (around 10%). The profiling floats of the Argo France program are funded by Ifremer, SHOM and SU, supported by the French “Ministère de l’Enseignement Supérieur, de la Recherche et de l’Innovation'' funding via the “Très Grande Infrastructure de recherche” (IR*), “Contrat de Plan État-Région” (CPER), PIA projects such as Equipex+ Argo-2030, and CNES. These purchases are operated by the IR* and the LOV in the framework of IR* Euro-Argo France activities. Between 50 and 70 T/S type profiling floats, so called “Core Argo” (Temperature/Salinity), T/S/DO (Dissolved Oxygen), Deep (“Deep Argo”) and BGC (Biogeochemical, “BGC-Argo”) are purchased every year. A special feature of the Argo France program is that these profiling floats are then made available to the national scientific community via the annual call for scientific proposals in the INSU/CNRS LEFE/GMMC framework. Profiling floats, that are not assigned to scientific teams as part of this call, are deployed via opportunity campaigns.

1.2 Objectives

The purpose of this document is to define the strategy of the Argo France program to prioritize the deployment zones and the default mode settings of the Argo France profiling floats. These recommendations are established and motivated by the expertise and historical interest of the French community, and in line with the international strategies and recommendations from the OneArgo program (AST, ADMT). Therefore, the present document is intended to evolve over time. These recommendations aim at providing :

- Guidance for the Operational Argo cell (COA) and french Principal Investigators (PIs) to set up the float defaults mode and priority deployment zones
- Guidance for LEFE/GMMC scientific committee to evaluate the PI’s Argo float deployment proposal

1.3 Procedure reminder

LEFE/GMMC call for scientific proposals

PIs or scientific teams respond to INSU LEFE/GMMC call for scientific proposals in September of each year (year N) to request profiling floats of T/S, DO, Deep, BGC type for deployment in the framework of their scientific proposal. Then, in November (year N), the Argo-France scientific committee (i.e. LEFE/GMMC) reviews the profiling float requests according

to the scientific relevance of the proposal, the Argo France recommendations and the availability of the profiling floats. **For the purpose of their research, the GMMC PIs have the possibility to apply the float setup they need, within the limit fixed by the Argo France and GMMC scientific committee (explained in the LEFE GMMC Call), and established in collaboration with Argo France steering committee.**

Then, the list of accepted float requests is communicated to COA in charge of T/S, DO and Deep floats management and to LOV in charge of BGC floats. The deployment plan for the year N + 1 is planned (GMMC projections, historic and opportunity) and submitted for validation to the Argo France Steering Committee before December of the year N. At the beginning of the following year (year N + 1), the responses are officially sent to the GMMC PIs.

The profiling floats are then assigned to PIs in the framework of their research project. They are now in charge of their profiling float : Deployment, CTD casts during the deployment for reference data, float monitoring, quality control in delayed time (DM-QC) and feedback to COA / LOV..

Limitations of the LEFE/GMMC call for scientific proposal

For several years, a significant part (> 50%) of the profiling floats made available to the community have not been allocated via the LEFE/GMMC scientific call. These non-GMMC deployments include recurring historical cruises (Pirata, Goodhope, Ovide). So, these floats are dedicated to sample the regions historically sampled by France and/or fill the sampling (potential) gaps of the Argo network. These profiling floats, which are not assigned via the LEFE/GMMC call, are put under the responsibility of COA (for their deployment and management at sea) and the Coriolis DAC for data processsing, including delayed time QC.

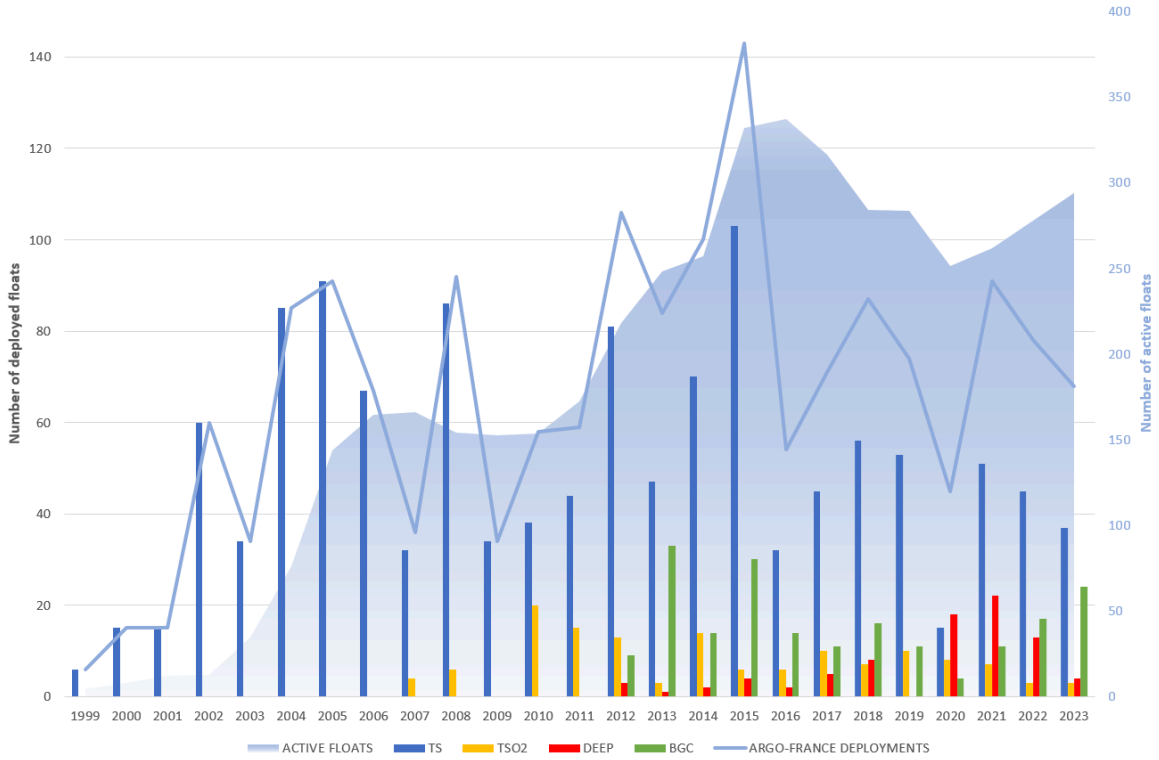

Figure 1: Number of Argo-France profiling float deployed per year since 1999 depending on the type of profiling float (T/S : Argo core, DO : Dissolved Oxygen, Deep : Deep Arvor, BGC : Biogeochemical)

1.4 Historical regions for french deployments

Historically, France has mainly deployed core Argo profiling floats in the Atlantic Ocean, the Southern Ocean, the Mediterranean Sea, and occasionally in the tropical Pacific and the Indian Ocean. More specifically, the regions that have been the aim of several scientific projects and campaigns are (see Figures 2 and 3):

- The subpolar gyre of the North Atlantic Ocean,
- The Southern Ocean, South Atlantic sector downstream of the Agulhas current,
- The West African coast, tropical Atlantic and Gulf of Guinea (Cape to Gibraltar),
- The Mediterranean Sea,
- The South Tropical Pacific and the Coral Sea,
- North Indian Ocean (Bay of Bengal and Arabian Sea),
- Eastern South Tropical-subtropical Pacific,
- Nordic Seas and Arctic Ocean.

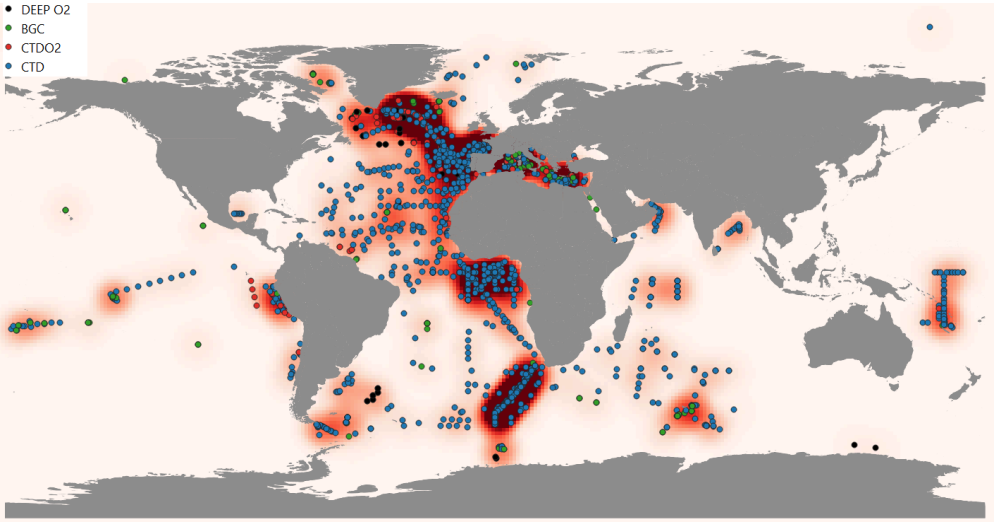

Figure 2: Position (and density) of Argo-France deployment since 1999

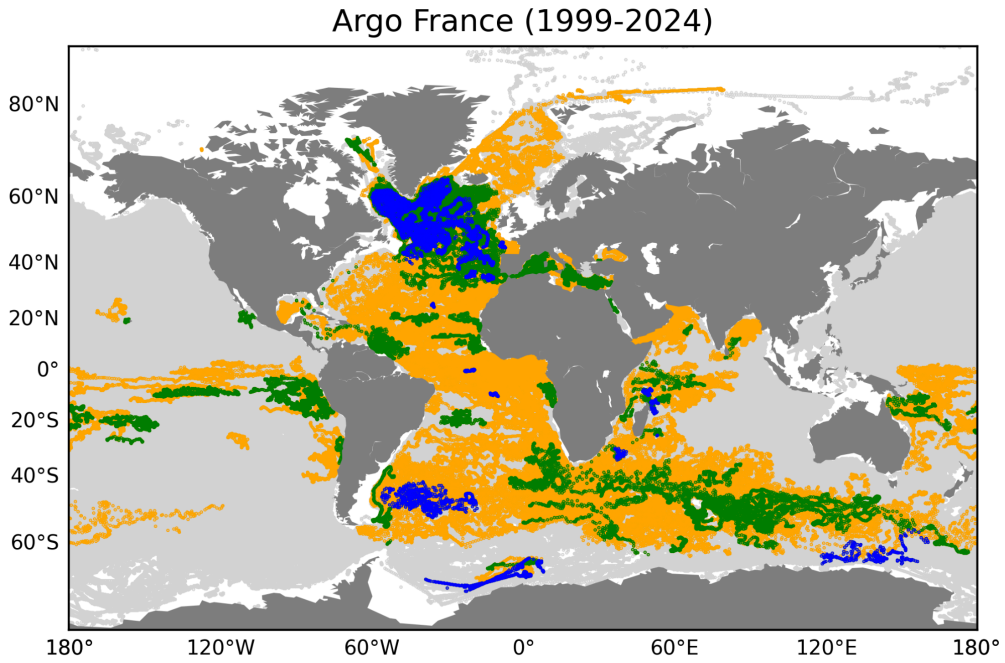

Figure 3: French Argo profiles since 1999 as a function of the mission (orange: Core ; blue: Deep ; green:BGC). Gray are the non-french floats.

1.5 Seek for Opportunity (excluding GMMC)

Deployments of opportunity are carried out from:

- FOF (Flotte Océanographique Française) Research Vessels
- SHOM (French Navy Hydrographic Service) Research Vessels

- European or other foreign Research Vessels
- Sailing vessels such as tall ships, merchant ships or racing ships
- Commercial ships
- French warships

2 Recommendation for core profiling floats (P/T/S/ 0-2000m)

→ **20-25 floats**[1]

2.1 Geographical Priorities

Priority 1 : **Southern Atlantic, Southern Ocean, Indian Ocean, Polar Ocean.** Areas under sampled in the global network (orange-red in Figure 4) are pointed out by AST with high priority for deployment.

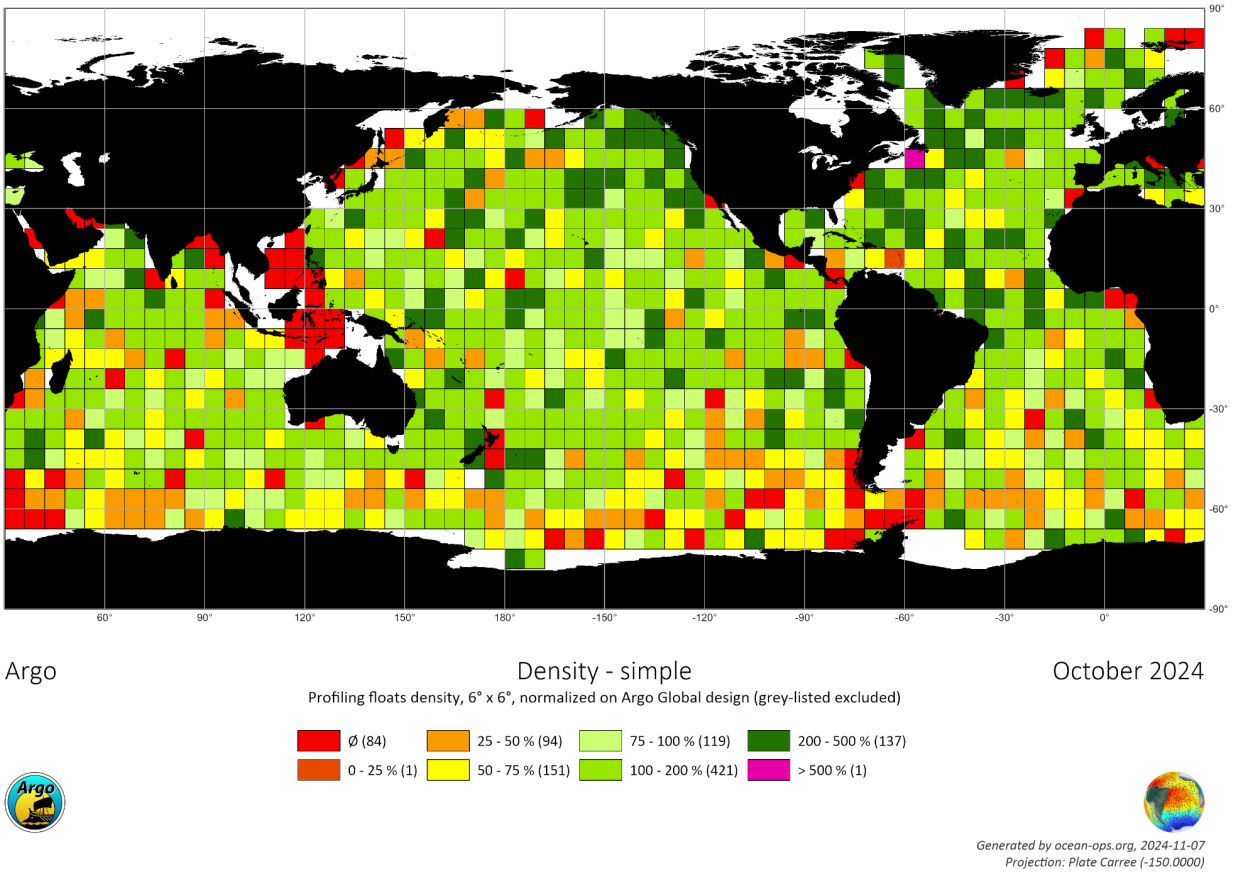

Figure 4 : Global Ocean Area that does not meet nominal sampling criteria (100 %) of the Argo core global network (1 profile / 3 °x 3 °x 10 days) in October 2024.

Priority 2 : French historical deployment regions

- If they are not sampled nominally following the objectives of the Core Argo network (following the AST OneArgo design identified in Figure 6).

[1] average number over the period 2016-2020. Funding: Ifremer, SHOM, CPER, NAOS

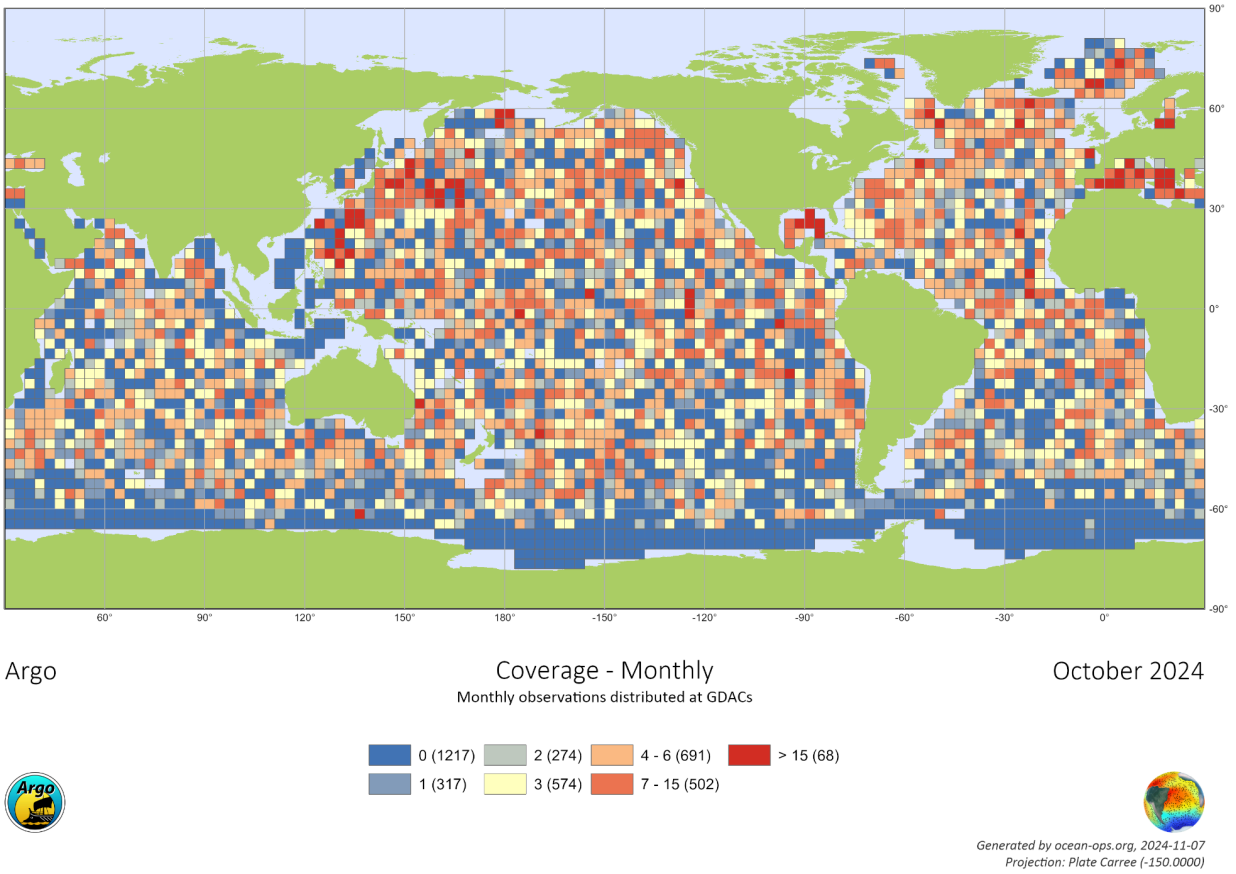

Figure 5 : Current coverage of the global Argo network (all missions combined, October 2024)

Priority 3 : Doubling the sampling in high variance regions (following the AST OneArgo design, Fig. 6). Specific work on the western boundary currents and piloting profiling floats to improve sampling has been conducted in the framework of the H2020 Euro-Argo-Rise project (2019-2022).

- Western Subtropical North Atlantic Ocean (profiling float units x 2; Fig. 6). Numerical simulation using virtual fleet of Argo floats suggests that it could be achieved by changing "on line" the cycling duration to 5 days for floats entering the box defined by (75°W/35°W-35°N/50°N). This should be tested with real floats.
- Equatorial Atlantic Ocean (profiling float units x 2 ; Fig. 6).
- South Atlantic Ocean (30°S/45°S-70°W-20°E - units of profiling floats x 2; Fig. 6)
- Equatorial Pacific Ocean (10°N/10°S-Units of profiling floats x 2; Fig. 6)

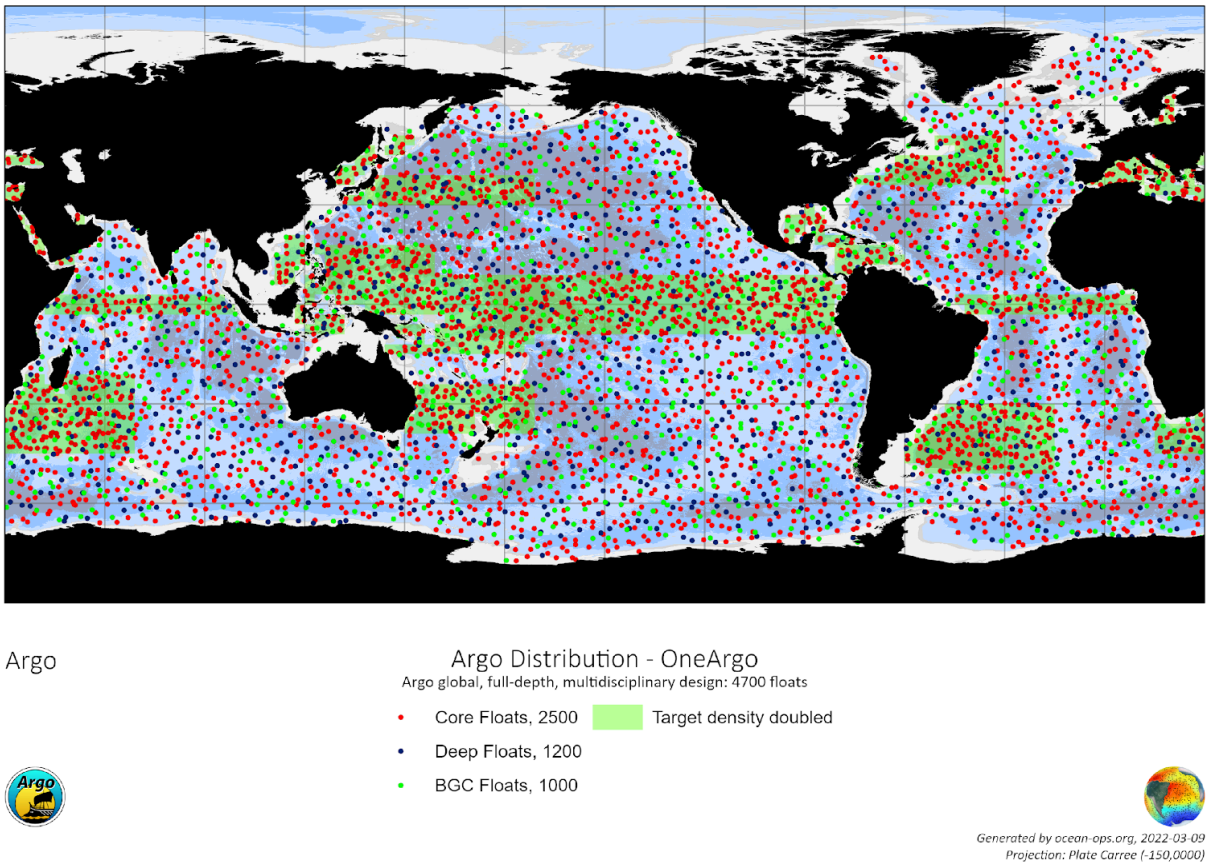

Figure 6: One Argo Design (1 prof / 10d x 3 ° x 3d = 1) and plan for Core, Deep and BGC, with double density in the western boundary currents and marginal seas.

Priority 4: Adjacent regions. The goal of the network: 1profil x 3°x3°x10days in areas where the mesh is not reached (see Figure 4)

2.2 Sampling scheme strategy

Profiling floats now all use Iridium and should **transmit around 1000 points evenly distributed over the vertical (i.e every 2 dbars)**. For floats equipped with pumped Sea Bird CTDs, the pump of the CTD should be stopped at 2dbar to avoid pollution of the cells. Floats equipped with RBR CTDs are sampling up to the surface.

CTD sampling during drift shall happen at regular intervals, **we recommended every 3 hours.**

Following AST recommendations in order to avoid biases in the climatic time series in near surface heat content and flux estimate, we recommend floats to profile every **235 hours**, to allow an around-the-clock daily sampling.

It is recommended to let the **float drift at surface for 20 minutes after each cycle and provide a 2nd GPS fix before its next dive** in order to calculate trajectories and surface drift

velocities, useful for derived products such as ANDRO (SNO Argo France). It is also anticipated that these 2 GPS fixes could be used for new applications related to the estimation of small scale surface currents (e.g. cal/val SWOT and surface current doppler remote measurements).

Finally, the Iridium communication system offers the possibility **to implement adaptive sampling strategies during the mission** in consultation with SNO Argo France scientists and following the recommendations of the Argo International regional strategies, especially in **the equatorial and western-westerly regions.** (Argo 2025 : AST, ADMT, Euro-Argo).

In Polar ocean, the sea ice/ice cape presence has a strong constraint on the floats operations. Ice evasion algorithm should be activated on float (extra coast to anticipate on NKE float to activate the option). Because of specificity of the operation in ice environment (e.g. larger probability to lose the floats), ad-hoc sampling scheme could be adapted to the region of deployment, in concertation with Argo France experts.

3 Recommendation for profiling floats equipped with DO sensor (P/T/S/DO 0-2000m)

→ 11 profiling floats per year[2]

Dissolved oxygen (DO) measurements in oceanography have historically been associated with measurements from bathysondes (CTD-O_2) of cruise surveys. Argo profiling floats are not initially equipped with this type of DO sensor. Thus, historical DO measurements are biased towards the 80-90's (mainly by bottle sampled).

In particular, the DO measurements make it possible to better characterize deep mixing layers, particularly at high latitudes, monitoring the ventilation of deep water masses, carbon cycle, and also the evolution of the oxygen minimum zones (OMZ) in tropical oceans.

Since the mid-2000's, oxygen sensors have been available to equip Argo profiling floats, and the real-time data processing chain is being implemented at the international level with DACs and GDACs. However, the oxygen data can not be used as it and must be monitored and corrected in delayed mode (DM-QC).

Scientific expertise and complementary measurements are needed to carry out these validations. Therefore, it is important to **prioritize the attribution of DO profiling floats via the GMMC call to PIs involved in the validation of the DO data. Performing a CTD-O_2 cast profiles when deploying** the Argo for the calibration of data is highly recommended but not mandatory.

For these same reasons, it is also important to **focus the deployment of opportunities in the areas of scientific expertise of SNO Argo France scientists** for which the DO measurements are of scientific interest.

In any case, it is recommended to program the profiling float to **perform DO measurements in the air at the surface at least once a month)** in order to quantify potential bias and drifts of the DO sensor.

[2] Average number of floats over 2022-2027. Funding: Ifremer, SHOM, CPER, NAOS

3.1 Geographical priorities

Priority 1 : North Atlantic sub-polar gyre,
Priority 2 : South of the Gulf Stream and North Atlantic Drift,
Priority 3 : Eastern areas of tropical Atlantic basins(OMZs).

The deployment priorities aim to allow for optimal sampling over time and space to determine a climatology and a seasonal cycle, reliable oceanic 3D structure of oceanic DO. This sampling will have the same objectives as the Core Argo T/S network : i.e. 1 profile by 3°x3 °x10j, in consultation with the objectives of BGC Argo, and 2 **GPS points during surface transmissions.**

3.2 Sampling scheme strategy

Floats equipped with an optode shall have the same sampling scheme as the standard CTD floats.

4 Recommendation for deep floats - Deep Arvor (P/T/S/DO 0-4000m)

The development of deep profiling floats is still recent and so far a global strategy for an Argo-deep network is that of setting up pilot areas and promoting a global implementation. At French level, the strategy is developed through pilote-array entrusting the deployment to scientists through the AO GMMC, and opportunity deployments.

Deep ocean variability is small, and probably of the same order of magnitude as the precision of the T/S SBE41 probe equipping the profiling floats. To ensure the quality of the measurements, **scientific campaigns performing CTD-O_2 and winkler profiles are preferred for Deep floats deployments.**

4.1 Geographical priorities

At the French level, the deep profiling floats that will not be assigned during the GMMC call will have to be deployed:

- **Priority 1 : In the subpolar gyre of North Atlantic so as to sustain a deep Argo network in this area.**
- **Priority 2 : In the Southern Ocean** for the monitoring of deep water masses formed along the Antarctic continent.
- **Priority 3 : In the the Atlantic Ocean** to strengthen and sustain a Deep-Argo array in that basin as part of OneArgo. We recommend concentrating deployments in a few given regions to ensure good coverage (i.e. sampling close to the Argo target) in those areas, rather than trying to achieve homogeneous coverage everywhere but far from the Argo target.

4.2 Sampling scheme strategy

The default programming of Deep floats, which are all equipped with a DO sensor will be the same

as for the standard and CTDO2 floats with the extension of the profile to full depth. They shall therefore have the same sampling scheme as standard floats in between 2000m and the surface (i.e every 2 dbars) and a vertical sampling of 5 dbars intervals below 2000 m.

Should the PI choose a deeper drifting depth than 1000m he should ensure that the float will remain in Deep area (depth >2000m) to maximize the use of the float capability.

In regions shallower than 4000 m, the floats will be able to sample the bottom boundary layer. In this boundary layer, mixing and turbulence processes are more intense due to current-topography interactions. Sampling may be increased in the bottom boundary layer to explore these still little known dynamic regimes. This sampling can be adapted according to the structures and bathymetry encountered but by default the Deep Arvor floats will be set to sample at 1 dbar resolution above the ground in case of grounding.

5 Recommendation for BGC floats (Provor, P/T/S/DO/PH/FLBB/PAR/NO_3)

5.1 Geographical Priorities

Priority 1: AST recommendation and priority as part of OneArgo

The analysis of the float density and coverage, along with its evolution over the past year, highlights four regions that have consistently shown a float deficit: the Gulf of Guinea, the Indian Ocean, the Western Pacific, and the Southeastern Pacific (Figures 7 and 8). Although several deployments are planned, they are unlikely to fully address the gaps in these oceanic regions. As a result, the community needs to intensify its efforts, prioritizing deployments in these areas.

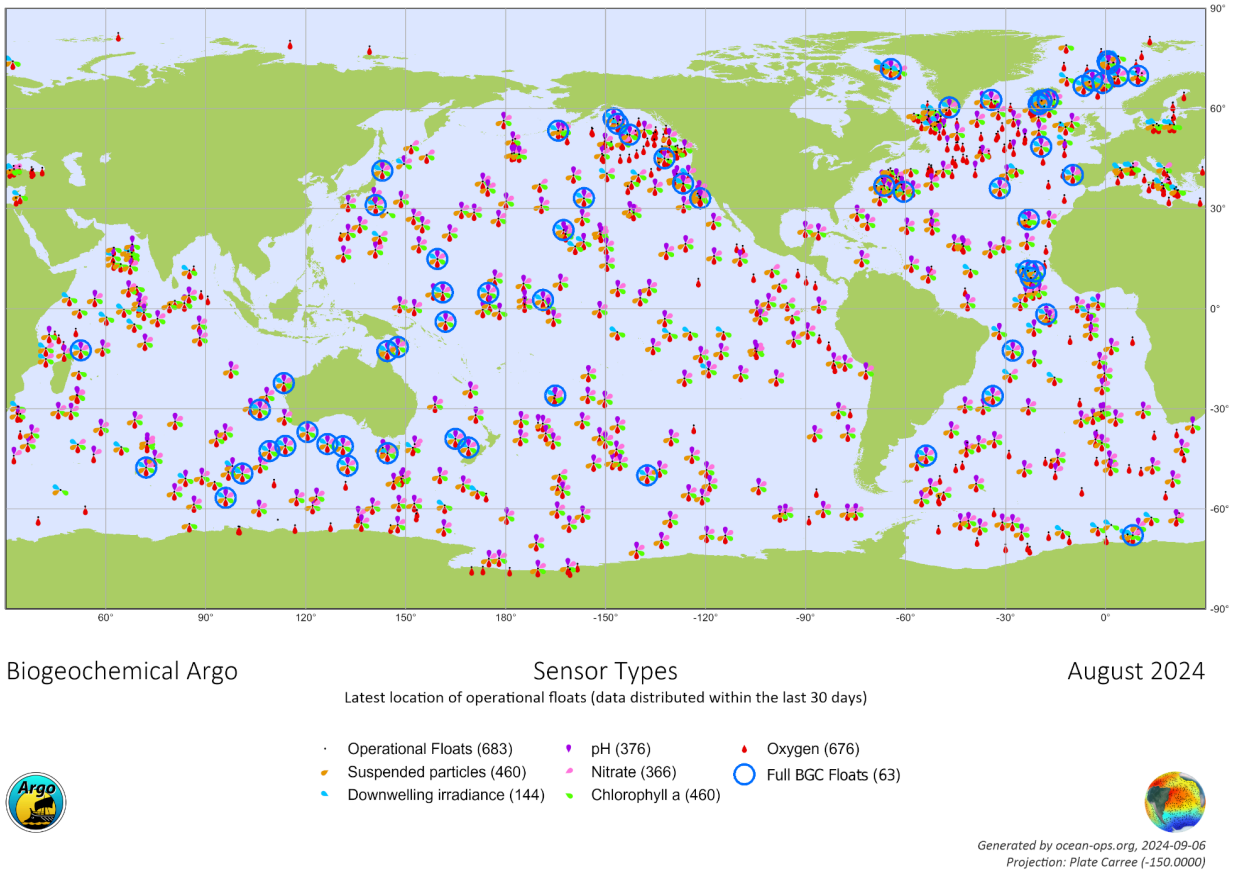

Figure 7: Current sampling of the global BGC-Argo network with the color/symbol code indicating the measured variable among the 6 BGC variables (pH, Dissolved oxygen, Suspended particles, Chlorophyll a, Downwelling Irradiance, and Nitrates).

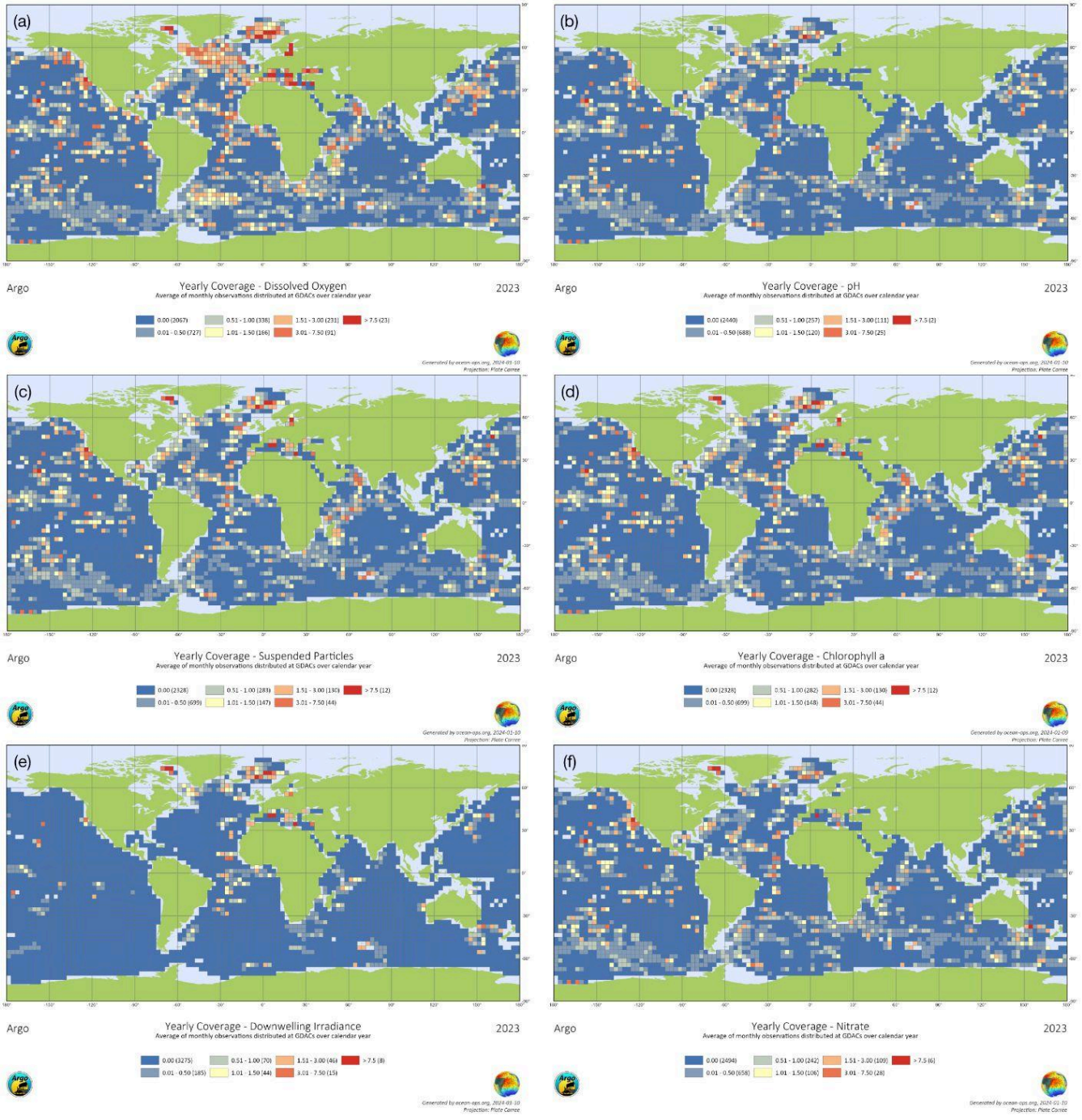

Figure 8: Density coverage of the global BGC-Argo fleet for each measured variable for the year 2023: (a) Dissolved oxygen (DO), (b) pH, (c) Chlorophyll a, (d) Suspended particles, (e) Downwelling irradiance, and (f) Nitrate.

Priority 2: Historical french regions of scientific interest

Many ocean regions are the focus of multidisciplinary collaborative efforts by the French community, as part

of long-term observation observatories and dedicated research projects. The SNO Argo France is seeking to contribute to this effort through deployments of BGC-Argo floats, either allocated via the LEFE GMMC call or via opportunities for deployments. These regions include, in particular, the Western Mediterranean Sea, the North Atlantic Ocean, the Southwestern Indian Ocean, or the Tropical Atlantic Ocean (Figure 9).

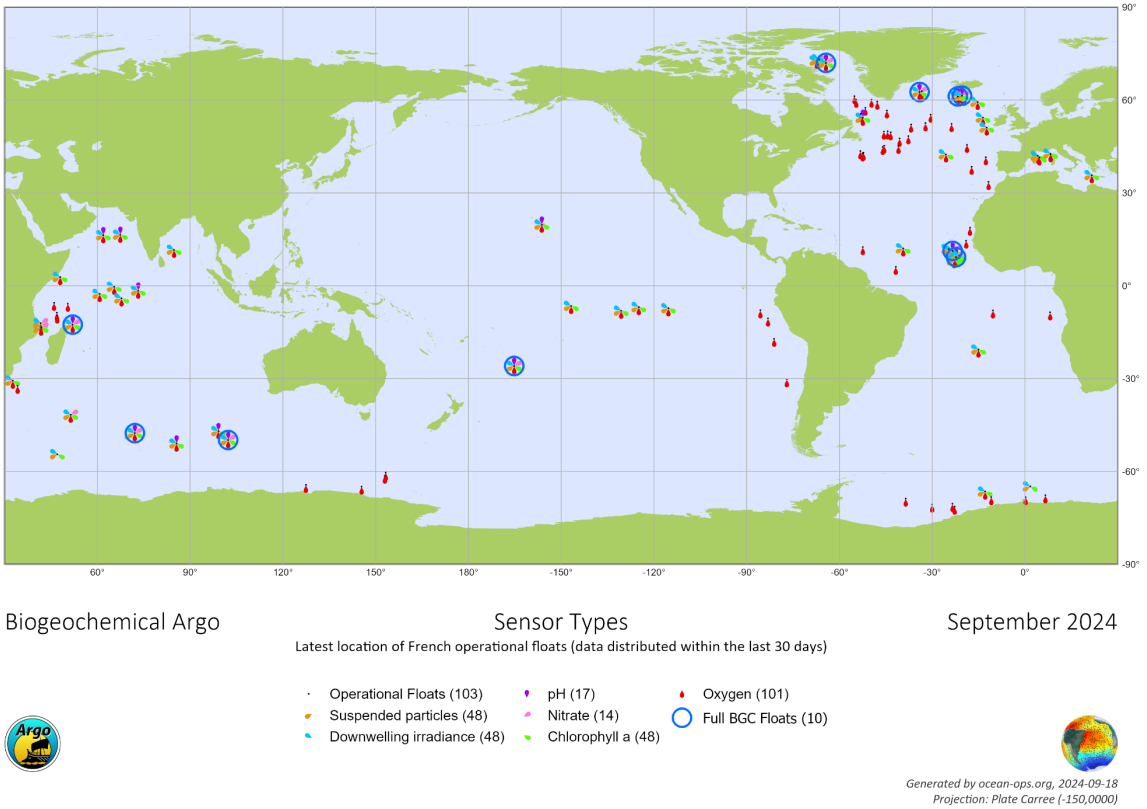

Figure 9: Location of the active BGC-Argo floats deployed by the French community with the color/symbol code indicating the measured variable among the 6 BGC variables (pH, Dissolved oxygen, Suspended particles, Chlorophyll a, Downwelling Irradiance, and Nitrates) as of September 2024.

5.2 Sampling scheme strategy

NKE CTS5 Provor (BGC-Argo) floats are attributed by the GMMC scientific committee following the proposals submitted by French PIs to the annual LEFE/GMMC call. CTS5 floats are equipped with sensors capable of measuring biogeochemical properties among which 6 Essential Oceanic Variables (EOVs), i.e. Suspended particles, Downwelling irradiance, Dissolved Oxygen, Nitrate, Chlorophyll-a and pH, in addition to the CTD parameters (P/T/S). The measurements have to be done during the ascent phase of the floats following the default vertical and along the drift (1000 dbar) sampling schemes for each BGC variable as described in Table 5.2. The CTS5 is also capable of integrating the new Ramses (TriOS) hyperspectral radiometer.

CTS5								
Variable	**Sensor type**	**Surface**	**0-1m**	**1-10m**	**10-300m**	**300-1000m**	**1000-2000m**	**DRIFT ALL ZONE**
DO	Optode	every 10sec for 120s	60 sec	10sec (1m)	25sec (2,5m)	100sec (10m)	200sec (20m)	0
P/T/S (0,5Hz, cut-off 3db)	CTD	0	mean slide 1	mean slide 1m	mean slide 2m	mean slide 10m	mean slide 50m	60 min
Chlorophyll a	Fluorometer/Backscatterometer (e.g. Seabird ECO FLBB)	0	60 sec	2sec (0,2cm)	10sec (1m)	25sec (2,5m)	200sec (20m)	30 min
Suspended particles	Fluorometer/Backscatterometer (e.g. Seabird ECO FLBB)	0	60 sec	2sec (0,2cm)	10sec (1m)	25sec (2,5m)	200sec (20m)	30 min
Downwelling irradiance	4 wavelength-radiometer (e.g. SeaBird OCR)	every 10sec for 120s	60 sec	2sec (0,2cm)	10sec (1m)	-	-	24 h
pH	pH sensor	0	60 sec	10sec (1m)	25sec (2,5m)	100sec (10m)	200sec (20m)	0
Nitrates	Nitrate sensors (e.g. SeaBird SUNA)	0	500 sec	25sec (2,5m)	100sec (10m)	500sec (50m)	500sec (50m)	0
	Sensor type	**Surface**	**0-20m**	**20-100m**	**100-200m**	**200-300m**	**300-2000m**	**DRIFT ALL ZONE**
Downwelling irradiance (Hyperspectral)	**Hyperspectral radiometer (e.g. TriOS Ramses)**	every 4sec for 120s	5 sec (+dec 0,1)	10 sec	20 sec	100 sec	-	24 h

Table 5.2: Vertical sampling scheme for NKE CTS5 floats (les résolutions verticales sont données pour une vitesse verticale de 10cm/s).

In the framework of OneArgo, the BGC Argo should contribute to CTD core measurements. The default cycling strategy defined for OneArgo will be 1 profile every 245 hours (i.e. 10 days plus 5 additional hours) to allow a random sampling around the clock in order to capture the diurnal variability and not to bias the climatic time series. Regarding BGC sampling, dissolved oxygen air calibration is suggested to be more accurate at night (Bushinky, 2016), while for satellite calibration purposes, radiometric measurements (downwelling irradiance) should be performed at local noon when the solar irradiance is maximum to minimize the calibration error. The estimation of Chlorophyll-A from fluorescence may be affected by the non-photochemical quenching (NPQ) during daytime, but methods to correct this effect have been proposed, based on backscattering measurement for example (e.g. Swart et al., 2015, Thomalla et al., 2018, Terrats et al., 2020). We have also dedicated floats equipped with hyperspectral radiometers for measuring radiance and irradiance, funded by the French Space Agency for ocean color product calibration and validation. For these floats, it will still be possible to maintain sampling at local noon, while all other floats will use around-the-clock sampling.

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