Dossier de labellisation 2025-2029
Service National d'Observation (SNO) Argo France

DESCRIPTION GÉNÉRALE DU SERVICE

A1- Nom du service : Service National d'Observation Argo france

A2- Adresse URL du site web du service : https://www.argo-france.fr/

A3- Résumé du service (1/2 page maximum) : Depuis le début des années 2000, le programme international Argo vise à déployer un réseau de plus de 3000 flotteurs profileurs autonomes dans l'ensemble de l'océan mondial, afin d'observer *in situ* les caractéristiques hydrologiques (température, salinité et pression) de la colonne d'eau de la surface à 2000 m de profondeur entre 60°N et S. En 2019, le programme Argo est devenu OneArgo. OneArgo est désormais un programme multidisciplinaire global des mesures *in situ* physiques et biogéochimiques de la surface au fond de l'océan global jusqu'aux latitudes polaires. En plus de la mission « Core » historique mesurant les paramètres physiques (P/T/S, 0-2000 m), trois nouvelles missions ont été ainsi définies : les missions BGC (paramètres biogéochimiques: oxygène dissous, chlorophylle-a, nitrates, irradiance, particules en suspension et pH), Deep (au-delà de 2000 m de profondeur) et Polaire (au-delà de 60°N/S). La série temporelle globale de qualité "recherche" pour les données physiques est maintenue depuis plus de 20 ans (2000-2023). Ainsi depuis 2 décennies, Argo révolutionne notre connaissance de l'océan et du climat, et est devenu la colonne vertébrale du système d'observation global de l'océan pour la recherche scientifique sur l'océan et le climat et l'océanographie opérationnelle.

Au niveau européen, Euro-Argo est une infrastructure de recherche à statut d'ERIC, basée en France, organisant et coordonnant les contributions européennes au programme international Argo.

Au niveau français, Argo France regroupe l'ensemble des activités françaises contribuant au réseau international OneArgo. Les activités d'Argo France regroupent : les développements technologiques sur les flotteurs (sur projet); l'IR* (Très Grande Infrastructure de Recherche) en charge du pilotage opérationnel d'Argo France (achat de flotteurs, coordination et organisation des déploiements, prise en charge et gestion de la base de données par le Centre de Données et de Service In situ Coriolis).

Enfin, au sein de l'IR* Argo France, le Service National d'Observation (SNO) Argo France prend en charge le pilotage scientifique d'Argo France : la mise en place du contrôle qualité et le suivi des données, la valorisation et la distribution des données et des produits de données Argo, la coordination scientifique du programme Argo France, l'expertise, et la représentation dans les instances nationales (GMMC, FrOOS, …) et internationales (Euro-Argo, Argo Steering Team AST, Argo Data Management Team ADMT, …), où notamment les membres du SNO Argo France sont leaders sur les différentes missions de OneArgo. Le SNO est porté par le LOPS à l'OSU IUEM et par le LOV/IMEV dans les OSUs partenaires STAMAR et EcceTerra (SU) pour la composante BGC-Argo.

A4- Nom du responsable : (nom, titre, adresse électronique) : Nicolas Kolodziejczyk, Physicien Adjoint CNAP, nicolas.kolodziejczyk@univ-brest.fr

A5- Laboratoire : Laboratoire d'Océanographie Physique et Spatiale (LOPS), UMR 6523

A6- OSU ou établissement/organisme de rattachement : OSU IUEM UBO

A7- Autres organismes associés : Ifremer, CNRS, SHOM, SU

A8- Signature du responsable :

A9- Signature du directeur OSU gestionnaire (ou établissement/organisme de rattachement) :

Frédéric JEAN
Directeur de l'IUEM

A10- Autres laboratoires et OSU intervenant dans le fonctionnement du service (pour chaque laboratoire concerné ou équipe impliquée, indiquer le nom et l'adresse électronique du responsable, et donner en deux lignes maximum, la nature de l'implication dans le service, hors exploitation scientifique) :
Expertise BGC Argo : Laboratoire d'Océanographie de Villefranche sur Mer (LOV), UMR 7093 Responsable : Frédéric Gazeau (frederic.gazeau@imev-mer.fr) ; Institut de la Mer de Villefranche (IMEV), FR3761 Responsable : Elisabeth Christians (dir-imev@imev-mer.fr; elisabeth.christians@imev-mer.fr) ; OSU STAMAR Responsable : Eric Thiebaut (thiebaut@sb-roscoff.fr ; OSU ECCETERRA Responsable : Arnaud Huguet (arnaud.huguet@sorbonne-universite.fr)

A11- Le service proposé consiste-t-il en une demande

- **de labellisation dans la continuité d'une labellisation existante (oui/non) ? Oui**
  Evolution d'Argo vers OneArgo : global, multidisciplinaire, surface-fond (nouvelles missions BGC, Deep et Polaire)
- **de labellisation d'un nouveau service (oui/non) ? Non**

A12- Lien avec une IR ou IR* (oui/non) : oui
Si oui, préciser la (les) IR/IR* (*inclure une lettre de soutien de la ou des IR/IR* en annexe au dossier*) :

- Le SNO Argo France fait partie de l'IR* Euro-Argo France, elle-même composante nationale de l'ERIC Euro-Argo
- Le centre de données Argo pour la France est pris en charge par le Centre de Donnée et de Servies In Situ Coriolis (CDS-IS-Coriolis), composante du pôle de données "Marines", ODATIS au sein de l'IR DataTerra
- Des transversalités existent également et naturellement avec les SNOs de mesures hauturières du projet d'IR OHIS (SSS, MEMO, PIRATA, OVIDE/GOSHIP) et également avec le SNO MOOSE de l'IR ILICO.

Si non, préciser les raisons : N/A

A13- Le service proposé comprend-il des activités stratégiques pour le spatial ? : oui

Le cas échéant, préciser la (les) mission(s) : SSS (SMOS, SMAP), Altimetrie (Topex-Poseidon, Jason, Sentinel…), gravimétrie (GRACE, -FO), couleur de l'eau (seawifs, Modis, …)
A14- Le service proposé comprend-il des activités stratégiques pour le polaire ? : Oui
Le cas échéant, préciser les moyens mobilisés : pas de moyen mobilisé

A15- Le service proposé comprend-il des activités stratégiques pour l'IRD (oui/non) : Oui
Si oui, préciser les moyens mobilisés : pas de moyen mobilisé

A16- Le service proposé comprend-il des activités stratégiques pour Météo-France (oui/non) : Non
Si oui, préciser la (les) moyens mobilisés : pas de moyen mobilisé

A17- Le service proposé relève-t-il

- **d'autres domaines de l'INSU ? : ☐ SIC ☐ TS ou ☐ AA**
- **d'autres instituts du CNRS ? : ☐ INEE ☐ INC ☐ INSIS ou autre préciser :**

A18- Lien avec un pôle ou un centre de données (oui/non) : oui
Si oui, préciser le(s)quel(s) (*inclure une preuve d'appartenance ou d'adhésion en annexe au dossier*) :
Le centre de données Argo pour la France est le Centre de Donnée et de Services In situ Coriolis (CDS-IS-Coriolis), composante du pôle de données "Marines" ODATIS, de l'IR DataTerra

DESCRIPTION DÉTAILLÉE DU SERVICE

B1. Contexte, motivations et objectifs scientifiques

In 2000, the international Argo program was launched by the International Oceanographic Commission (IOC) and World Meteorological Organization (WMO) to measure the global ocean *in situ* pressure, temperature and salinity (P/T/S), in order to monitor the ocean's variability and understand its role in the Earth climate system, in particular the amount of heat stored in the Global Ocean in response to the Anthropogenic Global Warming and natural ocean variability. To reach this scientific goal, the prerequisite was to provide near-real time profiles of ocean state parameters every 10 days for each 3x3 degrees area of the global ocean. This corresponds to about 3000 floats operating permanently at sea (*Riser et al.*, 2016[1]). Given the autonomous floats technology available at the beginning of the program in 2000, parameters were limited to P/T/S (so called "core-Argo" mission), sampling depth was limited to the first 2000m of the water column and sampling area was limited to the open ocean between 60°N/S, away from marginal seas and high latitudes. It took about 8 years for the international community to reach this sampling target (from 2000 to the end of 2007). Then, more than fifteen years later (2019 and ongoing), more than 2 millions quality controlled profiles have been distributed publicly (*Argo, 2024*, https://doi.org/10.17882/42182, *Wong et al.*, 2020), overwhelming in one decade the amount of profiles ever carried out in the history of oceanography. In addition to the major increase in high quality data quantity due to Argo, the historical northern hemisphere in data coverage is suppressed by the uniform global sampling design of the array. Argo also has rectified a major seasonal bias in sampling, particularly in the subpolar oceans. It is thus not surprising that the international Argo program is now the backbone of the *in situ* Global Ocean Observing System (GOOS) and has hence revolutionized our vision and scientific understanding of the ocean in unexpected ways for two decades (e.g. *Johnson et al.*, 2022 for scientific review of Core Argo achievements).

In 2019, the Argo international program has turned into OneArgo : "Global, Multidisciplinary and surface-depth" (AST20, March 2019, Hangzhou, China) implementing a coordinated global new design (*Roemmich et al.*, 2019): the extensions towards biogeochemical measurements, the so-called "BGC-Mission" (oxygen, pH, chlorophylle-a, nitrate, downwelling irradiance, suspended particles, ~1000 floats); the deep Ocean below 2000 m depth, the so-called "Deep-Mission" (~1200 floats); and towards the marginal seas and high latitudes, the so-called "Polar-Mission" (beyond 60°N/S), complementing the historical "Core-Argo" mission (~2500 floats). In addition, increasing regional resolution in key areas like the Western Boundary Currents and equatorial regions is envisioned. The Core and BGC variables are among the so-called Essential Ocean Variables (EOVs), Ecosystem EOVs (eEOVs), or Essential Climate Variables (ECVs). This new phase of the OneArgo program has come along with new scientific questions :

- The BGC Argo mission aims to address a large variety of scientific challenges. These encompass ocean acidification, the evolution of oxygen minimum zones and their role in nitrogen cycling, the exchange of CO_2 at the ocean-atmosphere interface, the functioning of the biological carbon pump and its contribution to carbon sequestration, the impact of phytoplankton communities in structuring higher trophic levels and the carbon cycle. In addition, BGC-Argo and its anticipated development towards enhanced biological and ecological observations (BGC-ECO-Argo) also have strong potential to address key societal questions, including: establishing refined global carbon budget to support mitigation actions; increasing the use of real-time data for improved fisheries management; developing in the near-future information-based governance in the high seas (e.g. Marine Protected Areas; monitoring, reporting and verification of marine carbon dioxide removal approaches).
- The Deep Argo mission is motivated by the need for a systematic sampling of the full ocean depth as Core Argo monitors only half of the ocean volume (*Zilberman et al., 2023*). Such sampling is required to close the planetary budgets of heat and freshwater, to close the global sea level budget and to monitor the strength and variability of the large-scale ocean circulations that extend from

[1] References in blue includes at least one co-author member of the SNO Argo France

the sea surface to the ocean bottom and play significant roles in the uptakes and transports of heat and freshwater, and melting of sea ice. Other benefits of Deep Argo are to establish relationships between fluctuations of the deep Meridional Overturning Circulation (MOC) and changes in ocean temperature and salinity and their representations in ocean reanalyses and forecasts.

- The Polar mission aims to address scientific challenges specific in ice covered and Marginal Ice Zone regions such as rapid oceanic changes at high latitudes in the context of climate change, freshwater cycle intensification, ocean-ice interaction and polar BGC cycles. Polar regions are also poorly sampled. In complementarity with other observing systems, Polar Argo will help to better monitor interannual to long term change in physical and BGC properties and patterns.

The scientific objectives of OneArgo come along with main operational objectives and values for operational activities:

- to implement new parameters and observation sites (BGC parameters, deeper Ocean, high latitudes, marginal seas) to achieve the OneArgo interdisciplinary *in situ* network of measurements to fill the observational gaps of the Core Argo Mission;
- to provide observations for calibration, validation and interpretation of satellite remote measurements (SST, SSS, Ocean Color, Sea Level…, *see ANNEXE D*) ;
- to provide observations to initialize and constraint numerical model simulations and operational ocean monitoring and forecasting systems (e.g. “Blue” and “Green” Mercator) ;

In order to reach these scientific and operational objectives, OneArgo needs to continually provide high quality data and long term timeseries to the ocean research community, including modeling and satellite communities, as well as national operational and climate monitoring services. OneArgo also provides high quality data to develop new dimensions of climate assessment for stakeholder and general public, educational resources for ocean and climate literacy. The high societal impact of OneArgo will enable:

- to improve climate intelligence to sensitive industries, such as agriculture, energy, aquaculture, fisheries, insurance, and resource extraction ;
- governments to better manage pollution dispersion, search and rescue, and national defense ;
- establish syntheses with satellite observations to close global and regional sea level rise, energy and biogeochemical budgets, and monitor the ocean health, vital for tracking global change ;
- develop more accurate climate projections enabling better societal adaptation.

To tackle these global challenges, the OneArgo Program relies on national commitments and contributions from about 25 countries that have signed up in the program. The Argo France national program is the French contribution to the international OneArgo program, including its new missions toward deep and biogeochemical measurements, high latitudes and marginal Seas. It is part of the Ministry of Research national roadmap on research infrastructure as the IR* Euro-Argo France.

The scientific activities of the IR* Euro-Argo France are organized through the SNO Argo France, which is affiliated with the OSU IUEM (Institut Universitaire Européen de la Mer, UAR3113, Plouzané, France). Two research laboratories are leading Argo France scientific activities: the "Laboratoire d’Océanographie Physique et Spatiale'' (LOPS UMR6523, Brest, France), and the "Laboratoire d’Océanographie de Villefranche / Institut de la Mer de Villefranche” (LOV UMR 7093 / IMEV FR 3761, Villefranche-sur-Mer, France) and are also supported by OSU Ecce Terra (UAR3455, Paris, France) and OSU STAMAR. The objectives of the SNO Argo France are the followings:

- to provide research quality OneArgo data to the French scientific community in order to foster and promote the French contribution to climate studies, and more generally to oceanographic research conducted with Argo data (physical and biogeochemical parameters) either directly or through re-analysis or assimilation products.
- to contribute and implement OneArgo including : sustain the OneArgo Core Mission (P/T/S), implement the global BGC Mission and Deep Mission, and promote the new Polar Argo Mission.

- to consolidate and organize the French contribution to the international Argo program and to the European research infrastructure Euro-Argo ERIC.

Euro-Argo is a legal European entity to organize a long-term European contribution to Argo and hosted in France (Ifremer, Brest). The main objective of the Euro-Argo research infrastructure consortium is to organize and consolidate the European contribution by maintaining 1/4 of the network and to sustain a research infrastructure in support of the global Argo program. The Euro-Argo project involves 25 organizations from 12 countries, including France, Germany and UK who are the 3 major European contributors to Argo. All partners join their efforts to optimize their collective contribution to relevant EU policies, programs and projects. Euro-Argo has been endorsed by the European Strategic Forum on Research Infrastructures (ESFRI) in 2006. The Euro-Argo ERIC was then officially set-up in May 2014.

B2. Mission d'observation

1) OneArgo Objectives

The observation missions design for the OneArgo array is the following (4700 floats, Fig. 1):

- **Core Argo (2500 floats, currently 2983)**: To measure Pressure/Temperature/Salinity from the surface to 2000m (historical Argo mission)
- **BGC Argo (1000 floats, currently 383)**: To measure 6 BGC variables (O_2 (DOXY), pH (PH_IN_SITU_TOTAL), Nitrate (NITRATE), Chlorophyll-a (CHLA), suspended particles (BBP) and downwelling irradiance (DOWN_IRR) from the surface to 2000m.
- **Deep Argo (1200 floats, currently 194)**: To measure Pressure/Temperature/Salinity from the surface to the deepest depth possible (4000m or 6000m).
- **Polar Argo :** extension beyond 60°N/S. At the moment, the design is under discussion.

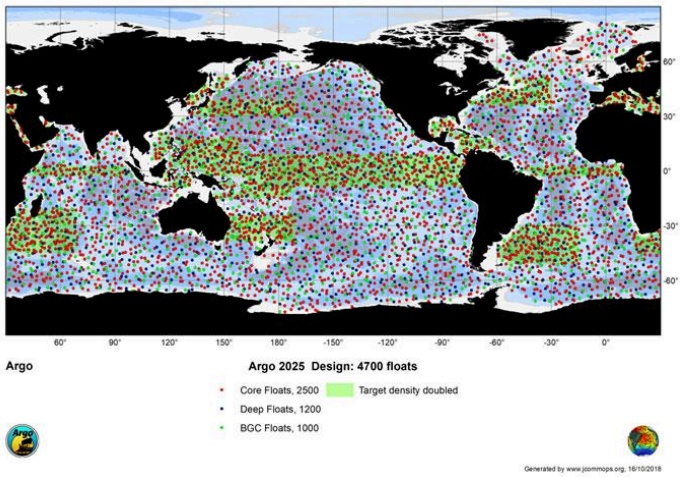

Figure 1*: OneArgo Design : 4700 floats including 2500 Core floats, 1200 Deep floats, 1000 BGC floats and the areas with double density of floats are defined in green. The Polar Mission target design is under discussion.*

To measure these variables **globally including latitudes beyond 60°N/S and marginal seas**, following a nearly random but uniform sampling strategy of at least **1 profile per 3°x3° every 10 days, with a sampling doubled in the western boundary currents and tropical areas.** Note that BGC and Deep floats also contribute to the Core mission since they are equipped with CTD sensors (P/T/S). The OneArgo design takes into account this complementarity.

The observation mission of Argo France is to contribute to about 10% of the global OneArgo array observation missions described above. France has become the 2nd contributor (behind the US) to OneArgo. Over the last 5 years the SNO Argo France has contributed to the consolidation of this contribution and started the implementation of OneArgo through different funded projects (CPERs, ANR, Ifremer, ERC, EU H2020 : see *Section B2.4b*). To achieve its mission, the SNO Argo France has set up clear objectives and reached the following achievements:

2) To provide "research quality" data to the scientific community

Since 2000, Argo France has qualified the total number of **296 792 profiles** of any mission (Core/BGC/Deep). Note that, the International Argo program has collected more than 2.9 millions profiles, of which, about 10% are of France origin. **From January 2019 to March 2024,** Argo France provided **77 828 new qualified 0-2000 m Core profiles** of the parameters pressure/temperature/salinity (P/T/S) and **24 429 new BGC profiles**, and **5 616 Deep profiles** to the community through Coriolis DAC (the French Argo Data Assembly Center; Fig. 2a). These profiles were quality controlled (QC) in real time (RT ; **39%**) and delayed mode (DM ; **61%**) (Fig. 2b) with peer reviewed methods to ensure the best data quality for operational oceanography and climate research (see *Section B4*; *Wong et al.*, 2020 ; *Cabanes et al.*, 2021 ; *Schmechtig et al.*, 2023 ; *Zilbermann et al., 2023 ; Wong et al.*, 2024;). There is always a delay of a couple of months/years between the distribution of a profile in Real-Time and in Delayed-Mode. It is due to the necessary delay for a careful validation with complex methods and operator's expertise.

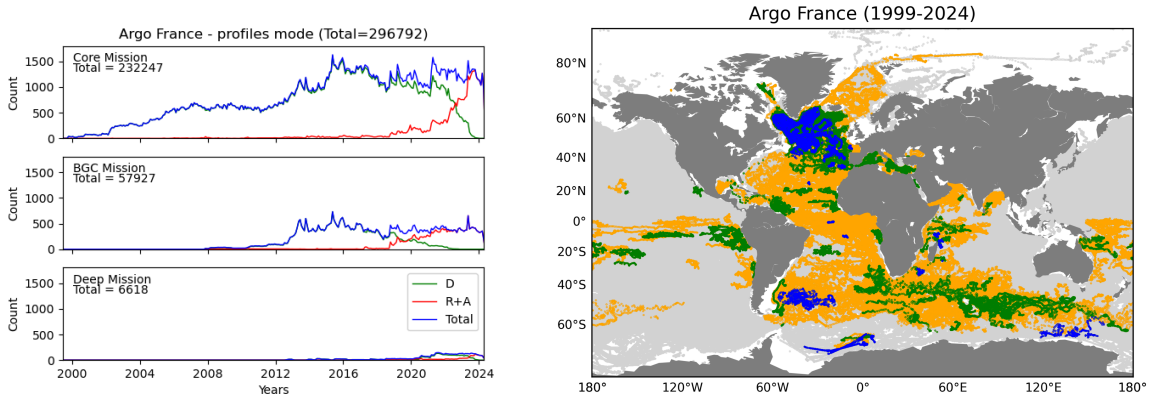

***Figure 2**: (**left**) Number of Argo profiles managed by Argo France from 1999 to March 2024 for (upper panel) P/T/S Core Argo, (middle panel) BGC profiles, (lower panel) Deep profiles. For each mission, the total number of profiles (blue) are divided in a delayed-mode (green) and Real or Adjusted mode (red). (**right**) Map of Argo France profile positions carried out over the period 1999-2024: Core Mission (orange), BGC Mission (green); Deep Mission (blue). The light gray positions are the non-French Argo profiles carried out over the same period.*

The SNO Argo France also has the lead on the **Argo Regional Center for the Atlantic** (A-ARC). Regional centers have the role to ensure the consistency of the validation procedures for P/T/S profiles between all the operators for a given oceanic region. Details will be provided in the upcoming sections but one can highlight here that, since 2015, the A-ARC made significant improvements to the salinity dataset by detecting erroneous delayed-mode corrections (*Cabanes et al.*, 2016, https://www.umr-lops.fr/SNO-Argo/Activities/A-ARC).

a) Core Mission (P/T/S-0-2000 m depth)

Beyond the distribution and qualification of the Core parameters in the form of research-quality vertical profiles, the SNO Argo France also provides **upper level products** derived from high quality vertical profiles : gridded datasets and indicators. The SNO Argo France has developed and maintains the **In-Situ Analysis System** (**ISAS**, *Gaillard et al.*, 2016), which designates a software (and the product) designed to produce a gridded version of the Argo profiles (but also any kind of *in situ* measurement such as Marine Mammals, Moorings, ITP, CTD). The ISAS product is developed, maintained, updated in research mode at LOPS, and widely used by Argo France and the international scientific community (*Kolodziejczyk et al.*, 2023; doi: 10.17882/52367 and https://argo.ucsd.edu/data/argo-data-products/). Then, the ISAS expertise, tools and products are distributed to the whole scientific and operational oceanography community.

In 2013, the SNO Argo France released ANDRO: the first ever dataset of Argo deep trajectory (mostly 1000 dbar) files qualified for research. **In 2024, the dataset, developed at LOPS** (*Ollitrault and Rannou*, 2013) **was updated and now contains research-qualified information for 1 602 964 deep displacements of Argo floats** (Fig. 3). ANDRO files led to the first ever delayed mode trajectory files distributed by Argo GDAC. From displacements, absolute ocean currents, heat and freshwater fluxes can be derived (*Colin de Verdière et al.*, 2019). Over the 2019-2024 period, the SNO Argo France and Coriolis

maintained a regular update of the ANDRO products (doi: 10.17882/47077), and will go on during the following 2025-2029 period.

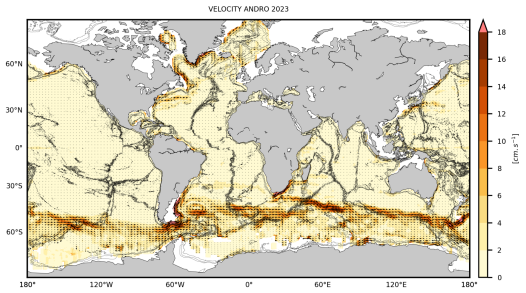

Figure 3: *1000 dbar Global Ocean mean circulation (in cm s^{-1}) averaged between 2000-2023 deduced by ANDRO updated dataset.*

As ANDRO is a costly effort in resources, the full Argo trajectory database has not been curated yet in Delayed Mode (71% in 2024). The SNO Argo France has developed tools for automatic controls on Argo trajectories (https://github.com/cabanesc/TRAJ_QC) that have been implemented in Coriolis to produce a Near-Real Time Argo displacement Atlas (ANDRO-NRT). The full NRT-ANDRO dataset is distributed at Coriolis Data Center via Copernicus (doi: 10.48670/moi-00041). A data paper describing the method is in preparation.

The SNO Argo France also developed **Global Ocean Indicators (GOI)** of the ocean state and variability based on the quality controlled data and peer reviewed published indicators. In particular, GOIs were developed, such as the global ocean heat content (Fig. 4), fresh water content, steric sea level, using ISAS fields. The developed GOIs at SNO Argo France are carefully determined and distributed with error bars that provide a clear and solid basis for climate research and in particular IPCC and WCRP international statements of global ocean long-term changes, see *IPCC report AR6 (2021)* **;** *WCRP, Sea Level Change, (Cazenave et al., 2018); von Schuckmann et al., 2023, WCRP GEWEX Earth Energy Imbalance (Hakuba et al., 2024, in revision) ; the Annual ICES Report on Ocean and Climate (IROC) since 2016 (González-Pola et al., 2019, 2022)* (see: www.umr-lops.fr/SNO-Argo/Products/ISAS-T-S-fields/Climatology-and-climate-indices). GOI methods developed by the SNO Argo France are now used by the Copernicus Marine Service (CMEMS) and updated on a yearly basis (marine.copernicus.eu/science-learning/ocean-monitoring-indicators/catalogue/).

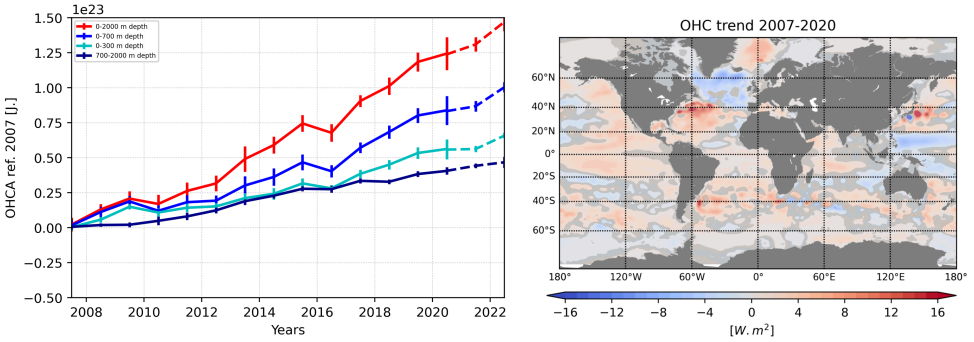

Figure 4*: Global Ocean Heat content computed from ISAS20 (solid) and ISAS-NRT (dashed) products between 0-2000 m depth over the Argo period 2007-2022 (left); and map of decadal Ocean Heat Content trend over 2007-2020 computed from ISAS20 (right) (adapted from Kolodziejczyk et al., 2019).*

b) BGC Mission

During the period 2019-2023, the SNO Argo France has strongly contributed to maturate **a rigorous data management and quality control of the BGC data**, which is a prerequisite to reach the high standard of the international Argo program. The SNO Argo France has worked in close collaboration with the international community to define format and delayed-mode processing procedures for these parameters. This is done through the active participation to Argo BGC meetings and ADMT, to discuss the BGC-Argo community agreement for data management and quality control procedures

(www.argo.ucsd.edu/meetings.html ; see *ANNEXE I*). The SNO Argo France was particularly involved in developing methods for data processing for DOXY (*Thierry et al.*, 2022, doi: 10.13155/39795), and CHLA and BBP (*Schmechtig et al.*, 2018, doi : *10.13155/39459*) variables. The SNO-Argo France has strongly contributed to set up quality control procedure implementation for BGC-Argo parameters (*Schmechtig et al.*, 2023, doi: 10.13155/40879), in particular DOXY (*Thierry et al.*, 2021, doi: 10.13155/46542), BBP (*Dall'Olmo et al., 2023,* doi : 10.13155/60262) and CHLA (*Schmechtig et al., 2023,* doi: 10.13155/35385). The first BGC DMQC workshop was also organized in Villefranche-sur-Mer in January 2023 (see *ANNEXE I)*.

The SNO-Argo France also developed the LOCODOX software that provides the necessary correction to DOXY values that are generally biased toward low oxygen concentrations and subject to a temporal drift (*Takeshita et al.*, 2013, *Bittig and Kortzinger* 2017, *Bittig et al.*, 2018, doi :10.13155/45915). Examples of DOXY data corrected with LOCODOX are available in *Gallian and Thierry* (2018, doi: 10.13155/58314). LOCODOX is freely available https://github.com/euroargodev/LOCODOX.

Thanks to this substantial progress, the BGC-Argo DAC (Data Assembly Center), which was initially operated by Catherine Schmechtig at LOV, was transferred at operational level to the DAC Coriolis in 2017. This was a major achievement for the BGC-Argo data management, and success for the SNO Argo France, which now allows it to move on towards a global BGC-Argo network.

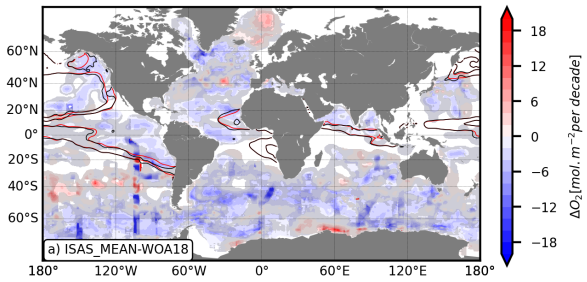

Figure 5 *: Estimation of the DO inventory change over the full water column for the period 1980-2013. Solid red (black) line inadequates the 80 µmol kg^{-1} isoline in the 80's (2010's, i.e. over the Argo period) (Kolodziejczyk et al., in review in ESSD).*

In parallel, further downstream in the data processing chain, the ISAS tool is being adapted to full depth oxygen data to produce gridded fields of DOXY. After complete validation and correction of all global oxygen profiles gridded global fields of Argo DOXY climatology have been produced (*Kolodziejczyk et al.*, under review in ESSD ; Fig. 5) and is freely available at ISAS doi (*Kolodziejczyk et al., 2023* ; doi: 10.17882/52367).

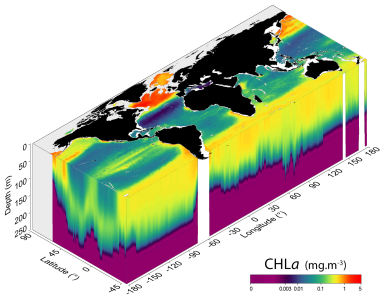

Figure 6*: Three dimensional climatological view of the Chlorophyll-a concentration derived from the BGC-Argo observation-based SOCA product derived operationally delivered by Copernicus Marine Service (https://doi.org/10.48670/moi-00046).*

Moreover, utilizing the SOCA neural network-based method (*Sauzède et al., 2016*), the Copernicus Marine Service product MULTIOBS_GLO_BIO_BGC_3D_REP_015_010 provides a 3D global reconstruction, at a resolution of ¼ degree for 36 vertical levels, of key biogeochemical properties derived from BGC-Argo observations (https://doi.org/10.48670/moi-00046, Fig. 6). These properties include the particulate backscattering coefficient (b_{bp}), its derived product particulate organic carbon (POC), and the total

Chlorophyll-a concentration. The LOV is responsible for developing and enhancing the methodologies to create the product and has been in charge of its operational release since 2020, with yearly updates. In this context of creation of BGC-Argo observation-based products, the SNO is actively involved in the 4D-BGC SCOR WG 168 on "Coordinating the Development of Gridded Four-Dimensional Data Products from Biogeochemical-Argo Observations" (France is co-chair) .

3) To implement OneArgo

a) BGC Mission

The French community has been a historic leader in the **development, promotion and scientific exploitation of the BGC-Argo extension of the Core Argo network**. Since 2016, the international community using biogeochemical sensors on Argo floats has been structured within the framework of BGC-Argo for the development and implementation of the original objective: a global BGC-Argo network as part of the Argo program.

The effort to realize a global array of new parameters has been initially devoted to implementing regional networks over specific regions: Atlantic Ocean, Southern Ocean, and Mediterranean Sea (*Johnson and Claustre*, 2017). The extension to a global array has been decided at the international level and will be achieved by a progressive increase of float density in specific areas and then by a further enlargement of float deployment zones (*Roemmich et al.*, 2019). Since 2019, the BGC-Argo Mission is part of OneArgo. France has been strongly active since 2010 in establishing the firsts regional BGC-Argo network (*Claustre et al.*, 2020). Since 2015, the SNO Argo France has been involved in major developments and implementation of BGC data QC at international level. Thus, Argo France is now in a leading position, including in data management: in 2024, **36% of the global BGC-Argo profiles** are managed and distributed by the French DAC Coriolis. The BGC expertise center of the SNO Argo France is under the responsibility of LOV-IMEV (all biogeochemical parameters) and LOPS (oxygen), ensuring the expertise, contributing to develop and share the international protocols for the national fleet, providing the required assistance for the BGC-Argo scientific use and promoting the BGC-Argo activity at national level.

Additionally, and in line with the initial support of the International Ocean Color Coordination Group (IOCCG) for "Bio-Optical Sensors on Argo Floats" working group (www.ioccg.org/groups/argo.html), successful collaborations between the **Argo/BGC-Argo community and Ocean Color scientists** have continued in the last years. Ocean Color radiometry data could be considered as the satellite equivalent of altimetry for BGC-Argo. Space agencies (CNES, ESA, NASA, EUMETSAT) acknowledge the unique role of dense BGC-Argo bio-optical (CHLA, BBP, radiometry) datasets to cost-efficiently contribute to the validation of Ocean Color and Lidar products (*see ANNEXE D*). By continuously involving the national Ocean Color community in BGC-Argo, the SNO Argo France aims to make greater use of BGC-Argo data for validation purposes and for the development of high-level products, merging float observations and ocean color data (*Section B2.2c*).

These developments are directly connected to the **enlargement of the national BGC-Argo community**. Since 2015, between 2 and 4 BGC-Argo floats per year have been distributed to the national community, through a specific call, after validation by a Scientific Committee (LEFE-GMMC, *Section B2.4a*). In the last 4 years, scientists from five different French laboratories (MIO, LOCEAN, LOPS, LOV-IMEV, SHOM) received, deployed and scientifically exploited BGC-Argo float data. In this context, the SNO Argo France provided all the necessary assistance in the float utilization and in the data management. In return, and exactly as for historical Argo, BGC-Argo PIs are involved in the data validation and consequently contribute to the development/consolidation of the BGC-Argo delayed-mode procedures.

b) Deep Mission

During 2019-2023, the French community has been recognized as a leader **in the Deep-Argo technology and in the implementation of the full depth Argo international network.** France is now co-chair of the Deep-Argo mission Team with the US.

Developments over the last 10 years of floats and CTDs capable of accurate measurements down to 4000 or 6000 dbar made global full-depth Argo implementation feasible. France contributed to the emergence of the Deep-Argo technology owing to the institutional and industrial partnership with NKE instrumentation (EQUIPEX NAOS 2011-2019) that led to the development and commercialization of the Deep-Arvor float with 4000 dbar capability (*Le Reste et al.*, 2016, *André et al., 2020*). Development of a new Deep-argo float model with 6000 dbar capability is ongoing as part of the Ifremer PIANO project (*Section B2.4b*). France has been involved in the implementation of the Deep-Argo array since the beginning. Of the 403 floats deployed over the last 15 years, 22% (88 floats) were deployed by France. There are currently 27 French Deep-Argo floats. While most of them sample the North-Atlantic area to maintain the pilot array initialized in mid-2010s as part of the Equipex NAOS project (*Le Traon et al., 2020*), a growing number of floats were deployed in other basins (Southern Ocean owing to under ice capability, Tropical Atlantic, Indian Ocean) to start the global implementation. The Deep-Argo floats were purchased through the IR* and CPER Brittany funding (Euro-Argo and Obsocean projects).

c) Polar Mission

Since 2023, France co-chairs the new Polar Argo mission Team with Australia. The French community has been recognized as a leader **in the Polar Argo** deployment and technology, i.e. specificity of Argo deployed in regions totally or partially covered by ice. At the moment, software and hardware technology to avoid damage on float in sea ice covered regions has been developed and tested in the framework of the EquipEx NAOS project (*André et al.*, 2020). The Ice Sensing Algorithm (ISA, Klatt et al., 2007) is the operational software technology that has been implemented in operational mode on Argo floats. As initiated in the framework of the EA-Rise project (*Section B2.4b*), Polar Argo good practices and under ice float configurations should be improved, as well as Polar design and scientific objectives should be established. France will promote the Polar Argo mission in the future years, as well as future technological and scientific development for a Polar Argo network. SNO Argo France will become strategic for Polar (*see more details in ANNEXE E*).

4) To organize and consolidate the French contribution to OneArgo

a) National coordination and international representation

Argo France activities and the contributions of each national institute involved in Argo are organized by the IR* Euro-Argo France through a Memorandum Of Understanding that has been signed by Ifremer, CNRS and SHOM in 2019.

The management board (*Section B8*) coordinates national efforts and provides a formal body to discuss a long-term strategy for the national contribution to the Argo program, independently from short-term project constraints. The committee has worked to produce a program strategy to face three challenges over the next 10 years: (i) sustain the Core Mission at its current state of excellence, (ii) contribute to implement the BGC and Deep Mission (iii) and promote the Polar Mission towards the achievement of a global full-depth multidisciplinary network. In order to ensure the **French contribution to the OneArgo global fleet**, Argo France has organized the French float deployment strategy. This strategy relies on two mechanisms : i) Every year French Principal Investigators (PIs) or scientific teams respond to CNRS INSU LEFE GMMC call for scientific proposals to request Argo floats (T/S, DO, Deep, BGC) for deployment in the framework of their scientific projects. The proposals are reviewed by the LEFE GMMC Scientific Committee, which is also the Argo France Scientific Committee (*see section B8*). ii) Generally, a part (>50%) of the available Argo France floats have not been allocated via the LEFE GMMC scientific call, leading to so-called “deployments of opportunity”on the basis of, e.g. recurring cruises associated with SNOs or observatories (PIRATA, MOOSE, OVIDE…), and/or occasionally, sailing, merchant and commercial ships (Core floats only). These profiling floats are under the responsibility of the CODEP (for their deployment and management at sea) and the DAC Coriolis for the processing of the data, including delayed-time QC (*see section B4*). The number of Argo France floats deployed since 1999 is reported in Figure 7. **Note that, finally the majority of the Argo France deployments rely on the scientific cruises operated by the IR* Flotte Océanographique Française (FOF) that are not primarily dedicated for Argo floats deployments.** This allows to better valorise the ship time of the IR* FOF.

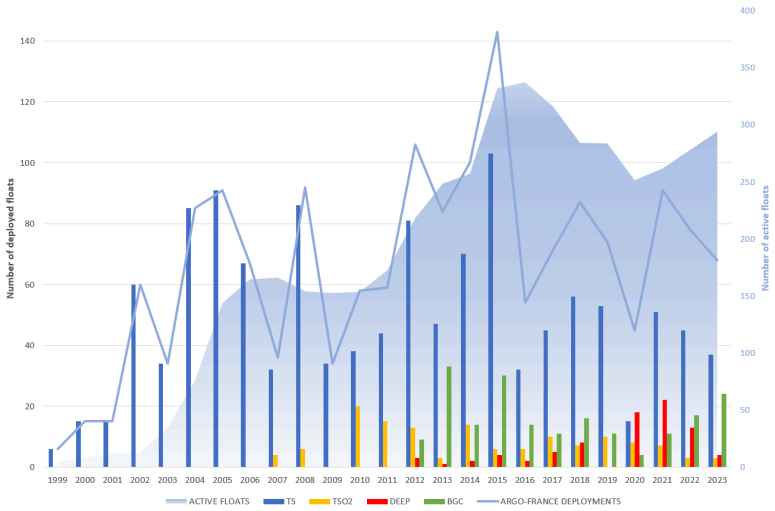

Figure 7*: Number of Argo France floats deployed between 1999 and 2023 for core-Argo (blue); BGC-Argo (green); P/T/S/O2 (orange) and deep-Argo (red).*

France is one of the leaders in the international governance bodies of the Euro-Argo ERIC and within the OneArgo program (*see Section B4 and B8*): in 2024, SNO Argo France members are co-chairing the Deep, BGC, and Polar Missions, as well as The Technological Task Team (TTT) and the BGC Data Management Team (ADMT; *see Table H4, ANNEXE H*). Every year since the early stage of the program in 1999 and up to now, France has participated in all annual international meetings (*ANNEXE I*) of the Argo Steering Team (AST, 1 per year), Argo Data Management Team (ADMT, 1 per year), Delayed Mode Quality Control (DMQC, ~1-2 per year) workshops, and the Argo Science Workshops (1 every 4 years). **The financial support from INSU and OSU to the SNO Argo France was critical to these participations and helped to organize the program at the national and international levels**.

b) Consolidation of Argo France contribution to OneArgo

The initial global sampling target being achieved in 2007, the optimal Core Argo time series is thus 17 years long as of January 2024. The improvement in sampling homogeneously the global ocean is dramatic compared with the previous century of measurements. However, we are still far from being able to study the low-frequency variability of the ocean at the targeted decadal timescale, hence the justification for a multi-decadal observation network. In 2024, Core Argo provided only 34% of the full 50-year T/S time series. The implementation of OneArgo is also far from being achieved, given the target for the BGC (approx 1000 floats) and Deep Missions (approx 1200 floats). Only 38% and 16% of the global BGC and Deep network is currently implemented, respectively. No floats have yet been deployed beyond 80°N in the Arctic Ocean. The funding of the full OneArgo missions remains a real challenge for the next decade.

For this new phase of OneArgo, Argo France aims to deploy around 80 floats per year: 30 Core floats, 20 Core floats with oxygen sensors, 15 Deep floats (Deep Argo) and 15 floats with full biogeochemical sensors (BGC Argo). During the 2019-2024 period and ongoing, as the IR* funding is only secured for a part of the recurrent French contribution to Core Argo Mission, Argo France needs to seek funding for consolidation and implementation of the OneArgo Missions. Over the period 2021-2028, Argo France teams have been funded for five leading and complementary investment projects (>20,9M€), tightly coordinated, aimed at consolidating the Argo Core network and implementing the BGC and Deep extensions (https://www.argo-france.fr/Projets/Pilotage-des-projets-en-cours) :

- **The Ifremer Exceptional Investment Project (PIE) PIANO (2021-2028)**
- **CPER Bretagne ObsOcean and Sud Mariosa - Argo component (2021-2027)**
- **Plan d'Investissement d'Avenir (PIA3) EquipEx+ Argo-2030 (ANR) (2021-2029)**
- **ERC REFINE (Robots Explore plankton-driven Fluxes in the marine twIlight zoNE, 2019-2026)**

The Argo component of the CPER Bretagne ObsOcean is essentially dedicated to the acquisition of floats (and associated data management) for the new phase of OneArgo 2021-2027 (Core, BGC, Deep). The ERC REFINE and PIE Ifremer PIANO are both dedicated to technological developments concerning the vector (float) and sensors to consolidate existing technologies and develop new capabilities for the observations of biological and ecological variables (BGC-ECO-Argo, in REFINE and PIANO) and Deep floats (Deep floats with 6000 m capability, in PIANO). REFINE also contributed to the acquisition and deployment of BGC floats. The EquipEx+ Argo-2030 is dedicated to the acquisition of standard and new generation BGC (BGC-ECO-Argo) floats with enhanced observation capabilities and new sensors to observe zooplankton (UVP-6 imager) and micronekton (micro-sonar) and Deep floats (Deep-6000) developed in the PIE PIANO and ERC REFINE projects. Given the cost of BGC floats, the annual purchase of about 11 BGC floats for the new OneArgo phase will be spread over the CPER ObsOcean and CPER Sud MARIOSEA projects, PIE PIANO, EquipEx Argo-2030 and ERC REFINE (around 2-3 floats/year/project). The PIE Ifremer PIANO project and the EquipEx+ Argo-2030 project both aim to enhance the Argo network. Overall, considering the budget of those projects, Argo France will be able to deploy about 55-60 floats/year over the next 4 years (20-25 core, 11 deep, 11 core-O2 and 11 BGC). This 30% less than the target of 80 floats/year.

During 2019-2022, Argo France has also participated and led WPs in the framework of the **European H2020 Project "Euro-Argo Rise" led by Euro Argo ERIC** (https://www.euro-argo.eu/EU-Projects/Euro-Argo-RISE-2019-2022) to consolidate the European contribution to OneArgo missions. The Argo France team has had a leading role in this EU project, contributing to homogenize the quality of Argo data at European level, and provide complementary funding for contribution to OneArgo missions (not funded by the IR*). Argo France has co-led a follow-up proposal, "Euro Argo One", submitted to EU HORIZON call in March 2024.

B3. Ouverture et Insertion du SNO, lien avec les IR/IR*[2]

1) Regional integration: OSUs and CPERs

At the regional level, the SNO Argo France is integrated within the OSU IUEM (UBO). The *Institut Universitaire Européen de la Mer* (IUEM) is the *Observatoire des Sciences de l'Univers* (OSU) to which the SNO Argo France is affiliated. The IUEM engaged in 2010 to support the Atlantic Argo Regional Center (A-ARC). In 2012, Cécile Cabanes (IR CNRS) has been affiliated to the UAR IUEM (3113) and SNO Argo France at LOPS (UMR 6523) as Core Argo DMQC expert. Since 2015, the SNO Argo France has welcomed the CNAP "Physicien Adjoint" at LOPS/IUEM, Nicolas Kolodziejczyk, who has taken the responsibility of the SNO in 2017. Since 2018, he is the national scientific coordinator of the Argo France management board. The LOPS is responsible for the physical (Core and Deep Missions) and Oxygen variable expertise.

The scientific activity relative to the BGC Mission was formalized by the co-responsibility of the SNO with the LOV laboratory (UMR 7093) at the partner OSUs Ecce Terra and STAMAR (created in 2019) at SU. The OSU partners support the BGC activities that are presently managed by the IMEV at Villefranche-sur-Mer. Catherine Schmechtig (IR CNRS) is affiliated to the OSU Ecce Terra since 2015 and Raphaëlle Sauzède (IR CNRS) has been affiliated to the IMEV since 2019, both as Data management and DMQC experts.

Argo France is also supported by CPER projects from Bretagne (ObsOcean held by the Ifremer) and Provence-Alpes-Côte-d'Azur (Sud MARIOSEA held by IMEV) Regions, for floats procurement and data management funding.

2) National integration: IR, CDS-IS-Coriolis and IR DataTerra*

At the national level, Argo France is an IR* (Very large Research Infrastructure). The IR* Argo France integrates the "Centre de Données et Services *In Situ* Coriolis" (CDS-IS-Coriolis since 2021, former Coriolis consortium). The CDS-IS-Coriolis objective is to consolidate and operate the Argo France (and european) data acquisition for data assembly, data validation and data distribution in real and delayed time in the

[2] *See letters of support in ANNEXE C.*

framework of the Argo international DAC/GDAC system. Argo France and CDS-IS-Coriolis integrates with the IR DataTerra in the framework of the "Pôle Océan" ODATIS dedicated to provide data, products, software, tools and/or services intended primarily for the French scientific community working in the field of oceanographic research. Since 2019, all data and products provided by the SNO Argo France are available in the ODATIS catalog (www.odatis-ocean.fr/). In this context, it should be noted that natural collaborative activities and tool sharing exists between the SNOs in the perimeter of the IR OHIS project, for the deep Ocean (SNO MEMO, SSS, PIRATA, and OVIDE) and IR ILICO (SNO MOOSE). These platforms are very complementary in regions sparsely sampled by Argo (e.g. SNO MEMO in the Southern Ocean). Moreover, SNO PIRATA, OISO,MOOSE and OVIDE-GOSHIP campaigns are yearly opportunities to deploy and maintain Argo floats in various regions of scientific interest for the French community.

Argo France has developed together with MERCATOR (The French operational oceanography forecast center) a strong connection with the French research community (*see Table, H3, ANNEXE H*) via the Mercator-Coriolis Mission Group (GMMC) within the LEFE program lead by INSU (*Section B2.4a and B8*). Yearly joint national workshops and meetings with GMMC have been organized. Argo France also organizes annual meetings, workshops and forums (e.g. forum DMQC) to federate the national community and promote the use of Argo data.

3) European and International integration

Argo France integrates at the European level as the French contribution to the Euro-Argo ERIC. The Euro-Argo office is managed by France and based at Ifremer, Brest, France. Yann-Hervé De Roeck is the Euro-Argo ERIC Program manager and SNO Argo France members contribute actively to the governance of Euro-Argo (*see Table H4, ANNEXE H*). Details on ERIC Euro-Argo can be found at: www.euro-argo.eu.

Argo France is integrated into the international OneArgo program, as it is committed to implement and disseminate the Argo protocols over the French scientific research and operational community. The SNO Argo France has kept playing over the last 5 years a very active role by engaging and co-chairing in the multiple groups that structure and coordinate the program at the international level (*see Table H4, ANNEXE H*).

The Argo network is now the backbone and essential component of the international Global Climate Observing System (GCOS) and Global Ocean Observing System (GOOS). In this context, Argo data notably complement the full water column high accuracy measurements from the GO-SHIP program (https://www.go-ship.org/) that provides reference high quality measurements for qualification and corrections of Argo data. Furthermore, the SNO Argo France has built collaborations with developing countries and IRD groups (*see ANNEXE F*). Eventually, the Argo data are strategic for spatial missions, e.g. Sea Level, Ocean Color, Sea Surface Salinity (*see ANNEXE D***)**.

B4. Protocoles de mesure

The SNO Argo France teams strongly contribute to discuss and establish the standards and protocols at the international level in the framework of the Argo Program. The protocols must be accepted collectively at the international level. These protocols are generally discussed and accepted in Argo meetings and workshops. A complete list of the meetings and workshops is provided in *ANNEXE I*. Then, Argo France is committed to apply and disseminate these standards and protocols in the French community to contribute to Argo. Note that a detailed overview of Core, BGC and Deep Argo Mission parameters, sensors, and data processing is provided in *Wong et al.* (2022), *Bittig et al* (2019) and *Zilberman et al. (2023),* respectively.

1) OneArgo parameters and sensors

a) Core and Deep Mission

All OneArgo floats from Core and deep missions systematically measure pressure (P), salinity (S) and temperature (T) from the surface down to 2000m depth of the water column while deep Argo can reach 4000 m depth or 6000 m depth (for more details on floats types: https://argo.ucsd.edu/how-do-floats-work/float-types/). **P/T/S from surface to 2000 m depth in the global ocean (0-2000m) are the core parameters of the international Argo array and of the SNO Argo France**.

These parameters are measured using a conductivity-temperature-depth sensor (CTD). The most used sensor is manufactured by Seabird Science (SBE41CP, see:www.seabird.com/sbe-41-argo-ctd, now the SBE61 (Deep floats) is available see:www.seabird.com/sbe-61-deep-argo-ctd. Due to the Abrupt Salinity Drift (ASD, *Wong et al., 2023*) issue with the SeaBird sensors since 2015, the international community and Argo France has promoted and tested alternatives to SeaBird sensors. Now, two RBR, for Core and Deep floats, are also available, see:rbr-global.com/products/standard-loggers#CTD). The Table 1 indicates units, accuracy, resolution and site of the distributed data.

b) BGC Mission

Complementary to the Core parameters (P/T/S), floats from the BGC-Argo Mission measure **6 BGC parameters qualified as EOVs on BGC floats equipped with extra sensors** (https://argo.ucsd.edu/how-do-floats-work/float-types/)**.** The standard suite of BGC sensors includes a SeaBird Scientific SBE41 CTD (P/T/S), an Aanderaa oxygen optode (dissolved oxygen), a SeaBird ECO sensor (chlorophyll a and suspended particles), a SeaBird SUNA (nitrates), a SeaBird OCR-504 radiometer (downwelling irradiance), and a SeaBird SeaFET sensor (pH). However, new sensors have become available, diversifying the range of BGC-Argo float equipment, such as the RBR Tridente (chlorophyll a and suspended particles), the TriOS Opus (nitrates) or the TriOS RAMSES radiometer. We also note that, because they also measure the P/T/S parameters, BGC-Argo floats make a complementary contribution to the Core Mission.

Table 1: Properties of the OneArgo parameters

Parameters	Unit	Accuracy	Resolution	Observation site	Reference
Core Pressure	dbar	2.4	0.1	Argo-Global/0-2000m	*Wong et al., 2022*
Core Temperature	°C	0.002	0.001	Argo-Global/0-2000m	*Wong et al., (2022)*
Core Salinity	PSU	0.01	0.001	Argo-Global/0-2000m	*Wong et al., (2022)*
Displacements	cm/s	2	10 jours	Argo-Global/1000m	*Wong et al., (2022)*
Oxygen	µMol/kg	8	0.001	Argo-Global/0-2000m	*Thierry and Bittig, (2021)*
Chlorophyll-a	$mg.m^{-3}$	0.01	0.001	Argo-Global/0-2000m	Schmechtig *et al.*, (2023)
Suspended particles	m^{-1}	0.0002	0.00002	Argo-Global/0-2000m	*Dall'Olmo et al.*, (2023)
Nitrates	µMol/kg	0.5	0.1	Argo-Global/0-2000m	*Maurer et al. (2021)*
Downwelling irradiance	$W.m^{-2}\ nm^{-1}$	depends on lambda		Argo-Global/0-2000m	*Jutard et al. (2021)*
PH		0.005	0.0004	Argo-Global/0-2000m	*Maurer et al. (2021)*
Deep Pressure	dbar	3	0.1	Argo-Global/0-6000m	*Zilberman et al. (2023)*
Deep Temperature	°C	0.001	0.001	Argo-Global/0-6000m	*Zilberman et al. (2023)*
Deep Salinity	PSU	0.002	0.001	Argo-Global/0-6000m	*Zilberman et al. (2023)*
Deep Oxygen	µMol/kg	1-2	NA	Argo-Global/0-4000m	*Zilberman et al. (2023)*

2) Sampling strategy

In order to reach the OneArgo sampling target (*Section B2*) Argo France first details the sampling strategy (horizontal and vertical) for the use of GMMC CS and PIs, and deployment of opportunity in a document describing the "National Strategy for Argo Global Network Profiling floats Deployments" (*Kolodziejczyk et al.*, 2022, doi.org/10.13155/59297). Deep and BGC floats, which are equipped with CTD

sensors, contribute to the Core Argo Mission. Their deployment strategy needs to satisfy the mission target of both Core and Deep/BGC. Deployed by French scientific teams, they are localized in regions with national scientific interests: the Atlantic, Southern Ocean, the Mediterranean Sea, North Indian, Tropical Pacific and Arctic regions.

a) Core Mission

Argo Core floats are autonomous platforms profiling every 10 days and measuring pressure, temperature and salinity between 0 and 2000m depth. Between two profiles, floats drift freely at a constant parking depth, generally 1000m depth. Displacements provide estimates on the oceanic currents. Once the float reaches the surface, profiles are localized by surface GPS fix and data is transmitted through satellite iridium communication systems to data centers, which then distribute data in near-real time, less than 24 hours. **The Core sampling strategy is one P/T/S core profile in boxes of 3°x3° every 10 days globally, including polar regions and marginal seas, and double density in the Western Boundary Current and Tropical area.**

The vertical sampling scheme is chosen by the PIs or following the Argo France recommendation when the float is deployed by opportunity. With Iridium, now available on all of the floats, measurements can be taken every 1 or 2 db, but are generally reduced to limit the transmission costs (see *Kolodziejczyk et al.*, 2022).

b) Deep Mission

The deep-Argo sampling is based on **one float every 5°x5° every 10-day sampling** (*Johnson et al.*, 2015) and a Deep-Argo float follows the same 10-day cycle as a Core-Argo float as described in *Zilberman et al.* (2023)(see *Kolodziejczyk et al.*, 2022).

c) BGC Mission

The functioning of the BGC-Argo floats is identical to the standard P/T/S floats (as described in the previous paragraph). Compared to the Argo P/T/S, they are equipped with additional sensors and systematically with Iridium (or equivalent) two-way transmission (see previous paragraph), because it provides higher data flux and more flexible sampling strategies (i.e. higher vertical resolution, high profiling frequency) thanks to the ability to transmit commands (see *Kolodziejczyk et al.*, 2022).

3) Quality Control (QC) procedures

a) Quality control flow

At this moment, the profiling floats are not (or rarely) recovered after their mission, thus neither post-calibration can be operated on the sensors or bottle cast during the time life of the floats. Documents and detailed procedures are available on the Argo Data management website (www.argodatamgt.org). The Argo Data Management Team (ADMT) has set up a unified framework in 3 steps for the Core, BGC and Deep missions to QC the dataset in order to fulfill requirements from its wide user community: **1) Real-Time QC, 2) Delayed-Time QC and 3) Consistency Check** (Fig. 8).

These 3 stages are organized and coordinated as follows (Fig. 8). Automatic quality control tests, performed in near *real-time* (*Table H1, ANNEXE H*) are agreed on and applied by all Argo data assembly centers (DACs) similarly. A working group, associated with the Argo Data Management Team (ADMT), is more specifically in charge of the *delayed-mode* quality control issues. This so-called "DMQC" group meets when needed (typically every year). A manual describes all QC procedures, for both real and delayed time. These procedures are accepted by the entire community and the manual is updated regularly, several times a year if necessary (last version is available here: *Wong et al*, 2024, doi: 10.13155/33951). Activities conducted by **Argo Regional Centers (ARCs)** are discussed within the DMQC group. Argo data from the SNO Argo France are processed along these procedures. It is an important mission of the SNO Argo France to develop new, and maintain existing, QC procedures in line with scientific progress and technological evolution of the platforms and sensors. At the national level, the SNO Argo France QC activities are coordinated and discussed between: the CDS-IS Coriolis component, research laboratories LOPS,LOV-IMEV and OSU Ecce Terra.

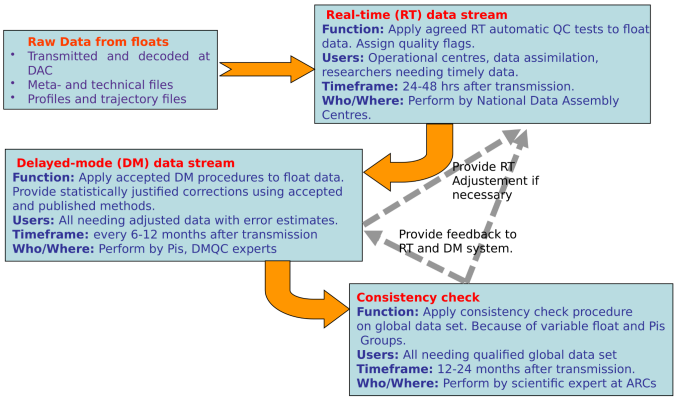

Figure 8 *: Argo Quality check and correction flow. RT automatic checks are described in Table H1, ANNEXE H. Quality flags are described in Table H2, ANNEXE H.*

With regard to the BGC mission and Deep mission (P/T/S and oxygen), the procedure is analogous. Since 2016, agreed procedures for delayed-mode quality control have been published in a cookbook with the leadership of the SNO Argo France (*Schmechtig et al., 2023*, doi:doi.org/10.13155/40879). Most of the QC procedures have been extracted from peer-reviewed scientific literature, including a strong French contribution (*Roesler et al.*, 2017; *Sauzède et al.*, 2017 ; *Bittig et al., 2018*; *Xing et al., 2011, 2012, 2018 ; Organelli et al., 2017*, *Jutard et al., 2021* ; *Pasqueron de Fommervault et al., 2015; Cabanes et al.*, 2016, 2019). It is thus a paramount achievement of the SNO Argo France to have over the last 5 years created and disseminated QC procedures from scratch for the BGC parameters. Most of the developments now internationally agreed upon were proposed by the biogeochemical branch of the SNO-Argo France.

b) Description of data Modes

1) Data transmission and decoding : meta-data, technical data and raw measurements

First, each Argo float sends a collection of meta-data, technical files and raw measurements transmitted through satellite communication. These data are decoded by different operators. In France, Coriolis DAC is in charge of the decoding data from the French floats. Since 2016, the BGC floats processing chain has been fully operational and integrated within the Coriolis data management stream (Coriolis Argo floats data processing chain, Core, doi:10.17882/45589). Since 2015, Coriolis and the SNO Argo France have maintained decoders up to date with new floats and telecommunication technologies, including trajectories and, since 2016, BGC measurements.

2) Real-time data mode

Real time mode profiles are primarily used by operational oceanographic centers and weather forecasts. At the DAC level, the real-time data qualification relies on 19 successive automatic tests (*Table H1, Annexe H*). For a few specific floats and sensors, it may be possible to adjust profiles in real-time to known and documented drift or bias. Data adjusted automatically are referred to as "A" mode in metadata of the Argo data files, standing for real-time but Adjusted; all other real-time data are referred to as "R" mode, standing for Real-time.

The real-time quality control method and tools are distributed and regularly improved and updated at the DAC level. In 2019, the real-time quality controlled data were only available for Core, Deep and trajectories data (*Wong et al., 2024*, doi:10.13155/33951), dissolved oxygen and chlorophyll-a parameters. During the 5 last years, a lot of activities have focused on other BGC parameters such as nitrates, suspended particles, pH and irradiance parameters. The French community participated actively to the discussions, tests, documentations which results to a consensus now adopted at international level for providing BGC data (*Johnson et al., 2021* https://doi.org/10.13155/84370, *Dall'Olmo et al,* 2023, doi : 10.13155/60262, *Johnson et al., 2023,* doi: 10.13155/97828, *Poteau et al., 2019,* doi: 10.13155/62466). Dissolved oxygen and

chlorophyll-A quality control procedures were also updated in this time frame (*Thierry et al, 2021,* doi: 10.13155/46542, Schmechtig et al., 2023, doi:10.13155/35385).

With the support of the SNO Argo France, the CDS-IS-Coriolis has maintained its international leadership for developing data processing and control methods that have built up the international standard for the real-time OneArgo data.

3) Delayed-time data mode

This is the highest data quality dedicated to the research community, with stronger requirements than operational oceanographic centers. Delayed-time data is referred to as "D" mode for Delayed time in the Argo data files. To do so, once a given Argo float is more than 1 year old, its profiles and trajectory data are carefully controlled and possibly corrected by floats PIs, experts at data centers and regional Argo centers such as the A-ARC under SNO Argo France responsibility. QC methods are developed by research laboratories, like LOPS and LOV for the SNO Argo France, as well as CDS-IS-Coriolis.

Core mission

While temperature sensors are slightly impacted by drift and bias, the conductivity cells are known to drift over time and are sensitive to bias due to fouling and clogging (*Wong et al., 2020*). Salinity measurements can be flagged, corrected and uncertainty can be reevaluated, if necessary, using the Owens-Wong-Cabanes (OWC) method developed and agreed by the international community and SNO Argo France (*Owens et Wong*, 2009, *Cabanes et al.,* 2016; https://github.com/ArgoDMQC/matlab_owc). Therefore salinity accuracy is about 0.01 (Table 1) after DMQC. Within this framework, the SNO Argo France maintains the OWC code. SNO develops and maintains the DM_FLOATS processing chain, used by LOPS operators and various European operators. In practice, corrected data in delayed mode are flagged (Table H2, ANNEXE H)) and put in the D-profiles files along with an estimate of the measurement error. To do so, a reference database including high precision CTD data acquired during hydrographic campaigns and curated profiles in Core Argo database, are crucial for this validation and calibration of delayed mode data. CDS-IS-Coriolis (C. Coatanoan, Ifremer) manages the Argo reference databases for the DMQC, available on: https://www.ifremer.fr/erddap/info/ArgoFloats-ref/index.html. Over the period 2019-2024, the last update of the Argo reference database for the global ocean was released, as part of the EA-Rise project (2019-2022).

Additional review of basin-wide data quality is crucial especially for salinity data to harmonize the QC and correction among different groups of PIs or from different batches of floats. This has been regularly performed at the A-ARC level since 2013. A web page has been created to monitor the suspicious floats whose PIs or delayed-mode operators have been warned: www.umr-lops.fr/en/SNO-Argo/Activities/NAARC/Consistency-checks-of-DM-salinity-corrections.

In addition, SNO Argo France participates in the training of new operators on delayed-mode QC procedures and tools. SNO Argo France made a significant contribution to the regular european and international DMQC workshop organized since the early stage of the Argo program. More recently, SNO Argo France was asked to participate in the training of the new UK delayed-mode operator, which was hosted at Ifremer during 2 days in March 2019. As part of the European project EA-RISE, Argo France experts led on writing a Delayed-mode QC cookbook that will help to harmonize delayed-mode QC procedures among different delayed-mode operators (*Cabanes et al., 2021*, doi: 10.13155/78994). Eventually, on yearly basis SNO Argo France organizes “Forum DMQC” to train and advertise the national community on DMQC procedure and update. DMQC forum has taken place 4 times between 2019-2024.

Since 2014, a larger than expected percentage of SeaBird conductivity sensors have drifted salty prematurely, eventually to an uncorrectable state (Abrupt Salty Drift - ASD). Changes at the manufacturing level were introduced in 2018 to reduce such occurrences. So far, 91 French Floats are listed as having a moderate or severe drift, this represents about 7% of the french float affected by this failure. The SNO Argo France has also a leading participation in an international working group tasked with monitoring this problem of ASD. Indeed, there is a larger proportion of sensors that are subject to unusual premature

salinity drift, and whose data quickly becomes unusable. SNO Argo France has contributed to a paper (*Wong et al,* 2023: https://doi.org/10.5194/essd-15-383-2023) describing the salinity bias in the raw Argo dataset and validating the delayed-time dataset to quantify residual errors and regional variations in salinity uncertainties. Thanks to the Argo community effort, SeaBird has now corrected the probe's design to solve this problem.

Since 2019, SNO Argo France has developed the "DMQC-PCM '' method involving Artificial Intelligence. It is based on Profile Classification Models (PCM), a machine-learning method for identifying recurring structures in a collection of vertical ocean profiles (e.g. *Maze et al, 2017, Maze et al 2017b*). The idea behind the DMQC-PCM procedure is to use a PCM-type classifier to organize and select reference data more appropriately for quality control of Argo float measurements. During the EA-RISE project, a proof of concept was developed to study the performance and characteristics of the procedure. DMQC-PCM tools and software for DMQC are available on gitub https://github.com/euroargodev/argodmqc_owc repository.

Trajectories

The development of the DMQC method for the Argo Trajectory files is currently under development and at this stage basic procedure is provided by the Argo manual (*Wong et al., 2024*; doi: 10.13155/33951) and the expected accuracy and target are described in *Wong et al.* (2020). In 2019-2024, and from its long lasting expertise on ANDRO dataset, SNO Argo France teams have been involved in an international ADMT working group to specify a detailed protocol for DMQC Argo trajectories files. SNO Argo France is currently working on a procedure to convert ANDRO curation procedure (*Ollitrault and Rannou*, 2013) in a finalized DMQC trajectory file to be distributed on DAC/GDAC. During 2025-2029, the SNO Argo France will continue its involvement in this ongoing international effort, by participating in an international working group and leading the effort to achieve a comprehensive DMQC recommendations and method for Argo Trajectory Files.

Deep mission

Over the period 2019-2024, SNO Argo France has taken part in an international working group tasked with establishing and documenting the procedure for delayed mode processing of Deep Argo floats (*Wong et al., 2024*). In particular, a procedure for correcting a pressure-dependent bias linked to the compressibility term of the conductivity cell (Cpcor) has been established, and a code has been made available: https://github.com/ArgoDMQC/DM_Cpcor. The SNO Argo France organized a workshop (https://www.euro-argo.eu/News-Meetings/Meetings/Others/Deep-Argo-DMQC-workshop, June 5-6, 2023, *ANNEXE I*) so that off-line operators could share their experiences of Cpcor correction and conductivity sensor drift assessment. SNO Argo France also contributed to the definition of the delayed-mode quality control of the Deep-Argo data and to the evaluation of the three probes available for Deep-Argo applications: SBE41CP, SBE61 and RBR*argo*|deep6k (*Thierry et al., submitted to JAOT*). The authors show that after delayed-mode processing, the Deep-Argo data from those probes comply with the Deep-Argo accuracy target of ±0.001°C, ±3 dbar, and ±0.002, respectively.

BGC mission

Over the period 2019-2024, the SNO Argo France has strongly contributed to the definition of the methods in an international framework, at European (Euro-Argo) and Global (ADMT, BGC-Argo task team) levels. In this context, a whole work package of the European project EA-RISE, led by and including experts of the SNO Argo France, has been devoted to ensure and organize the BGC-Argo DMQC mode at European level.

As part of the EA-RISE project, the delayed-mode procedure for CHLA was developed. This method can be applied on a global scale thanks to the development of a new neural network-based method called SOCA-light, which enables synthetic radiometric profiles to be estimated for floats not equipped with radiometers (*Renosh et al.*, 2023). An article detailing the off-line processing of CHLA and making this qualified global database available is currently being written.

The discrepancy between the real-time and delayed-time adjusted CHLA data is such that it was decided during the first BGC-Argo DMQC workshop (*see ANNEXE I*) not to apply the delayed-time correction in order to maintain consistency in the dataset. In this context, and in order to propose a solution to minimize the impact of integrating these corrected data, we presented a new map at ADMT24, enabling us to apply this correction in real time. This map, still under development, is based on SOCA products from the BGC-Argo database and will be presented to AST25 for validation (*ANNEXE I*). In this context, work is being carried out on the quantitative evaluation of the improvement of the CHLA database through the development of machine learning methods.

As part of the EA-RISE project, the delayed mode of downwelling irradiance was developed, published (*Jutard et al., 2021*), endorsed internationally and applied to French and UK floats.

The BBP audit, available online (ftp://ftp.mbari.org/pub/BGC_argo_audits/BBP700) since June 2021, was updated at the end of 2023. The anomaly report was sent to the Argo mailing list. The results of this audit were presented yearly and lastly at ADMT24. The audit is based on a comparison of BBP measurements with reference data corresponding to the BBP weekly climatological fields from SOCA product (https://doi.org/10.48670/moi-00046). The audit update has enabled a total of ~110,000 BBP profiles to be inspected in 2023. This is 35,000 more profiles than in 2022 (compared with 10,000 more in 2021). Of the profiles inspected, 875 were reported as abnormal (~1% of data vs. 1.5% last year).

4) High level products

The SNO Argo France has a historical expertise and commitment in valorizing Argo data by providing high level products from Argo QCed profiles. Mapping irregularly distributed profiles over the ocean onto a regular space/time grid is sensitive to Argo sampling and helps to assess sampling and representativeness errors on spatial and temporal scales resolved by Argo data. It enhances the set of 1D profiles within a 4D dataset, thus facilitating their use for research, modeling and climate assessment. Furthermore, employing new machine learning-based methods to estimate augmented variables enhances the BGC-Argo dataset by incorporating poorly or non-measured parameters, enables novel applications.

Core and Deep Missions

Over the last 4 years, the SNO Argo France has developed and maintained such a mapping tool, named **ISAS** (In Situ Analysis System), based on an objective analysis of temperature and salinity in situ data including Argo data (see *Gaillard et al., 2016*). The ISAS tool is developed in research mode at LOPS by SNO Argo France team, and regular update of the T/S products are distributed to the international community (*Kolodziejczyk et al., 2023* ; doi:10.17882/52367). ISAS tools and expertise are also provided to the operational community by SNO Argo France : CDS-IS-Coriolis to be distributed in Near-Real Time (NRT) and to map the CORA dataset distributed by Copernicus Services. Depending on the application NRT (ISAS-NRT) or research (ISAS17 and ISAS20) ISAS products rely on the mapping of real-time QCed or Delayed-time QCed profiles.

Anticipating the BGC and Deep Argo extensions, ISAS tools and products have recently evolved towards T/S full depth (0-5500 m instead of 0-2000 m depth) and oxygen configuration for climatologies (ISASO2, *Kolodziejczyk et al.*, under review in ESSD ; doi:10.17882/52367).

Finally, ISAS very last version is permanently made available, through the SVN server at Ifremer, to provide updated code to Coriolis data center experts. On demand any user can be included on this repository and commit its own version. The SNO SSS (UPS, Toulouse) is currently working with ISAS dedicated configuration (ISAS-SSS on doi: 10.17882/52367) to produce its own SSS interpolated products distributed by the SNO SSS (https://sss.sedoo.fr/). Given its multi-usage, ISAS is a strategic tool for Argo France and the operational french community.

BGC mission

In parallel to the ISAS extensions to the BGC parameters (which is limited to the O_2 parameter), other **L3 BGC products are developed in the framework of the SNO (3DBGC;** Table 1**)**. First, a dedicated statistical method (*Sauzède et al. 2016*), based on a neural network approach, has been developed to generate gridded 3D products for particulate organic carbon (POC) from the backscattering coefficient (BBP) parameter. This method combines satellite ocean color data with float Temperature/Salinity (T/S) profiles, using training based on BGC-Argo observations to estimate BBP. Following successful implementation for POC/BBP, this methodology has been refined (*Sauzède et al., 2020*) and expanded to produce similar products for the chlorophyll-a concentration (CHLA) parameter (*Sauzède et al., in prep.*) and radiometric parameters such as Photosynthetically Active Radiation (PAR) (*Renosh et al.*, 2023). The 3D BBP/POC and CHLA gridded BGC products derived from this SOCA methodology applied to satellite ocean color and ARMOR 3D T/S gridded fields, have been made available from the European Copernicus Marine Service since early 2020, with yearly updates (https://doi.org/10.48670/moi-00046).

Second, using CANYON-B/CONTENT methods (*Sauzède et al., 2017; Bittig et al., 2018; Fourrier et al., 2020*), augmented profiles of nutrients concentration (i.e. nitrate, phosphate and silicate) and carbonate system parameters (i.e. pH, total alkalinity, dissolved organic carbon and pCO2) are released from Qced O2/T/S BGC-Argo profiles. This product has been made available from Copernicus Marine Service since late 2019 with yearly updates (https://doi.org/10.48670/moi-00048). Currently, ongoing development is made to make this product available in near real time with associated refined uncertainties from mid 2024. S

OCA and CANYON-B/CONTENT products are of great interest to end-users, and particularly modelers, for data assimilation or initialization and validation of biogeochemical models. Moreover, it is important to note that these products are largely used for BGC-Argo data management to qualify and adjust data (e.g. BBP audit and CHL new calibration protocols in RT and D-mode).

B5. Archivage des données et leur mise à disposition

OneArgo data are decoded, processed and archived by 11 national Data Assembly Centers (DAC) that have the responsibility of their fleet (decoding, RT-DMQC). All DACs must synchronize their dataset with 2 Global DACs (GDAC) that have the responsibility to distribute the entire Argo dataset to the international community. GDACs are operated by the National Oceanographic Data Center (NODC, US) and CDS-IS-Coriolis (Ifremer, France). Coriolis is also a DAC for French float as part of the IR*, but also for European floats (except UK floats). The CDS-IS-Coriolis is a component of the “Pôle de données” ODATIS (https://www.odatis-ocean.fr/) as part of the IR Data-Terra (www.data-terra.org/). Argo France data, as well as operational products derived from SNO Argo France tools are referenced, described, and distributed in the ODATIS catalog.

Data processing, format and management procedures are made uniform at the international level and coordinated during annual meetings of the Argo Data Management Team (ADMT, www.argodatamgt.org). For a given float, uniquely identified by its WMO number (X9XXXXX type, for Argo floats), Argo Data is stored into a collection of autodescriptive **netcdf files** in a strict format following the recommendations of ADMT and described in the Argo user’s manual (*ADMT, 2022*, doi:10.13155/29825):

- **Meta-data and technical data** (*_meta.nc and *_tech.nc, * being the WMO number) are made available as conventional netcdf files after each float deployment, and are updated by DACs within 24 to 48 hours after each new transmitted profile. These netcdf files are distributed by GDAC on their ftp servers.
- **Profiles** are stored in different kind of netcdf files :
    - profiles files contain each individual profile transmitted by a given float. The profiles are labeled by R, A or D following the data mode (*Section B4*). A new profile file is created after transmission and decoding of a new cycle made by the float.
    - B profile files contain each individual profile transmitted by a given float with the complete BGC information, the profiles are labeled by R, A or D following the

PARAMETER_DATA_MODE, as soon as one BGC parameter is controlled in DM, the filename changed its prefix from “BR” to “BD”.
    - S profile files contain each individual profile transmitted by a given float with only scientific relevant information (no intermediate parameters). Given the variety of BGC sensors, each BGC sensor measurements are not necessarily aligned with each other in terms of timing or pressure (as it is the case for P/T/S carried out by an unique CTD sensors). For convenience of the user, the Synthetic profiles provide aligned measurements by interpolation of BGC measurements.
    - *_prof.nc files contain concatenated profiles and are updated as each new profile is decoded.
    - *_Sprof.nc files (Synthetic profiles): files contain concatenated S profiles.
- **Trajectory files** (*_traj.nc) : provide the time series of all the events transmitted by the float during its life and decoded by the DAC, including measurements during profiles, drift at parking depth and at the surface, etc … The file is updated at each new transmission from the float. The trajectory file is the most complete record of measurements of the float. For instance, the trajectory files are used to derive the deep displacement and velocities data (e.g ANDRO).
- **Aux directory** : The SNO members are particularly active regarding the integration of new sensors and derived parameters, in R&D mode. The R&D variables or derived parameters, not yet accepted by the Argo community, are stored in the auxiliary directory. For example the UVP6 (Hydroptics) imager or the hyperspectral RAMSES radiometers. The SNO strongly works in order to document these new sensors and qualify the data. All the data from these sensors (for which Argo endorsement is pending) are made freely available to the whole scientific community.

All data are freely available to users, whether it is parameter measurements or technical or meta-data. Real-time access to the full dataset is described on the Argo web site and complies with quasi all the protocol of downloading: https://argo.ucsd.edu/data/data-from-gdacs/ (http, ftp, doi, rsync, ERDDAP, …).

The legal status of these data is set at the international level by the 1999 Resolution XX-6 of the Twentieth IOC (International Oceanographic Commission) Assembly requiring that *“the concerned coastal states must be informed in advance, through appropriate channels, of all deployments of profiling floats which might drift into waters under their jurisdiction, indicating the exact location of such deployments.”* This resolution states that a country must be notified when a float enters its Exclusive Economic Zone (EEZ). This notification is handled at the international level by the **Argo Information Center (AIC)** and the Joint Commission in situ Observing Platform Support Centre (www.ocean-ops.org, V. Turpin).

B6. Diffusion et rayonnement scientifique

1) Teams and programs using the dataset

Argo is now one of the essential datasets used in oceanographic and climate studies and operational activities and products. At the French level, the list of teams using the Argo dataset can precisely be obtained by looking at the affiliations of French co-authors in the bibliography section (see below and *ANNEXE B and Table H3, ANNEXE H*).

2) Scientific production

The complete lists of the **6269 peer-reviewed articles and 451 PhD theses** to date and bibliometric statistics, based on or using Argo data, are available online at https://argo.ucsd.edu/outreach/publications/bibliography/ and https://argo.ucsd.edu/outreach/publications/thesis-citations/. The specific list of French peer-reviewed articles, i.e. have used Argo observations and have been co-authored by a French contributor, more than **611** since 2012, and **42** PhD since 2003, thesis are available on : https://www.argo-france.fr/Bibliographie/Publications**.** Note that since 2002, France is the 3rd most publishing country with Argo data behind USA and China. Besides the vitality of the French Argo community, this highlights the benefit for the scientific community of the investment of the french institutes and government in Argo France and confirms that the SNO Argo France reached its objectives.

3) Data, products and tools

Argo program webpage provides a large and comprehensive amount of data access tools and products (https://argo.ucsd.edu/data/), including products and tools distributed by Argo France to ease the Argo data dissemination and use. Data, products and tools specifically developed and distributed by Argo France and Euro-Argo (in the framework of European projects) are available on the Argo France webpage: www.argo-france.fr/Argo-Data-Products/

1) Data

- For a better traceability, the Argo dataset (doi: 10.17882/42182) DOI (Digital Object Identifier) has been monitored between 2019-2023 : more than **7356 Argo downloads** (**+894%** compared to the period 2016-2018) from more than **68 countries** over the world have been recorded from Seanoe DOI services. To acknowledge Argo, it is recommended to cite the paper *Wong et al.* (2020) and the appropriate Argo doi, and use the following sentence in the Acknowledgment : *"These data were collected and made freely available by the International Argo Program and the national programs that contribute to it (http://www.argo.ucsd.edu, http://argo.jcommops.org). The Argo Program is part of the Global Ocean Observing System." (https://argo.ucsd.edu/data/acknowledging-argo/).*"

2) Products

- **ISAS** temperature and salinity products downloads are also monitored since 2019 more than **4679 downloads** (**+328%** in comparison to 2016-2018 period ; a sample of citations using ISAS is available on doi:10.17882/52367) have been recorded from more than **70 countries** over the five continents (*Table K1, ANNEXE K*). Proper citation is *Gaillard et al.* (2016) and recommended Acknowledgment sentence is : "ISAS temperature and salinity monthly gridded field products are made freely available by SNO Argo France at LOPS Laboratory (supported by UBO/CNRS/Ifremer/IRD) and IUEM Observatory (OSU IUEM/CNRS/INSU) at doi: https://doi.org/10.17882/52367".
- **ANDRO** DMQC Argo trajectory products have been **downloaded** more than **518** times since (**+384%** in comparison to 2016-2018; non exhaustive list of citations using ANDRO is on doi:00360/47077/) from **37 countries** over the five continents (*Table K2, ANNEXE K*). It should be noted that such visibility of ISAS and ANDRO products is made possible since they are included on the international project web page : www.argo.ucsd.edu/Gridded_fields.html. Proper citation is *Ollitraut and Rannout* (2013) and recommended Acknowledgment sentence is: "ANDRO argo floats displacements product is made freely available by SNO Argo France at LOPS Laboratory (supported by UBO/CNRS/Ifremer/IRD) and IUEM Observatory (OSU IUEM/CNRS/INSU), and was funded by Ifremer, Coriolis, SOERE-CTDO2 and SNO Argo France at doi: https://doi.org/10.17882/47077".
- **SOCA**-based 3D gridded BBP/POC and CHLA products have been made available from Copernicus Marine Service since early 2020 and are yearly updated (https://doi.org/10.48670/moi-00046). This product was downloaded by **563 users** over the five-year period (as counted by Copernicus Marine Service).
- **CANYON**-based product making available nutrient and carbon profiles from floats has been made available from Copernicus Marine Service since late 2019 and is yearly updated (https://doi.org/10.48670/moi-00048). This product was downloaded by **153 users** over the five-year period (as counted by Copernicus Marine Service).

3) Tools

In order to ease the accessibility and the visibility of Argo dataset and products, over the period 2019-2023, several useful tools have been developed by Argo France in the framework of SNO Argo France and the European EA-RISE project:

- Visualization tools to monitor Argo fleets technical, trajectory and scientific data such as Euro-Argo fleet monitoring tool includes a dashboard with all information contained in the Argo netcdf files for each individual float.

- The Euro-Argo data selection tool is specifically designed for users to select, visualize and download Argo scientific data (profiles files) in different formats.
- An interactive map dedicated to the BGC-Argo mission allowing float and variable selection and visualization, access to netcdf file and also supporting the adopt a float outreach program.
- Argopy is an advanced software tool based on a python library that aims to ease Argo data access, manipulation and visualization for standard users as well as Argo experts (*Maze and Balem, 2020*). Argopy has 9 code contributors, accumulates around 400 downloads per month and has been cited 10 times in peer-reviewed articles. This library is continuously developed and maintained by the SNO Argo France and integrates with BGC floats capabilities.
- ISASviewer (https://data.umr-lops.fr/app/isasviewer/) has been totally redesigned to allow more dynamic viewing and computing of interpolated maps, profiles, sections and times series from ISAS products. ISASviewer is accessible on https://www.argo-france.fr/.
- https://github.com/euroargodev/BGC-ARGO_R_WORKSHOP , Argo data access, manipulation and visualization for standard users for BGC Argo Data in R language
- The euroargodev platform was set up and is primarily maintained by the SNO Argo France. Euroargodev is an online collaborative platform used to communicate, discuss, develop, document and distribute Argo related tools, codes and softwares. The platform has 78 collaborators registered and 83 projects/repositories.

4) Link with numerical modeling

Both Core, Deep and BGC Argo data are used in numerical models for:

- Data assimilation in near-real time in oceanographic and meteorological operational systems;
- Data assimilation for seasonal forecast
- Data assimilation in oceanic re-analysis for research and climate studies

Physical data are assimilated for global and regional ocean forecasts and reanalysis at the national (Mercator Ocean International; https://www.mercator-ocean.eu/science-oceanique/glorys/), European (Copernicus Marine and Climate Services, ECMWF, https://www.ecmwf.int/en/forecasts/dataset/ecmwf-reanalysis-v5) and international levels (GODAE Ocean View, NASA ECCO Group, https://www.ecco-group.org/). These models are in turn used to initialize seasonal forecast simulations. Besides assimilation, Argo data can be used by hindcast or free forward numerical simulations as initial conditions. This is the case most notably within the international DRAKKAR research group.

Physical Argo data are also used to validate numerical simulations. With more than 2 millions profiles evenly distributed over the global ocean, Argo data provide a robust and precise climatology of the global ocean for the early 21th century against which numerical models can be validated (e.g. *Feucher et al.*, 2019; *Kolodziejczyk et al.*, 2023) and thus provide a reference state against which to validate statistics from eddy resolving numerical simulations.

Biogeochemical Argo data are increasingly used in combination with numerical models. This activity, which is organized at national level in the framework of several already funded GMMC projects (MERCATOR Vert, SIMED, AmicoBio, DEWEXTEND, CIENPERU, EXPLORE, SOFRESH, GREEN-GROG, PISCO), implies the whole spectrum of scientific researches around data-model interactions: initialization, assimilation tests, validation, OSSEs, network design. From initial activities essentially focused on the CHLA and NITRATE parameters, which were considered the most innovative in the data-model framework, additional BGC-Argo parameters either measured or derived (e.g. CANYON products see above) are now considered. Particularly a PhD co-funded by MOI and the ERC REFINE project uses new techniques of model parameterization and data from the BGC-Argo fleet to optimize the ~90 parameters of the PISCES Biogeochemical model. Additionally, a specific effort is also dedicated to the satellite-in situ merging/intercalibration (e.g. SOCA products see above) as, before BGC-Argo, satellite data were the only data set having the required spatio-temporal resolution to be used in this context.

B7. Fonctionnement et ressources humaines (hors exploitation scientifique)

The Argo France program gathers all French activities contributing to the international OneArgo program. These activities are organized in 4 domains coordinated by 1 management board (Fig. 9) :

1. The Argo France **management board** is in charge of the coordination between all the Argo France components.
2. **Scientific Coordination, Expertise and representation**: is coordinated by SNO Argo France in the framework of IR*, and steered by LOPS and LOV-IMEV. It is the scientific steering of Argo France in close interaction with CDS-IS-Coriolis at the national (IR DataTerra "Pôle mer ODATIS", GMMC), European (Euro-Argo management board) and international level (AST, ADMT, DMQC).
3. **Data acquisition at sea**: As part of IR*, it is operated by CDS-IS-Coriolis, this domain encompasses: floats procurement, coordination of deployments and fleet monitoring.
4. **Data management**: As part of IR*, the data center is operated by CDS-IS-Coriolis (DAC and GDAC), the data quality control is operated by Coriolis (*real-time* system) and conducted with the SNO Argo France expertise (for *delayed-mode* and contribution to A-ARC systems).
5. **Technological developments**: are conducted and operated by institutes (Ifremer, CNRS, SHOM SU,...) with flagship projects such as ANR Equipex+ Argo-2030, Ifremer PIE PIANO, ERC REFINE, … This activity is not formally included in the IR*, but are necessary for the development and consolidation of the future capabilities of Argo.

Note that the IR* Euro-Argo France has the specificity of being associated with only one SNO. Therefore, all the activities of Argo France are totally integrated (as demonstrated in this document) and, for sake of clarity, we choose to show one integrated organization chart (Fig. 9). All human resources contributing to the IR* are listed in *Table H5, ANNEXE H*.

***Figure 9**: Organisation of activities and manpower of Argo France including activities labeled as SNO (red) taken in charge by the LOPS and LOV laboratories, and in the framework of IR*. The IR* activities (yellows) are funded by yearly ministry dotation, except SNO activities that are funded by INSU and OSU yearly funding (red). Technological R&D activities are founded by projects (lower-right hand blue box)*

The activities specifically labeled by the INSU as SNO are in the red box of Figure 9. In this sense, the SNO is a critical instance to pilot the IR* operational tasks and to coordinate all the links with the scientific community. N. Kolodziejczyk is SNO responsible from 2018 up to now. F. D'Ortenzio coordinated the BGC mission at a national level over the period 2014-2023. J. Uitz took over at the beginning of 2024. Nevertheless, given the surge in BGC activity in recent years, **it is essential to recruit a CNAP researcher to**

coordinate and provide consistent support for BGC expertise. SNO gathers a total of 77.34 person-month per year (~ 8.6 full time). Thus, with resources from CNRS, OSU-IUEM, Ifremer and SU (OSU EcceTerra, OSU STAMAR) through research laboratories (LOPS and IMEV-LOV), the SNO Argo France takes in charge the main following activities (red box, Fig. 9):

- **Scientific coordination, animation and representation** of the national program in close interactions with Argo international and Euro-Argo ERIC.
- **QC protocols development, expertise, tools and products** : for all French floats and the Atlantic Argo Regional Center (post delayed-mode assessment of research-quality procedures for floats in the Atlantic).
- **Coordination with operational Coriolis activities** (deployments, DAC, IR*).

Table 2 : Implication of people in SNO Argo France (yearly basis of 9 months, i.e. 9 SNO pm means 100% or full time on SNO).

NOM, Prénom	statut	Employeur	SNO pm	Tâches
Balem, Kevin	Engineer	Ifremer	3.5	Software and tools development
Cabanes, Cecile	Engineer	CNRS	8	Coordination on Core and Deep with Coriolis, expertise on DMQC and product development (Core, Deep, trajectories), A-ARC, ADMT exec.
Claustre, Hervé	Scientist	CNRS	5.4	AST BGC Mission chair, expertise on QC and DMQC
Carracedo, Lidia	Scientist	Ifremer	0.5	O_2 expertise
Desbruyères, Damien	Scientist	Ifremer	0.5	Deep Mission expertise
Leymarie, Edouard	Engineer	CNRS	5.94	BGC float and sensor expertise, AST Technological Task Team co-Chair
Kermabon, Catherine	Engineer	Ifremer	4	Software and tools development - LOCODOX expertise
Kolodziejczyk, Nicolas	Scientist	CNAP	4	SNO and scientific coordination, animation, expertise and product development (P/T/S, trajectories), expertise ISAS, AST Polar Mission Chair
Maze, Guillaume	Scientist	Ifremer	3	Software and tools development - Euroargodev coordination
Prigent, Annaig	Technician	Ifremer	8	ISAS, DMQC Core and Deep
Reynaud, Thierry	Engineer	Ifremer	4	O_2 DMQC and expertise
Schmechtig, Catherine	Engineer	CNRS	6	Coordination on BGC-Argo with Coriolis, expertise on DMQC, ADMT BGC co-Chair
Sauzède, Raphaëlle	Engineer	CNRS	9	Expertise on BGC DMQC and BGC products development, ADMT BGC France representative
Thierry,Virginie	Scientist	Ifremer	2	IR* coordination , animation, expertise O2 and Deep-Argo, AST France rep. and Deep Mission co-Chair, Euro-Argo board
Poteau, Antoine	Engineer	SU	7.2	Logistic, sensors performances and support to the users for BGC component
Uitz, Julia	Scientist	CNRS	6.3	Coordination, animation, expertise on BGC-Argo Mission
		Total pm	**77.34**	

B8. Gouvernance

1) Internal instances

a) The management board

The management board ensures the coordination of the Argo France activities and their compliance with OneArgo the requirements ; ensure the coordination between scientific and investments projects and operational Argo France activities, especially for technological floats development ; develop the strategy for

Argo deployments in line with OneArgo Missions and provide a recommendation on the annual deployment plan elaborated by the operational team before validation by the Scientific Council.
The action of management board are to :

- establishes an annual plan of activities of the program and associated human and financial resources,
- proposes technical and scientific orientations and objectives as well as strategic choices to the Board Director,
- ensures the establishment of the material, scientific and technical environment necessary for the advancement of Argo France,
- organizes interfaces with MOI and other operational oceanographic systems (e.g., data quality, impact of observations in analysis and forecasting systems, future requirements),
- defines, in liaison with the Scientific Council, the scientific priority axes necessary for Argo France and contributes to the preparation of the annual call for tender of the Mission Mercator Coriolis Group (GMMC),
- educates and proposes the admission of a new partner.

Over the period 2019-2023, the management board has been enlarged to encompass all the OneArgo missions, and will be reconducted over the period 2025-2029 (Fig. 9):

- IR* coordinator (V. Thierry*[3], Deep),
- SNO scientific coordinator (N. Kolodziejczyk*, Core/Polar),
- BGC scientific coordinator/ GMMC representative (J. Uitz*, F. D'Ortenzio, H. Claustre*)
- a technical coordinator (Core/Deep: V. Thierry*, BGC: E. Leymarie*),
- operational coordinators (Core/Deep: N. Poffa, N. Lebreton and BGC: A. Poteau*),
- data management coordinators (Core/Deep: T. Carval, C. Coatanoan, and BGC: C. Schmechtig*),
- a technology coordinator (X. Andre, Ifremer/RDT),
- DMQC coordinator (Core/Deep: C. Cabanes*, BGC: R. Sauzède*)

To strengthen the link between ERIC Euro-Argo, Operational community (Mercator) and GMMC, the management board invites C. Gourcuff and R. Cancouet (ERIC Euro-Argo), E. Remy (MOI) and W. Llovel (GMMC), respectively. The management board has met 3 to 4 times a year since 2014. All reporting, expertise and recommendations are available upon request on Argo France website www.argo-france.fr/sendform/contact.

b) The Board of Directors (BD)

The Argo France Board of Directors is that of the IR* Euro-Argo France. The BD brings together the directors (or their representatives) of the Argo France partner organizations. Among its missions, fully described in the corresponding MoU, it sets the general orientations and objectives of Argo France, approves the annual activity plan and the distribution of the budgets and resources allocated to Argo France by each organization, interface with the Ministry of Research, and decides on the evolution of the scope of Argo France in relation to Euro-Argo ERIC.

c) The Scientific Council (GMMC)

The Argo France Scientific Council is that of the joined Coriolis and Mercator Ocean councils (*i.e.* GMMC). It is an advisory body whose mission is to make recommendations on the strategic scientific orientations of Mercator Ocean and CDS-IS-Coriolis taking into account the national, European and international context. Vis-à-vis Argo France, it gives opinions, in particular, on the scientific articulation of Argo France activities with those of national, European or international projects having the same purpose.

The Scientific Council evaluates the proposals submitted in response to the annual call for tender (LEFE GMMC) of the Mission Mercator Coriolis Group (GMMC). The Scientific Council ensures the adequacy of the proposals with the recommendations of the Argo international committee on float deployment strategies. The Scientific Council may also be required to formulate opinions for deployments of opportunity. It may be referred by the management board to any scientific question concerning the

[3] * Indicates SNO members.

activities of Argo France, on which it wishes opinion, proposal or recommendation, in particular concerning the deployment strategy of Argo France.

2) External instances

Different members of the Argo France project are involved in external governance instances. IR* and SNO Argo France members have leading implications in external instances from the national to the European (Euro-Argo ERIC) and international levels (AST, ADMT, …)(Table 2). The list of responsibilities and representations are detailed in *Table H4, ANNEXE H*.

B9. Budget

The reader is reminded that, the ensemble of Argo France activities, **except for SNO activities : expertise, coordination, representation and valorization**, are directly funded via the IR* and dedicated projects led by SNO Argo France members (Equipex+, ERC, PIE, CPER, EU...). A yearly recurrent funding for the IR* is provided on the road map of the Ministry (up to 2027) and by SHOM. Since 2010 IR* Argo France recurring funding is 1,1M€ per year mainly dedicated to **Core floats only** procurement (1541 floats purchased since 2000), fleet piloting and Core data management (via CDS-IS-Coriolis). **Additional funding from projects increases this yearly budget to 3.8M€ until 2027-2028. This budget will ensure the acquisition of about 55-60 floats for the OneArgo mission.**

Over 2019-2023, the main recurring expenses for the SNO activities (expertise, coordination, representation and valorization) were :

- Given the new BGC and Deep Argo missions added to the historical Core mission, the number of SNO Argo France experts and steering teams have doubled. Traveling for representation in annual Argo meetings (AST and ADMT) and occasional workshops (DMQC, Science, …). This is partially funded by the SNO dotation (e.g. C. Schmechtig BGC ADMT co-Chair ; N. Kolodziejczyk, Polar Mission co-Chair ; C. Cabanes, ADMT exec.) and by projects or IR* funding (V. Thierry, France representative, Deep Mission co-Chair ; H. Claustre, BGC co-Chair ; R. Sauzède, BGC France representative ; E. Leymarie, TTT co-Chair) (*Table H4, ANNEXE H*). Although we limit our overseas travels (and favor train for national and european travels) for reducing GHG emissions, using remote participation when it is feasible, the SNO recurring funding (12.5 k€/yr) cannot cover the travel expenses in the worst case of no extra funding from projects (on average 18k€/yr, Table 3,4,5) .
- A typical SNO activity is developing new methods and tools, such as the development of the NRTQC algorithm through Master training (stage) and CDD IR (INSU). 12 month of CDD for BGC data processing was also funded on projects. These training or CDD are crucial in a context of heavy workload and lack of permanent manpower at SNO (coordination, SNO activities, …, Table 4).
- Another typical SNO activity, that are not fully taken in charge via the IR*, is curating advanced dataset when method already exists, but needs manpower to regularly update the data set. A exemple is the ANDRO dataset that is an unique trajectories product used by the whole international community. The curation of ANDRO is operated by subcontracting the Capgemini's engineers that have the expertise on ANDRO since the beginning (*Ollitrault and Rannou, 2013*). The regulated update of ANDRO is funded partially on SNO dotation and mainly from projects (CPER, …). DMQC of LOPS and LOV floats acquired on projects need also to be done by subcontracting experts usually involved in the Argo DMQC process at DAC level (Table 4).
- Regular renewal of the computers and servers is also mainly funded on projects (Table 4).

Therefore, for the 2025-2029 period the annual SNO dotation required will be 36k€/year, to support enlarged requirements for SNO scientific coordination and representativity at international level, and support SNO expertise and tools developments (Table 5).

Table 3 : Ressources of the SNO Argo France 2019-2023

Ressources récurrentes sur 2019-2023			Ressources occasionnelles sur 2019-2023		
Origine[1]	***Montant (k€)***	***Commentaire***	***Origine***	***Montant (k€)***	***Commentaire***
CNRS/INSU	*50*	*SNO dotation : 10k€/yr*	*ANR Equipex+ , equipex NAOS (reliquats), ERC REFINE, EU H2020 EA-RISE , LEFE ,...*	*133.5*	*Argo-2030: subcontracting Argo France website update, missions, materiel, fonctionnement, CDD data BGC*
OSU/IUEM	*14*	*Note that the OSU IUEM dotation has been reduced from 3k€/yr to 2.5 k€/yr since 2022*	*IR* Euro-Argo*	*3.4*	*Missions*
			Ifremer	*52.9k€*	*CPER ObsOcean, ANDRO database update, DMQC O2 and DMQC T/S*
			INSU-Coriolis	*24*	*6 m CDD*
TOTAL	*64*		*TOTAL*	*213.8*	

Table 4 :Expenses of the SNO Argo France over the periode 2019-2023

Dépenses récurrentes sur 2019-2023			Dépenses occasionnelles sur 2019-2023		
Nature[2]	***Montant (k€)***	***Commentaire***	***Nature***	***Montant (k€)***	***Commentaire***
Missions	*24.0*	*annual meeting AST, ADMT (COVID 2020-2021 : online meetings), Workshop (Science, DMQC), missions Brest/VF*	*Missions*	*65.9*	*annual meeting AST, ADMT; Workshop, mission Brest/VF*
equipement	*10.8*	*computer, server, backup, small material*	*equipement*	*16*	*Server OAO/storage LOV/IMEV*
subcontracting	*28.8*	*Data processing ANDRO database update, DMQC T/S*	*subcontracting*	*54.9*	*ANDRO database update, DMQC O2 and DMQC T/S, site web Argo France*
			miscellaneous	*3*	*Orga. ADMT VF 2019 and AST Monaco 2022*
			CDD (12m) + CCD (12m)	*74*	*IR CNRS dev. algo. NRTQC traj, CDD BGC data processing*
TOTAL	*63.6*	*no mission during the COVID years 20-21*	*TOTAL*	*213.8*	

Table 5 : Proposal for funding the SNO Argo France over the periode 2025-2029

Demande de soutien sur 2025-2029 (y compris soutien CNES)		
Nature[2]	***Montant (k€)***	***Commentaire***

Travel	*90*	*Argo France, AST, ADMT, DMQC, Argo Science Meeting and workshop for BGC, Core and deep missions, Brest/VF (22.5 k€/yr)*
equipement	*25*	*computers for OSU and CNAP members, server, storage*
subcontracting	*30**	*ANDRO, DMQC, data curation (6 k€/yr)*
stage	*30*	*QC methods & products developments, 1 stage LOPS and 1 stage LOV (6k€/yr)*
occasional	*5*	*techno dev., website, outreach*
TOTAL INSU + OSU	*180 k€*	*180k€ INSU+OSU dotation shared between LOPS and LOV (36 k€/yr)*

*This does not include the CDD contracts, which is also needed for our activities (~18 m over 2019-2023).

B10. Formation, communication, diffusion des connaissances et impact sociétal

1) Teaching

Over the period 2019-2023, both Core-Argo and BGC-Argo data continue to be part of lectures provided by SNO Argo France Member in graduate schools (M2) associated with OSU/IUEM/UBO and OSU STAMAR/SU. A complete list of the teachings are provided in *ANNEXE J.*

2) Outreach

Argo France has continued to develop outreach activities based on Argo. One of the highlight of the period 2019-2023, is that the program adopt a float (https://adoptafloat.com/) was extended to Britany region, with a leading effort by Ifremer (https://www.ifremer.fr/fr/la-mediation-scientifique-l-ifremer/nos-offres-pedagogiques/adoptafloat), as well as internationally with currently more than 90 classes in several countries (*ANNEXE J*)

SNO Argo France contributes to the Euro-Argo/OceanOps outreach activities, in particular to the 2nd Ocean Observer workshop (30 Nov.-1 Dec. 2021, online), which was an international meeting gathering scientific, teachers and education actors who are invested in outreach with oceanographic data including Argo.
(see:https://www.euro-argo.eu/News-Meetings/News/News-archives/2021/2nd-Ocean-Observers-Workshop-new-connections-and-lots-of-experience-sharing). A complete list of outreach activities are provided in *ANNEXE J*.

3) Communication

Over the period 2019-2023, SNO Argo members have participated to yearly “Fêtes de la Science”, “Nuit des chercheurs”, open days of Ifremer, IUEM/UBO, or LOV/IMEV. The SNO Argo team has promoted and disseminated the Argo program and science in “conférence grand public” organized by CNRS at Brest (Nov. 2023). They also participate in videos and podcasts (Universcience, Euro-Argo, …). In 2022, the common kick-off meeting of 3 Argo projects led by Argo members (Equipex+ Argo2030, PIE Ifremer PIANO and CPER ObsOcean), has been largely broadcasted in the press (radio, TV, newspapers). This was an unprecedented opportunity to talk about Argo with a very large regional and national audience (a complete list of the communications and link is provided in *ANNEXE J*).

B11. Difficultés rencontrées et propositions envisagées pour amélioration

The SNO has and continues to face challenges related to:

- Insufficient budgetary resources for the SNO to ensure the representation of Argo France in international governance bodies, tools developments and data curation. In particular, it is sometimes difficult to involve our national experts and coordinators at meetings where important decisions are taken (e.g. technical recommendations, network design, given procedures). This is due

to the enlarged mission of OneArgo now including Core, BGC, Deep Argo and Polar missions. Up to now, especially for the BGC component, these missions and travel have been funded by independent projects (Table 4).

- Long-term financing of the French contribution through the IR* is ensured for the Core Mission (P/T/S, 0-2000 m depth). However, after 2027 the BGC, Deep and Polar Missions need much more funding than the current recurrent budget. Indeed, the BGC and Deep OneArgo missions are currently funded by the Equipex+ Argo 2030, Ifremer PIE PIANO and ERC REFINE projects. Argo France team is working hard for Including BGC, Deep and Polar missions to the IR* recurrent funding on the Ministry roadmap. This is key to the France's leadership in OneArgo and to maintain the France contribution around 8% in OneArgo. This increase is justified by the number of floats to be acquired (80 vs 55) and by the extended capabilities of the floats (Deep floats will reach 6000 dbar vs 4000 dbar, BGC floats with all 6 BGC sensors and core floats with O2 sensors).

Empreinte environnementale du SNO

C1. Précisions disponibles concernant les impacts environnementaux générés par le fonctionnement de l'outil proposé pour labellisation.

The Argo program is a unique and global research infrastructure to the benefit of global research, global operational services and global policy makers. If we consider that Argo France contributes to 10% of the network, this scaling could be applied to the Argo global impact to estimate Argo France environmental impact.

Since 2019, the OneArgo program and Euro-Argo have started to evaluate the global environmental impact of the Argo Network. An "Argo's environmental impact statement" is available (https://argo.ucsd.edu/wp-content/uploads/sites/361/2020/05/final.Argo_Environmental_Impact.2020.05.10-1.pdf) and a poster (https://argo.ucsd.edu/wp-content/uploads/sites/361/2021/06/Environmental_Impact_Euro-Argo_POSTER.pdf) for the global network, included to dedicated webpage on the Argo website: https://argo.ucsd.edu/about/argos-environmental-impact/ . In summary, the following key messages related to the environmental impact of Argo floats:

- If all Argo floats deployed thus far were laid side-by-side, they would take up the space of only two football fields.
- When considering the maximum value of 900 floats dying and requiring replacement each year, the following chemical inputs from various float's component (aluminum, plastic, lead, lithium, …) among others, to the ocean are noted :
    - It would take over 176,000 years of Argo operations to introduce the same amount of aluminum into the ocean that is employed annually to produce drinking cans (200 billion per year at 15 grams/can).
    - A single year of the human contribution of plastic to the ocean is equivalent to 4.4 million years of plastic input from Argo floats.
    - One year of the natural flux of lead into the ocean is equivalent to 83 million years of Argo operations.
- In addition, given the large spatial distance between each Argo floats (typically 300 km apart), and mixing processes within the water column, it is highly unlikely that a concentration of chemicals will accrue in any given region when an Argo float sinks.
- It would take many vessels traveling across ocean basins, emitting CO2 and polluting the atmosphere to recover all Argo floats deployed before they sink, canceling out any environmental value the Argo Program has brought to global ocean observations and the understanding of Earth's climatic system.
- By design, Argo floats are autonomous instruments meant to survive maximum lifetimes after they are deployed. They have been designed and manufactured with state-of-the-art technologies and could be considered as models of low energy consumption, providing outstanding information and ocean interior knowledge that few other devices could bring with such battery capacity.

In addition, qualitative consideration can be made:

- The full Argo dataset has a volume of about 60 Go (10^9), and has been downloaded about 7400 times over 2019-2023 (from seanoe.org). For comparison, the volume of digital data created or replicated worldwide has increased more than thirty-fold over the past decade, from 2 zettabytes (10^{21}) in 2010 to 64 zettabytes in 2020 (one zettabyte is equivalent to one billion terabytes, or one thousand billion gigabytes) source: https://www.bercynumerique.finances.gouv.fr/big-data-limpact-environnemental-des-donnees-et-du-numerique
- The CO2 impact of the Argo fleet relies mainly on the manufacturing, transportation and deployment effort. Most Argo floats are deployed by ship of opportunity, including commercial ships, research vessels (doing other work), and sailboats. **This is probably the main difficulty, but**

also the main leverage of GHG emissions removal for the Argo program, to be able to design a full low emission and circular Argo economy.

- As being an international project, the main CO2 impact of the Argo program is the intercontinental flights to attend the 2 or 3 meetings per year (note that since Covid Pandemic the meetings are now hybrid and about 50/50 in person/remote. **This is a second main leverage of GHG emission removal for the Argo program.**

C2. Évaluation des bénéfices à mettre au regard de ces impacts

- The Argo array provides a vital operational and research data stream that underpins important nowcast and forecast services, science, and policy assessments. The array contributes to saving lives, avoiding property damage, informing the public and government's response to environmental variability and change, and to sustainable management of marine resources and the preservation of ocean health.
- Argo presently collects about 120,000 surface-to-2000 meter profiles per year from the world ocean, from an array of over 3000 floats. Assuming 300 km spacing between floats or stations, a time of 3 hours to carry out a shipboard CTD cast to 2000 m, and a typical vessel speed of 10 knots (18 km/h), more than 15,000 days of dedicated ship time per year (41 boats 365 day per years) would be required to collect the equivalent of the annual Argo data production using ships alone (saving 1 million tonnes of CO2 per year).
- Presently there is no method of observing the subsurface global ocean that is more cost effective and less environmentally damaging than Argo. Since Argo floats are mainly deployed from ships-of-opportunity, the marginal financial and environmental costs of float deployment are each relatively small. The main environmental effect of Argo comes from foreign substances released from old, dead floats on the seafloor, but the amount of these pollutants entering the ocean is extremely small compared to natural and anthropogenic fluxes.

C3. Réflexion générale sur les évolutions engagées ou envisagées du compromis bénéfices-impacts actuel.

In the future there may be a cheaper and cleaner global observing system that results from improvements in Argo technology or from some new methodology that is presently unknown. In this vein, Argo will continue to work with its manufacturers to advance the technology in order to further reduce its environmental footprint, and to carry out float recoveries in cases where the added environmental footprint is not too large.

Concrete actions taken by Argo France over the period 2019-2023 and that will continues over 2025-2029:

- Ongoing estimation of GHG emission of IR* and SNO Argo France activities.
- As Argo is an international effort, involving more than 25 countries around the world, meetings take place regularly overseas. Argo France tried to reduce the number of travels for missions in representative meetings, using trains in Europe when it is feasible, using visio each time it is possible.
- Study the feasibility of recovering the Argo floats by global marine traffic (*González-Santana et al., 2023*)
- Development of recovering tools to ease the recovering of Argo floats by opportunity positioning the floats in End of Life mode and proximity of vessels (https://floatrecovery.euro-argo.eu/).
- Deployment and recovery experiments in the Atlantic Ocean by the dedicated sailing ship expedition (https://www.meteorologicaltechnologyinternational.com/news/oceans/scientific-sailing-expedition-to-deploy-argo-floats-in-remote-atlantic-locations.html)
- Pro-active involvement of Argo France on the topic of float recoveries in the framework of PIANO, GEORGE and Euro-Argo ONE EU projects. Dedicated low-impact recovery cruise planned mid-2024 as part of a proof of concept within GEORGE project. The campaign is ongoing, and 6 floats (4 Arvors, 2 Deep-Arvors) have been successfully recovered in various sea state conditions (video).
- Reflection on how to design a refitting chain for a circular Argo float economy and how to involve the Argo floats and sensor manufacturers in the process.

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Annexe A : Production scientifique des <u>acteurs</u> du SNO (publications de rang A, thèses, indiquer quels sont les articles associés à ces thèses) ; préciser obligatoirement l'adresse url ouverte de cette production scientifique propre du SNO.

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Annexe B : Production scientifique des utilisateurs du SNO (publications de rang A, thèses) ;
The complete lists of the **6269 peer-reviewed articles and 451 PhD thesis** to date, based or using Argo data, are available online at https://argo.ucsd.edu/outreach/publications/bibliography/ and https://argo.ucsd.edu/outreach/publications/thesis-citations/. The specific list of **French peer-reviewed articles, i.e. have used Argo observations and have been co-authored by a French contributor, more than 611 since 2012, and 42 PhD** since 2003, thesis are available on : https://www.argo-france.fr/Bibliographie/Publications**.** Note that since 2002, France is the 3rd most publishing country with Argo data behind USA and China. This reveals the vitality of the French Argo community

Annexe C : lettres de soutien et d'engagement (dans l'ordre)

Lettres de soutien:

1. AST: S. Wijffels, B. King (AST Co-chairs)
2. ADMT : M. Scanderbeg, C. Gourcuff (ADMT Co-chairs)
3. Euro-Argo : Y.-H. De Roeck (Executive Director)
4. OceanOps : V. Turpin (Technical Coordinator of Argo International)
5. Mercator Ocean International : P.-Y. Le Traon (Scientific Executive Director)
6. LEFE/GMMC : W. Llovel (President)
7. IR ILICO : A. Le Guen, A. Lefebvre (IR responsibles)
8. Projet IR OHIS: S. Speich, P. L'Herminier (Responsibles)
9. SMOS: J. Boutin, N. Reul (PIs)
10. TOSCA Ocean (Satellite Observations): J. Boutin (President TOSCA Ocean),Y. Faugère (Program Responsible Ocean CNES)
11. SNO SSS: G. Alory (SNO responsible)
12. SNO Pirata : J. Llido (responsible)
13. UAR IMAGO: B. Bourlès (DU)

Lettres d'engagement:

1. LOPS: J. Paillet (DU)
2. OSU IUEM : Fred Jean (Director)
3. LOV, IMEV, OSU STAMAR : Frédéric Gazeau (DU), Elisabeth Christians (Director), Eric Thiébaut (Director)
4. OSU EcceTerra (partner): Arnaud Huguet (Director)

Lettres d'appartenance:

1. Pôle ODATIS/IR DataTerra: Erwann Quimbert (Responsible)
2. IR* Euro-Argo France : V. Thierry (IR* Responsible)

Annexe D : SNO stratégique pour les activités spatiales

Context and funding

The SNO Argo France is strategic for space activities because it is one of the main sources of *in situ* surface data necessary for calibration/validation of satellite measurements. CNES does not directly fund Argo activities but can participate through project financing, e.g. indirectly supporting ISAS activities via TOSCA SMOS OCEAN. For the BGC component, CNES contributes by financing the sensor load for 3-4 floats/year (150 k€/year), which are distributed by the GMMC LEFE committee.

Relevance of OneArgo data for space

OneArgo's physical parameters:

- Core Argo data, together with the analyzed ISAS products produced by the SNO Argo France, are key elements in the process of calibrating and validating sea surface salinity (SSS) data measured by L-band satellites. Argo measurements are used in a number of projects linked to remote salinity measurements: TOSCA SMOS OCEAN for the cal/val, and valorization of SMOS measurements (active since 2009)(e.g. *Vinogradova et al., 2019 ; Reul et al., 2020; Boutin et al.*, 2022); the ESA PIMEP project in collaboration with NASA (*Guimbard et al., 2021*), a validation platform for L-band SSS measurements widely used in the L-Band SSS international community; the ESA CCI+SSS project to intercalibrate time series from different satellites in order to produce a homogeneous SSS climate series (e.g. *Boutin et al.*, 2021); or calibrate satellite SSS products in the framework of CNES/CATDS (*Kolodziejczyk et al., 2021*) project and NASA project (https://salinity.oceansciences.org/oi-climatology.htm)
- The coverage of Core Argo and Deep Argo T/S profiles has enabled us to estimate global and regional trends in the thermohalosteric component of sea level. Complementing data from gravity satellites (GRACE, GRACE-FO) and altimetry satellites (Topex-poseidon, the Jason constellation, Saral-Altika, ENVISAT, etc.), Argo data can now be used to test the closure of the global sea level budget over the period common to the different time series (e.g. *IPCC, 2018* ; *Barnoud et al.*, 2021).

For the OneArgo biogeochemical parameters, among the six main variables of the BGC-Argo mission, three are “bio-optical” variables: chlorophyll a concentration (Chla), particulate backscatter coefficient (b_{bp}) proxy of the suspended particulate stock (POC), and radiometric variables, currently photosynthetically available illuminance (PAR) and multispectral downwelling illuminance ($E_d(380)$, $E_d(412)$, $E_d(490)$). These same variables can be measured, or derived, from space using satellite ocean color sensors (Ocean Color Radiometry) or LIDAR remote sensing for b_{bp}. The gradual densification of the BGC-Argo observation network, together with the development of ever-improving quality control methods, now produce an interoperable global database for these bio-optical variables. Four domains of activity based on synergy between BGC-Argo and satellite observations are currently emerging:

- Synergetic use of BGC-Argo and satellite data to generate 3D/4D “gridded” Chla, b_{bp} (or POC) and radiometric products (*Sauzède et al. 2016; Renosh et al. 2023*). Based on artificial intelligence methods such as machine learning, some products are currently distributed by the Copernicus Marine Service, while others are under development. These products can be used for a range of applications, from data quality control (through audits), to reference measurements to initialize or validate biogeochemical models, to name but a few.
- The use of the BGC-Argo bio-optical database to examine the variability in bio-optical relationships (*Organelli et al. 2017; Uitz et al. 2023*) and validate products derived from Chla, b_{bp} or radiometric satellite observations (*Xing et al. 2020*). The BGC-Argo database offers undeniable advantages over historical bio-optical databases, in particular a broad representation of the different bio-optical regimes of the open ocean, greater consistency and interoperability.
- The integration on BGC-Argo floats of new sensors performing hyperspectral radiometric measurements of downwelling illuminance (E_d) and upwelling luminance (L_u) opens up new application prospects for the satellite observation community (*Organelli et al. 2021*). The recent launch of the PACE hyperspectral satellite makes BGC-Argo floats equipped with hyperspectral sensors the platform of choice for rapidly developing dense reference databases. These databases

will also be used to validate new types of products (e.g. ocean surface heat deposition, phytoplankton communities).

- Finally, as the uncertainties associated with float-based radiometric measurements are beginning to be well characterized, the BGC-Argo fleet could, in future, be used in synergy with optical moorings to carry out fiducial reference measurements (FRM), essential to satellite recalibration activities throughout their lifetime.

Activities and Funding proposal for 2025-2029

- For the period 2025-2029, a funding of 150 k€/year (~750k€ over the 5 year period) is expected from CNES to support the procurement of standard BGC sensors, including hyper spectral radiometers to contribute to the calibration/validation of multi- and hyperspectral ocean color missions.
- The growing amount of data and number of different variables in the BGC-Argo mission implies an increased workload in terms of developing and implementing appropriate data flows as well as real-time and delayed-mode qualification procedures. This increased workload cannot be fully handled by the existing 2-person team. In this context, we have submitted several proposals, and will continue to do so, to obtain funding and recruit staff to support data management. At least 12 months at the IR level are needed (50 k€ / an). Additional support is needed for the logistics and testing of BGC-Argo sensors and floats, in a context of an increasing number of sensors per float and growing diversification of sensor technologies and suppliers. Logistical activities also require more resources, considering the increasing complexity of administrative tasks linked to purchasing, transport and customs clearance. The increase in the number of floats recovered at sea also involves a growing need for human resources to manage the return and reconditioning of equipment.
- The global and regional Sea Level indicators of the SNO Argo France will be consolidated in the context of a proposal submitted to OSTST in June 2024. The work will provide new regional and closure of the global sea level indicators in routine for the SNO Argo France that will be distributed via the Argo France website.
- Part of ISAS activity and expertise in relation to the calibration/validation of L-Band satellite will continue to be proposed to be funded in the framework of the TOSCA SMOS OCEAN project (missions, small material, stages).

Annexe E : SNO stratégique pour les activités polaires

Context

To address the challenge of the rapid change of the ocean, climate and subsequent environmental changes in the Polar regions, as well as specific ocean processes in link with ocean and ice interactions, in situ monitoring of the ocean condition are mandatory. However, sparsity of in situ physical and biogeochemical observations prevents the consistent monitoring of the Polar regional changes. Winter harsh conditions and presence of sea ice cover has been the main issue to carry out regular measurements of the water column. Recent technological progress in autonomous floats has made it possible to complement existing Polar observing systems, especially in regions of seasonal sea ice or Marginal Ice Zone.

Polar Argo refers to the subset of Argo floats operating in ice-covered areas south of 60°S and north of 60°N. Although these regions were not included in the original Argo design, floats have been deployed there since the early stages of the program, with the first floats deployed as early as 1999 and 2001, poleward of 60°S and 60°N, respectively. Argo has considerably improved our ability to observe the full seasonal cycles of the physical processes in the Polar oceans. In 2023, Argo floats in the Southern ocean had collected almost 78 000 profiles, from which about 50% were winter profiles (April to September) and 20% were under ice. In the Arctic domain, about 39 000 profiles have been collected, half during winter and 3% under ice.

The presence of sea ice, however, represents a hazard for the integrity of the floats and prevents their communication with satellites, which is necessary for data transmission and the determination of the profiles positions. Klatt *et al.* (2007) introduce Ice Sensing Algorithm (ISA) software that can be activated on any standard Argo floats. The ISA is based on temperature criteria in the upper layer of the ocean to assess presence of sea ice by detecting cold water near the freezing point. Then, the float aborts its ascent and stores the data in its memory, waiting for emergence in the free ice area or next summer. This new capability has made possible implementation of several Polar Argo Pilot Arrays both in the Southern Ocean and Arctic Ocean.

However, the ice avoidance strategies (such as ISA), does not allow to get associated GPS position along with the under ice profiles. This is a serious drawback for the Argo floats in the ice covered region.. Although, post processing data algorithms have been developed to reconstruct trajectories of under ice floats and estimating positions (e.g. *Yamasaki et al., 2020 ; Wallace et al., 2020 ; Oke et al., 2022*), these methods are still limited such as in the Arctic deep basin, where the floats can remain under the permanent sea ice pack during all their life span. Very recent developments of floats with acoustic localisation and communication capabilities have allowed them to collect under-ice profiles along with localisation in the Canadian Basin (*Lee et al.*, 2022). These new capabilities give us a glimpse of what a future Argo network could look like in the Arctic and can complement existing observation systems.

OneArgo Polar Mission in the framework of Argo France

The OneArgo Polar Mission was launched in 2023 along with the formation of the Polar Mission Team. The Polar Argo mission team acts as a scientific committee of Polar Argo national representatives, which provide recommendation and guidance for the progressive development and implementation of a Polar Argo program in the context of the global One-Argo array. The Polar Argo mission team will closely liaise with and report to the international Argo Steering Team. The co-chairs of the Polar Argo Mission Team will be members of the International Argo Steering Team. Polar Argo Mission Team is co-chaired by SNO Argo France members (*Table H4, ANNEXE H*). Argo France through collaboration with French PIs (Project SOCHIC, PI. J.B Sallée ; ARcticGO Project ; Takuvik collaboration with GREENEDGE and NOAS project ; *André et al., 2020*) has developed an expertise in Polar Argo mission. Polar Argo mission will also naturally closely interact with the 3 other OneArgo Missions (Core, Deep, BGC), to tackle the climate and environmental challenges in the Polar regions.

For the period 2025-2029, the Argo France will contribute foster the Polar Mission with main primary objectives:

- Promote the Polar Argo France deployments and implementation of the Polar Argo array, by providing guidance and recommendations to the French PIs.
- Contribute to the international working group to establish the Polar Argo design, standard recommendations for deployments and under ice data processing (in the framework of the proposal EU HORIZON “Euro-Argo One” and the Argo Polar Mission).
- Share knowledge and expertise of technological advances and issues for Polar Argo (including hardware and software), mission programming, ice avoidance algorithm tuning and under ice positioning capability (e.g. navigation, acoustic geolocation and post-processing techniques).

Annexe F : SNO/SI/IN/CC/PIN stratégique pour les activités en partenariat avec des pays au Sud - IRD

Argo program is an international effort to provide qualified data profiles freely distributed to the scientific community with no restriction. Thus, emerging countries that have not the capabilities to contribute to the Argo program can however use the Argo data freely for monitoring their offshore environment (if relevant). In this context, IRD researchers in the framework of their project and in collaboration with Argo France can provide capacity building to deploy floats in specific regions and training for use of Argo data. It should be noted that SNO Argo France high level products (freely distributed such as ISAS, CANYONB, …) can ease the use of Argo data for beginner users.

On specific occasions, partnership is progressively developed between the Argo France community and Small Island Developing States or emerging countries that have not the capability yet to acquire and deploy floats. This was the case for Seychelles and Mauritius as part of the Monaco Explorations Indian Ocean cruise in fall 2022 or in the context of the nascent Argo-Dome project with Costa-Rica. Following a submission of a dedicated project, floats allocated by LEFE-GMMC were (or will be) deployed in very close collaboration with local partners. This serves the base for the progressive development capacity building activities with respect to float preparation deployment (and possibly retrieval) and data access and analysis. Furthermore and in the specific case of the Argo-Dome project, float operation in the so-called Costa-Rica thermal Dome is expected, over long-term, to support better knowledge of the area for developing a better and science-informed management (e.g. fisheries, maritime traffic). Finally and in all cases, the partnership with these countries allows to launch outreach and educational Ocean Literacy related actions in the context of the "adopt a float" project.

An other concrete example of collaboration between emerging countries and SNO can be illustrated by the deployment of Argo floats equipped with DO sensors in the Oxygen Minimum Zone (OMZ) of the South East Pacific and Off Senegal, around the scientific question of the Ocean deoxygenation and expansion of the OMZ. This question is crucial for environmental monitoring and fisheries of emerging countries coasting the OMZ. In this context, the procedure of Delayed Mode DO qualibration (*Thierry et al, 2021,* doi: 10.13155/46542) has been adapted by SNO members to qualify floats deployed off Peru in delayed mode, notably by Chilean PI Osvaldo Ulloa. In fact, in this oxygen minimum zone, zero oxygen concentration is reached and it was necessary to split the delayed mode procedure in two

1. First, an offset is determined to reach zero concentration.
2. Once the offset has been subtracted, the gain and potential drift are estimated.
3. Once the offset and gain coefficients have been determined, we apply them and check the spatial consistency of the corrected concentrations. (Fig. F1)
4. The corrected data are also checked for agreement with the GLODAP validation database https://glodap.info/ (Fig. F2).
5. Corrected data are made available on GDAC

This work can also be carried out in collaboration with IRD researchers (Aurélien Paulmier, Gérard Eldin) and in particular those who have deployed floats obtained under the LEFE GMMC call for tenders (Boris Dewitte) or for floats deployed during PIRATA campaigns off Senegal, another OMZ.

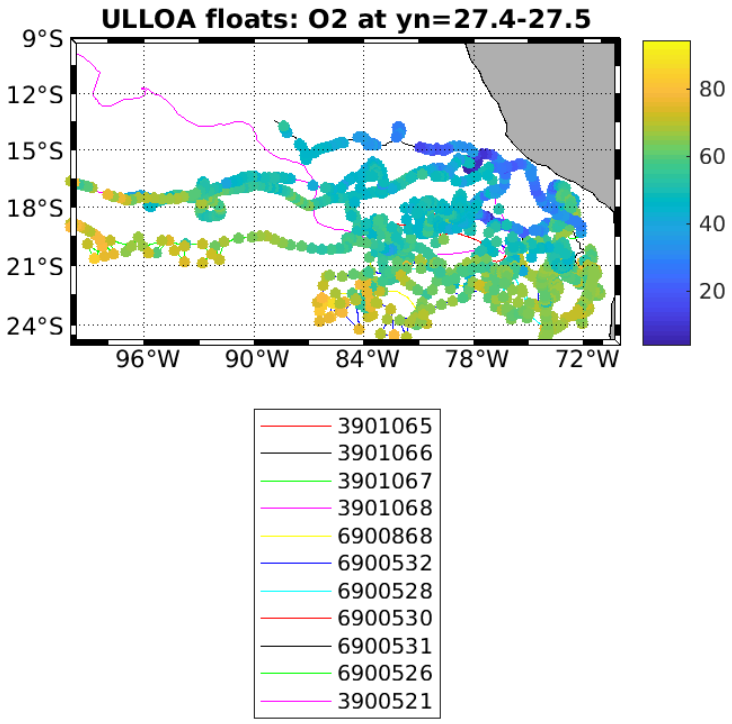

***Figure F1**: Oxygen concentration corrected for differents floats deployed in the Peruvian oxygen minimum zone*

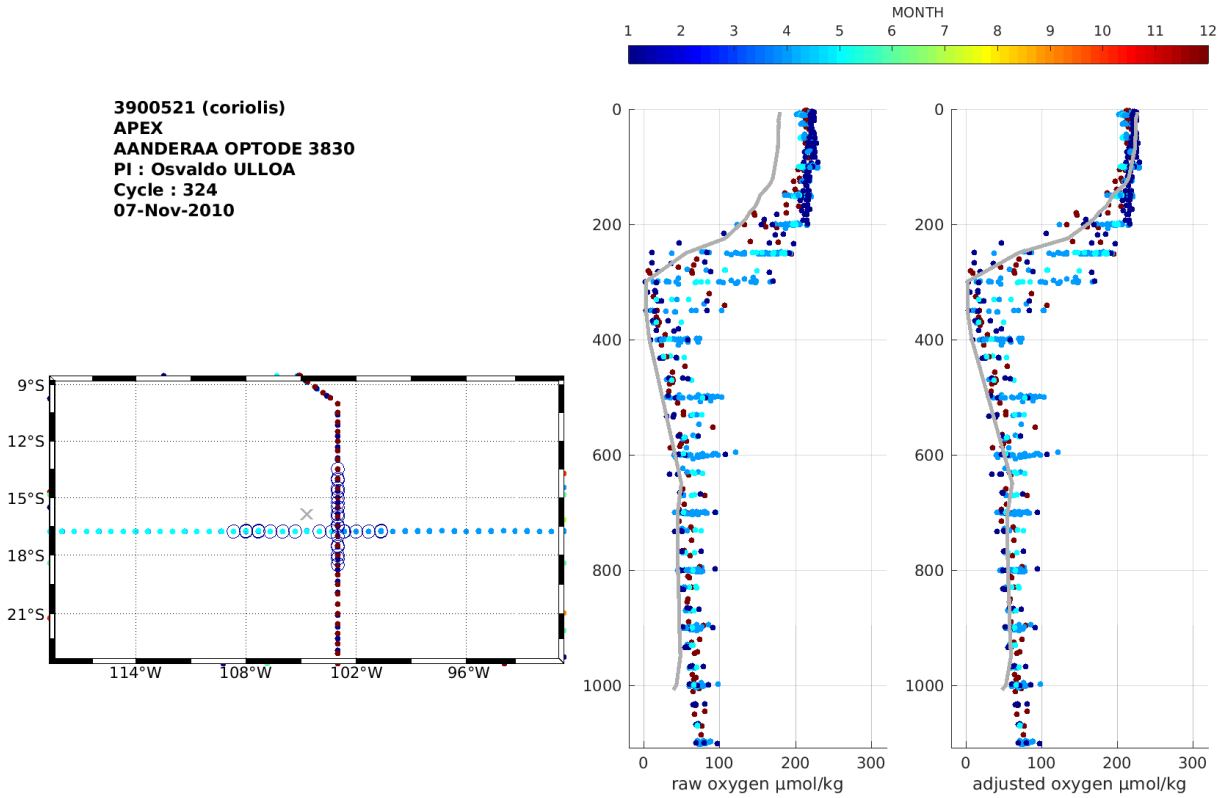

***Figure F2** : Comparison between raw (left) and corrected (right) 3900521 float data and the GLODAP database*

Annexe G : SNO/SI/IN/CC/PIN stratégique pour les activités en lien avec la météorologie et le climat - Météo-France

No specific collaboration has been built between SNO Argo France and Météo-France. The strategic link with climate studies is fully detailed in the **Section B** of the main proposal.

Annexe H: Supplementary Tables

Table H1: List of automatic tests performed on data distributed in near real-time.

Order	Test ID	Test name
1	19	Deepest pressure
2	1	Platform identification
3	2	Impossible date
4	3	Impossible location
5	4	Position on land
6	5	Impossible speed
7	6	Global range
8	7	Regional range
9	8	Pressure increasing
10	9	Spike
11	10	Top and bottom spike, deprecated
12	11	Gradient
13	12	Digit rollover
14	13	Stuck value
15	14	Density inversion
16	15	Grey list
17	16	Gross salinity or temperature sensor drift
18	18	Frozen profile
19	17	Visual QC

Table H2: Quality flags for the research-quality dataset

Flag ID	Flag name	Definition for L3/L4/L5 product levels (issued by *delayed-mode* and *regional-center* systems)
0	No QC was performed	No QC was performed
1	Good data	The adjusted value is statistically consistent and a statistical error estimate is supplied
2	Probably good data	Probably good data
3	Bad data that are potentially correctable	An adjustment has been applied, but the value may still be bad.
4	Bad data	Bad data. Not adjustable.
5	Value changed	Value changed
6	Not used	Not used
7	Not used	Not used
8	Interpolated value	Interpolated value
9	Missing value	Missing value

Table H3: List of labs, institutions and groups using Argo France data

List of the French labs and group and institution using Argo data :

- LOPS (UMR 6523, Laboratoire d'Océanographie Physique et Spatiale, Brest)
- LOV (UMR 7093, Laboratoire Océanographique de Villefranche-sur-mer)
- IMEV (UMS 829, Institut de la Mer de Villefranche)
- LOCEAN (UMR 7159, Laboratoire d'Océanographie et du Climat, Paris)
- LEGOS (UMR 5566, Laboratoire d'Etudes en Géophysique et Océanographie Spatiales, Toulouse), MIO (UMR, Institut Méditerranéen d'Océanologie, Marseille)
- LGGE, MEOM group (UMR 5183, Laboratoire de Glaciologie et Géophysique de l'environnement),
- CNRM (UMR 3589, Centre National de Recherche Météorologique)
- CERFACS

from many other different groups within institutions, most notably:

- DT INSU, ISI/TSI/SISMER Ifremer
- SHOM (Service Hydrographique de la Marine),
- UAR Imago
- IRD
- CNES

At the national level, the following program is using Argo data:

- Mercator Ocean International.

At the European level:

- Copernicus (Copernicus Marine Environment Monitoring Services),
- GODAE Ocean View (former Global Ocean Data Assimilation Experiment).

At the international level:

- GCOS (Global Climate Observing System),
- GOOS (Global Ocean Observing System),
- WCRP (World Climate Research Program),
- OOPC (Ocean Observation Panel for Climate) sponsored by GCOS, GOOS and WCRP, CLIVAR (Climate and Ocean - Variability, predictability and Change)

Table H4: Participation of Argo France in external governance instances. * indicates SNO members.

Level	Instance	Name	Responsibility
France	IR* Euro-Argo France	V. Thierry*	Coordination with IR*
	CS GMMC	J. Uitz*, V. Thierry* , N. Poffa	Coordination with GMMC
	FrOOS	V. Thierry*	Coordination IR*/FrOOS
	Coriolis DAC	C. Coatanoan, C. Schmechtig*	Coordination with Coriolis DAC
Europe	ERIC Euro-Argo	JM Flaud	Council France delegate
		V. Thierry*	Management Board France delegate
International	ADMT	C. Cabanes*, T. Carval, C. Coatanoan	Executive board
		C. Schmechtig*	BGC ADMT co-chair
		R. Sauzède*	BGC ADMT France representative
	AST	V. Thierry*	France representative
		C. Gourcuff	ADMT co-chair
		H. Claustre*	BGC Mission co-chair
		V. Thierry*	Deep Mission co-chair
		N. Kolodziejczyk*	Polar Mission co-chair
		E. Leymarie*	Technical Task Team co-chair

Table H5: IR* human resources in person-month annually dedicated to the Argo France program, on average 2019-2023.

Institute	Coordination	Data acquisition at sea	Data center	DMQC and products	Outreach, tools, other	Total
IFREMER	9,1	8,3	26,5	17,4	7,3	68,6
SHOM		10,8				10,8
CNRS-INSU	5,4	3,8	4	23,8		37
UBO	4					4
SU		9,6				9,6
Total IR*	18.5	32	30	30		**130 person-month**

ANNEXE I : List of Argo international meetings and workshops attended by SNO members over the period 2019-2023. Meeting in **bold** are organized by Argo France.

Argo Steering Teams meetings

- AST24, Twenty-fourth Argo Steering Team Meeting, Halifax, Canada, Hybrid Meeting, 20 – 24 March 2023
- AST23, Twenty-third Argo Steering Team Meeting, Monaco, Hybrid Meeting, March 2022
- AST22, Twenty-second Argo Steering Team Meeting, Virtual Meeting (COVID), March 2021
- AST21, Twenty-first Argo Steering Team Meeting, Virtual Meeting (COVID), April 2020
- AST20, Twentieth Argo Steering Team Meeting, Hangzhou, China, March 2019

Argo Data Management Team meetings

- ADMT24, Twenty-fourth Argo Data Management Team Meeting, Hobart, Tasmania, Australia, Hybrid Meeting, 23 – 27 Oct 2023
- ADMT23,Twenty-third Argo Data Management Team Meeting, Miami, FL, Hybrid Meeting, 5 – 9 Dec 2022
- ADMT22, Twenty-second Argo Data Management Team Meeting, Virtual Meeting (COVID), Dec 2021
- ADMT21, Twenty-first Argo Data Management Team Meeting, Virtual Meeting (COVID), Nov/Dec 2020
- **ADMT20, Twentieth Argo Data Management Team Meeting, Villefranche-sur-mer, France, Oct 2019**

Argo Workshops

- Deep & BGC Argo Workshop, (EURO-SEA/EA-Rise project), virtual, 27 Sep.- 1 Oct. 2021
- 7th Argo Science Workshop, Euro-Argo, Bruxelle, Belgique, 11-13 October 2022
- **1st Argo BGC DMQC-Workshop, Villefranche/mer, 23-26 janvier 2023**
- **Deep-Argo delayed-mode quality control (DMQC) workshop, virtual, 5-6 juin 2023**

Other meetings:

- DMQC discussion : regular international meeting : to share and discuss DMQC procedure among the Argo community.

ANNEXE J : List of Argo France teaching, outreach and communication

Teaching

- H. Claustre (4h/yr): Teaching module dedicated to the scientific exploitation of BGC-Argo observations for Master 2 students (Sciences de la Mer, OPB, MIO).
- N. Kolodziejczyk (UE/MIS/25h/yr); TThe course largely presents the Argo float technology, the built up of the global networks, the issues and achievements that makes the Argo data management as a case study among the most elaborated data flow. Argo data are used as training material during training sessions (M2, Marine Sciences, UBO) https://formations.univ-brest.fr/fr/index/sciences-de-la-mer-et-du-littoral-SML/master-XB/master-marine-sciences-INRBS5NZ/parcours-physique-ocean-et-climat-INRBS5R5.html).

Outreach activities with classes

- "Adopt a float" is an educational program to the Ocean and its sciences. It aims to help the youngest to discover the global ocean and the importance of its study to better understand and protect it. The concept is based on the idea that a class could adopt an Argo float and follow it during its scientific journey. The trajectory of the float brings the pupils into an oceanic zone and, in real-time, allows them to participate in the observations collected by the float as well as to the sciences that are associated. This approach allows pupils of all ages to be confronted with real scientific data and to question the importance of science, particularly in a context of climate change. This approach is complemented by several classroom meetings with scientists and scientific mediators during the school year. The scientific voyage of a profiling float can last between 2 and 4 years. All during this time, it can be accompanied to better understand the marine environment and the scientific approach including the questions posed by the researchers. The program started in 2011 with 3 French pilot classes. Since then, the adopt a float team has grown and the number of classes has constantly increased and spread around the world. During the 2023-2024 school year, more than 90 classes from several countries (metropolitan France and its overseas departments and territories, Belgium, Italy, Spain, United-Kingdom and USA) have adopted a float and worked on the Ocean and its sciences. Additional information on the adopt a float website : https://adoptafloat.com/

- Argo was regularly at the program of the summer school at IUEM "Mer Education" (https://nouveau.univ-brest.fr/mer-education/fr). This yearly outreach event is dedicated to develop the ocean science literacy toward the middle school teachers in order to broaden ('teach the teachers') the dissemination toward the middle schools pupils. The summer school schedules researcher talk, pedagogic activities and immersion in the research laboratories at IUEM and Ifremer. For instance in 2021 Deep Argo was presented, in 2022, the development of the future Argo float technology was presented. The program of past edition was available in : https://nouveau.univ-brest.fr/mer-education/fr/page/programmes-des-editions-precedentes

Press/radio/TV

- Vidéo et conférence de presse OneOceanScience, 2021 : https://oneoceanscience.com/

- IfremerLive (https://www.youtube.com/watch?v=poP4i_XK-XU) et conférence de presse suite au kick-off meeting des projets Argo, 2022. Nombreuses retombées médiatiques et intervention dans

les médias (France Inter, France Culture, France 3, Le Figaro, Armen, France Bleu Armorique et France bleu Breizh-Izel)

- The Conversation : Article « Images de science : Des petits robots autonomes qui révolutionnent l'observation de l'océan » , 2021 https://theconversation.com/images-de-science-des-petits-robots-autonomes-qui-revolutionnent-lobservation-de-locean-163524

- France 3, 2021: https://s3-eu-west-1.amazonaws.com/kmplus-account-files/583798/2021/10/26/4k8IVZrpkGNMbix17xRAA.mp4

Projet REFINE

- "Flotteurs Argo, de la surface à la profondeur", Techniques de l'ingénieur, 02/08/2021
- "Robots Explore the Ocean Twilight Zone", ECO, Hiver 2021
- "4 robots à l'assaut de la "Twilight zone" des océans", Sciences et Avenir, 10/01/2022
- "Operational Monitoring of Open-Ocean Carbon Dioxide Removal Deployments: Detection, Attribution, and Determination of Side Effects", Oceanography, 21/02/2023
- "DES SCIENTIFIQUES DE VILLEFRANCHE DÉPLOIENT DES ROBOTS POUR DÉCOUVRIR COMMENT LA MER STOCKE LE CO_2", France 3, 13/03/2022, avec Hervé Claustre et Antoine Poteau, https://vimeo.com/688854986
- "MISSION REFINE : COMMENT LA MER CAPTE LE CO_2", BFM TV, 16/03/2022, avec Hervé Claustre, https://www.bfmtv.com/cote-d-azur/replay-emissions/bonjour-cote-d-azur/mission-refine-a-villefranche-comment-la-mer-capte-le-co2_VN-202203160110.html
- "ROBOTS ET BIG DATA POUR OBSERVER LE PLANCTON, SENTINELLE DU CHANGEMENT CLIMATIQUE", France Inter, 24/03/2022, avec Sakina-Dorothée Ayata, Lionel Guidi et Hervé Claustre, https://www.radiofrance.fr/franceinter/podcasts/la-terre-au-carre/la-terre-au-carre-du-jeudi-24-mars-2022-5277474
- "EXPLORATIONS DE MONACO : DEUX MOIS DE MISSION DANS L'OCÉAN INDIEN", Monaco Info, 14/10/2022, avec Hervé Claustre, https://monacoinfo.com/video/explorations-de-monaco-deux-mois-de-mission-dans-locean-indien/
- "ENVIRONNEMENT : UN ROBOT SOUS-MARIN DONNE LA LEÇON À DES ÉLÈVES DE CM2", France 2, 29/12/2022, avec Hervé Claustre et Thomas Jessin, https://www.francetvinfo.fr/monde/environnement/environnement-un-robot-sous-marin-donne-la-lecon-a-des-eleves-de-cm2_5569887.html

Programme éducatif adopt a float

- Livret de restitution Monaco Ocean Week 2022; https://www.monacooceanweek.org/wp-content/uploads/Livre_2022_FR.pdf (p.68)

- Dossier de Presse - Mission Océan Indien (p. 62-63), Septembre 2022, https://www.monacoexplorations.org/wp-content/uploads/2022/09/Dossier-Presse_Explorations-de-Monaco_mission-ocean-Indien.pdf
- “Students board S.A. Agulhas to experience Monaco Explorations”, Seychelles Nation, 05/11/2022, https://www.nation.sc/articles/15698/students-board-sa-agulhas-to-experience-monaco-explorations
- Magazine Municipal de Villefranche-sur-Mer, Décembre 2022, https://fr.calameo.com/read/0059614733169e8edd475 (p.24 et 59)
- “À Brest, trois scientifiques en visite à l’école Jacques-Kerhoas”, Le Télégramme, 16/11/2022, https://www.letelegramme.fr/finistere/brest/saint-marc/a-brest-trois-scientifiques-en-visite-a-l-ecole-jacques-kerhoas-16-11-2022-13221607.php
- “Avec le flotteur Dolphin Float, les collégiens étudient l'océan Indien”, Le Dauphiné, 22/12/2022, https://www.ledauphine.com/education/2022/12/22/avec-le-flotteur-dolphin-float-les-collegiens-etudient-l-ocean-indien
- “Un robot flotteur adopté par une classe, JT 12/13 Côte d'Azur de France 3, 30/04/2022, https://vimeo.com/709409616
- “Quand les robots sous-marins font la leçon”, JT12/13 de France 2, 29/12/2022, https://vimeo.com/787600623
- “Adopt a float, découvrir l’Océan au Lycée Costebelle”, Var-Matin, 22/01/2023
- “Retiers. Les collégiens ont découvert à quoi servent les robots sous-marins”, Ouest France, 16/02/2023, https://www.ouest-france.fr/bretagne/retiers-35240/retiers-les-collegiens-ont-decouvert-a-quoi-servent-les-robots-sous-marins-32fff7d8-ac4d-11ed-b2b7-e76971879b8d
- “Les collégiens de Retiers connectés aux océans”, Nous Vous Ille, 06/2023
- “Retiers. Les 6es du collège et l’Ifremer dans des eaux communes”, Maville, Ouest France, 14/06/2023, https://vitre.maville.com/actu/actudet_-retiers.-les-6es-du-college-et-l-ifremer-dans-des-eaux-communes-_7-5812220_actu.Htm
- “Le collège des Dauphins une nouvelle fois récompensé”, Le Dauphiné Libéré, 05/07/2023, https://www.ledauphine.com/education/2023/07/05/isere-pays-turripinois-le-college-des-dauphins-une-nouvelle-fois-recompense
- “adopt a float educational program”, Today in Seychelles, 21/07/2023
- “Des collégiens adoptent des flotteurs pour mieux comprendre nos océans”, Le Dauphiné Libéré, 03/04/2024, https://www.ledauphine.com/education/2024/04/02/des-collegiens-adoptent-des-flotteurs-pour-mieux-comprendre-nos-oceans
- “La Classe Avec Bob, Le Robot Sous-Marin”, Arte Junior Le Mag, 08/01/2023, https://vimeo.com/788699962

- “Journée « Adopt a Float » à l’IMEV avec les enfants de l’école élémentaire Joseph Calderoni”, Site web & réseaux sociaux de Villefranche, 20/05/2022, https://villefranche-sur-mer.fr/journee-adopt-a-float-a-limev-avec-les-enfants-de-lecole-elementaire-joseph-calderoni/, https://www.youtube.com/watch?v=kddymKRi5Ds
- Les Niouzz - Adopt a float : des élèves d’Alleur à la conquête des richesses des mers et des océans, RTBF, 13/04/2024, https://vimeo.com/925400125/bcdb2f3585?share=copy

Video

- J. Uitz, F. D’Ortenzio, A. Poteau takl about the role of Argo and BGC-Argo observations in climate research: “Dans les coulisses du climat : Sonder les océans”, Le Blob, B Vignaux & P De Parscau, Universcience, CNRS, IRD, Inrae, 2021. https://leblob.fr/series/dans-les-coulisses-du-climat.
- European Ocean Observing Awareness campaign, 2023 : https://youtu.be/im4HVlK4hVU

Podcast

“SUNA ou la découverte de l’Océan Austral”, Podcast en 7 épisodes, idée originale, scénario et dialogues Marin Cornec et Théo Sciandra, production Culture Océan, 2023, https://bit.ly/3VSPbBo

Exhibitions

- Since October 2018, Argo is at museum of ‘Cité des Sciences et de l’Industrie’, Paris. SNO Argo France, tightly collaborates with the ‘Argonaute’ exhibitor to build up the new permanent exhibition entitle ‘Sous l’Océan’ including basic physical oceanographic concepts, presentation of the Argo global observing system, float exhibitions and outreach activities (see:www.cite-sciences.fr/fr/au-programme/expos-permanentes/sous-locean)
- Une exposition temporaire aux Capucins de Brest dans le cadre des 300 ans du SHOM avec un espace pour un flotteur ARVOR démo transparent et un poster descriptif, 29 avril-2 novembre 2021
- Le salon/conférence merXXL, Nantes, 29 juin au 10 juillet 2019

Annexe K: Supplementary Figures

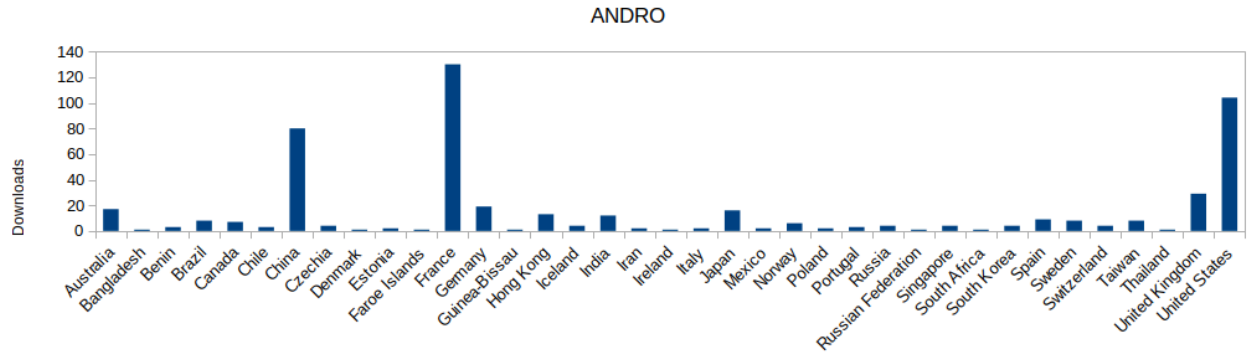

***Figure K1**: Number of downloads of ANDRO SNO Argo France's products by country between 2020 and 2023 : France, China, US, UK, Germany, Australia and Japan lead. Data from www.seanoe.org.*

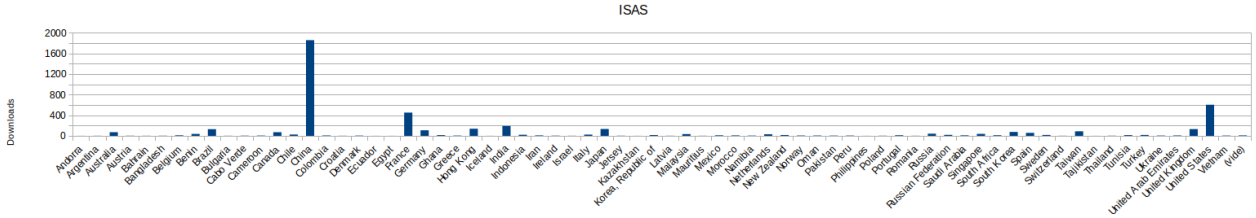

***Figure K2**: Number of downloads of ISAS SNO Argo France's products by country between 2020 and 2023. Data from www.seanoe.org.*