SNO Argo-France

2010-2014 report
&
2015-2019 evolution

Guillaume Maze (Ifremer,LPO), Fabrizio D'Ortenzio (CNRS, LOV),
Virginie Thierry (Ifremer, LPO), Cécile Cabanes (CNRS, LPO, OSU-IUEM)
and Catherine Schmechtig (CNRS, LOV)
and
the Argo-France Management Board

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2010-2014 REPORT

1) Context, motivations and scientific objectives

Status and evolution over the 2010-2014 period

a) Context and motivations

In 2000, the international Argo observational program was launched by the IOC and WMO to observe the global *in situ* ocean temperature and salinity, in order to monitor the ocean's variability and understand its role in climate. To reach this scientific target, the pre-requisite was to provide in 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 (Argo Science Team, 1998). Given the autonomous floats technology available at the beginning of the program in 2000, parameters were limited to temperature and salinity, sampling depth was limited to the first 2000m of the water column and sampling area was limited to the open ocean, away from marginal seas as well as high latitudes. It took about 8 years to the international community to reach this pre-requisite (from 2000 to the end of 2007). The resulting improvement in sampling the ocean achieved by Argo compared with the previous century of measurements is dramatic. In addition to the major increase in data quantity due to Argo, the historical northern hemisphere and near-coastal biases are greatly reduced in the much more uniform Argo sampling. Argo also has rectified a major seasonal bias in sampling, particularly in the polar oceans: presently Argo delivers more winter profiles in the Southern Ocean in one year than the total sum of all winter data collected before 2000. It is thus not surprising that the Argo program is now the major source of in situ observations of the ocean and hence revolutionizes our vision and understanding of the ocean in unexpected ways days after days.

The international Argo program aims to build and sustain a global real-time observational network of in-situ measurements integrated to other observational systems of the Earth in order to:

- detect climate variability from the seasonal to decadal timescale and to observe climate change of the oceans. This includes regional and global changes in oceanic heat, salt, fresh water content, sea surface steric height and large scale circulation.
- provide observations to calibrate and validate satellite remote measurements.
- provide observations to initialize and constraint numerical model simulations.
- promote new parameters and observation sites (biogeochemical parameters and deeper layers)

The French Argo national program aims to contribute to the international Argo program and to do so, relies on the SNO Argo-France and the Coriolis partnership. Argo France gathers all the French activities related to Argo and its extension toward deep and biogeochemical measurements. Argo France scientific activities are organized through the SNO Argo-France, which is part of the OSU IUEM (Institut Universitaire Europeen de la Mer). Two research laboratories are leading Argo France scientific activities: the "Laboratoire de Physique des Océans" (LPO, Brest, France) and the "Laboratoire d'Océanographie de Villefranche" (LOV, Villefranche, France). Argo France operational activities are organized through the Coriolis partnership (IFREMER, SHOM, INSU, IRD, Météo France, CNES and IPEV) and its governance bodies. Euro-Argo central infrastructure and Argo France are part of the Ministry of Research national roadmap on large research infrastructure (TGIR).

The objectives of the SNO Argo-France as defined in 2011 for the first SNO accreditation are the following:

- to provide research quality Argo 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) ether directly or through re-analysis or assimilation products.
- to consolidate and organize the French contribution to the international Argo program and to the European research infrastructure Euro-Argo
- to promote biogeochemical parameters measurements from Argo floats and an Argo-bio network development

We now provide a state of progress and achievements for each one of these objectives. More details will be provided in the next sections of the document.

b) Scientific objectives

To provide research quality data to the French scientific community

From January 2010 to December 2014, the SNO Argo-France provided 90 484 qualified profiles of the core parameters pressure/temperature/salinity (P/T/S) to the French scientific community through Coriolis DAC (the national Argo data center). These profiles were quality controlled (QC) in real and delayed time with different methods to ensure their best possible quality for operational oceanography and climate research (details of these procedure are given in section 3)c), see also Cabanes et al, 2014). Since 2013, Argo-France provides about 1800 P/T/S profiles per month.

Figure 1 plots A and B represents the time evolution from the beginning of the Argo program of the number of P/T/S profiles collected, qualified and distributed by Coriolis DAC. Over the last 5 years the SNO Argo-France provided as many data as in the previous period, which was 11 years long (2000-2010). Figure 1 maps C and D represents the location of these profiles. They are localized in the regions with the most scientific interests for the French community: the Atlantic and Southern oceans, and the Mediterranean Sea. The North Indian and East/Western Pacific regions also received interests.

Figure 1 plots A and B provide details of the fraction of distributed profiles in real-time and delayed mode. As of January 2015, around 65% of the profiles managed by Coriolis DAC are in delayed mode. There is always a delay of a couple of 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. The time series show that the 2011-2012 period was marked by a doubling in the number of monthly profiles to manage (from around 1000 to almost 2000) which has stabilized since then.

Beyond the distribution and qualification of the core parameters in the form of vertical profiles, the SNO Argo-France also provided research quality data in the form of **higher levels products**: gridded dataset and indicators. The SNO Argo-France developed and maintained the **In-Situ Analysis System** (**ISAS**, Gaillard et al, 2009), which designates both a software designed to produce a gridded version of the irregularly sampled Argo data and the gridded dataset itself. ISAS implements an objective interpolation method to produce monthly, global, 1/2x1/2 degree, 152 vertical levels (from the surface down to 2000m) temperature and salinity fields. ISAS is used for research (a gridded monthly time-series is produced annually by the SNO using qualified data from the previous year) and operational oceanography (a gridded monthly snapshot is produced every month by Coriolis using real-time data). ISAS is also used as a validation tool, both in real-time and delayed mode (residuals from the objective interpolation can detect outliers and bad profiles). ISAS is a tool that can evolve and is being adapted to manage new parameters (such as oxygen) or local configurations (higher resolutions over specific regions).

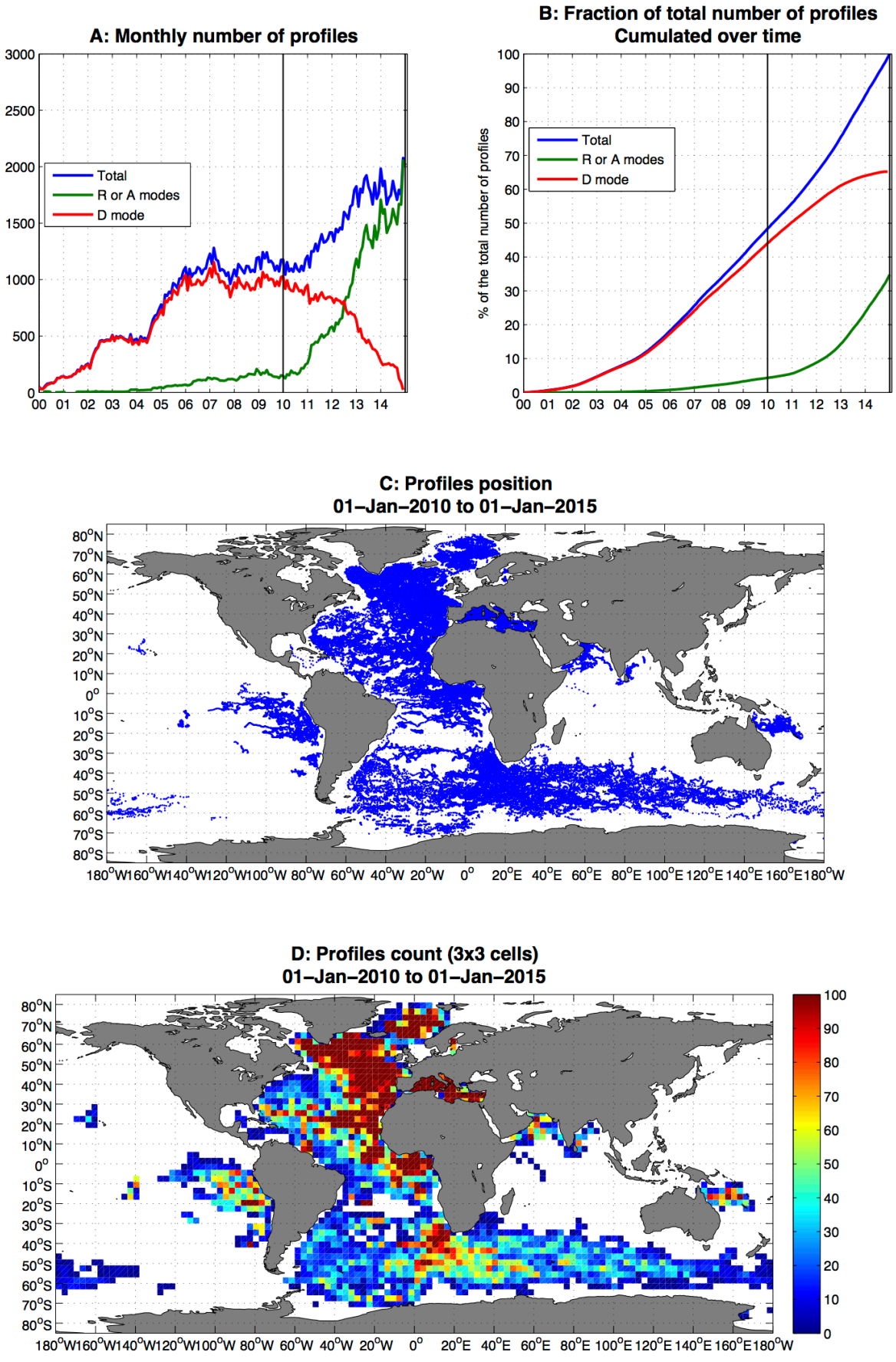

Figure 1: 2010-2014 Argo-France distributed dataset

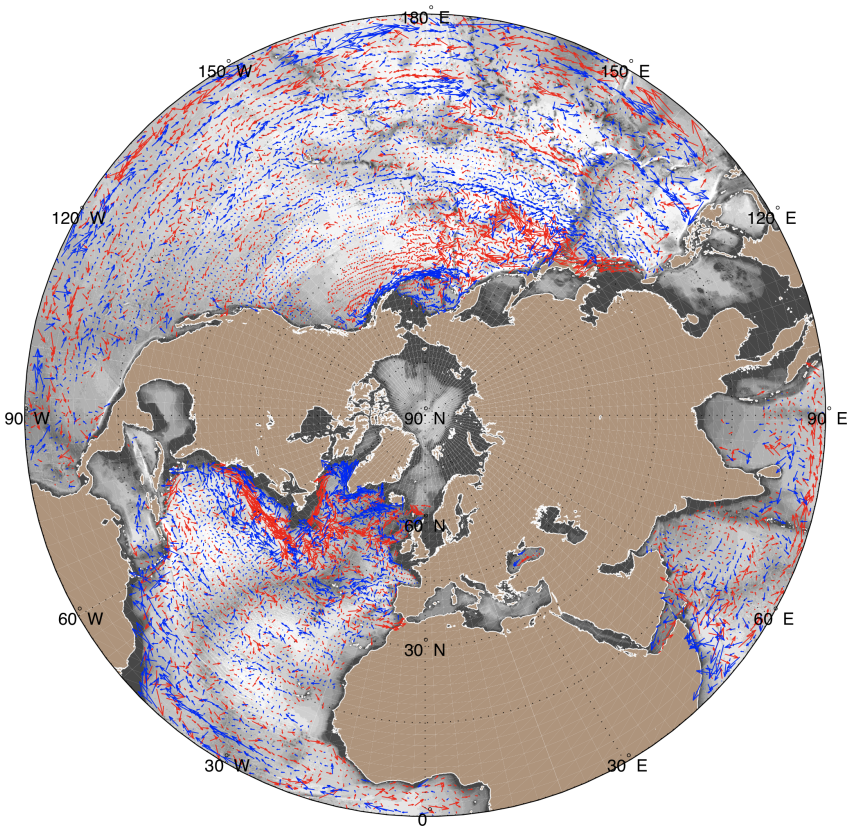

Figure 2: ANDRO absolute currents at 1000m from Argo data (Ollitrault, Rannou, JAOT, 2013)

The SNO Argo-France also developed indicators of the ocean state and variability based as much as possible on the original qualified dataset of profiles. In particular, **Global Ocean Indicators (GOI)** were developed such as the global ocean heat content, fresh water content and steric sea level using either ISAS or new statistical tools (von Schuckmann et al., 2009; von Schuckmann and Le Traon, 2011). The developed GOIs are carefully determined and distributed with error estimates that provide a clear and solid basis for climate research and in particular IPCC statements of global ocean long-term changes (IPPC report, 2013). GOI methods developed by France are now used by the MyOcean In-Situ Thematic Center, a component of the GMES Marine Core Services.

In 2013, the SNO Argo-France released ANDRO: the first ever dataset of Argo trajectory files qualified for research. The dataset, developed at LPO (Ollitraut and Rannou, JAOT 2013) contains research-qualified information about 680,000 deep displacements of Argo floats, from which a regional snapshot is given Figure 2. ANDRO files lead to the first ever delayed mode trajectory files distributed by Argo GDAC. From displacements, absolute ocean currents can be derived (Ollitrault and Colin de Verdière, 2014). One should recall that the Argo program was named after the Jason altimetry satellite missions to embody the complementarity of the observational programs. Indeed, satellite altimetry provides surface currents estimates but only relative to a reference level that was expected to be provided by in-situ measurements from Argo data. This complementarity was totally under-exploited during the build-up period of the Argo array, primarily because of the tremendous efforts needed to develop the core parameter dataset (vertical profiles of pressure, temperature and salinity, Le Traon, 2013).

One important feature of ANDRO is that the pressures measured during float drifts at depth, and suitably averaged, are preserved. To reach this goal, it was necessary to reprocess most of the Argo raw data, because of the many different decoding versions (roughly 100) not always applied by

the DACs to the displacement data because they were mainly focused on the P/T/S profiles. The result of this work was the production of comprehensive files containing all the possibly retrievable float data. Argo data have previously been used to study ocean currents, but it is the very first time that a research quality dataset of float trajectories is developed in close interaction with Argo Data Management teams and benefits the community for a long term improvement of the dataset. Indeed, it led to an improvement in the format of the trajectory file and in the decoding of the raw data (Scanderberg et al, doi: 10.13155/29824). However, this dataset presently contains Argo float displacements before January 1st 2010. So it will be key but also a challenge to the SNO Argo-France to sustain this effort to keep the dataset updated and qualified (see the "Evolution" part of the document).

At the time of the SNO accreditation in 2011, only 4 years of optimal sampling were achieved because the Argo program reached its operational core target at the end of 2007. From this time series, tremendous progress was made in two directions: (i) our knowledge and understanding of the ocean seasonal variability, especially for salinity and circulation and (ii) our estimate of the post 2000s ocean reference state at global scale. But as the program consolidated the time series, thanks to national programs support like SNO, the 2010-2014 period has been marked by the studies of the inter-annual variability from in-situ observations (e.g. Kolodziejczyk et al, 2013, Keerthi et al, 2013). However, it is obviously impossible to review here the diversity of the research activities and achievements based on Argo data and conducted in France. So perhaps the single most powerful metric of the value of Argo and the achievements of the SNO Argo-France is the widespread use by the national community of the data that the program produces: **since 2010, at least 130 papers in the refereed science literature have used Argo observations and have been co-authored by a French contributor**, attesting to the array's value in expanding our fundamental understanding of the oceans and climate within the national community (the complete list of articles is given in appendix 1). This is a very significant contribution to the international achievements of the Argo program because it represents between 15 and 20% of the global scientific production (depending on the year) and France is ranked 3rd, just after USA and China. Moreover, about 2 PhD per year defended in a French university used Argo data in a significant way. This metric reveals the adoption of the Argo dataset by the upcoming generation of research scientists.

In 2011, the SNO Argo-France also took the lead of the **Argo Regional Center for the North Atlantic** (NA-ARC). Regional centers have the role to ensure the consistency of the validation procedures between all the operators for a given oceanic region. Details will be provided in the upcoming sections but one can highlight here that the NA-ARC made significant improvements to the dataset by detecting erroneous delayed-mode corrections of salinity data (Cabanes et al, 2014, http://www.ifremer.fr/lpo/naarc).

To consolidate and organize the French contribution to the international program

France is one of the leader in the international governance bodies of the Argo program. Every years since the early stage of the program in 1999, and so during the 2010-2014 period, France participated to all annual international meetings of the Argo Steering Team (AST), Argo Data Management Team (ADMT) and Delayed Mode Quality Control (DMQC) workshops. The financial support from INSU to the SNO Argo-France was critical to these participations and helped to organize the national program.

Indeed, the years 2010-2014 were intense for the Argo France program. They were marked by its SNO and TGIR accreditation (2011), governance re-organization at the national (renewal of the Coriolis partnership, creation of the SOERE CTD-O2) and international level with the leadership in setting up the Euro-Argo Research Infrastructure (SIDERI: 2011-12, then E-AIMS: 2013-15 and ERIC creation in 2014).

In order to consolidate the core Argo mission, to develop its extensions and to provide a European level for the management of the international Argo program, Argo France led the creation of a **European research infrastructure (ERIC) called Euro-Argo**. Argo France is the French contribution to the Euro-Argo ERIC that organizes and federates European contributions to Argo.

Ministries from 12 European countries have agreed to form a new legal European entity to organize a long-term European contribution to Argo. The ERIC was prepared over the 2011-2014 period and finally set up in May 2014. The Euro Argo infrastructure is made up of distributed national facilities and a central infrastructure based in France (Ifremer, Brest), which is owned and controlled by the Euro-Argo ERIC. The distributed national facilities operate with direct national resources. As part of the Euro-Argo research infrastructure, they agree to a **multi-annual commitment of resources** (in particular in terms of floats to be deployed and for the data system), and to coordinate their activities through the Euro-Argo ERIC.

Argo-France operational activities were managed by the **Coriolis** consortium based on a convention valid for 5 years (2009-2013). In 2013-2014, the French community set-up different working groups to prepare a new convention for the Coriolis consortium for the 2014-2020 period. The new partnership was accepted in June 2014 and signed by the 7 participating institutes and organisms (Ifremer, CNRS, SHOM, IRD, IPEV, Meteo-France and CNES). Coriolis gather several SNO (Argo, PIRATA, SSS, MEMO), assembles data into a common data center and provide integrated services for operational oceanography (Mercator Ocean, GMES Marine Core Services and MyOcean) and research laboratories.

The French community was also very active in setting-up an **international Argo coordination for new biogeochemical measurements**. The effort to realize a global array of new parameters has been initially devoted to implementing regional networks over specific regions: Atlantic, Southern Ocean, and Mediterranean Sea. The realization of a global array will be realized, then, by a progressive increase of float density in specific areas and by a further enlargement (as suggested in the OceanObs09 seminal paper, Claustre et al, 2010). France has been strongly active since 2010 in establishing the firsts regionals Argo-Bio networks, and is now in a leading position also in the framework of data management and QC (see section 3)b)). At national level, the biogeochemical branch of the SNO Argo-France is under the responsibility of the LOV (all biogeochemical parameters, except O2) and LPO (O2), ensuring the respect of international protocols for the national fleet, providing the required assistance for the Argo-Bio floats scientific use and promoting the Argo-Bio activity at national level.

Given the aforementioned activities in organization, development, and consolidation of the Argo array, we decided to create an **Argo-France scientific steering committee.** The steering committee will coordinate national efforts and provide a formal body to discuss a long-term strategy for the national contribution to the Argo program, independently from short-term projects constrains. The committee will work to produce a program strategy to face three challenges over the next 10 years: (i) sustain the core program at its current state of excellence, (ii) raise mature extensions to core standards (trajectories, oxygen, chlorophyll-a and nitrate) and (iii) consolidate the extension of the program toward new configurations (abyss, pH). Since its creation in 2014, the committee met 2 times (October 2014, February 2015).

To promote biogeochemical parameters measurements

The years 2010-2014 were marked by technological breakthroughs led by multimillions flagship projects that are still ongoing (ERC RemOcean, EQUIPEX NAOS and FP7 EAIMS, starting in 2010, 2011 and 2013). **Technological developments were conducted with success and data from new parameters are available in the Argo database**. France is leader in the development, promotion and scientific exploitation of Argo-Bio, one of the more promising extensions of the core Argo network. Oxygen and Chlorophyll parameters have reached a high degree of maturity in the last years, and the French community contributed massively to the advancements obtained in the float technology, data management and QC of this parameters (see later).

Overall, about 100 floats with O2 sensor were deployed by France since 2006. Those floats contributed to the ~80 000 oxygen profiles from ~650 floats collected and distributed by the Argo data stream. As an illustration, the number of floats deployed each year in the North Atlantic is shown Figure 3. We can see the tremendous increase in available oxygen data starting in 2010.

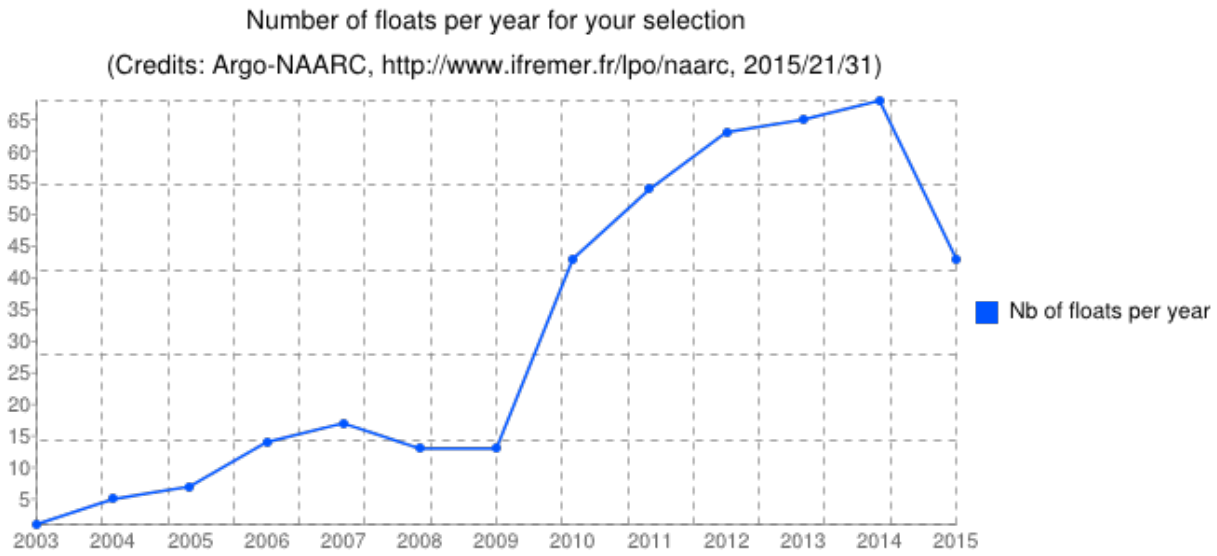

Figure 3: Number of floats with Oxygen sensors in the North Atlantic. (Figure realized with the NA-ARC website developed by the SNO Argo-France)

With floats providing in real time new parameters such as oxygen, pH, chlorophyll-a and nitrate concentrations, Argo France developed data management procedures (real-time QC tests) and good practice cookbooks (decoding, quality control methods) for some of the most innovative dataset in environmental sciences. The most mature of these datasets (Chlorophyll and Oxygen) now reach the end of their development phase and start a new one, which is as ambitious as in the early days of the Argo program for temperature and salinity: to become mainstream and of the best quality for climate research. To do so, the SNO Argo-France worked in close collaboration with the international community to define delayed mode procedures for these parameters. This is done through the participation of the SNO to the SCOR WG 142 on "Quality Control Procedures for Oxygen and Other Biogeochemical Sensors on Floats and Gliders" (http://www.scor-int.org/Working_Groups/wg142.htm).

Additionally, successful links between **Argo/Argo-Bio community and Ocean Color scientists** has been achieved in the last years. Ocean Color space data could be considered the satellite equivalent of the altimetry for Argo-Bio. Consequently, space agencies (CNES, ESA, NASA) have already realized that, although not enough accurate to a real calibration of space sensors, Argo-Bio could provide a cost-efficient and global scale network for validate ocean color products. By continuously involving in Argo-Bio the national ocean color community, the SNO Argo France aims to a larger utilization of Argo-Bio national fleet and to the development of high level products, merging floats and ocean color data (see later).

The ISAS tool was also adapted to oxygen data. After validation and correction of all oxygen profiles localized in the North-Atlantic region following Takeshita et al. (2013), gridded fields of oxygen were produced (see Figure 4).

These developments are directly connected to the **enlargement of the national Argo-Bio community**. Since 2011, 4-8 Argo-Bio floats per year are distributed by the GMMC, after validation by the GMMC Scientific Committee. In the last 4 years, scientists from five different French laboratories (MIO, LOMIC, LOCEAN, LPO, LOG) received, deployed and scientifically exploited Argo-Bio floats. In this context, the SNO Argo-France and its Biogeochemical branch, managed by the LOV and LPO, furnished all the necessary assistance in the float utilization and in the data management. As counterparty, and exactly as for Argo, GMMC Argo-Bio PIs are involved in the data analysis and contribute to the national effort for the establishment of Argo-Bio protocols.

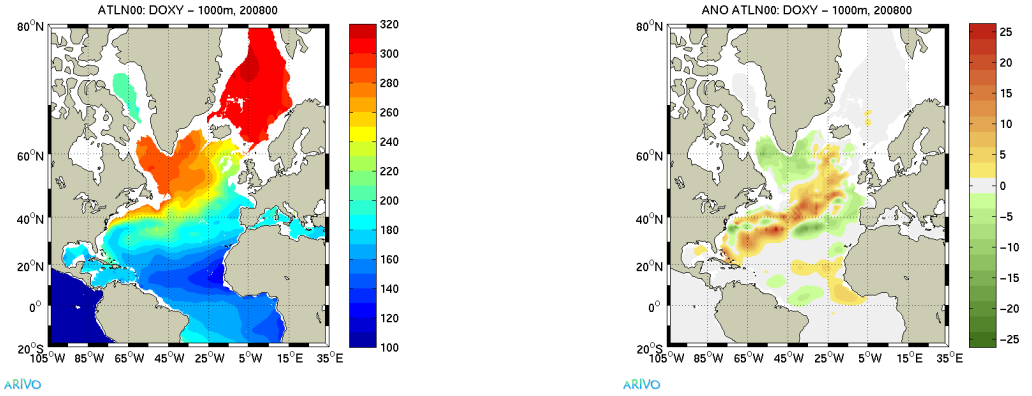

Figure 4: Dissolved oxygen concentration (mumol/kg) at 1000 m depth in the North-Atlantic Ocean using all Argo-O2 data over the period 2004-2012. (Left panel) Gridded field. (Right panel) Anomaly relative to the WOA05.

Finally, the promotion of those new biogeochemical parameters measurements is done through dedicated Argo-Bio sessions at the Argo-France or Euro-Argo science meetings (see for instance http://www.euro-argo.eu/News-Meetings/Meetings/Users-Meetings/5th-User-Workshop-March-2015/Workshop-Programme).

2) Missions of the Observational Service

All Argo floats systematically measure pressure (P), salinity (S) and temperature (T) from the surface down to 2000m depth of the water column. **P/T/S are the core parameters of the international Argo array and of the SNO Argo-France**. These parameters are measured using a conductivity-temperature-depth censor (CTD). The most used sensor is manufactured by Seabird (SBE41CP, see http://www.seabird.com/sbe41-argo-ctd for more details) but other sensors can be used on particular float models.

As for the international Argo program, the primary **site of interest for the SNO Argo-France is the *global* ocean (0-2000m, 60N-60S).** However, France has historically a particular scientific interest in the Atlantic and Southern Ocean as well as the Mediterranean Sea. So the SNO Argo-France has a special engagement in providing research quality data for the Atlantic Ocean through its leading role in the North-Atlantic Argo Regional Center (see below section 3)c)).

The SNO Argo-France has engaged in 2010 in providing a research-quality dataset of P/T/S profiles as measured from autonomous Argo profiling floats, in the *global* ocean. Table 1 indicates units, accuracy, resolution and site of the distributed data. Accuracy is generally worst than what is announced by sensor manufacturers because of our incapacity to post-calibrate censors at the end of a float life (floats are not recovered).

Table 1: Properties of the core parameter of the SNO Argo-France

Parameters	Unit	Accuracy	Resolution	Observation site
Core Pressure	dbar	2.4	0.1	Argo-Global / 0-2000m
Core Temperature	Degree Celsius	0.01	0.001	Argo-Global / 0-2000m
Core Salinity	PSU	0.01	0.001	Argo-Global / 0-2000m

Other parameters include floats displacements, new biogeochemical parameters and a deeper observation site (deeper layers below 2000m) based on new floats technology. The SNO Argo-France has also engaged in 2010 in promoting and developing these extensions. Table 2 synthesizes these

extensions together with their status in being incorporated to the "core" mission of the SNO Argo-France expertise.

Table 2: Properties of the "extension" parameters and observation site of the SNO Argo-France

Parameters	Unit	Accuracy	Resolution	Observation site	Status
Displacements	cm/s	2	0.1	Argo-Global / 1000m	Eligible
Oxygen	µMol/kg	8	0.001	Argo-Global / 0-2000m	Eligible
Chlorophyll-a	$mg.m^{-3}$	0.01	0.001	Argo-Global / 0-2000m	Testing
BBP	m^{-1}	0.0002	0.00002	Argo-Global / 0-2000m	Testing
Nitrates	µMol/kg	0.5	0.1	Argo-Global / 0-2000m	Testing
Deep Pressure	dbar	NA	NA	Argo-Global / 2000-4000m	R&D
Deep Temperature	Degree Celsius	NA	NA	Argo-Global / 2000-4000m	R&D
Deep Salinity	PSU	NA	NA	Argo-Global / 2000-4000m	R&D
Deep Oxygen	µMol/kg	NA	NA	Argo-Global / 2000-4000m	R&D

NA: Not available. These properties depends on float technology and scientific target which are still being defined at the international level (n.b.: SNO Argo-France co-organizes an international Argo-Deep implementation workshop in May 2015).

Depending on the QC procedures a data has been through and on the possibility it can be gridded or not, the Argo dataset can be categorized into different product levels. Following a nomenclature widely used by the remote sensing community, we constructed Table 3 to synthetize such product levels. The table is also color-coded to reflect product status with regard to their proximity to operational distribution, ether by Coriolis DAC/GDAC or research laboratories involved in the SNO Argo-France. For most products, this reflects the degree of achievement and international agreement on quality control procedures (see next section for more details). To evaluate the activities conducted by the SNO Argo-France during the 2010-2014, one has to compare this table with the one of the 2011 state given Table 10 in annex Annex - 2011 SNO products status.

Table 3: SNO Argo-France products and parameters (2015 status)

January 2015 Status						
Product level	**L0**	**L1**	**L2**	**L3**	**L4**	**L5**
Description	**Raw** data transmitted by floats and decoded	**Profiles** Data Quality-controlled in near **real**-time	**Profiles** Data Quality-controlled in **delayed**-time	**Mapped** Data Quality-controlled in near **real**-time	**Mapped** Data Quality-controlled in **delayed**-time	**Oceanic indicators**
Core P/T/S	raw data, meta and tech.nc files	A-R mode prof.nc files	D-mode prof.nc files	ISAS-Coriolis	ISAS-SNO (Arivo)	GOIs-GMES
Displacements	raw data, meta and tech.nc files	R mode traj.nc files	D-mode traj.nc files, based on ANDRO	Testing	ANDRO based 1000m absolute currents	R&D
Oxygen	raw data, meta and tech.nc files	A-R mode Bprof.nc files	Testing	Testing	ISAS-O2 for North-Atl.	R&D
Chlorophyll-a	raw data, meta and tech.nc files	A-R mode Bprof.nc files	Testing	R&D	R&D	
BBP	raw data, meta and tech.nc files	Testing	R&D	R&D	R&D	

Nitrate	raw data, meta and tech.nc files	Testing	R&D	R&D	R&D	
Deep P/T/S	raw data, meta and tech.nc files	R&D	R&D			
Deep Oxygen	raw data, meta and tech.nc files	R&D	R&D			

Status	**Definitions (**of product and QC procedures)
Achieved	The protocols and the methods are developed (i.e. published), implemented at DAC/GDAC level, and operational. International consensus.
Testing	The protocols and the methods are developed (i.e. published) and being implemented at DAC/GDAC level. International consensus on the methods is depending on tests (i.e. consolidation of consensus). Still in test phase to verify pertinence and performance.
R&D	The protocols and the methods are being developed (not published). No implementation at DAC/GDAC level. Discussions in the framework of the dedicated task teams (Argo-bio and Argo-deep)
10 years target	Technology is being developed. Methods not yet identified.

3) Measurement protocols

a) Measurements of the physical component

The "physical" component of Argo relates to physical parameter measurements: pressure, temperature, salinity and displacements. Argo 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 depth, generally 1000m. Displacements provide estimates on the oceanic currents. Once the float reaches the surface, data are transmitted through satellite communication systems to data centers, which then distribute data in near-real time, less than 24 hours. The nominal sampling of the Argo network is one profile for each 3x3 degrees cell of a global grid between 60S and 60N out of marginal seas. This sampling, proposed by the Argo international science team (AST) and accepted by all participants to the network, has been defined based on studies: of the global XBT network, statistics from altimetry and hydrographic sections from WOCE. This network allows determining the sea surface temperature with an error smaller than 0.5degC. With the Argo communication system, the vertical sampling is typically one measurement every 10 or 25 dbar, depending on the chosen configuration. With Iridium, now available on the majority of the floats, measurements can be taken every 1 or 2 db. Since 2013, more than 1 float over 2 deployed globally is equipped with Iridium. It has been chosen to profile every 10 days in order to ensure independent measurements over a seasonal cycle and longer time scales. Beside, satellite altimetry sampling frequency is also 10 days.

At least 3000 floats are permanently at sea to fulfill the nominal sampling of the global network. To sustain such a fleet, around 800 new floats must be deployed every year. Europe (through the Euro-Argo ERIC) aims to consolidate a contribution of 250 floats/year. France has engaged in contributing to 80 of these floats.

b) Measurements of the biogeochemical component

The functioning of the biogeochemical Argo floats (or Argo-Bio) is identical to the standard P/T/S floats (as described in the previous paragraph). Compared to the Argo P/T/S, they are additionally equipped with more sensors (see later) and systematically with IRIDIUM (or equivalent) double-way transmission (see previous paragraph), because it provides greater data flux and more flexible sampling strategies (i.e. higher vertical resolution, high profiling frequency).

Four biogeochemical parameters have reached in the last years the required level for research quality: chlorophyll (CHLA), nitrate (NO3), dissolved oxygen (O2) and particulate backscattering (BBP). Among the four, however, CHLA and O2 parameters are undoubtedly more mature than the 2 others. This is explained by historical reasons (i.e. CHLA and O2 sensors were the first to be mounted on floats) but also by the large number of scientists working on these parameters.

c) Quality Control procedures

For the Argo-core P/T/S data, the Argo data management has set up 3 systems to quality control the dataset in order to fulfill requirements from its wide user community:

- The first system is the ***real-time*** QC that performs a set of international agreed automatic checks on all float measurements. Real-time data with assigned quality flags are available to users within the 24-48hrs timeframe. They feed product levels L1 and L2 (see Table 3) and they target operational oceanographic applications.
- The second system of quality control is the ***delayed-mode***. Operators responsible for floats use their expertise and complex methods published in peer-reviewed literature to validate profiles data. These data feed product levels L3, L4 and L5 (see Table 3). They target research applications with possibly climate studies.
- The third system of quality control is the ***regional center***. This ultimate system is required to verify that *delayed-mode* QC conducted on floats by different operators, from different countries and different DACs are consistent with each others. This last stage ensures a coherent global dataset. Five regions of the ocean have been identified by the ADMT/AST groups and placed under supervision of 5 regional centers or ARC. The SNO Argo-France has the responsibility with Coriolis of the North-Atlantic Argo Regional Center or NA-ARC. Data validated by this system are incorporated into L3, L4 and L5 products (see Table 3).

These 3 systems are organized and coordinated as follows. Automatic quality control tests, performed in near *real-time* are agreed on and applied by all Argo data assembly center (DACs, see section 5)) similarly. A working group, associated to the Argo Data Management Team (ADMT, again see section 5)), is more specifically in charge of the *delayed-mode* quality control issues. This so-called "DMQC" group meet when needed (typically every other 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 doi: 10.13155/33951). Activities conducted by *regional centers* 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. At the national level, the SNO Argo-France QC activities are coordinated and discussed between: the R&D Coriolis component, research laboratories LPO and LOV and the SOERE CTD-O2.

With regard to Argo extensions developed over the last 5 years: biogeochemical parameters (oxygen, chlorophyll-a, BPP and nitrate) and deep measurements (P/T/S and oxygen), the QC strategy is exactly the same than for the Argo-core P/T/S: to develop a 3 stages system with procedures agreed upon at the international level by the ADMT, DMQC and AST groups. The advancement of the QC procedures is, however, different for each new extension. This advancement is color-coded in Table 3) and will be described in more details below for each product level. One should recall that in 2010, none of these extensions existed. In 2009 a DMQC group dedicated to biogeochemical parameters have been created under the leadership of Argo-France (Schmechtig et al, 2014). It is thus a paramount achievement of the SNO Argo-France to have over the last 5 years created QC procedures from scratch for these new parameters. Most of the developments now internationally agreed upon were proposed by the biogeochemical branch of the SNO-Argo France (see list of contributors of the ADMT document).

We now review QC procedures and 2010-2014 SNO Argo-France activities for each of the product levels described in Table 3. Details of the procedures are given in the Argo quality control manual for core (Wong et al, 2014, doi: 10.13155/33951) and biogeochemical (Schmechtig et al,

2014, doi: 10.13155/35385) parameters as well as on the Argo Data management website (http://www.argodatamgt.org/).

L0 product level is a collection of meta-data, technical files and raw measurements transmitted by floats through satellite. These data are decoded by different operators. In France, Coriolis DAC is in charge of the decoding of the core P/T/S and oxygen data from French floats, while LOV processes biogeochemical floats. CHLA data are then send to Coriolis and distributed through the global web site. Since 2010, Coriolis and the SNO Argo France have maintained decoders up to date with new floats and telecommunication technologies. The SNO Argo-France has also developed and enhanced decoders for trajectory data. Indeed, data related to measurements timing and position previously transmitted, were not entirely or properly decoded. They did not allow a research quality analysis of trajectory data. The SNO Argo-France has also developed and enhanced decoders for oxygen measurements. In 2011, floats equipped with different oxygen censors (e.g. optode Anderaa or SBE31) were transmitting their measurements with miscellaneous units, protocols and were not related to similar definition of oxygen concentration. A strong effort lead by the SNO Argo-France resulted in the publication of an oxygen measurement decoding cookbook and on a standardization of oxygen related parameters among each DAC (Thierry et al, 2013). This work on trajectory and oxygen data has lead to an improved dataset and more precise decoders used by DACs.

L1 product level is a collection of netcdf files filled with profiles and trajectory data distributed in near real time (24 to 48 hours after sampling). So, L1 primary users are from operational oceanographic centers. The L1 product is based on automatically validated L0 raw data. For a few specific floats and censors, it may be possible to adjust L0 data in real-time to known and documented drift or bias. L1 data adjusted automatically are said in "A" mode, for real-time but Adjusted; all other L1 data are said in "R" mode, for Real-time. In both cases, the L0 raw data of P/T/S from the Argo global-0-2000m subset are quality controlled by DACs with 19 successive automatic tests to produce L1 data. These tests are summarized in Table 4:

Table 4: 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

Since 2010, the SNO Argo-France worked to international agreements on updated tests for this automatic QC procedure based on its expertise, more specifically for the density inversion test and flagging of surface measurements (important for satellite data validation, especially salinity). Argo-France produced detailed technical notes on these issues (Cabanes and Thierry, 2013, Thierry et al, 2013).

Argo-France also created or adapted such automatic tests for: displacements data, oxygen and chlorophyll-a biogeochemical parameters. These tests are now adopted at the international level. Indeed in 2010, L1 product level was only available for the core P/T/S measurements while extensions were in early development phase. It is a strong achievement of the SNO Argo-France in coordination with Coriolis, that as of January 2015, the L1 product is now also available for the displacements, oxygen and chlorophyll-a parameters. Indeed, lots of the activities over the last 4 years were focused on the CHLA and O2 parameters, which have now reached an international consensus (cf Schmechtig et al, doi: 10.13155/35385) for the *real-time* system filling L1 product (both files in "R" and "A" modes). For the NO3 and BBP parameters, the French community continues to participate to discussions at the international level. A French proposition for NO3 QC procedure for the *real-time* system has been recently published (D'Ortenzio et al. 2014).

In strong coordination with Coriolis, Argo-France has also developed and then implemented a new automatic test based on a daily objective analysis of temperature and salinity (Gaillard et al, 2009). A new profile can be objectively mapped using a climatology and the analysis error allows to detect anomalous profiles automatically. For flag correction on those profiles, daily automatic feedbacks (in text files, by email) are sent to the appropriate operators. The email message contains the list of Argo profiles highlighted by the objective analysis, and examined by a Coriolis operator, with the recommended flag correction listed at the end.

L2 product level is a collection of netcdf files filled with profiles and trajectory data distributed with a delayed time (one or more years after sampling). So, L2 primary users are from the research community with stronger requirements than operational oceanographic centers. L2 data are said in "D" mode for Delayed time. The L2 product is a research-quality controlled version of L1 data. QC procedures are applied by the *delayed-mode* and *regional-center* systems. It is important to note that most, around 90%, of L1 core P/T/S data controlled by the *delayed-mode* and *regional-center* systems populate unchanged the L2 product. This is a significant achievement of the core Argo program that highlights the robustness and sustained quality of the observational platforms. This is also true for the subset of French data acquired by floats developed and produced in France.

For research applications, and more specifically for studies on global climate change, Argo data must have high accuracy and systematic errors must be minimized. To do so, once L1 data are more than 1 year old, they are carefully controlled and possibly corrected by floats PIs, data centers and regional Argo centers like the NA-ARC under France responsibility. This research quality control process is made of both the *delayed-mode* and *regional-center* systems described above and lead to the generation of L2 product level. Obviously, one of Argo top priority is to work on the detection and correction of measurements errors and more especially on those inducing systematic errors and biases. QC methods are developed by research laboratories, like LPO and LOV for the SNO Argo-France, as well as the R&D component of Coriolis because some methods can be implemented by data centers to detect as soon as possible bad data, which have been through automatic tests in the early stages of the data flow. QC studies have also been performed during the preparatory phase of the Euro-Argo ERIC within the E-AIMS project framework.

The research-quality validation of Argo data is particularly difficult because floats are not recovered at the end of their life time and hence, sensors cannot be post-calibrated. This explains why temperature and salinity accuracy is about 0.01 (see Table 1), less than one could expect from manufacturers fact sheets. Temperature is rarely corrected because it is measured by a sensor very stable in time. Surface pressure measurements can be used to correct if necessary a possible drift on the conductivity sensor (Owens et Wong, 2009). But it is impossible to list here all validation methods. One can simply say that they mostly rely on comparisons with some co-localized statistics (for instance a range of possible values determined with all historical measurements). Thus, QC methods evolve constantly because this research-quality validation is based on fine statistics and on scientific knowledge at a given time. Note that high precision CTD data acquired during hydrographic campaigns and possibly at the time of float deployment, are crucial for the research-quality validation and generation of L2 products. In practice, the added information with regard to L1, is into finely grained quality flags attributed carefully by operators to each measurements, down to each parameter and vertical levels. These flags reflecting the quality of the data are summarized in Table 5.

Table 5: 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

It may happen that more than one QC procedure is applied to a data. It this case, successive quality flags are not overwritten but are stored along the "history" dimension of the L2 product. This added complexity to the product aims to provide all information to users in order for them to understand how data have been validated and more importantly to allow for QC methods to evolve and to revisit previous flagging or corrections according to new discoveries and improvements. Indeed, this situation has been encountered by France in 2013. The SNO Argo-France, by its contribution to the NA-ARC, has improved a widely used salinity correction method applied in delayed time (OW method). This improvement was based on a recent better understanding of the interannual variability of the North Atlantic subpolar gyre and lead to updates in over-corrected data (see Cabanes et al, 2014 for more details).

L2 product level are for oxygen (O2) and chlorophyll-a (CHLA) are now in testing phase. L2 products are not yet available for the other biogeochemical data because methods for the *delayed-mode* and *regional-centre* QC systems have not been established yet for BBP and NO3. Since 2010, the SNO Argo-France has worked on moving Argo-Bio data from the research and development phase to the testing one, and this has been achieved with success for O2 and CHLA. So, for the upcoming 2015-2019 period, most of the SNO Argo-France R&D activity will be devoted to develop L2 products and associated QC procedures for all of the Argo-Bio parameters: O2, CHLA, BBP et NO3.

Research-quality validation methods from the core P/T/S data cannot directly be adapted to biogeochemical non-conservative tracers. We noticed above that core parameters validation mostly relies on fine climatological statistics. For instance, deep measurements of stable water masses can help detect upper layers drift or biases. But CHLA and BBP are highly variable at the surface and generally zero at depth, whereas O2 and NO3 are slowly variable at depths. The use of a climatology to qualify NO3 and O2 then appears appropriate (i.e. as P/T/S) and several attempts have already been performed with success. On the other hand, for CHLA and BBP the use of a climatology appears less appropriate and two others approaches are presently tested. In the first approach, surface Adjusted values are compared to concurrent ocean colour satellite estimations. Performed on an annual basis, this comparison could highlight permanent or temporary discrepancies, which could be ascribed to float errors and then be used to detect suspicious or wrong profiles (Lavigne et al, 2013; Boss et al 2010). The second approach implies the use of additional floats data (e.g. radiometry) to evaluate independently CHLA profiles with bio-optical methods (Xing et al 2010). Alternative methods are based on the pure analysis of the shape of the profiles (Mignot at al, 2014; Lavigne et al. submitted).

The SNO Argo-France strongly contributes to the definition of these methods in an international framework, at European (Euro-Argo) and Global (ADMT, Argo-Bio task team) levels. The processing data chain existing at LOV (which implements the above listed methods) treats all the

data of the national fleet as well as a number of floats of international institutions (see later), providing to the respective PIs preliminary feedbacks on the data quality.

The **L3** and **L4** product levels are the respective gridded versions of the L1 and L2 products. **L3** and **L4** products are collection of netcdf files filled with gridded data. L3 is distributed in near real time, L4 is distributed once a year. The Argo dataset is irregular in space and time. To facilitate its use for research and modeling, it is crucial to map the irregular dataset onto a regular space/time grid. Over the last 4 years, the SNO Argo-France has developed and maintained such a mapping tool (named ISAS) based on an objective analysis of profiles. There is no specific QC procedure for L3 and L4 products, they rely solely on L1 and L2 quality, respectively. However, the objective analysis provides an error estimate of the mapping based on the distance of the data to the climatology for a given local co-variance matrix. This error estimate is used to quality control the objectively mapped data. This system is used in near real time for L3 and in delayed-time for L4. It is a strong achievement from Argo-France that L3 is now computed automatically and distributed in near-real time by Coriolis DAC. One must note that ISAS is the same numerical code that is used for the daily automatic validation (see previous paragraph on L1 QC) and for the mapping of profiles. **Given its multi-usage, ISAS is a strategic tool for Argo-France.** Moreover, ISAS can be used for regional configurations and extension parameters. For instance, a L4 product based on L2 oxygen data have been developed at LPO in 2013-2014 for the North-Atlantic region (see Figure 4).

Last, **L5** products are oceanic highest level indicators. L5 products are based on peer reviewed methods and aim to provide a synthetic information for a given component of the ocean and its long-term monitoring. Over the last 5 years, there has been a tremendous amount of studies exploiting the growing length of the Argo time series, which culminated in the last IPCC report being largely based on Argo data. In 2010, global ocean indicators (GOIs) such as: global ocean heat content, global ocean fresh water content and global ocean sea level were in research phase (von Schuckman et al, 2009, 2011). These GOIs are now routinely computed and distributed by Coriolis. They have been incorporated to the GMES Myocean in-situ TAC product catalogue. The SNO Argo-France supports GOIs development based on peer reviewed validation methods.

4) Length of the time series

It took about 8 years to the international community to reach the operational pre-requisite of 3000 floats permanently active at sea (from 2000 to the end of 2007). The optimal Argo time series is thus 7 years long as of January 2015. The improvement in sampling homogeneously the global large scale 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 time scale. If one account for a correct sampling of a decadal signal (50 years), the scientific target would be the length of a 2 hours movie from which Argo provided only the first 17 mins ! Moreover, given the societal requirements, it remains crucial to be able to monitor the state of the ocean; and Argo has proven to be a perfect tool for that.

After 10 years of program build-up, the Argo role within the Global Observing Systems has been clearly re-stated during the Ocean Obs 2009 international conference (Freeland, et al, 2010). Each country contributing to the program seeks to maintain its contribution to the network for at least 20 more years. From the very beginning, France has been committed to the Argo program. France was among the first nation to deploy Argo floats in the North Atlantic during the POMME experiment in 2000-2001, and during the European Gyroscope project. Since then, France remained very active in the Argo program and contributed to the deployment of more than 65 floats per year. Over the last 4 years the SNO Argo-France contributed to the consolidation of this contribution through the ERIC Euro-Argo set-up (see previous section 1)). Table 6 below summarize the Argo-France time series of deployed floats and profiles collected since the beginning of the program. Since 2000, more than 800 floats have been deployed.

Table 6: The 2000-2014 SNO Argo-France time series

Year	Funding (k€)	Floats deployed	QC profiles
2000	300	11	990
2001	633	12	2109
2002	980	7	4674
2003	900	34	5773
2004	1400	85	6672
2005	450	89	10939
2006	900	51	12935
2007	900	36	13326
2008	1200	90	13156
2009	1200	35	13879
2010	1400	55	18044
2011	1400	53	17872
2012	1400	82	17781
2013	1400	81	18175
2014	1400	96	18612
Total	**15863**	**817**	**174937**
Total 2010-2014	**7000**	**367**	**90484**

Data from annual France reports to the AST. For 90484 profiles distributed by Argo-France, that's about 246 profile/float with a consolidated cost of 77€/profile.

Following the revolution path set by the core Argo P/T/S measurements, the biogeochemical component continues to develop and grow. The French Argo-Bio fleet is presently the world second largest fleet in terms of number of floats: 66 French Argo-Bio floats have been deployed in the period 2012-2015, and 42 are still active (as of January 2015). Presently, 4886 Biogeochemical profiles have been collected by the French fleet over the period 2009-2015. They come principally from the NAOS and RemOcean project (about 80%). However, the number of profiles collected in the framework of GMMC projects (where the LOV is not involved) is continuously increasing. Note, also, that the Biogeochemical branch of the SNO Argo France (LOV) processes also a large portion of the Argo-Bio floats of the European fleet (850 profiles): Argo-Italy, Argo-UK and E-Aims. Moreover, collaboration between the LOV and US colleagues (K. Johnson, MBARI and E. Boss, Univ. Maine, both involved in the Argo-Bio Argo task team) leads to a sharing of data and methods, which are tested on the LOV data processing.

5) Data management

Argo core P/T/S data are decoded, processed and archived by 11 national data centers (so called DAC) which have the responsibility of their float fleet. All DACs must synchronize their dataset with 2 global DACs (so called GDAC) which have the responsibility to distribute the entire Argo dataset to the community. The long-term Argo data archive is managed by the U.S. National Oceanographic Data Center (NODC). At the French level, Argo data are archived by SISMER/Ifremer, the national center for long term ocean data storage.

Argo core P/T/S and oxygen data from the SNO Argo-France are decoded, processed and archived by the Coriolis data center. Coriolis is a partnership between 7 institutions (Ifremer, CNRS, SHOM, IPEV, IRD, Meteo France and CNES) and is mainly operated by Ifremer-Brest. Coriolis is one of the two European DAC and one of the two global GDAC.

Data processing and management procedures are made uniform at the international level and coordinated during annual meetings of the Argo Data Management Team (ADMT, http://www.argodatamgt.org). S. Pouliquen, head of the Coriolis data center, is co-chair of the ADMT since its creation in 2000. Validation procedures were described in section 3)c). Note that the compliance of file formats to international agreements as described in the Argo User manual has to be verified by GDACs.

Data can be organized into different product levels as described in Table 3: SNO Argo-France products and parameters, and data availability can be summarized as follows:

- Meta-data and technical data are made available as conventional netcdf files after each float deployment, and are updated by DACs within 24 to 48 hours after each new profile. These netcdf files are distributed by GDAC on their ftp servers. They are part of the L0 product category.
- Measurements validated in near real-time are set in "R" or "A" modes and are available to users within 24 to 48 hours in conventional netcdf files on GDAC ftp servers. These files are in the L1 product category. Note that unlike meta and technical data, raw measurements transmitted by satellite are only accessible to float operators. Indeed, it has been decided by the ADMT at the beginning of the program to distribute measurements only once they have passed a series of automatic tests (described in section 3)c)).
- Measurements processed through research-quality validation methods are set in "D" mode and are distributed in conventional netcdf files on GDAC ftp servers generally around 1 year after sampling. These files are in the L2 product category.

All data are freely available to users, whether it is parameter measurements or technical or meta-data. The Argo official file format is netcdf and data format convention is determined at the international level by the ADMT group. Data can be downloaded from the ftp server: ftp://ftp.ifremer.fr/ifremer/argo but also through web services like opendap. In 2012, the SNO Argo-France developed and publically released a web API (Application Programming Interface) for the NA-ARC region that allows to qualitatively explore the entire dataset or a subset of it in any programming language supporting web connections (Maze et al, 2012). This new tool is maintain since then, and has been recognized by the AST and ADMT as a significant added value product to help new users engage with the Argo dataset.

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 (http://argo.jcommops.org/, M. Belbeoch).

Argo biogeochemical data (all but oxygen) from the SNO Argo-France are decoded, processed and archived by the LOV. LOV also manages a large portion of the Argo-Bio floats of the European fleet (850 profiles from Argo-Italy, Argo-UK and E-Aims). Except for a two-format separation (see later), Argo-Bio data are processed and archived following exactly the same strategy than the P/T/S data, as explained above. Over the last 4 years, a DAC for biogeochemical data have been under development at the Coriolis level. The four Biogeochemical parameters considered as priority have been introduced in the first step of the Argo data chain (i.e. decoding) and a specific data format has been implemented. Biogeochemical data are available under two formats:

- A first format, distributed at DAC level, has been conceived to provide all the data to evaluate the Argo-Bio geophysical parameters. This format is implemented under so-called "B" netcdf files. This format contains the raw data, all the intermediate data and derived parameters, as well as the "final" parameters (i.e. O2, CHLA, NO3 and bbp). It contains also the pressure parameter associated.
- A second format is then created and distributed at GDAC level. This file is a merged version of the "final" Argo-Bio parameters and of the associated physical data observations (i.e. P, T, S).

The double format strategy provides a two-fold aim: an easy and rapid distribution of all the ocean variables in a unique file (i.e. the second version), although provides all the information (i.e. the first version) required by expert users to reprocess the data with non-standard algorithms.

6) Data exploitation and valorization

a) Teams and programs using the dataset

Argo is now one of the essential datasets used in oceanographic studies. At the French level, the list of teams using the Argo dataset can precisely be done by looking at the affiliations of French co-authors in the bibliography (see below). These are mostly from the following groups:

- LPO (UMR 6523, Laboratoire de Physique des Océans, Brest)
- LOV (UMR 7093, Laboratoire Océanographique de Villefranche-sur-mer)
- 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)
- SHOM (Service Hydrographique de la Marine)
- Mercator Océan
- LOG
- LOMIC

and from many other different groups within institutions, most notably: DT INSU, ISI/TSI/SISMER Ifremer, US Imago IRD and CNES.

At the national level, the following programs are using Argo data:

- Mercator

At the European level:

- Copernicus, previously known as GMES (Marine Core Service and MyOcean in-situ TAC)
- 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)

b) Scientific production

The complete lists of the almost 2000 peer-reviewed articles and 148 PhD thesis to date, based or using Argo data, are available online at http://www.argo.ucsd.edu/Bibliography.html and http://www.argo.ucsd.edu/argo_thesis.html.

Annex 2) provides the list of articles published in peer-reviewed literature, with at least one co-author affiliated to a French institution, and using Argo data. This list may not be exhaustive. Between January 2010 and December 2014, at least 130 articles using Argo data have been published by France. This is a very significant contribution to the international achievements of the Argo program because it represents between 15 and 20% of the global scientific production (depending on the year) and France is ranked 3rd, just after USA and China, in the to publishing country.

In France, about 2 PhD/year are based on Argo data. Annex **Erreur ! Source du renvoi introuvable.** provides the list of the 11 PhD thesis defended between 2010 and 2014 in a French university and using Argo data. Note that 2 to 3 PhDs have been defended in early 2015 instead of the end of the university year in 2014.

c) Link with numerical modeling

Both physical and biogeochemical 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 (e.g. ECMWF)
- data assimilation in oceanic re-analysis for research and climate studies

Physical data are assimilated for global and regional ocean forecasts at the national (Mercator Ocean), European (Copernicus and MyOcean) and international levels (GODAE Ocean View). These models are in turn used to initialize seasonal forecast simulations. Note that Mercator oceans re-analysis assimilate Argo data. 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 national DRAKKAR project.

Physical Argo data are also used to validate numerical simulations. Between 2010 and 2014, the Argo dataset has more than double in size. Argo data provide a robust and precise climatology of the global ocean for the early 20th century against which numerical models can be validated. Over the last few years, Argo data have also been started to be used to compute higher order moments of the ocean reference state. Beside the mean and standard deviation, the Argo data set is now rich enough to compute skewness and kurtosis of local measurement probability density functions. This allows for a characterization of the observed internal structure of small scale eddy activities (e.g. Roullet et al, 2014) and thus provide a reference state against which to validate statistics from eddy resolving numerical simulations. Up to now, numerical modeling eddy statistics were mostly validated against sea surface satellite data. With an ever growing Argo data set, this will change over the next 4 years.

Biogeochemical Argo data are 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), implies the whole spectrum of scientific researches around data-model interactions: initialization, assimilation tests, validation, OSSEs, network design. Most of the activities focus on the CHLA and NO3 parameters, which are considered the most innovative in the data-model framework. A specific effort is also dedicated to the satellite-in situ merging/intercalibration, as, before Argo-Bio, satellite data were the only data set having the required spatio-temporal resolution to be used in this context. Finally, operational models are also used to drive Argo-Bio deployments and to adapt sampling strategies (GMMC project MESOLAB, FP7 project OSS2015), in order to provide scientific results on the Argo-Bio network implementation.

d) Other applications and valorization

The Argo data set is becoming one of the most important tool for oceanographic studies. Over the last 4 years, Argo France has promoted the use of the data for research and education through outreach activities conducted within projects.

The "Adopt a float" initiative (more details on the webpage here http://www.monoceanetmoi.com/web/index.php/fr/adopt-a-float) was launched in 2012. The concept is based on the idea that a class could adopt an Argo float and follow it during its scientific voyage. The trajectory of the float brings the students into an oceanic zone (e.g. the Mediterranean or the North Atlantic) and, in real-time, allows them to participate in the observations collected by this float as well as to the sciences that are associated. 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.

Argo data have also been used and the focus of summer schools targeting young scientists, most notably: OBIDAM14 (Maze et al, 2014). The "Ocean's Big Data Mining, 2014" summer school was held in Brest in September 2014 and focused on new numerical statistical tools to investigate and analyze the ever growing and complex Argo dataset.

7) Integration of the Observational Service

a) Regional integration: OSU IUEM and CPER

At the regional level, Argo-France integrates within the OSU IUEM and was supported by CPER projects.

The *Institut Université Européen de la Mer* (IUEM) is the *Observatoire des Sciences de l'Univers* (OSU) to which the SNO Argo-France is affiliated to. IUEM is the only OSU where all observational time series have a coherent domain of application: the ocean. Three domains are particularly of interest for the OSU IUEM: ocean climate and circulation, geophysics and coastal environment. The SNO Argo-France supports the ocean climate and circulation domain for the two key regions of interest identified by the OSU IUEM: the North-Atlantic and Atlantic-Indian exchange zone. The SNO Argo-France provides the large-scale, open ocean, boundary conditions to many of the coastal and more regional time series supported by the OSU. The IUEM engaged in 2010 to support the North-Atlantic Argo Regional Center (NA-ARC). In 2012, C. Cabanes (IR CNRS) was affiliated to the UMS IUEM and SNO Argo-France to take in charge the NA-ARC. Last, since 2014, the OSU department of the IUEM is being coordinated and re-organized by a CNAP physicist (C. David-Baussire).

In order to coordinate and federate the Brest scientific and technological expertise on the Argo program (CREST), a regional project named CREST-Argo was set-up for the 2008-2013 period. The CREST Argo was funded by the CPER Bretagne (2.9M€) to buy 15 floats and biogeochemical sensors. This regional coordination was centered around the Coriolis data center (operated by Ifremer, Brest) in partnership with Ifremer, IUEM, SHOM, IRD and the Brittany region. More details on the CREST Argo can be found here: http://wwz.ifremer.fr/lpo/SO-Argo/Activities/CREST-Argo.

In 2014, Ifremer with SHOM and Euro-Argo ERIC (see below) submitted a new CPER project for the 2015-2020 period. The "Euro-Argo" CPER project aims to support the central infrastructure of the ERIC and to consolidate the national Argo program by funding new floats, especially deep profiling and oxygen floats.

b) National integration: Coriolis and SOERE CTD-O2

At the national level, Argo-France integrates with the consortium Coriolis. Coriolis is a partnership between all national institutions involved in oceanography (CNES, Ifremer, INSU, IPEV, IRD, Météo France and SHOM). The Coriolis objective is to consolidate and operate data acquisition, data assembly, data validation and data distribution in real and delayed time from in situ operating platforms, like Argo. Coriolis is dedicated to provide services to oceanic forecasting and analysis systems for operational and research oceanography communities at the national, European and international levels. Operational activities managed by Coriolis are vital to deployment and maintenance of the global observational systems (e.g. Argo, sea surface salinity measurements from ships, surface drifters and moorings). It is within this framework that a large bulk of Argo-France activities are managed. The Coriolis partnership has been renewed in 2014 for the 2014-2020 period.

The SNO Argo-France provides scientific and technological expertise to Coriolis. The SNO Argo-France was indeed solicited by Coriolis to provide expertise on the management and validation of Argo data. Four particular items were addressed over the 2010-2014 period:

1. the ISAS tool development (V6, F. Gaillard) which is used by Coriolis for quality control (both real and delayed time) of all data managed at Coriolis (not only Argo) and for production of L3 and L4 products using merged dataset of in-situ observations.
2. the ANDRO atlas of Argo floats deep displacements which lead to: (i) the development of a new data format for trajectories (version 3.1) being adopted by all DACs, (ii) the first ever research-quality controlled trajectory dataset (*delayed-mode* trajectory files) and (iii) a new decoding scheme of raw data.
3. research-quality validation procedures for North-Atlantic Argo data within the NA-ARC framework (C. Cabanes). These procedures have been transferred to Coriolis and have lead to an improved salinity correction for about 20 floats managed by Coriolis.

4. a new data flow for biogeochemical parameters which have reached the Argo data management system through the development of a new file format dedicated to Argo-Bio data.

All these items have been discussed during more than 10 regular meetings between the SNO Argo-France and Coriolis and over the 2011-2014 period. More issues have been discussed: oxygen data decoding, detection of density inversions, problems links to pressure sensor drifts, QC of surface salinity data and all successive evolution of data formats.

The SNO Argo-France integrates at the national level with the SOERE CTD-O2 ("Coriolis-temps différé Observations Océaniques"). The SOERE CTD-O2 integrates all national SNO relevant to Coriolis mission to provide validated oceanic observations: SNO Argo-France, SNO Sea Surface Salinity, SNO Pirata and SNO MEMO. Argo-France participated to SOERE annual meetings (28/03/11, 10/12/12, 24/05/13, 26/11/13, 25/09/14) where activities were presented and discussed. The SNO Argo-France also participated to the research-quality validation of Southern Ocean Argo floats conducted by SOERE CTDO2 (J. Lepesqueur). More specific discussions between the biogeochemical component of Argo-France took place with the SNO MEMO.

The SNO Argo-France naturally integrates at the national level with the research community. Argo-France organizes annual meetings and workshops to federate the national community and promote the use of Argo data. National events have been organized every year, but 2014, since 2009 (more details here: http://wwz.ifremer.fr/lpo/SO-Argo/Activities/Argo-France-meetings). Moreover, Coriolis has developed together with MERCATOR (The French operational oceanography forecast center) a strong connection with the French research community via the Mercator-Coriolis Mission Group (GMMC). It consists of about one hundred researchers (with some turnover each year) following a scientific announcement of opportunities and call for tender. Its task is to support the Mercator and Coriolis scientific activities and to participate in product validation. The call for tender proposes to the community "standard" Argo floats as well as floats equipped with oxygen and biogeochemical sensors. These new opportunities strengthens ties between the French scientific community and Coriolis with regard to the development of qualification procedures for "Argo extensions" floats.

c) European integration: ERIC Euro-Argo

The SNO Argo-France integrates at the European level with the Euro-Argo ERIC. Euro-Argo is the European contribution to the international Argo program. The main objective of the Euro-Argo consortium is to organize and consolidate the European contribution (by deploying 250 floats/year) 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 wish to optimize their collective contribution to relevant EU policies, programs and projects. Euro-Argo having been endorsed by the Esfri (European Strategic Forum on Research Infrastructures) in 2006, a preparatory Phase Project was ongoing in 2010. This preparatory phase took more time than initially planned and lasted for 2 additional years. The Euro-Argo ERIC was then officially started in July 2014. The Euro-Argo organization is given in the Figure 1 below. Note that V. Thierry, SNO Argo-France coordinator for the period 2011-2013, seats to the Euro-Argo management board as France representative. S. Pouliquen, head of Coriolis, is the Euro-Argo project office manager. Extensive details on Euro-Argo can be found at: http://www.euro-argo.eu/.

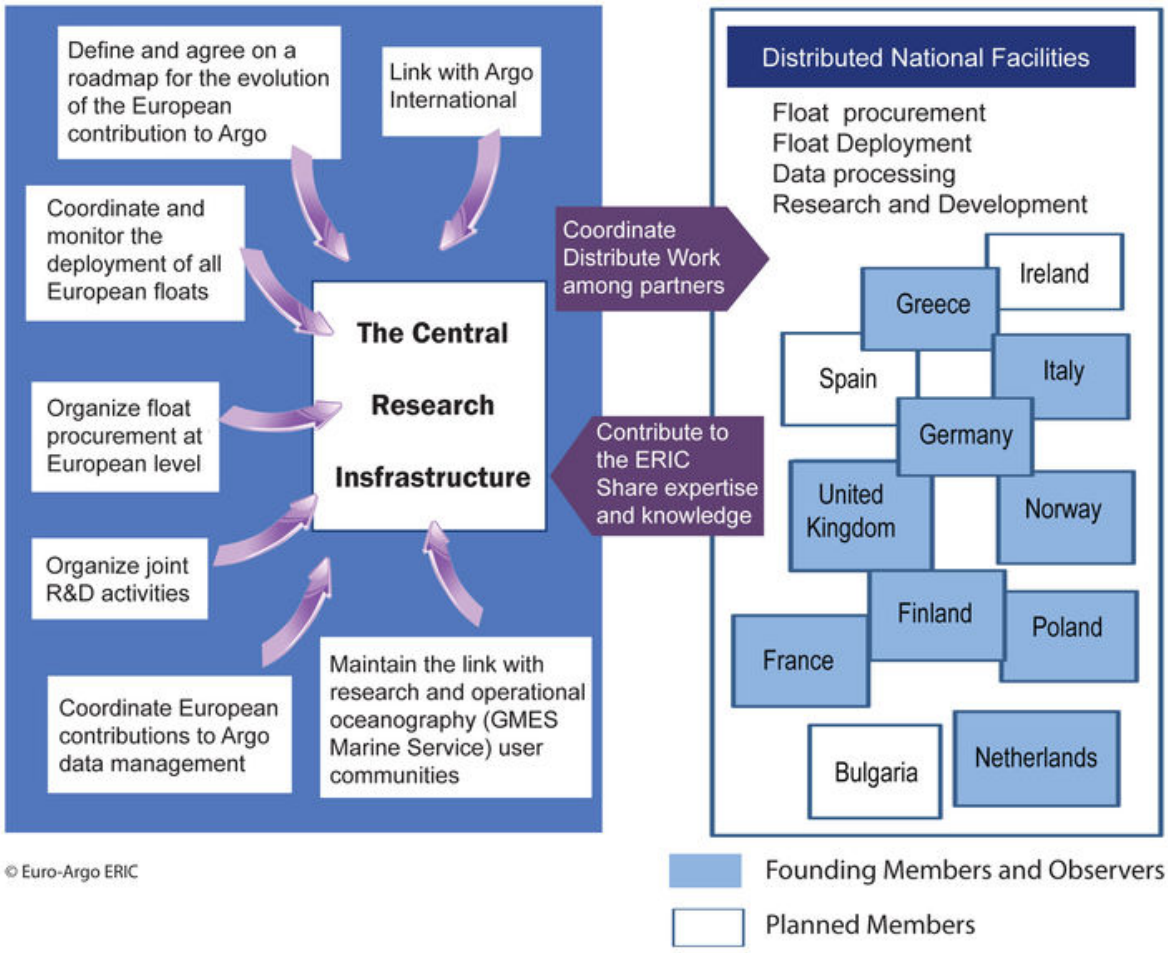

Figure 5: ERIC Euro-Argo organization

d) International integration

Argo-France is the French contribution to the Argo array. As such, Argo-France is integrated to the international Argo program and has keep playing over the last 5 years an already existing very active role by engaging in the multiple groups that structure and coordinate the program at the international level: the steering committee AST, the data management group ADMT and the data quality control group DMQC.

Moreover, the Argo network have been defined historically to be a key element and perfectly integrated to the international Global Climate Observing System (GCOS):

- Argo has been defined to complement altimetry satellite missions like Jason (hence the name "Argo": ship's name of the Argonauts lead by Jason in its quest on the Golden Fleece). Altimetry provides surface current estimates but only relative to a missing reference level. Argo provides this absolute reference. Over the last 5 years, the SNO Argo-France work on the L2 product for displacements based on ANDRO (Ollitrault and Rannou, 2013). This work set a milestone in the joint analysis of altimetry and Argo. Moreover, Argo provides the thermosteric and halosteric contributions to the absolute sea surface height. This secondary point is critical to understand all together sea level rise and ocean's warming.
- Argo also provides a mean to extent equatorial/tropical moorings array: TAO/TRITON in the Pacific, PIRATA in the Atlantic and RAMA in the Indian ocean. Argo and PIRATA are two SNOs which have been in tight contact within the SOERE CTD-O2 since 2011. The added value of Argo to TAO/TRITON was spectacularly demonstrated in 2012 when the later array was disrupted by the USA dropout of the program.

- Argo data are also used in the calibration/validation of satellite measurements of the sea surface temperature and salinity. Argo is the most reliable global in situ observation network of salinity. As such it is crucial to the cal/val of salinity measurements from space, like those of the SMOS mission. Since 2010, SMOS provides sea surface salinity validated with Argo data (e.g. Boutin et al, 2013). This complementarity is important because fundamental changes are happening to the chemistry of the world's oceans and salinity information from SMOS mission (and soon Aquarius) can be used with other Earth observation data like Argo, to obtain information on ocean acidification and the pH of seawater and therefore to provide accurate information to help address the growing problem of ocean acidification.
- Ocean color data and Argo-Bio observations are strongly complementary and, for this reason, they are considered crucial in the roadmaps of space agencies. This implies satellite Cal/Val activities (Val with the existing network, Cal with a specific type of Argo-Bio floats exclusively dedicated to calibration of space sensors; PROVAL CNES project), space/in situ data merging (to generate climatology and/or L3-L4 derived products, Lavigne et al. 2012), assimilation tests for operational biogeochemical models.
- Argo data also complement full water column high accuracy measurements from the GO-SHIP program that provides better resolution of small scales and boundary currents.

8) SNO organization

The Argo-France program gathers all French activities linked to the international Argo program. These activities are organized in 4 domains as represented Figure 6:

1. **Technological developments**: are conducted and operated by institutes (Ifremer, CNRS, SHOM,...) with flagship projects like the EQUIPEX NAOS and ERC RemOcean.
2. **Data acquisition at sea**: operated by Coriolis, this domain encompasses: floats acquisition, deployment and monitoring.
3. **Data management**: the data center is operated by 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 NA-ARC *regional-center* systems).
4. **Scientific steering**: is coordinated by SNO Argo-France and conducted jointly by LPO, LOV and Coriolis at the national (SOERE, GMMC), European (Euro-Argo management board) and international level (AST, ADMT, DMQC).

Last 3 domains with the Euro-Argo ERIC central infrastructure are accredited for 2012-2020 as a "Large Scale Research Infrastructure" (**TGIR**) by the French Ministry of Higher Education and Research. Operational activities are managed within Coriolis, research and animation within SNO Argo-France.

Thus, with resources from CNRS, OSU-IUEM and institutional contributions through research laboratories (LPO and LOV), the SNO Argo-France takes in charge the main following activities:

- **Scientific coordination and animation** of the national program in close interactions with Argo international and Euro-Argo. This is done by G. Maze, F. D'Ortenzio, V. Thierry and S. Pouliquen.
- **QC protocols development and expertise** for: all French floats and the North-Atlantic Argo Regional Center (post delayed-mode assessment of research-quality procedures for floats in the North-Atlantic). This is done under the supervision of C. Cabanes for physical parameters and F. D'Ortenzio for biogeochemical ones.
- **Coordination with operational Coriolis activities** (deployments, DAC, TGIR). This is done by S. Pouliquen with C. Cabanes and C. Schmechtig.
- **Promotion** of new measurements (biogeochemical) and observation sites (deep ocean). This is done by F. D'Ortenzio, V. Thierry and G. Maze.

Note that 2010-2014 achievements for these activities have been reviewed through out the previous sections of this document.

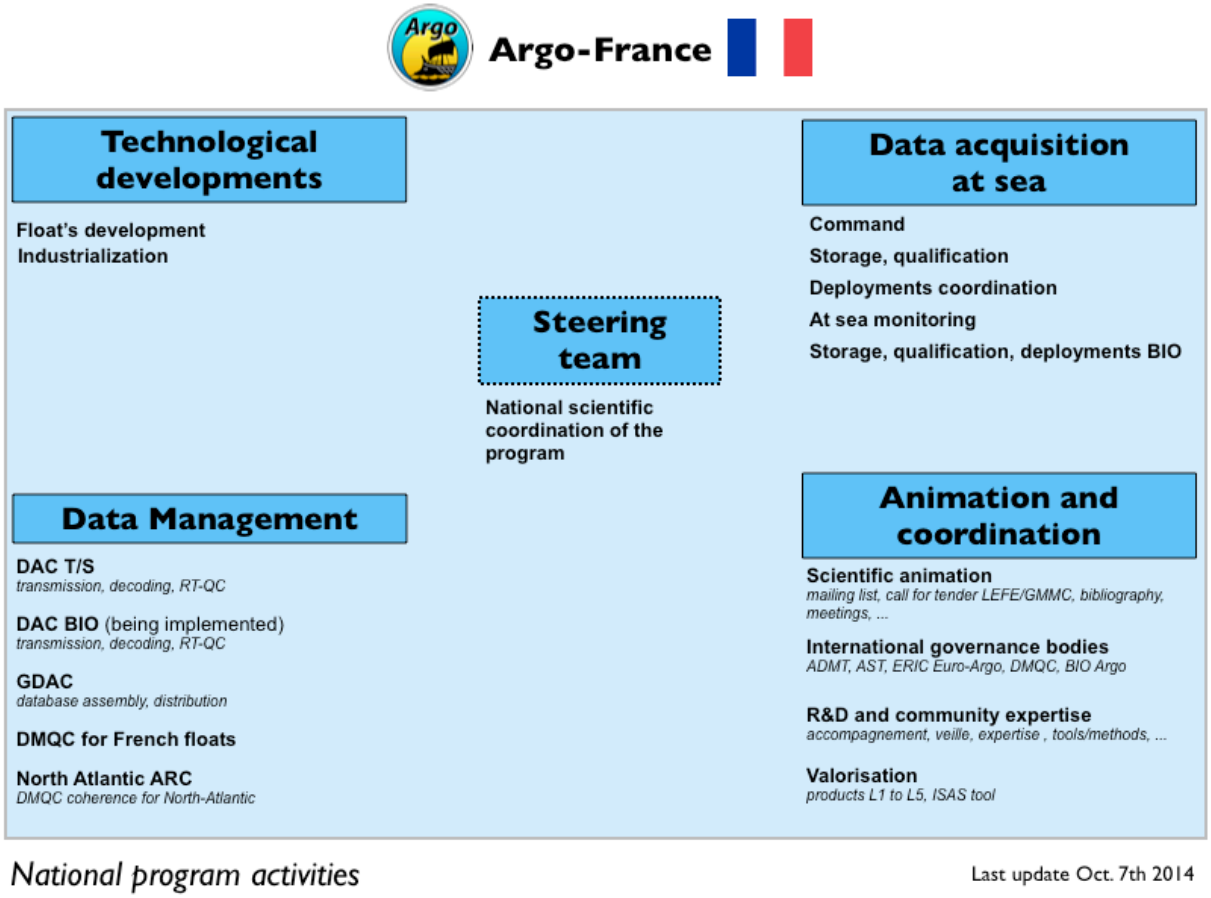

Figure 6: All Argo-France program activities

All SNO Argo-France activities are organized since 2010 as in Figure 7. V. Thierry was national coordinator from 2010 to 2012, G. Maze from 2013 up to today. The SNO Argo-France aims to maintain existing and develop new expertise with regard to physical and biogeochemical measurements from Argo floats. There is thus a strong activity linked to the R&D of new floats and sensors conducted within projects. Note that the SNO Argo-France provides qualified Argo data in different products levels constantly under improvement and development, hence the emphasis on products. The respective contributions of all human resources are listed in Table 8.

9) Governance

a) Internal instances

2010-2013: Coriolis & Projects

Over the 2010-2013 period, the SNO governance was distributed because conducted by the following instances:

1. Coriolis for operational activities under its responsibility (data acquisition at sea and data management). People involved: S. Pouliquen, N. Lebreton and T. Carval, C. Coatanoan.
2. Projects governance bodies: most notably Equipex NAOS and ERC RemOcean, for R&D activities under research laboratories responsibilities. People involved: P.Y. Le Traon, V. Thierry, F. D'Ortenzio, H. Claustre, S. Le Reste.
3. OSU IUEM and UMR research laboratories implied in the SNO: LPO and LOV. People involved: F. Gaillard, C. Cabanes, V. Thierry, F. D'Ortenzio, G. Maze.

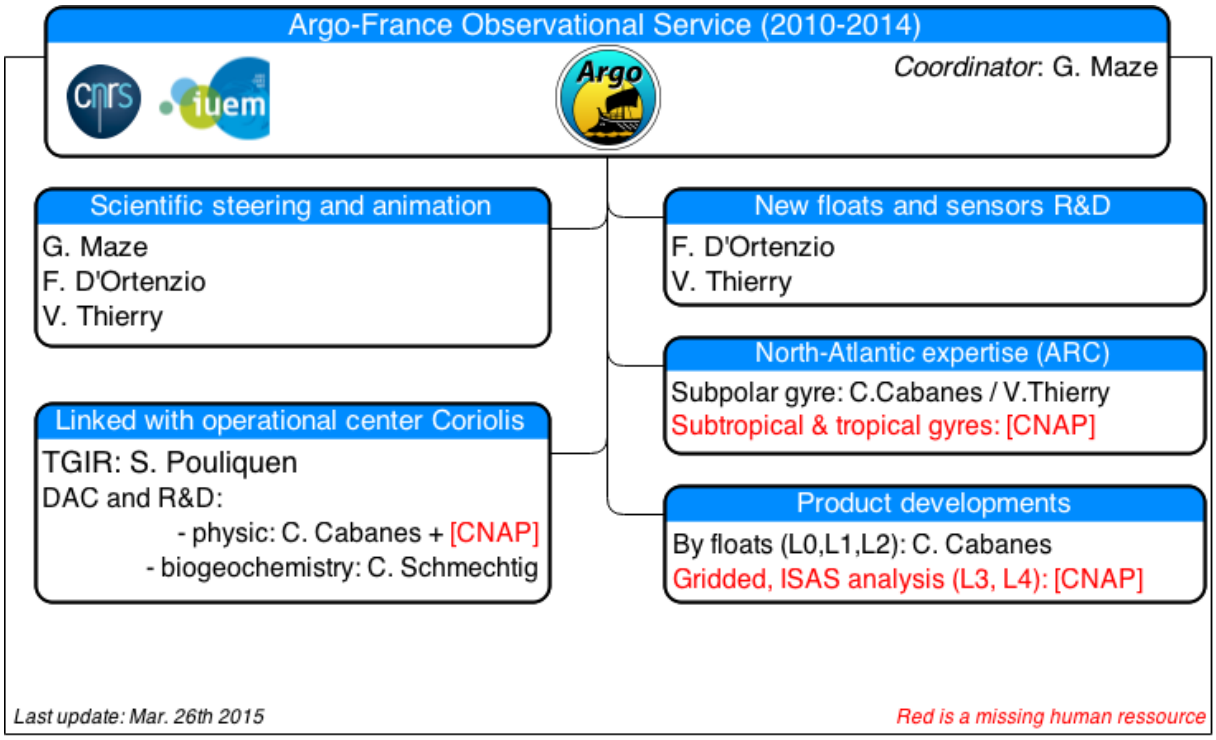

Figure 7: Organization of SNO Argo-France activities. The role of an expected CNAP-CSOA position is highlighted in red.

Outside of Coriolis, projects and OSU&UMR, no centralized internal governance instance was really implemented between 2010 and 2014. This can be explained by the fact that most efforts have been dedicated to maintain and consolidate growing operational activities on one hand and to DMQC and R&D for Argo core and extension on the other hand. Obviously and as already noted, regular meetings were held between Coriolis and SNO, SOERE and SNO, Argo-France and the community so that operational and research activities have been conducted in a constructive and complementary direction through out the period. Although clear successes have been achieved, an evolution was necessary in term of coordination.

2014-onward: Scientific steering committee

In 2014 several milestones were reached: (i) a new Coriolis convention for the 2014-2020 period, (ii) successful R&D on new floats and scheduled pilot arrays and (iii) a consolidated Argo-France contribution to the network with the Euro-Argo setup. After several years of intense re-organization and evolution it was time to enact that the Argo-France program covers a large number of activities under the responsibility of several institutions (Ifremer, CNRS, SHOM, ...) or consortium (Coriolis) and that all or subsets of activities are accredited with different labels (SNO, TGIR, ...) while some are conducted within specific projects (funded by ERC, ANR, CPER, EQUIPEX, ...). Throughout this complex landscape, people strongly involved in Argo-France were missing an independent body to coordinate and plan the mid-to-long term national effort to the Argo array.

Beginning in late 2014, an Argo-France scientific steering team is in charge for the internal coordination of the Argo-France program in order to provide to each component of the program (operational and research communities) a mid-to-long term perspective on the evolution of Argo in France. **The Argo-France scientific steering team will gather and disseminate the technological and scientific information needed for strategic planning and decision making of the national program**. Members of the steering team are the scientific coordinators of the core and extension missions (G. Maze: core + deep, F. D'Ortenzio: bio and V. Thierry: core + oxygen) and coordinators of operational and infrastructure activities from Coriolis (N. Lebreton for data acquisition at sea, T. Carval for the data center and S. Pouliquen for the data management and TGIR). The steering team objectives are:

- to ensure that strategic choices made in different domains of activity are coherent and in line with needs of the national research community,

- to promote interactions between projects and operational activities, especially between technological floats development, at sea operations, Coriolis DAC and research conducted in laboratories,
- to develop a strategy for mid-term deployments (>2 ans) for the French Argo fleet (core mission and extensions),
- to provide a recommendation on the annual deployment plan elaborated by the data acquisition at sea Coriolis component,
- to supervise the annual report on the Argo-France program transmitted to the AST.

The steering team already met 2 times on September 29th, 2014 and March 23rd 2015. In the future, it will meet at least 3 times a year: (i) in February/ March to prepare the AST meeting, (ii) in June to assess progress and status of the annual deployment plan and (iii) in October to prepare the ADMT/DMQC meeting, to review GMMC call proposals and the upcoming deployment plan. The steering team has its own mailing list (pilotage-argo-france@listes.ifremer.fr) to exchange information internally.

b) External instances

Different members of the Argo-France community are involved in external governance instances. From the national to the European and international levels, responsibilities and representations are explained in **Erreur ! Source du renvoi introuvable.**.

Level	Instance	Name	Responsibility
France	Coriolis Steering Committee	G. Maze	SNO Argo
	SOERE CTD-O2	C. Cabanes	Coordination SNO - SOERE
	TGIR Euro-Argo	S. Pouliquen	Coordination with ERIC
Europe	ERIC Euro-Argo	P.Y. Le Traon	Council France delegate
		V. Thierry	Management Board France delegate
		S. Pouliquen	Project office manager
International	ADMT	S. Pouliquen	Co-chair
	DMQC	C. Cabanes	P/T/S/Traj expertise (SNO, NA-ARC)
		C. Coatanoan	P/T/S/Traj expertise (R&D Coriolis)
		F. D'Ortenzio	BIO expertise (SNO)
	AST	P.Y. Le Traon	European Union GODAE
		G. Maze	France delegate
		S. Pouliquen	Data Team co-chair

Table 7: Participation of SNO Argo-France in external governance instances.

10) Difficulties

a) Difficulties in operational activities:

Since 2010, the data center Coriolis has to manage more and more complex data parameters and validation procedures. With two-ways communication system like Iridium and more complex floats cycling definition, the existing data format and procedures for L0 and L1 products revealed not appropriate. Thus the SNO Argo-France, together with Coriolis DAC and R&D, contributed to an updated data format (version 3) that is now able to preserve the quality of the core P/T/S 0-2000m parameters and allows for seemingly incorporation of new floats technology and parameters (oxygen, chlorophyll-a).

Argo-France *data acquisition at sea* is an activity operated by Coriolis. Since 2013, the Argo-France deployment group encounters ever growing difficulties in the management of floats. The long-term increase of floats to be managed by Coriolis (10 to 15 additional floats/year) is a success on one hand for the program, but stretches to the limit the existing human resources on the other hand. This

difficulty must be alleviated in the future with additional resources and enforced commitments to Coriolis by participating institutes. More generally, Argo-France needs to improve its operational flow with a better monitoring of the fleet, from the commercial command down to the fleet performance monitoring at sea.

b) Difficulties in research related activities:

ISAS (see Section xxx) is a key element of the Argo-France data flow and product generation for both the operational and research oceanographic community users. ISAS has been developed at LPO by F. Gaillard (Ifremer research scientist) who is in charge of the national "Pôle de données" initiative since 2014. As she cannot maintained ISAS any longer, Argo-France is facing important difficulties to sustain its effort in delivering a research-qualified dataset to its user community. To be able to maintain ISAS, Argo-France seeks a CNAP/SCOA position since 2014.

Since 2010, Argo-France is under intense activities of re-organization and evolution. The Argo-France program covers a large number of activities under the responsibility of several institutions (Ifremer, CNRS, SHOM, ...) or consortium (Coriolis) and all or subsets of activities are accredited with different labels (SNO, TGIR, ...) while some are conducted within specific projects (funded by ERC, ANR, CPER, EQUIPEX, ...). Throughout this complex landscape, people strongly involved in Argo-France were facing difficulties in coordinating their efforts. It was missing an independent body to coordinate and plan the mid-to-long term national effort to the Argo array. The Argo-France Scientific Steering Team was created to face this difficulty (see previous section).

11) Human resources

Human resources badging to SNO activities are summarized in Table 8. Contributions are in man/month. SNO gathers a total of 2 man/month.

All other human resources contributing to the Argo-France program are badging to operational infrastructure in the Coriolis consortium. Their averaged contributions for the 2010-2014 period is summarized Table 9 for each institute and each Coriolis component. A total of 9.1 man/month are contributing to Argo-France program through the Coriolis consortium.

Name	Position	Affiliation	M/M	Role in SNO Argo-France (2014)
Cabanes, Cecile	Engineer	CNRS	1	Coordination on P/T/S with Coriolis and SOERE, expertise on DMQC and North-Atlantic, product development (P/T/S, trajectories)
D'Ortenzio, Fabrizio	Scientist	CNRS	0.05	Animation, expertise on Argo-bio extension and DMQC
Maze, Guillaume	Scientist	Ifremer	0.2	Coordination, animation, expertise on Argo-Deep extension
Pouliquen, Sylvie	Engineer	Ifremer	0.05	Coordination with TGIR Euro-Argo
Schmechtig, Catherine	Engineer	CNRS	0.5	Coordination on Ago-Bio with Coriolis, expertise on Argo-Bio extension and DMQC
Thierry,Virginie	Scientist	Ifremer	0.2	Animation, expertise on Argo-bio (oxygen) extension and North-Atlantic and DMQC
		Total SNO:	**2 man/month**	

Table 8: Human resources badging to SNO Argo-France as of 2014

Institute	Coordination	Data acquisition at sea	Data center	R&D	Total
IFREMER	0.8	0.9	2.7	1.1	5.5
SHOM		1.4	0.9		2.3
CNRS-INSU		0.5		0.5	1
IRD		0.3			0.3
Météo-France					
CNES					
Total Coriolis	0.8	3.1	3.6	1.6	**9.1 man/month**

Table 9: Coriolis human resources dedicated to the Argo-France program, average 2010-2014

12) Funding

SNO Argo-France activities are directly funded by CNRS-INSU and OSU-IUEM:

Regular funding 2010-2014*			Occasional funding		
Source	*Amount (k€)*	*Comment*	*Source*	*Amount (k€)*	*Comment*
CNRS	10	SNO dotation 2011			
CNRS	10	SNO dotation 2012			
CNRS	10	SNO dotation 2013			
CNRS	10	SNO dotation 2014			
OSU-IUEM	2.5	SNO dotation 2011			
OSU-IUEM	2	SNO dotation 2012			
OSU-IUEM	1.6	SNO dotation 2013			
OSU-IUEM	2.7	SNO dotation 2014			
TOTAL	48.8		TOTAL		

Note that human resources can be funded by other institutes, like Ifremer, through their support to SNO research laboratories: UMR LPO and LOV.

Regular expenses 2010-2014			Occasional expenses		
Nature**	*Amount (k€)*	*Comment*	*Nature*	*Amount (k€)*	*Comment*
Other expenses	*3.7*	*Workshop org., etc ...*	*Custom fees*	*1.7*	*Oxygen sensors (2011,2013,2014)*
Travel	*33.1*	*Argo-France, AST, ADMT, DMQC, ...*	*Outsourcing*	*3*	*ANDRO decoders update (2013)*
Equipment	*3.3*	*Computers for C.C, etc ...*	*Techno. Dev.*	*4*	*Argos for ASFAR (2014)*
TOTAL	*40.1*		*TOTAL*	*8.7*	

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1) Annex - 2011 SNO products status

January 2011 status (at the time of 1st SNO accreditation)						
Product level	**L0**	**L1**	**L2**	**L3**	**L4**	**L5**
Product Description	**Raw** data transmitted by floats	**Profiles** Data Quality-controlled in near **real**-time	**Profiles** Data Quality-controlled in **delayed**-time	**Mapped** Data Quality-controlled in near **real**-time	**Mapped** Data Quality-controlled in **delayed**-time	**Indicators**
Core P/T/S	Decoders at DAC	A-R mode prof.nc files	D-mode prof.nc files	ISAS-Coriolis	ISAS-SNO	R&D
Displacements	ANDRO R&D	ANDRO R&D	ANDRO R&D	R&D	R&D	
Oxygen	R&D	R&D	R&D			
Chlorophyll-a	R&D	R&D	R&D			
BBP	R&D	R&D				
Nitrate	R&D	R&D				
Deep P/T/S						
Deep Oxygen						

Table 10: SNO Argo-France products and parameters (2011 status)

Status	**Definitions (**of product and QC procedures)
Achieved	The protocols and the methods are developed (i.e. published), implemented at DAC/GDAC level, and operational. International consensus.
Testing	The protocols and the methods are developed (i.e. published) and being implemented at DAC/GDAC level. International consensus on the methods is depending on tests (i.e. consolidation of consensus). Still in test phase to verify pertinence and performance.
R&D	The protocols and the methods are being developed (not published). No implementation at DAC/GDAC level. Discussions in the framework of the dedicated task teams (Argo-bio and Argo-deep)
10 years target	Technology is being developed. Methods not yet identified.

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2015-2019 EVOLUTION

4) Context, motivations and scientific objectives

Evolution for the 2015-2019 period

The priority of the SNO Argo-France for 2014-2019 is to continue existing activities in order to sustain the level of quality of the Argo time series.

The main challenge for the Argo-France program over the upcoming 2015-2019 period will be to succeed in moving all R&D activities conducted within projects (new floats, new parameters, new sites and the associated QC procedures) into consolidated operational activities operated by Coriolis and based on expertise from the research community structured within the SNO framework. What is at stake is to maintain the national Argo activity in an international leadership position and to accompany the national community in an ever more competitive activity at European and global levels.

In the 2010-2014 report, we highlighted important evolutions of the infrastructure associated with Argo-France: a new Coriolis convention, a TGIR Euro-Argo and the ERIC Euro-Argo. It is difficult to foresight what will be the impact of these new structures on the specific SNO Argo-France activities. However, **the goal of the SNO Argo-France will be to accompany the infrastructure's evolution by structuring and coordinating research-related activities conducted within laboratories.**

For the 2015-2019 period, the SNO Argo France will continue activities described in the 2010-2014 report and **move forward with a set of updated objectives**. To reflect more closely the projected status of evolution of the different Argo parameters and extensions, the proposed objectives for the next 5 years are:

- to provide research quality Argo 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) ether directly or through re-analysis or assimilation products.
- to consolidate and organize the French contribution to the international Argo program and to the European research infrastructure Euro-Argo
- *to consolidate and strengthen the Argo-bio network development of biogeochemical parameters measurements from Argo floats*
- *to promote extension of observation sites from new Argo deep profiling floats and an Argo-deep network development.*

In practice, these new set of objectives will lead to a change of status for all parameters and associated products distributed by Argo-France. The targeted changes are color-coded in Table 11 (to be compared with table 3 from the 2010-2014 report). Note that the long-term objective of the SNO Argo-France is to take all products and parameters to an achieved/operational *green* status sustained over a long period (at least 20 years). Proposed evolutions will concern:

- The stabilization and consolidation of data management and QC procedures for trajectory data. Goals: accompany adoption of new data format and L0/L1 products real-time QC procedures, to move from national LPO-ANDRO dataset to research-quality QC procedures adopted at the international level and applied by all DACs.

- The stabilization and consolidation of data management and QC procedures for biogeochemical measurements. Goals: achieve data management and research-quality QC procedures for O2, CHLA, BBP and NO3.
- The creation and development of data management and QC procedures (for all products levels) for data from the new Argo deep profiling floats.

It is important to note that these evolutions are already initiated and no tremendous changes are required to reach the proposed goals. The point here is to "upgrade" these activities from a phase of "R&D" (then for the most driven by research laboratories and in the framework of specific projects) to an operational and consolidated phase (then directly managed by CORIOLIS based on scientific SNO expertise). The new phase of consolidation will provide also an enrichment (in terms of quality and quantity) of the products generated and distributed by the SNO. This point, which is implicitly related to an enlargement of the national community interested to Argo, determines a critical needs of human resources detailed below.

In order to reflect the proposed evolutions, the SNO Argo-France will modify its organization schematic. This change is also motivated by the upcoming creation of the "Pole de Données". The national "Pole de Données " initiative will identify data experts and data managers to help users and the national community to engage with all available datasets and products. In the section below we will detail how the SNO Argo-France organization will evolve to be centered around two pole of expertise, one for physical and one for biogeochemical measurements from Argo floats.

5) Measurements protocols

The priority of the SNO Argo-France for 2014-2019 is to continue existing activities in order to sustain the level of quality of the time series. These activities require a constant monitoring at all level of the observation program (float technology to QC procedures). Argo-France will possibly have to face new issues from un-expected origin.

The next phase of activities for the physical branch of the SNO Argo-France will also be devoted to the consolidation of the data processing and QC for trajectory data and the development of QC procedures for the Argo-deep extension. The next phase of activities for the biogeochemical branch of the SNO Argo-France will be devoted to the consolidation of the data processing and QC for O2, CHLA, BBP and NO3.

The expected results are summarized in the table below (to be compared with table 3 from the 2010-2014 report).

Argo-France, 2019 target						
Product level	**L0**	**L1**	**L2**	**L3**	**L4**	**L5**
Description	**Raw** data transmitted by floats and decoded	**Profiles** Data Quality-controlled in near **real**-time	**Profiles** Data Quality-controlled in **delayed**-time	**Mapped** Data Quality-controlled in near **real**-time	**Mapped** Data Quality-controlled in **delayed**-time	**Oceanic indicators**
Core P/T/S	raw data, meta and tech.nc files	A-R mode prof.nc files	D-mode prof.nc files	ISAS-Coriolis	ISAS-SNO (Arivo)	GOIs-GMES
Displacements	raw data, meta and tech.nc files	Rtraj.nc files	Dtraj.nc files	Maps of absolute currents	Maps of absolute currents	WBC & NA-MOC index
Oxygen	raw data, meta and tech.nc files	A-R mode Bprof.nc files	D-mode Bprof.nc files	ISAS-Coriolis	ISAS-SNO	O2 content, OMZ

Chlorophyll-a	raw data, meta and tech.nc files	A-R mode Bprof.nc files	D-mode Bprof.nc files	ISAS-Coriolis	ISAS-SNO	Biomass basin scale long term evolution[1]
BBP	raw data, meta and tech.nc files	A-R mode Bprof.nc files	D-mode Bprof.nc files	ISAS-Coriolis	ISAS-SNO	Biomass basin scale long term evolution[1]
Nitrate	raw data, meta and tech.nc files	A-R mode Bprof.nc files	D-mode Bprof.nc files	ISAS-Coriolis	ISAS-SNO	Nitrate basin scale long term evolution[1]
Deep P/T/S	raw data, meta and tech.nc files	A-R mode prof.nc files	R&D	ISAS-Coriolis	ISAS-SNO	
Deep Oxygen	raw data, meta and tech.nc files	A-R mode prof.nc files	R&D	ISAS-Coriolis	ISAS-SNO	
Radiometry [2]	raw data, meta and tech.nc files	A-R mode Bprof.nc files	R&D	R&D	R&D	
pH [3]	raw data, meta and tech.nc files	A-R mode Bprof.nc files	R&D	R&D		

Status	**Definitions (**of product and QC procedures)
Achieved	The protocols and the methods are developed (i.e. published), implemented at DAC/GDAC level, and operational. International consensus.
Testing	The protocols and the methods are developed (i.e. published) and being implemented at DAC/GDAC level. International consensus on the methods is depending on tests (i.e. consolidation of consensus). Still in test phase to verify pertinence and performance.
R&D	The protocols and the methods are being developed (not published). No implementation at DAC/GDAC level. Discussions in the framework of the dedicated task teams (Argo-bio and Argo-deep)
10 years target	Technology is being developed. Methods not yet identified.

Table 11: SNO Argo-France products and parameters (2019 target)

[1] Long term evolution of biogeochemical parameters has been up to now proposed by merging satellite and historical in situ data (Boyce et al al. 2010, Gregg et al, 2005). Similar analysis should be adapted to include also Bio-Argo floats, when the network will attaint a sufficient density.

[2] Radiometry is already operational on most of the Bio-Argo floats of the national fleet. This parameter is particularly relevant for the exercise of Cal with ocean color sensors. It provides also an independent method to estimate biomass and could be then used to establish QC method on CHLA (Xing et al. 2011).
Xing, X., Morel, A., Claustre, H., Antoine, D., D'Ortenzio, F., Poteau, A., Mignot, A. (2011). Combined processing and mutual interpretation of radiometry and fluorimetry from autonomous profiling Bio-Argo Floats. The retrieval of Chlorophyll a, Journal of Geophysical Research, 116, C06020, doi:10.1029/2010JC006899.

[3].pH sensors are presently in a test phase on two float models (Apex and PROVOR). French community is particularly dynamic in this activity and we could reasonably imagine an integration of this parameter in a future Bio-Argo network that could open new opportunity to enlarge Bio-Argo end-users.

6) Length of the time series

With the CPER Euro-Argo (Brittany region), Argo-France will secure 80 floats/year for the 2015-2019 period, 15 more floats than the historic contribution of 65 floats/year (50 funded by Ifremer ,15 by SHOM). The expected technology for these floats will be 50% core P/T/S, 20% Argo-Deep and 30% core over fitted with an oxygen sensor.

At national level, and for the considered period (2015-2019), the consolidation of the national Argo-Bio fleet is assumed by three LOV projects (i.e. NAOS: 14 floats in Mediterranean; RemOcean: 2 floats in the North Atlantic; SOCLIM: 8 floats in the southern ocean), and by the CNES-GMMC-LEFE activity (i.e. 4 floats/year), which distributes Argo-Bio floats at the national community on the basis of proposals evaluated by the GMMC. CPER PACA is also assured, with a component Bio-Argo clearly established (4-5 floats/year) for the period 2015-2019.

At international level, US (i.e. SOCOM NSF project), ERIC Euro-Argo (i.e. roadmap of ESFRI and AtlantOS H2020 project) and also emerging country (i.e. China, Brazil) have planned deployments for the next 4 years. Existing collaborations with these foreign partners (at European and International level) will assure the sharing of data and methods for the next years, placing the biogeochemical branch of the SNO in a leadership position.

7) Data Management

No change, see 2010-2014 report.

8) Integration of the Observational Service

No change, see 2010-2014 report.

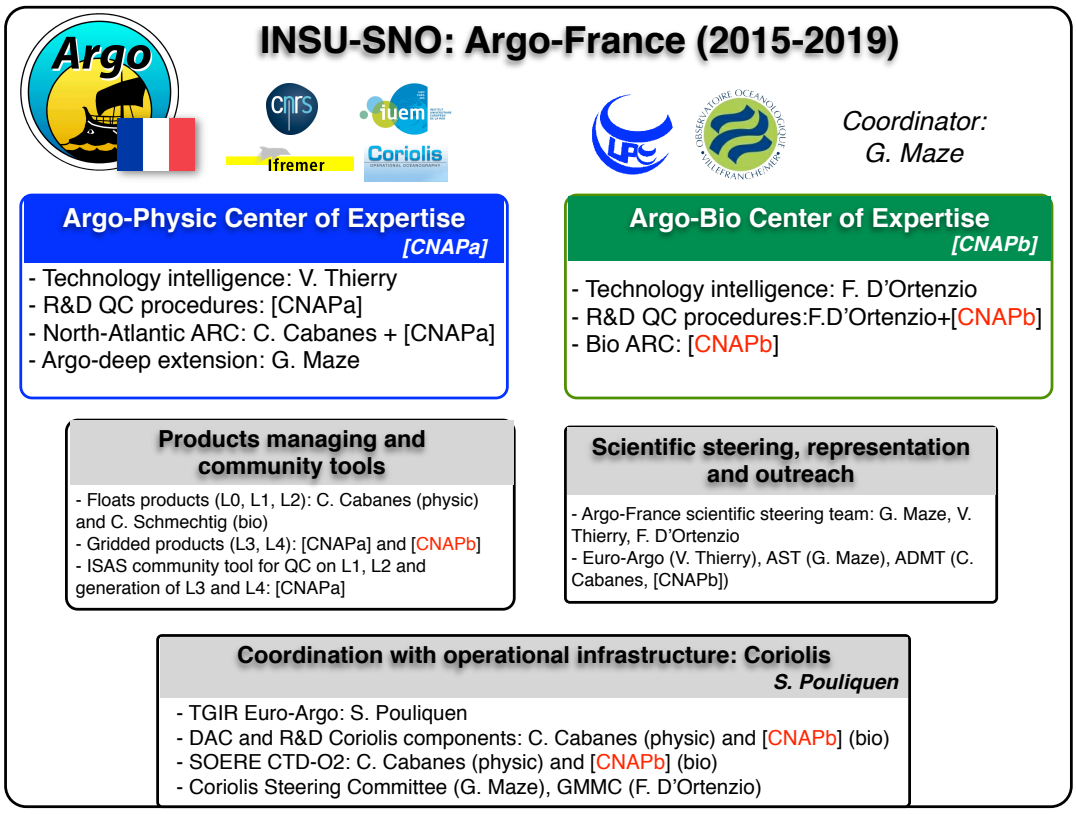

Figure 8: Updated SNO Organization of activities

9) SNO Organization

We propose an update to the organization of the SNO Argo-France to highlight its two-fold core expertise. The new schematic of the SNO organization is given Figure 8. This implies:

- a new "Argo-Bio center of expertise" dedicated to the biogeochemical component of the national program that will reflects the strong implication of the national community on this activity,
- a re-organization of the *physical* parameters activities of the program into a "Argo-Physic center of expertise" that will reflects the evolution of the historical core activities on P/T/S.

This new organization will also highlight and strengthen the positive feedbacks existing in France between scientists involved in the core P/T/S parameters and those directly implicated in the Argo-Bio researches by clearly creating a transverse activity.

A new national "Argo-Bio center of expertise"

The main aim of the Biogeochemical branch of the SNO-Argo-France for the next 5 years is the consolidation of the biogeochemical activities at national level. This implies:

1. the finalization (up to the operational phase) of QC protocols, by structuring the national community and by gathering French expertise to contribute to the international effort;
2. the participation to the international and European effort in the Argo-Bio fleet growing.

To reach these two goals, a national "Argo-Bio center of expertise" is proposed (see new organization schematic). This center, which will be functioning exactly as the physical expertise center will be devoted to organize the growing Argo-Bio activity at national level. An important role of the "Argo-Bio center of expertise" will be also the participation to the international Argo instances around Argo-Bio. In this framework, note that the Argo Steering Team endorsed recently (Dec 2014) a Argo-Bio

task team, in order to organize the existing international effort to the evolution of the Argo network toward the biogeochemical parameters.

This new structure of the SNO Argo-France will be for the most organized around the peoples already involved. The evolution toward a more operational functioning (see next paragraph) will require, however, the recruitment of more dedicated human resources (i.e. CNAP).

10) Governance

No change, see 2010-2014 report.

11) Resources needed for the proposed evolutions

a) Human resources

To be able to sustain its planned activities, the organization of SNO Argo-France will need additional human resources (see table below). SNO Argo-France has two priorities:

1. a CNAP dedicated to Argo physical parameter, to provide and develop expertise for the North-Atlantic and research and development linked to the community tool ISAS is necessary. This research scientist will take in charge the coordination of the SNO (middle term).
2. a CNAP dedicated to Argo biogeochemical parameters, to provide and develop expertise for the Argo-Bio regional center.

As explained in the difficulties of the 2010-2014 activity report, these human resources are crucial to consolidate the 2010-2014 period efforts of research and technological developments for the core and extension missions.

Table 12: Human resources needed for the SNO Argo-France

Nom	corps	organisme	ETP (homme-an)	Fonction dans le SO	Ressource existante ou demandée
-	physicien-adjoint	CNAP-CSOA	10	SNO coordinator, QC procedure, NA-ARC expertise, ISAS R&D	1 CNAP demandé et soutenu par le SOERE CTD-O2 (poste colorié au concours CNAP 2015).
-	physicien-adjoint	CNAP-SCOA	10	BIO expert, QC procedure	-

Institute	Coordination	Data acquisition at sea	Data center	R&D	Total
IFREMER	1.45	1.7	2.5	2	7.65
SHOM		0.75			0.75
CNRS-INSU	0.4	0.6	0.5	1	2.5
IRD		0.05			0.05
Météo-France					0
IPEV		0.05			0.05
CNES					0
Total Coriolis	1.85	3.15	3	3	**11 man/month**

Table 13: Coriolis human resources dedicated to the Argo-France program for 2014-2020

b) Funding

The SNO Argo-France requires more financial resources in order to be able to structure, animate and support an ever increasing user community. In particular, the SNO Argo-France would like to:

- continue to be able to organize regular workshops,
- develop and consolidate training activities for new users,
- help the national research community engage with the data set (and foster positive feedback on the SNO dataset and expertise),
- develop and consolidate outreach activities toward the public.

Regular funding 2015-2019*			Occasional funding		
Source	*Amount (k€)*	*Comment*	*Source*	*Amount (k€)*	*Comment*
CNRS	12	*SNO annual dotation (+2k€ vs 2010-2014 to fund aforementioned activities)*			
OSU-IUEM	3	*SNO annual dotation*			
TOTAL	75*k€* for 2015-2019		TOTAL		

These funds will be used as follow:

Regular expenses 2015-2019			Occasional expenses		
Nature*	*Amount (k€)*	*Comment*	*Nature*	*Amount (k€)*	*Comment*
Other expenses	*11.5*	*Workshop, Training sessions, outreach*	*Custom fees, outsourcing, etc ...*	*13*	*Estimate based on 2010-2014 history*
Travel	*41.5*	*8.3k€/year to participate in national and international Argo steering and governance meetings (Argo-France, AST, ADMT, DMQC, ...)*			
Equipment	*9*	*Computers for OSU and CNAPs, etc ...*			
TOTAL	*9*		*TOTAL*	*13*	