AtlantOS

Project	AtlantOS – 633211
Deliverable number	D 3.15
Milestone title	Argo Dataset production: Real-time data-management and delayed-mode qualified dataset for O_2, Chlorophyll-a, backscattering and NO_3
Description	Assessment of Data flow and availability on the assembly centre. Description of the O_2 delayed mode quality control
Mean of verification	Real-time data are available on the data assembly centre. DMQC started on additional variables
Work Packages involved	WP3
Lead beneficiary	Euro-Argo ERIC
Lead authors	Grigor Obolensky – Euro-Argo ERIC
Contributors	Romain Cancouët – Euro-Argo ERIC Antoine Mangin – ACRI-ST Antoine Poteau – LOV/SU/CNRS Catherine Schmechtig – OSU ECCE TERRA/SU/CNRS Virginie Thierry – IFREMER
Submission date	15th of March 2019
Due date	M45
Comments	

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Stakeholder engagement relating to this task*

WHO are your most important stakeholders?	☐ Private company If yes, is it an SME ☐ or a large company ☐? ☒ National governmental body ☒ International organization ☒ NGO ☐ others Please give the name(s) of the stakeholder(s): …
WHERE is/are the company(ies) or organization(s) from?	☒ Your own country ☒ Another country in the EU ☒ Another country outside the EU Please name the country(ies): Countries surrounding the Atlantic Ocean
Is this deliverable a success story? If yes, why? **If not, why?**	☒ Yes, because the report shows the effective results achieved within AtlantOS WP3 for the improvement of Argo Data qualification for both core Argo parameters and BGC parameters ☐ No, because …..
Will this deliverable be used? **If yes, who will use it?** **If not, why will it not be used?**	☒ Yes, by in-situ observation data system managers, by users of in-situ Atlantic Ocean observation data, by data providers ☐ No, because …..

NOTE: This information is being collected for the following purposes:

1. To make a list of all companies/organizations with which AtlantOS partners have had contact. This is important to demonstrate the extent of industry and public-sector collaboration in the obs community. Please note that we will only publish one aggregated list of companies and not mention specific partnerships.
2. To better report success stories from the AtlantOS community on how observing delivers concrete value to society.

*For ideas about relations with stakeholders you are invited to consult D10.5 Best Practices in Stakeholder Engagement, Data Dissemination and Exploitation.

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1 Introduction

This document summarizes the activities on Real-Time (RT) processing of the AtlantOS profiling floats fleet, and explains the delayed-mode (DM) processing as forecasted for the years to come. Data processing for AtlantOS floats is compliant and makes use of the Argo Data System for temperature and salinity measurements and the 6 BGC variables endorsed by Argo.

The RT processing of the AtlantOS fleet is organised through Euro-Argo data centres also partners of the AtlantOS program.

The DMQC of AtlantOS floats will be performed by AtlantOS partners delayed-mode operators according to the area of deployment and taking into account their area of expertise. Temperature and Salinity for both BGC and Deep floats (0-2000m for the first and 0-4000m for the latter) as well as Oxygen are performed by IFREMER/Coriolis, Chlorophyll-a/Nitrates concentrations and Radiometry by the Laboratoire d'Oceanographie de Villefranche (LOV), and backscattering coefficient by Plymouth Marine Laboratory (PML).

In addition to Euro-Argo Data Monitoring tool dedicated to the technical parameters and metadata (http://www.ifremer.fr/argoMonitoring/floatMonitoring/650), ACRI-ST has integrated the AtlantOS Bio-Geochemical floats in the SeasideRendezVous Web service allowing the matchup of Chlorophyll-a/nitrates concentrations and Backscattering coefficient with global GlobColour dataset computed from various Water colour satellites (http://seasiderendezvous.fr).

2 Data Availability

2.1 Network

13 profiling floats have been deployed funded by the AtlantOS project:

- 6 BGC floats with a 2000m depth rating, measuring Temperature, Salinity, Dissolved Oxygen, Downwelling Irradiance at 3 wavelengths and Photosynthetically Available Radiation (PAR), Chlorophyll-a concentration, Backscattering coefficient and Nitrates concentration, covering 5 of the 6 core Essential Ocean Variables (EOVs) as defined by the BGC scientific steering team – only pH missing.
- 7 Deep floats with a 4000m depth rating, measuring Temperature, Salinity and dissolved Oxygen

All floats are implemented with in-air measurement ability for Dissolved Oxygen, as required by the O_2 working group for in-field calibration purpose, and one of the Deep floats deployed in the Austral Ocean carries a software enhancement enabling the under-Ice measurements (first European Deep float with this feature).

The deployments have focused on the Atlantic Ocean as a key Area for AtlantOS scientific and networking goals, and a special effort has been pushed on collaboration with long-term existing observing networks to ensure an eased inter-comparison of the results and sustain the temporal coverage extending the on-going time series.

Paired deployments for both BGC floats and Deep floats have also been executed, allowing a better assessment of cross-platform comparisons in the beginning of their life at-sea.

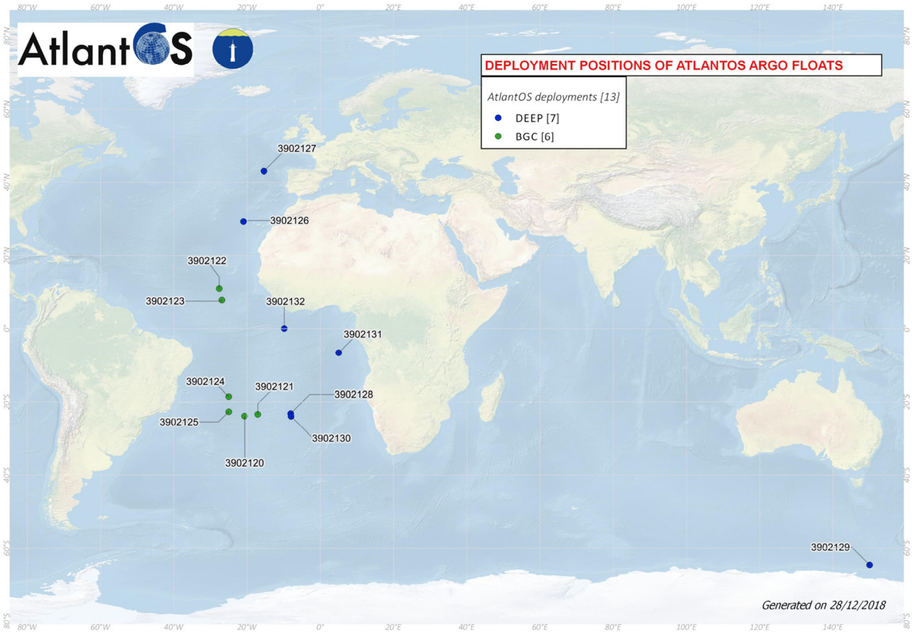


Figure 1. Deployment positions of AtlantOS profiling floats

2.2 Status

The whole BGC floats fleet is functioning properly, automated programming of changes in their mission parametrization has been set to be able to capture the entire range of bio-geochemical cycles expected to be observed. For those platforms, cycling period is comprised between 5 and 10 days.

All Deep floats fleet is functioning properly, but one platform (WMO #3902126) which died prematurely probably due to repeated grounding on the continental shelf when drifting towards the Canarias Island’s coast.

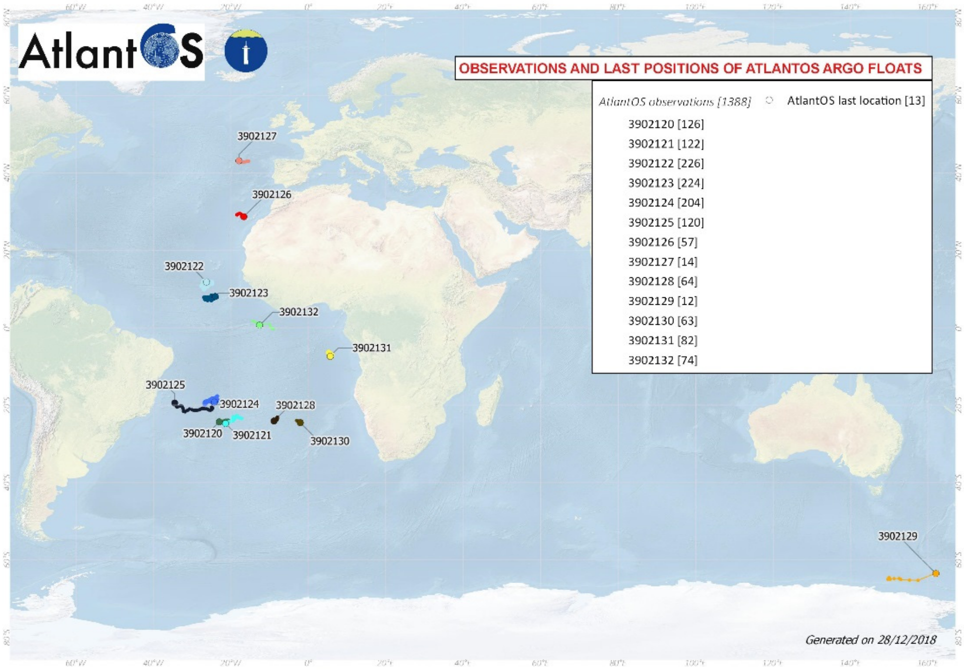


Figure 2. Observations of AtlantOS profiling floats

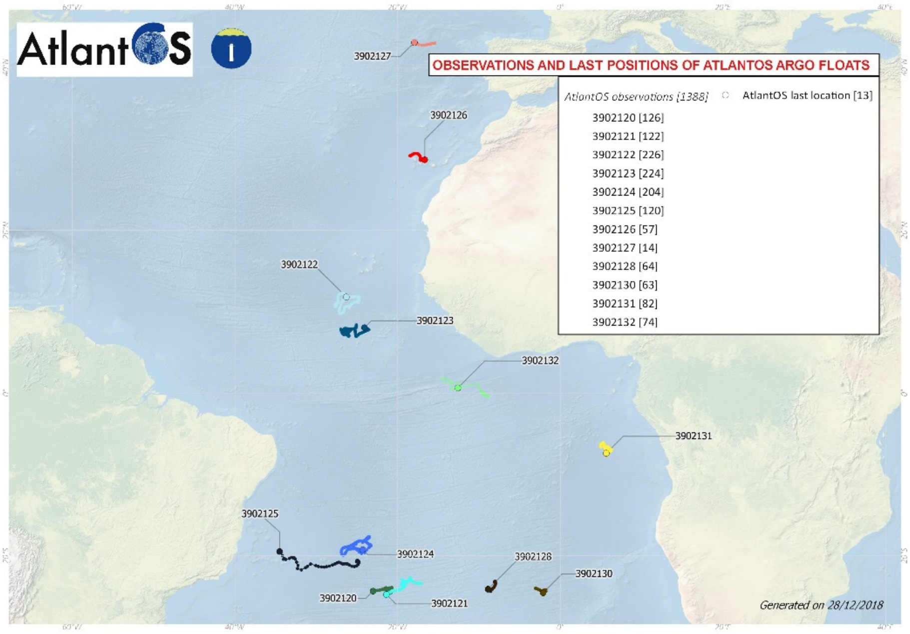


Figure 3. Observations by AtlantOS profiling floats (Atlantic Ocean detailed)

2.3 Repository statistics

Due to the large temporal range of floats deployments (October 2017 to August 2018) and the variations in their cycling period (shortened period in the first months, then cycling period between 5 and 10 days) the number of profiles per platform is ranging from 13 to 130. A complete overview is presented in the Figure 4.

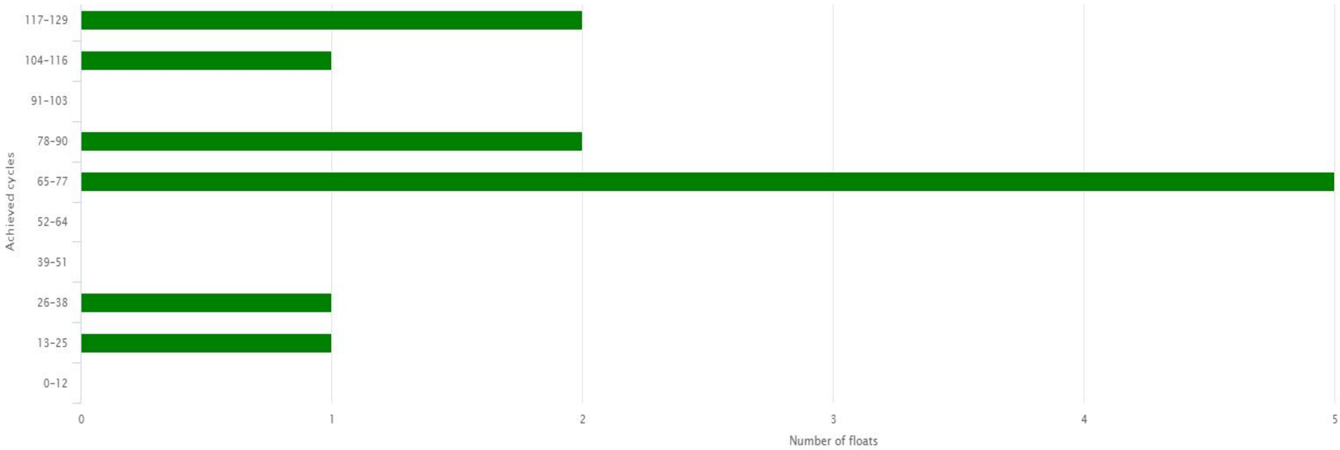


Figure 4. Number of cycles grouped by floats number

3 Argo Data System Overview

The overall quality control performed automatically on archived profiles is based on the Argo Data Management Team (ADMT) specifications for Temperature and Salinity, and on the Bio-Geochemical Argo Data Management Team (ADMT) recommendations for Dissolved Oxygen, Chlorophyll-a, Nitrates, Backscattering and Radiometry.

RT Data processing for AtlantOS floats is compliant and makes use of the Argo Data System. It is organised through Euro-Argo data centres.

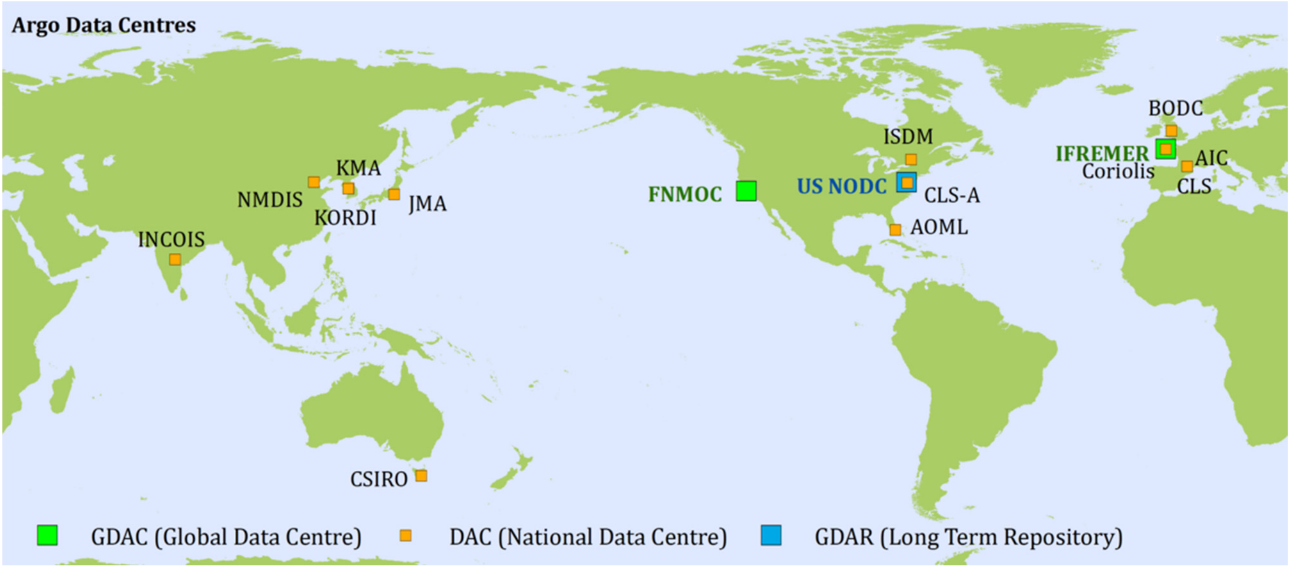


Figure 5: Argo Data System (© Argo Information Centre)

The international Argo Data System is based on two Global Data Assembly Centres, a series of 11 national Data Assembly Centres and several Argo Regional Centres. Their functions are summarised below:

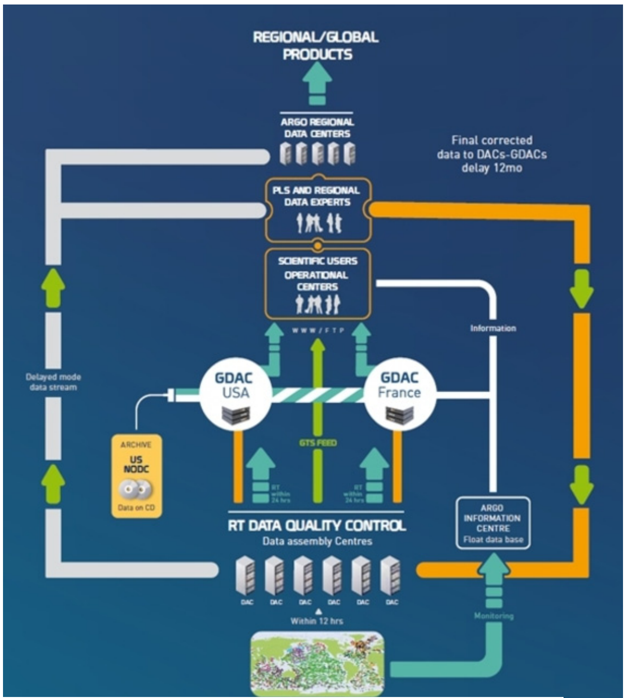


Figure 6 : Argo Data Flow

- **GDACs** (Global Data Assembly Centres), located at Ifremer/France and FNMOC/USA, are in charge of collecting the processed Argo data from the 11 DACs and to provide users with access to the best version of an Argo profile. Data are available, in a standard NetCDF format both on FTP and WWW. The two GDACs synchronise their database every day.

- **DACs** (Data Assembly Centres), they receive the data from the satellite operators, decode and quality control the data according to a set of 19 real time automatic tests agreed by the international Argo programme. Erroneous data are flagged, corrected where possible and then passed to the two GDACs and to the WMO GTS. The GTS data stream does not presently include quality flags and bad data and grey-listed data are not transmitted on the GTS.

- **ARCs** (Argo Regional Centres) provide wide expertise on specific geographical ocean regions in order to provide the most comprehensive data sets (including non-Argo data) of the highest quality. ARCs provide three main services: act as the delayed mode operator for "orphan" floats (i.e. float deployed by an institute that does not have a capability to perform delayed mode QC); gather the recent complementary in situ ship-based data needed for delayed mode validation; check the overall consistency of the Argo dataset in an area.

3.1 Euro-Argo Data Centre for AtlantOS

The Euro-Argo ERIC plays an active role in Argo data management:

- France **(IFREMER) hosts one of the two Global Data Assembly Centres (GDAC)**

- **Two DACs are operated by France (Coriolis) and UK (BODC)**:

    - The French DAC: The French Argo Data Assembly Centre, Coriolis, which is located within IFREMER-Brest and operated by IFREMER with support of SHOM, processes float data deployed by France and from other European (Germany, Spain, Netherlands, Norway, Italy, Finland, Greece, Bulgaria) and several non-European countries (e.g. Chile, Mexico).
    - The UK DAC: The UK Argo Data Assembly Centre, which is established at BODC, processes all UK, Irish and Mauritian float data.

- Euro-Argo partners lead and contribute to three ARCs:

    - Atlantic ARC (NA-ARC): France has taken the lead in establishing the NA-ARC, which is a collaborative effort between Germany (IFM-HH, BSH), Spain (IEO), Italy (OGS), Netherlands (KNMI), UK (NOCS, UKHO), Ireland (IMR), Norway (IMR), Canada (DFO), and USA (AOML). Within the NA-ARC BSH and Hamburg University coordinate the activities in the Nordic Seas.
    - Mediterranean and Black Seas ARC (Med-ARC): Italy (OGS) has taken the lead in establishing the MED-ARC, which is a collaborative effort between Greece (HCMR), Spain (IEO), France (IFREMER, UPMC/LOV), Bulgaria (IOBAS, USOF).
    - Southern Ocean ARC (SOARC): UK has taken the lead in establishing the SOARC. This is a collaborative effort between BODC, CSIRO (Australia), BSH (Germany) and a representative from the SOCCOM project partners (USA).

4 Real-Time Quality control

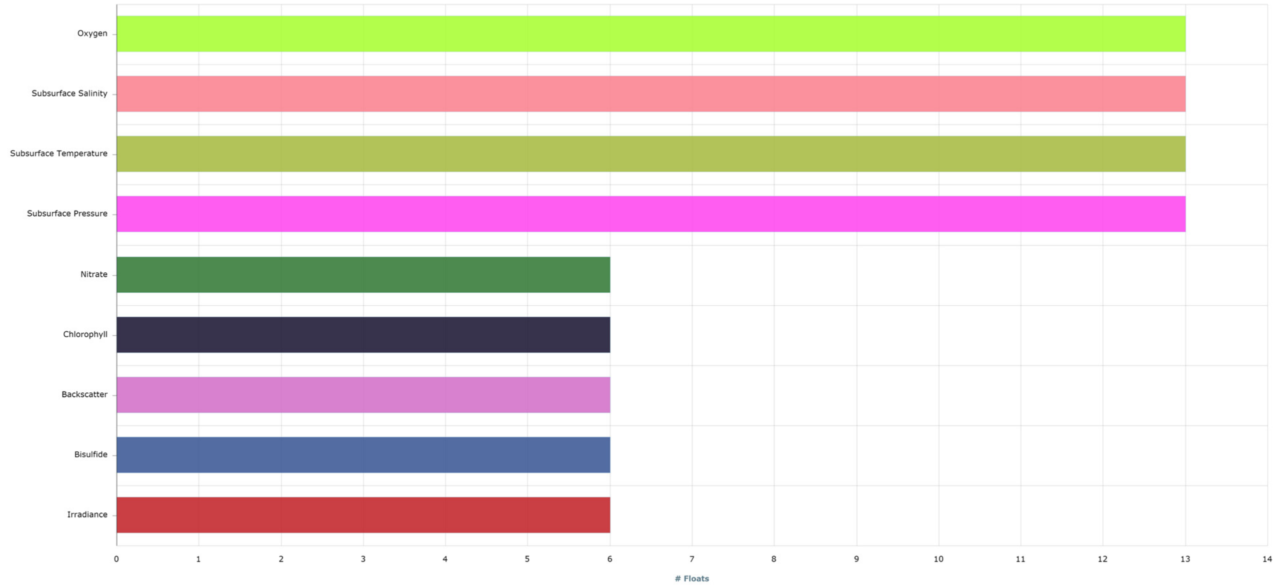


Figure 7. EOVs sampled by AtlantOS profiling floats

4.1 Temperature and Salinity

Temperature and Salinity are the core Argo parameters. All AtlantOS floats are fully compliant with the Argo network requirements (real-time data processing, 10 days cycling period, scientifically and technically assessed sensors – Sea-Bird Inc. SBE41-CP model, standardized data and metadata files formatting).

RT processing is usually carried out by DACs. Procedures flag the gross errors in the data but some subtle errors may remain like sensor drift, float trajectory problems, etc. Elaborate procedures have been devised, based on statistical methods, and scientific expertise from principal investigators (PIs). The procedures are constantly assessed and updated as necessary, following the recommendations of AST and ADMT (http://www.argodatamgt.org/).

4.1.1 Workflow

As partner of the AtlantOS project, IFREMER is committed with the RT quality control of Temperature and Salinity measurements, taking the advantage of the expertise gained over years by specialists in data analysis and processing chain development within the NA-ARC, and a direct link to the European GDAC both hosted in the IFREMER-Brest premises.

At IFREMER/Coriolis DAC, internal procedures include:

- Loading of float metadata, including configuration and technical metadata, to Coriolis database for enabling automated data processing;
- Incoming data is saved to a secure archive;
- The MATLAB chain is used to process raw data, generate Argo NetCDF files and apply the RTQC tests on the profiles;
- The generated NetCDF files are loaded in Coriolis database and send on the Argo GDAC;

- The Coriolis system manages generation of formats for the WMO GTS;
- Operator can change the flags if any alert is detected by the Objective analysis (run daily) by using Scoop3 software;

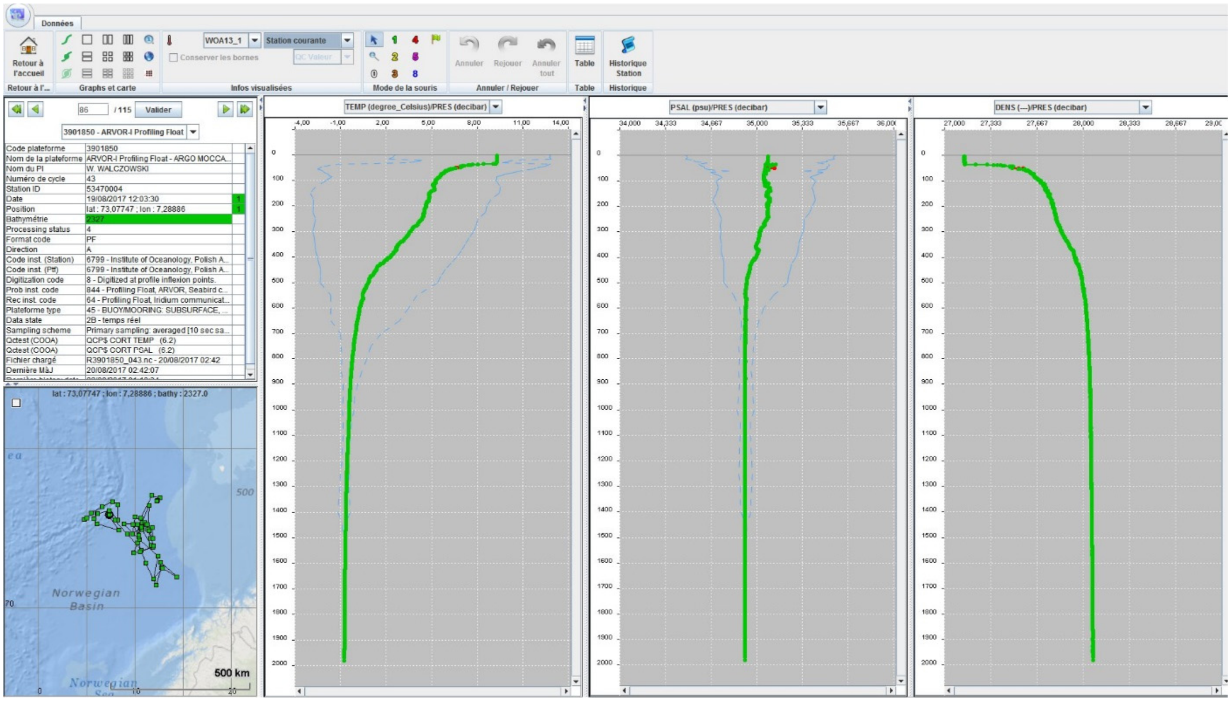
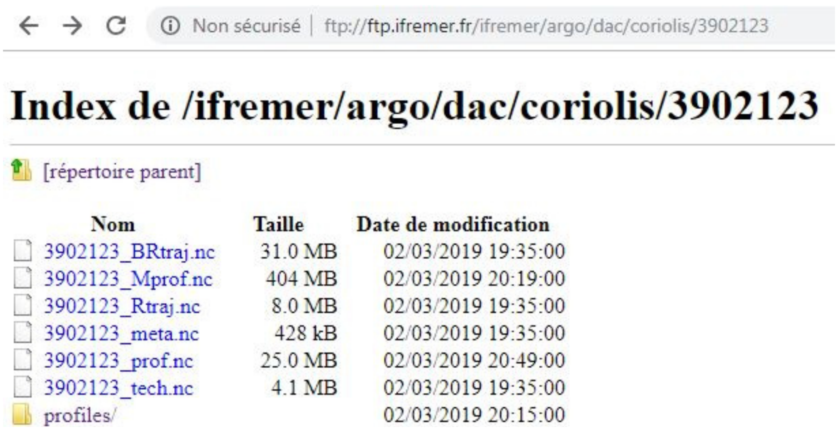


Figure 8: Scoop3 software screenshot

- Daily system monitoring is undertaken by the Coriolis Argo team to identify any processing issues and action undertaken to resolve them when they are encountered.

Figure 9: IFREMER/Coriolis real-time processing dashboard sample

After the automated RTQC, data are integrated into the GDAC and provide users with access channels adapted to various modes of use: ftp access allowing data download for operational users, and Web access allowing data visualisation, selection and extraction with specific temporal and geographical criteria specified by users.


Non sécurisé | ftp://ftp.ifremer.fr/ifremer/argo/dac/coriolis/3902123

Index de /ifremer/argo/dac/coriolis/3902123

[répertoire parent]

Nom	Taille	Date de modification
3902123_BRtraj.nc	31.0 MB	02/03/2019 19:35:00
3902123_Mprof.nc	404 MB	02/03/2019 20:19:00
3902123_Rtraj.nc	8.0 MB	02/03/2019 19:35:00
3902123_meta.nc	428 kB	02/03/2019 19:35:00
3902123_prof.nc	25.0 MB	02/03/2019 20:49:00
3902123_tech.nc	4.1 MB	02/03/2019 19:35:00
profiles/		02/03/2019 20:15:00

Figure 10. an example of repository content for AtlantOS float # 3902123 (BGC float)

4.1.2 Results

The Real-Time processing phase started in October 2017 with the deployments of first floats. The processing chain developed by IFREMER is available to the Euro-Argo and Argo communities. IFREMER/Coriolis DAC (Data Assembly Centre) implemented the chain for processing the first floats in January 2018. A specific processing chain has been implemented for the Deep float deployed in the Austral Ocean, taking into account the potential delay in data delivery occurring when float comes back to communication after an extended period under Ice (delayed profiles, no positioning under Ice, usual loss of data when float overpasses its storing capacity if under-Ice period exceeds several months).

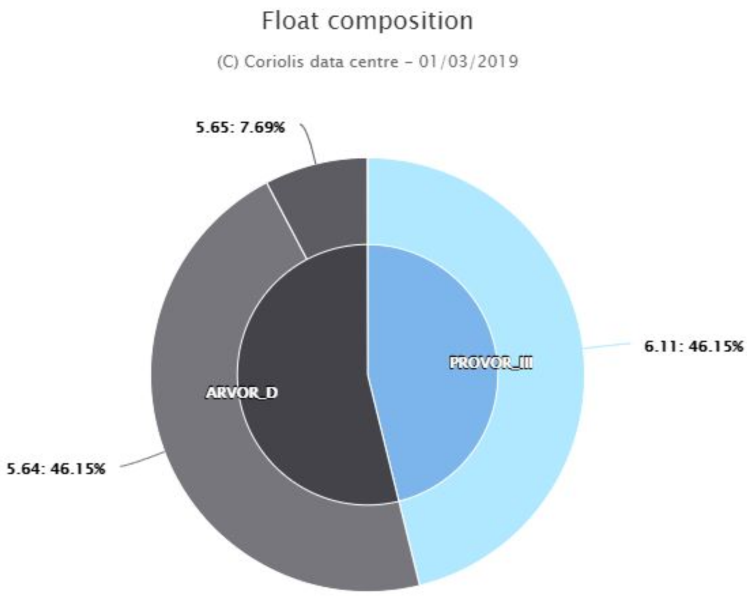


Figure 11. Float Composition of AtlantOS fleet, with decoding software reference.

Anomalies are detected according to the rules specified in the RT quality control documentation (see Figure 12) and corresponding flags are reported on an AtlantOS dedicated dashboard.

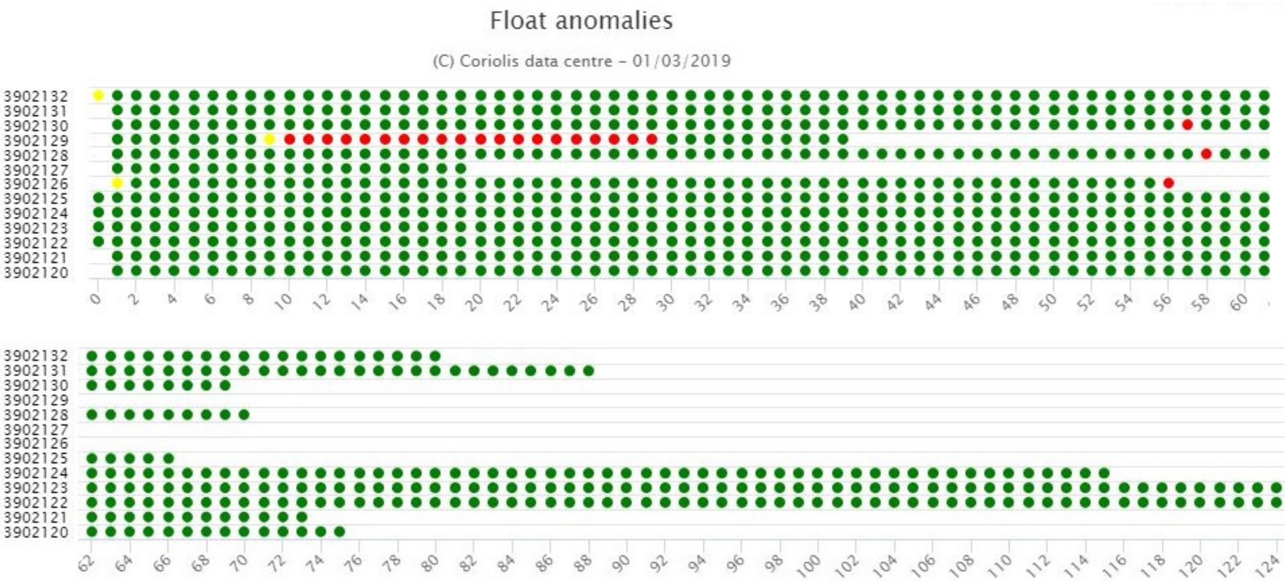


Figure 12. Anomalies automatically detected during RT quality control for Temperature and Salinity profiles

The Deep float deployed in the Austral Ocean (WMO # 3902129) RT processing shows 21 cycles with anomalies. This corresponds to the period this platform has been trapped under Ice; over the 21 cycles, 11 have been lost due to the available memory space on-board for data storing, and 10 profiles are tagged as bad due to the lack of positioning, but data are available for process studies. The bad positioning flag will be changed for floats measuring under-ice in the next months.

Anomalies on Deep floats with WMO # 3902128 and # 23902130 have one cycle each tagged as bad because of uncomplete cycles due to communication issues (loss of data during transmission). These data have been recovered from a backup system, and the flags will be modified correspondingly at the next metadata reprocessing.

Deep float with WMO # 3902126 transmitted its last profile on its 56th profile. This unique platform is lost at sea, probably because repeated grounding on the continental shelf when drifting towards Canarias island's shore during its drift phase. This occurred on several deep floats of the same type, and a corrective action on the float's software has been done by the manufacturer to better repositioning the float when grounded during drift.

After cycle 59, all active floats are working properly without any real-time anomalies detected.

4.2 BGC parameters

The RT processing of the BGC parameters was a challenging topic at the start of the AtlantOS project as the procedures were still under discussion at BGC-Argo International level. In 2015, although many BGC floats (more than 120) were deployed in the Global Ocean, their handling and data quality control was driven by institutions/laboratories having a strong interest in the scientific outcomes of such a network and the BCG Argo Data management system strategy was under discussion.

Within the AtlantOS project timeline, the official BGC-Argo program emerged (http://biogeochemical-argo.org/) and has been endorsed by the Global Argo Program, establishing a community assessed implementation plan (https://doi.org/10.13155/46601) including the definitions of RT and DM data stream for the data quality control of various sensors (http://dx.doi.org/10.25607/OBP-102).

At BGC Argo international, BGC-Argo RT procedures specifications are available and have been implemented at the European DAC level. Concerning the RT Quality Control procedures agreement have been reached for most of the EOVs as shown on Figure 13.

Parameters	Decoding	RT quality control specified	RT quality control implementation status
O_2	DOI 10.13155/39795	DOI 10.13155/46542	Implemented
NO_3	DOI 10.13155/46121	Drafted	Pending
pH	DOI 10.13155/57195	DOI 10.13155/57195	Implemented
Chl-a	DOI 10.13155/39468	DOI 10.13155/35385	Implemented
Bb_p	DOI 10.13155/39459	Drafted	Implemented
Irradiance	DOI 10.13155/51545	Drafted	Partially implemented

Figure 13. Status of DAC decoding and RT quality control for BGC data

RT quality control procedures specifications for Nitrates concentration and Radiometric data are in progress, they will be assessed and probably accepted during the next ADMT meetings in 2019, and finally implemented in the DACs by the end of year 2019.

The relevant information can be found on Argo Data Management Team Website (http://www.argodatamgt.org/Documentation) and on the dedicated pages on BGC-Argo website (http://biogeochemical-argo.org/data-management.php).

QC flag #	description	Meaning
0	Unqualified	No QC applied
1	Good data	All real time QC passed
2	Probably good	
3	Bad data but potentially correctable	Not to be used without scientific correction
4	Bad data	
5	Value changed	Value changed using a method described in the QC manual
8	Estimated/Interpolated value	Value changed using interpolation or extrapolation method
9	Missing value	Value lost in the transmission to shore

Figure 14. Description of Real Time QC flags in use at Argo Program Data Management level

4.2.1 Backscattering coefficient

Calibration issues have been identified for all backscattering meter so far deployed as part of the BGC-Argo international program (Poteau et al., 2017, doi: 10.1002/2017gl073949). New calibration files have been subsequently distributed by manufacturer (https://doi.org/10.17882/54520) and a reprocessing has been coordinated in 2018 by Coriolis and LOV in close cooperation with other DACs. Backscattering data provided by AtlantOS floats are quality controlled (range, spike, bias) and can be considered as of sufficient quality for operational and scientific purposes. In this context, recent discussions (December 2018) at the Argo Data Management Team level have considered that the quality of the backscattering should be reflected through transferring all data after a last visual inspection from the BBP700 parameter in R mode through BBP700_ADJUSTED in D mode without any specific adjustment. This should be soon reflected with the release of the appropriate documentation.

4.2.2 Chl-a concentration

The procedure recommended at the international level has been followed for the distribution of a real-time adjusted Chl-a, including the treatment and correction of the so-called Non-photochemical quenching bias that affects Chl-a when measured by a fluorometer sensor. Additionally, it has been shown (Roesler et al., 2017, DOI: 10.1002/lom3.10185) that the global fleet of fluorometers is on average overestimating the concentration of Chl-a by a factor of 2. As for backscattering coefficient a reprocessing of Chl-a has been coordinated in 2018 by Coriolis and LOV in close cooperation with other DACs. Chl-a data provided by AtlantOS floats are quality controlled (spike, range), adjusted and corrected of the quenching effect with a QC set to 5 in the area of quenching.

4.2.3 Dissolved Oxygen concentration

The floats deployed as part of AtlantOS represent an upgraded version of the technology that has integrated the new capabilities of referencing the measurements to air, thanks to the implementation of the oxygen optode sensor on a stick. The duration of data acquisition, close to two years, is now sufficient long to envisage adjustment for any sensor drift according to international recommendations.

4.2.4 Nitrate concentration

The consensus has not yet been reached internationally regarding the real time qc tests for the NITRATE concentration (mainly for saturated channels of the sensor and spikes), so the official documentation is still pending. Hopefully the NITRATE sensors of the AtlantOS floats are not affected by the saturation issue. The need for an adjustment at depth has been several times illustrated at the BGC-Workshop of the ADMT, so NITRATE concentration data of the AtlantOS floats have been adjusted according to a reference dataset (World Ocean Atlas). Note that, this real time adjustment is already in good agreement with a neural network-based method developed, as part of AlanttOS, thanks to GlODAP v2 to retrieve reference NITRATE profiles for any geolocation assuming that qualified P, T, S and O2 are available (Bittig et al., 2018, DOI: 10.3389/fmars.2018.00328). This method has been adopted by the community as the method of reference for further qualification of nitrate data in delayed mode. It will be implemented in 2019.

4.2.5 Radiometry

Radiometric data are presently not qualified in RT. Using reference dataset is not appropriate to qualify radiometric quantities which are highly dependent on cloudiness and biogenic water constituents. It has been proposed that the method of choice for this qualification should be based on a so-called "clear-sky model. The principle of this qualification has been accepted by the international community and data will be qualified once the appropriate document is released.

4.2.6 pH

As part of the AtlantOS project, a pH sensor was mounted on a float (6902879) to test the global workflow. All the procedures (decoding, calculation, QC) have been implemented in the Coriolis processing chains.

4.2.7 Statistics on RT QC of AtlantOS BGC floats

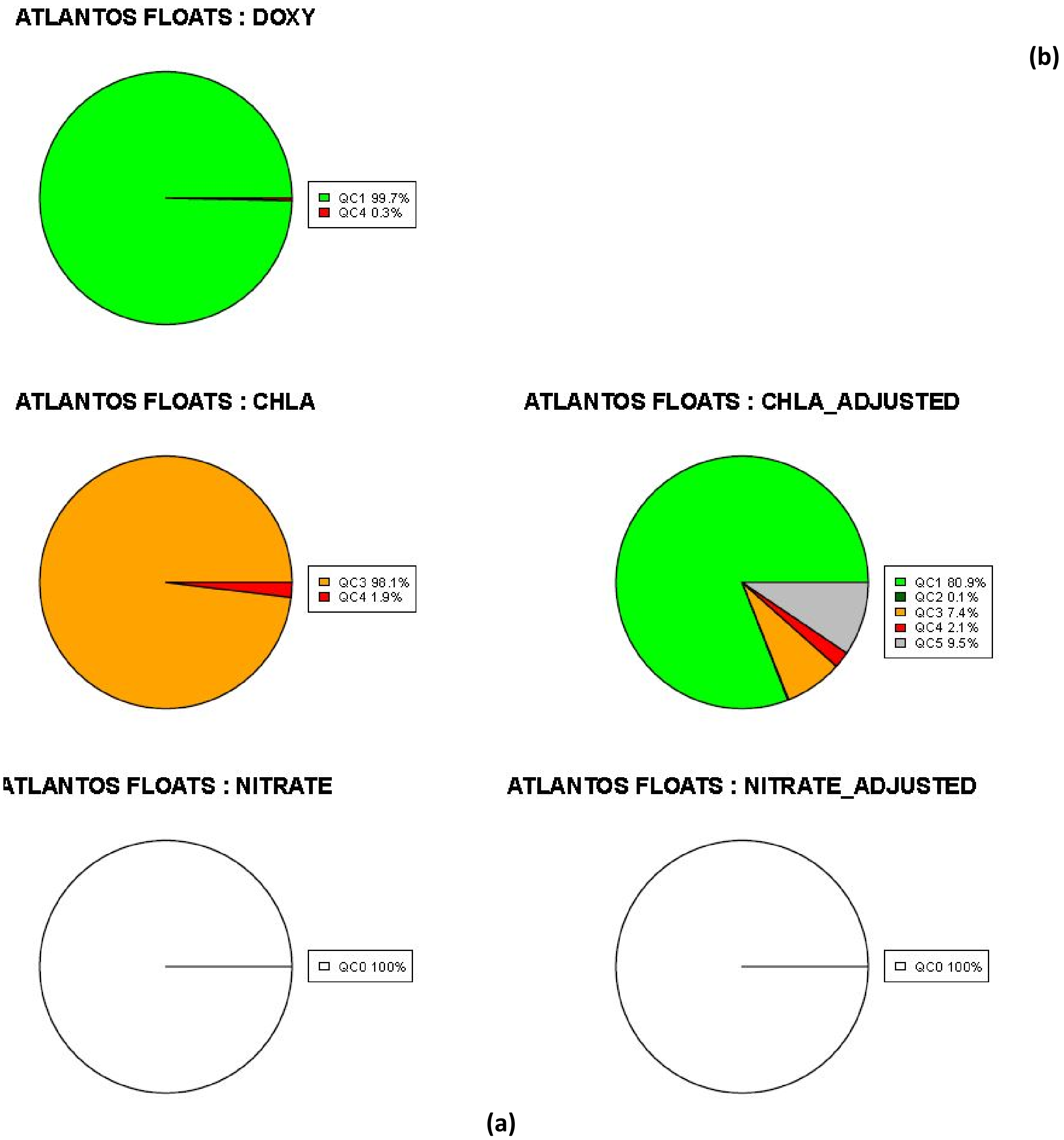


Figure 15. Assessment of the status of data qualification of Dissolved Oxygen, Chlorophyll-a and Nitrates for the 6 AtlantOS BGC-Argo floats in both Real-time (a) and adjusted mode (b). On each panel the variables are color-coded for each Quality Control Flag. The numbers express the % of data that have received a given quality flag with respect to all the data that have been acquired by the AtlantOS fleet so far.

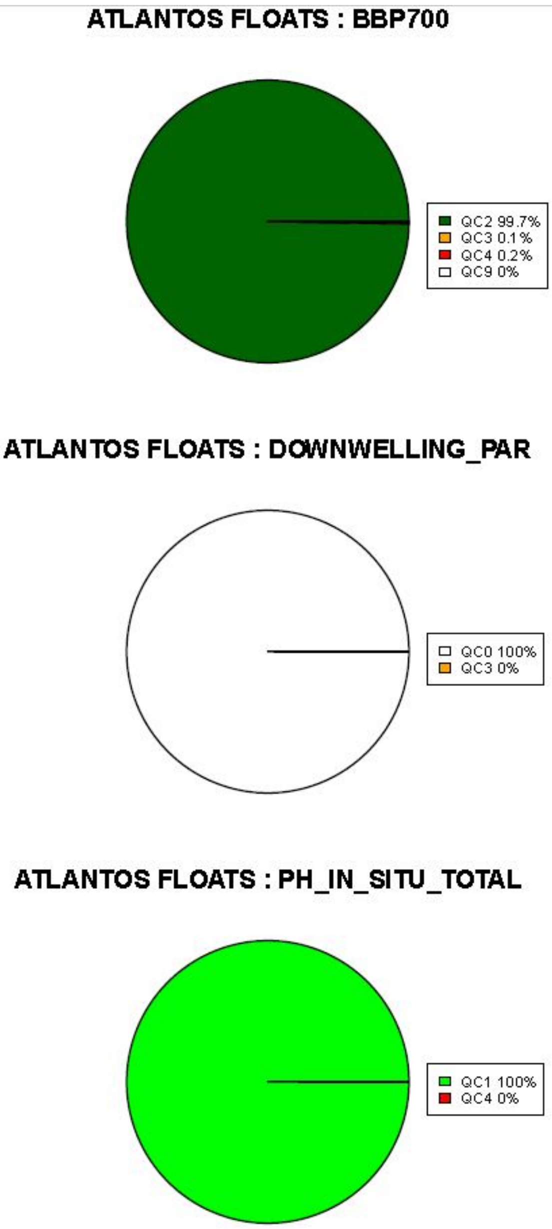


Figure 16. Assessment of the status of data qualification of the Backscattering coefficient, Radiometry and pH for the 6 AtlantOS BGC-Argo floats in both Real-time. The variables are color-coded for each float referenced by their Quality Control Flag. The numbers express the % of data that have received a given quality flag with respect to all the data that have been acquired by the AtlantOS fleet so far.

4.2.8 Processing delay from data acquisition time

All RT processing considered, the **median delay between a float observation and its availability on the GDAC since January 2019 is about 4.5 hours**, much less than the Argo objective of 24 hours (see Figure 17).

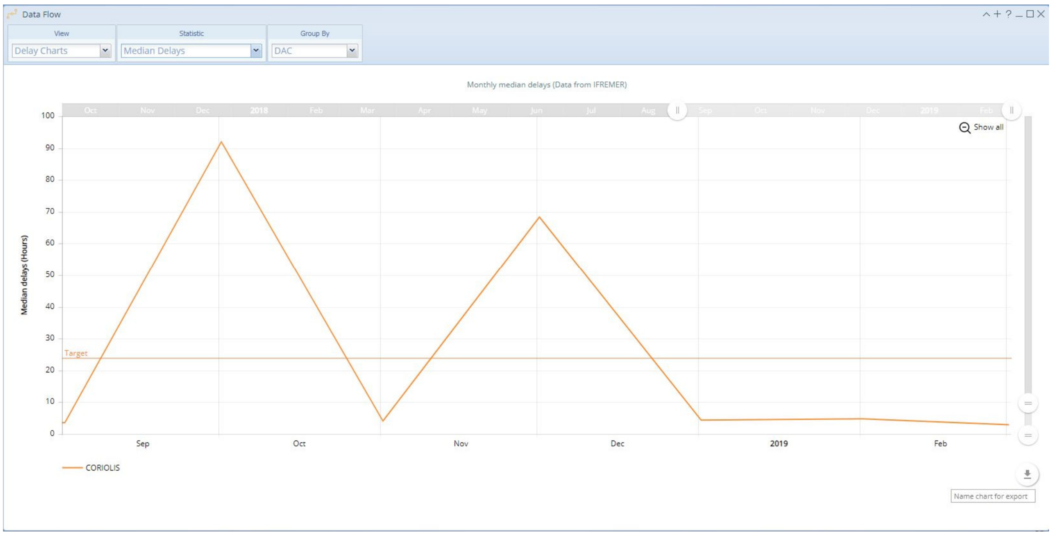


Figure 17. Median delays between AtlantOS floats observations and their availability on the GDAC. Variations represent the reprocessing timing

5 Delayed Mode quality control

A minimum of 1 year of data is needed before the delayed mode processing can be performed, for both Temperature/Salinity and BGC datasets.

5.1 Temperature and Salinity

5.1.1 Methodology

The DMQC of AtlantOS floats for Temperature and Salinity follows the guidelines provided by the Argo Data Management Team, and is documented in the following manuals:

- Argo user's manual V3.2 (http://dx.doi.org/10.13155/29825)
- Argo quality control manual for CTD and trajectory data, version 3.1 (http://dx.doi.org/10.13155/33951)

Each DM operator might use its own tools but by essence Argo data is corrected in delayed mode using agreed procedures. Nevertheless, a brief overview of the DMQC workflow is described hereafter.

5.1.2 DMQC workflow

RT processing is carried out by DACs (Data Assembly Centres). Procedures flag the gross errors in the data but some subtle errors may remain like sensor drift and or offset (Figure 18), float trajectory problems, etc. Elaborate procedures have been devised, based on statistical methods, and scientific expertise from principal investigators (PIs). The procedures are constantly assessed and updated as necessary. A minimum of 1 year of data is needed before the delayed mode processing can be performed.

The improvement of data quality from RT data to DMQC data is achieved by comparing Argo to other observations (climatology, altimetry, reference databases, deployment CTD, etc.) and viewing inspection by an operator. Pressure, temperature and salinity data are extensively analysed. Especially salinity data needs to be carefully examined since over time, the conductivity sensor can experience instrumental drift that gives salinity measurements an artificial trend. By using reference deep CTD data (Figure 19) and objective analysis, we can estimate what salinity should be at float locations.

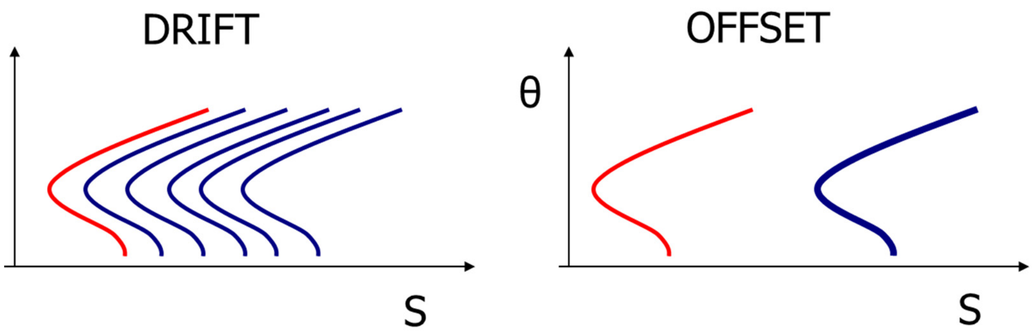


Figure 18: Example of drift or offset problems in the salinity time series.

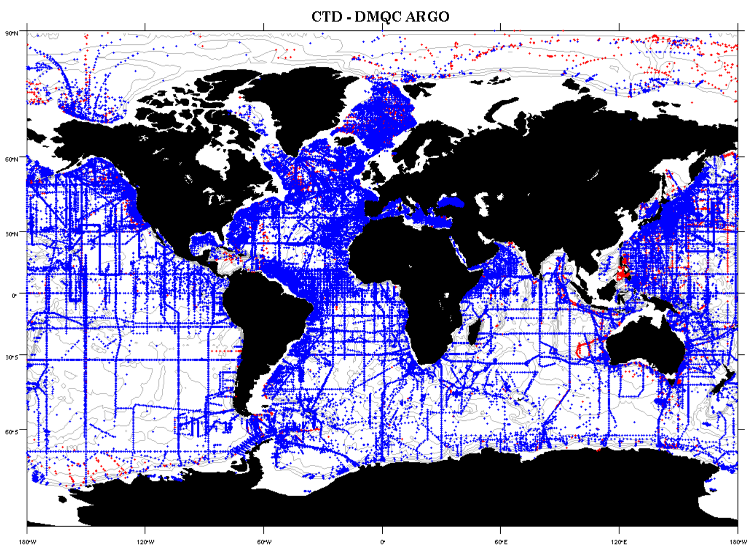
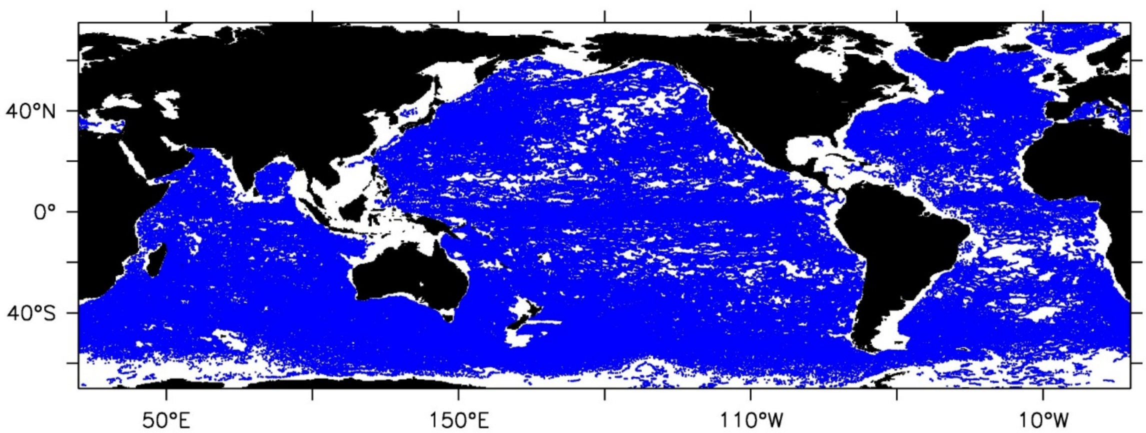


Figure 19: Recent high quality CTD database (left) and Argo good profile database (bottom).



A typical DMQC process includes:

- Look at the main float characteristics (cycle settings, mission number, etc.)

- Review of float trajectory, positions and dates, raw sections, raw theta/S diagrams
- Verification of RT QC flags
- Quality check on basic parameters (surface pressure, battery, etc.)
- Choice of reference CTDs and Argo profiles databases for comparison
- OW method configuration and runs
- Comparison with deployment CTD profile (if available)
- Comparison with the closest (in time and space) CTD reference profiles and good Argo float profiles (if available)
- Look at sections based on the adjusted data and respective theta/S diagrams (above all the most uniform part of the curve)
- Analysis and decisions by the DM operator: changing QC flags, applying correction or calibration to one or more parameters
- Production and submission of D files[1] and submission to the relevant DAC

5.1.3 Timeline

Recommendations from ADMT are to complete the **first DMQC not later than one year after float deployment**. Indeed, the operator needs to look at a significant number of measurements to detect potential drifts in the dataset.

Then it is encouraged to **revisit the DMQC every two years**. If potential drifts or problems were identified during the first DMQC then the revisit should take place sooner.

Feedback from **Objective Analysis** (statistical tests performed monthly at Coriolis) and **Altimetry Test** (performed by CLS) are also part of the Argo Quality Control Process**. In case of warnings issued for a float that has not been quality controlled already, it is highly recommended that the DM operator** in charge of the float performs a **first DMQC even if the float is recently deployed.**

5.2 BGC Variables

Within the AtlantOS project timeline, working groups within BGC-ARGO data team have been set up to elaborate for each BGC variable common procedures of the DM quality control.

As reported in the annual BGC-Argo data management meeting reports (http://www.argodatamgt.org/Data-Mgt-Team/Meetings-and-reports) scientific teams involved in those international groups are still as the level of comparing the different methodologies and defining strategy for BGC data DMQC .

5.2.1 Dissolved Oxygen

The most advanced procedure is regarding the Oxygen (https://doi.org/10.13155/46542) where different method of DMQC have been agreed:

- Adjustment against reference in situ profiles (climatological atlas or ship-based O_2 profiles) (Takeshita et al., 2013)
- Adjustment against in-air measurements (Bittig et al, 2015).

[1] Argo netCDF profile file that has been through the delayed-mode process. It replaces the real-time file (R).

The LOCODOX toolkit has been developed by IFREMER. It offers the opportunity to correct oxygen data from each of the agreed method. It works with Argo profiles in format 3.1 and produces delayed mode NetCDF files complying with Argo 3.1 format and following the BGC/DOXY QC manuals.

LOCODOX training

The adjustment against reference *in situ* profiles has been used to correct oxygen data acquired by 29 Argo floats deployed in the North-Atlantic Ocean since 2012.

The qualification procedure is done in different steps:

- Correct the real-time Quality Control flag (QC) in order to put a QC=4 (bad data) to the outliers and "hooks" at the base of the profiles (generally over the first 50m of the ascending profile)
- When necessary, add an additional pressure correction on DOXY in the form $DOXY_{corrpres}$=DOXY*(1+coef*PRES/1000);
- Apply the correction estimated by LOCODOX

The qualified dataset is available through the Argo data stream and the detail of the correction is provided in dedicated reports (https://doi.org/10.13155/58314). The table below list the WMO numbers that went through this careful delayed-mode process.

Float	Drift	Correction based on	Status	Cycles corrected	Pressure effect correction	Sending date to Coriolis
6901023	Yes, degree 1	DOXY	Inactive	1 to 212		22/11/18
6901027	Yes, degree 3	DOXY	Inactive	1 to 207		22/11/18
6901030	Yes, degree 1	DOXY	Inactive	1 to 202		22/11/18
6901593	Yes, degree 1	PSAT	Inactive	1 to 128	0.008	22/11/18
6901627	Yes, degree 2	DOXY	Inactive	1 to 126	0.003	22/11/18
6901631	No	PSAT	Inactive	1 to 32	0.003	22/11/18
6901632	Yes, degree 1	PSAT	Inactive	1 to 120	0.003	22/11/18
6901595	Yes, degree 1	PSAT	Inactive	1 to 22		22/11/18
6901602	Yes, degree 2	PSAT	Inactive	1 à 33	0.006	22/11/18
6901628	No	PSAT	Inactive	1 to 7		22/11/18
6901750	Yes, degree 1	PSAT	Active	1 to 120	0.004	22/11/18
6901751	No	DOXY	Active	1 to 103		22/11/18
6901752	Yes, degree 1	PSAT	Active	1 to 105		22/11/18
6901757	Yes, degree 1	PSAT	Inactive	1 to 129	0.01	22/11/18

Float	Drift	Correction based on	Status	Cycles corrected	Pressure effect correction	Sending date to Coriolis
6901758	Yes, degree 2	PSAT	Inactive	1 to 63	0.004	22/11/18
6901759	Yes, degree 1 and constant drift from d=60	PSAT	Inactive	1 to 10	0.005	22/11/18
6901457	No	PSAT	Inactive	1 to 64		22/11/18
6901753	No	PSAT	Active	1 to 66	0.004	22/11/18
6901754	No	DOXY	Active	1 to 66	0.006	22/11/18
6901755	No	PSAT	Inactive	1 to 34	0.003	22/11/18
6901762	Yes, degree 2	DOXY	Inactive	1 to 66	0.005	22/11/18
6901603	Yes, degree 3 and constant drift from day 40	PSAT	Inactive	1 to 12	0.004	22/11/18
6902686	No	PSAT	Active	1 to 43		22/11/18
6902805	No	PSAT	Active	1 to 44	0.002	22/11/18
6902807	Yes, degree1	PSAT	Active	1 to 43	0.004	22/11/18
6902808	No	PSAT	Active	1 to 43		22/11/18
6902810	No	PSAT	Inactive	1 to 10		22/11/18
6902811	Yes, degree 2	PSAT	Active	1 to 31	0.004	22/11/18
6902819	Yes, degree 1	PSAT	Active	1 to 47	0.009	22/11/18

While the adjustment against reference *in situ* profiles has been widely used and validated (see previous paragraph), the adjustment against in air measurements is only available since early March 2019. It has been tested on AtlantOS BGC and Deep-Arvor floats (See Figure 20 for float 3902127 for instance). While LOCODOX works well on Deep-Arvor floats, additional development needs to be done to cope with some specificities of the BGC floats. The results on the Deep-Arvor floats suggest a pressure effect that cannot be corrected based on the in-air measurements only. We thus wait for validated reference measurements acquired at float deployment to correct a possible pressure bias.

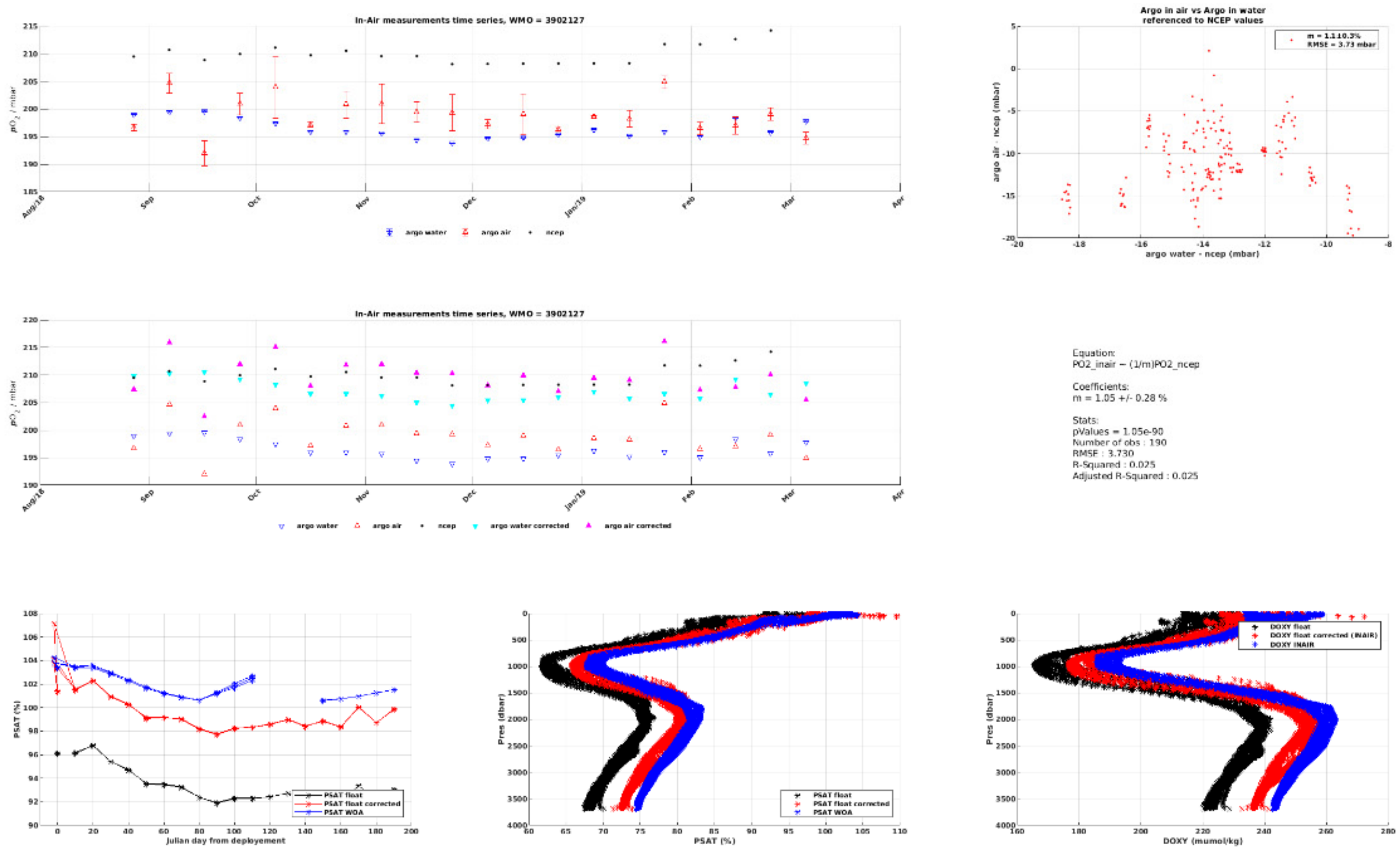


Figure 20: WMO 3902127 (Deep O2 float). Control plots provided by the LOCODOX software. (Upper left panels) Comparison between the atmospheric partial pressure of O_2 provided by NCEP (black dots) and that are measured by the float before correction (red dots) and after correction (magenta dots). (Lower left panel) Percentage of saturation in the surface water (between 10m and the surface) based on World Ocean Atlas (blue line), the raw O2 data from the float (black line) and the corrected data (red line). (Lower middle and right panels) Raw O_2 profiles from the float (black lines), corrected float profiles (red lines) and WOA data interpolated at the float position (blue lines). Float data are expressed in percentage of saturation (middle panel) or in µmol/kg (right panel).

Once validated, LOCODOX will be shared with the community. It is currently tested by NOC.

6 Tools for visualisation

6.1 Euro-Argo/Coriolis tool

Within the global Euro-Argo/Coriolis at-sea monitoring tool, a specific group has been set to follow the AtlantOS profiling floats at a glance.
Statistics and performance on the complete fleet are available, and each float might be controlled on dedicated pages for individual technical monitoring.
The tool is accessible at http://www.ifremer.fr/argoMonitoring/floatMonitoring/650. It provides access to data repositories, and an at-a-glance visualization of Temperature, Salinity, Dissolved Oxygen/Chlorophyll-a/Nitrates concentrations.

Work is on-going to also present the Radiometry, Backscattering and pH data.

Figure 21. Example of float webpage with metadata, trajectory and oceanographic profiles displayed.

6.2 BGC-Argo/OAO tool

In parallel to the Euro-Argo/Coriolis visualization system, all AtlantOS floats are also monitored on a specific BGC-Argo/OAO tool developed at LOV.
All BGC variables are represented, and basic technical parameters are scanned for at-sea monitoring for both Deep and BGC AtlantOS floats.
The tool is available at http://www.oao.obs-vlfr.fr/mapsg/en/

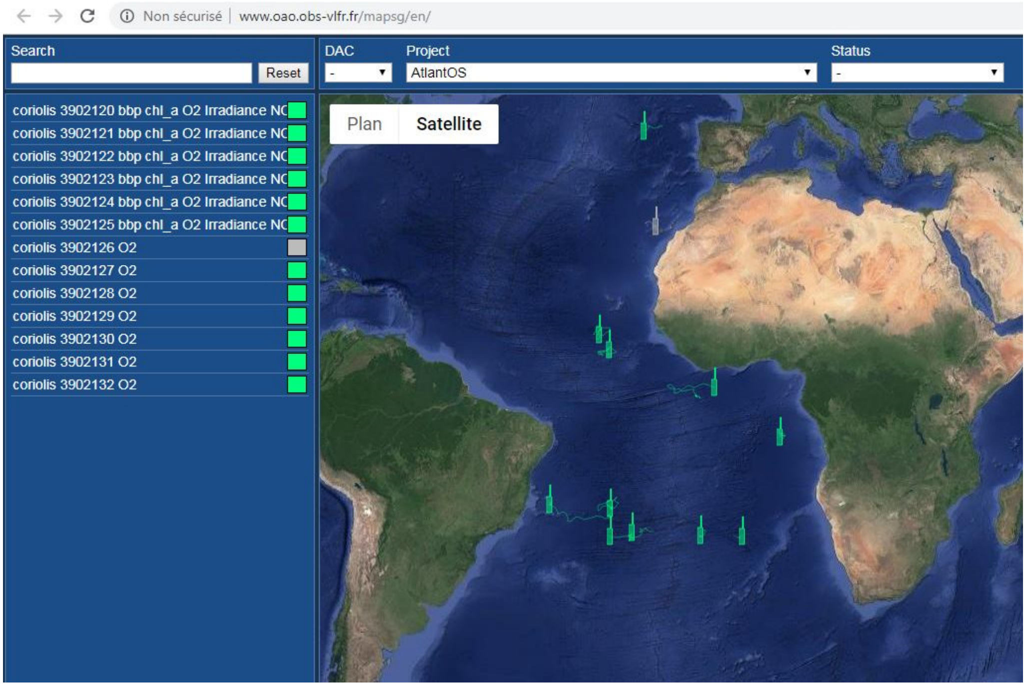


Figure 22. BGC-Argo/OAO representation of AtlantOS fleet.

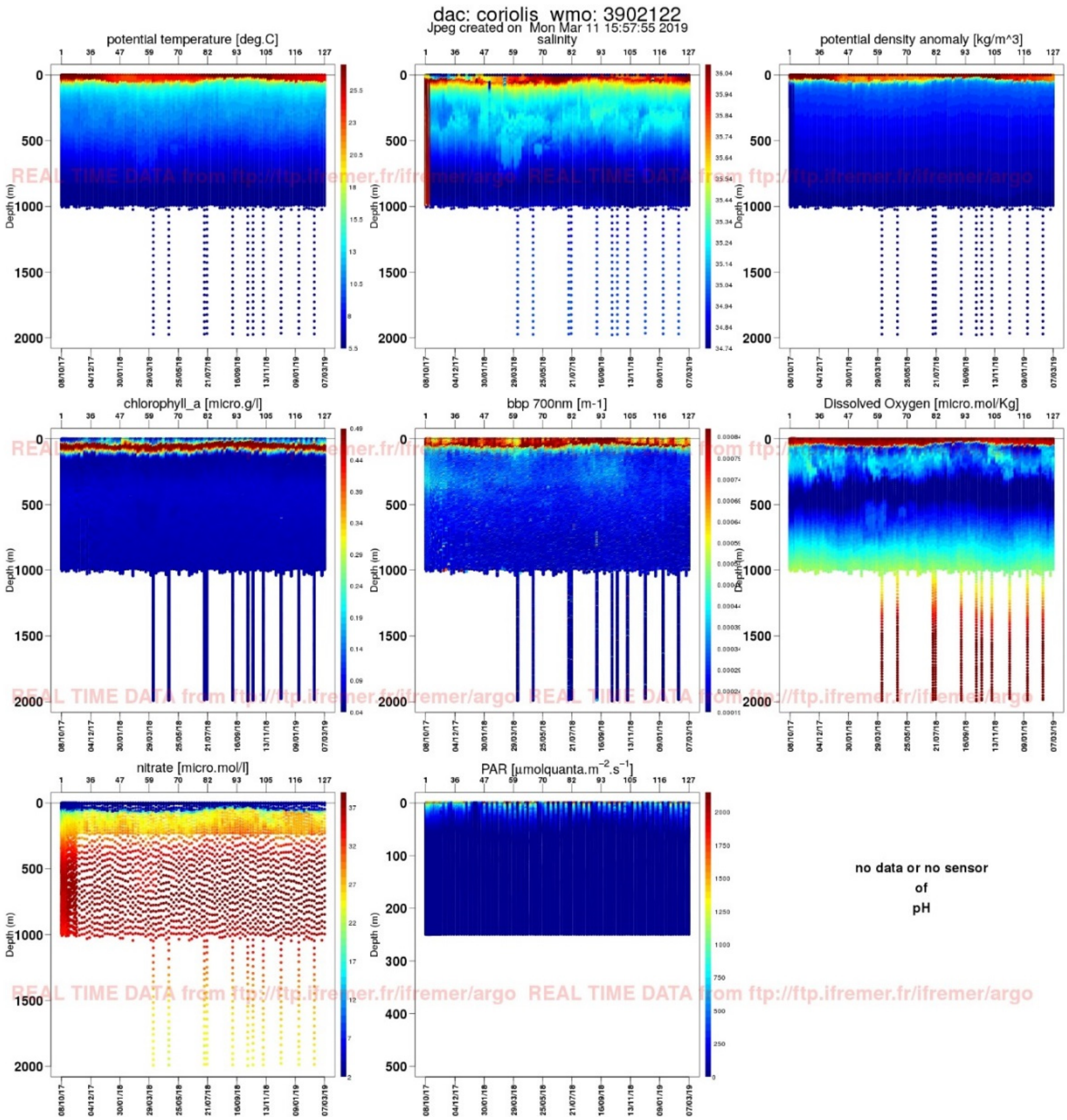


Figure 23. BGC float # 3902122 data time series representation at BGC-Argo/OAO tool

6.3 Seasiderendezvous.eu portal

6.3.1 Tool development and improvement

The *Seasiderendezvous* tool (http://www.seasiderendezvous.eu) has been continuously improved during the project. BGC-Argo floats measuring chlorophyll-a, Backscattering or Irradiance are now selected from the list (argo_bio-profile_index.txt), and are directly downloaded from the Coriolis GDAC FTP site (ftp://ftp.ifremer.fr/ifremer/argo).

Profiles of selected parameters (Chlorophyll-a, Chlorophyll-a Adjusted, Backscattering, Temperature, Salinity and Log(PAR)) are then locally stored to compare measured profiles (close to

30.000 profiles[2] are available, 530 of which have been acquired with AtlantOS floats) to the Ocean Colour derived information.

The Chlorophyll-a measured from the float is integrated over the first optical depth that gives a value which is directly comparable with the Chlorophyll-a 'surface concentration' seen and retrieved from the satellite. The optical depth is given by the inverse of the coefficient of diffuse attenuation of light (Kd), which itself is derived from the Chlorophyll-a estimates from space by using estimation in Morel et al., 2007. The preparation of matchups is done in a similar way for the Bb_p. The database used for Earth Observation derived information is GlobColour which is freely available and for which an estimate of uncertainties is attached to each product. GlobColour is containing multi-sensors products (for instance VIIRS+OLCI) as well as mono-sensor product. Comparison with other datasets is also possible from the seasiderendezvous interface.

The Bb_p is measured on the float at 700 nm. It has to be extrapolated to 443 nm to be compared to satellite products. This extrapolation is done by using the approach from Loisel et al. (2006)

$$bbp(\lambda) = bbp(\lambda_0) * (\frac{\lambda}{\lambda_0})^{-\gamma} \text{ with } \gamma = -2.5$$

6.3.2 Quality control dashboard

Information on the cross-correlation between successive profiles, noise (standard deviation and bias) and dark value are retrieved for each profile with some improvement in the data processing. Figure 24 shows an example for the AtlantOS float 3902123 trajectories; note that all profile locations are indicated with a green symbol which means that the QC was successful at Coriolis). Only one profile is represented by a red symbol, this profile has been flagged as 'probably bad' (i.e. average profile QC score is around 3).

Figure 25 illustrates the quality control dashboard for the same float. The red dot on all graphs (but the central one) indicates same acquisition time. A high level of noise at depth (left-middle) indicates that a problem occurred, which is confirmed by a very low correlation (graph in the middle-top) between consecutive profiles. This particular case corresponds to the profile flagged as bad in Figure 24 (see location of the red point on the float trajectory – left-top panel).

In this case there has been only one matchup during the period, so there was no computation of regression line (graph in the centre-middle).

[2] When considering floats providing either Chlorophyll and/or bbp measurements

Figure 24. Trajectory of AtlantOS float 3902123 through the seasiderendezvous interface

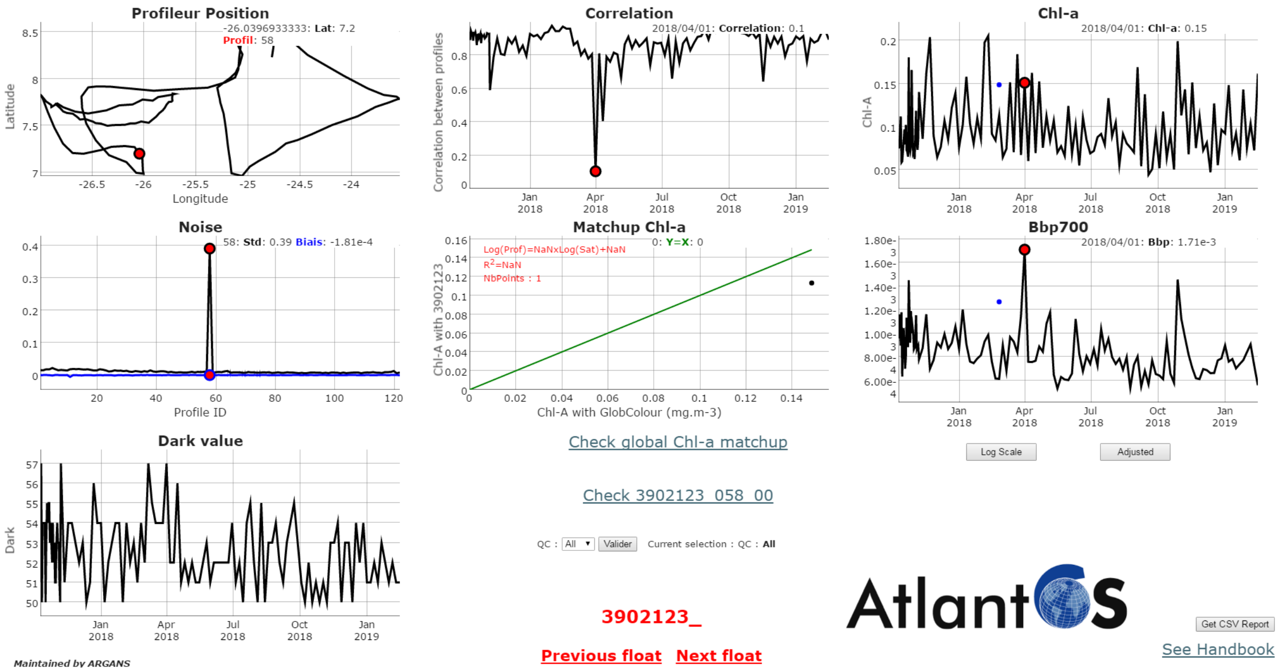


Figure 25. BGC float # 3902123 – control panel (dashboard)

6.3.3 Intercomparing AtlantOS floats surface observations and Ocean Colour

The analysis is focused on two parameters that are the surface concentration of Chlorophyll-a and the Bb_p coefficient. Initially the comparison was made with MODIS, but it is now well accepted that the quality of this sensor is continuously degraded. We have therefore used four different satellite data: OLCI-A (ESA), MODIS (NASA), VIIRS (NOAA) and a merging of the three. Results are presented in the following. A general statement is that, due to cloudy conditions, there are few matchups available for all floats (in final and in total only 66). Also we don't have significant differences by using the four different dataset.

By comparison it seems to be in line with analysis that are routinely done with OLCI in the frame of the OC TAC of the CMEMS (http://octac.acri.fr) where BGC Argo data is used to detect anomalies in satellite observations (see Figure 30). The Relative Percentage Difference (RPD) for the AtlantOS floats is here lower than 20% which can be considered as well acceptable for such comparison.

These plots also indicate that two floats (3902122 and 3902123) move away from the ideal regression (1:1). It should be noted that these two particular floats are located in the same region of the tropical Atlantic.

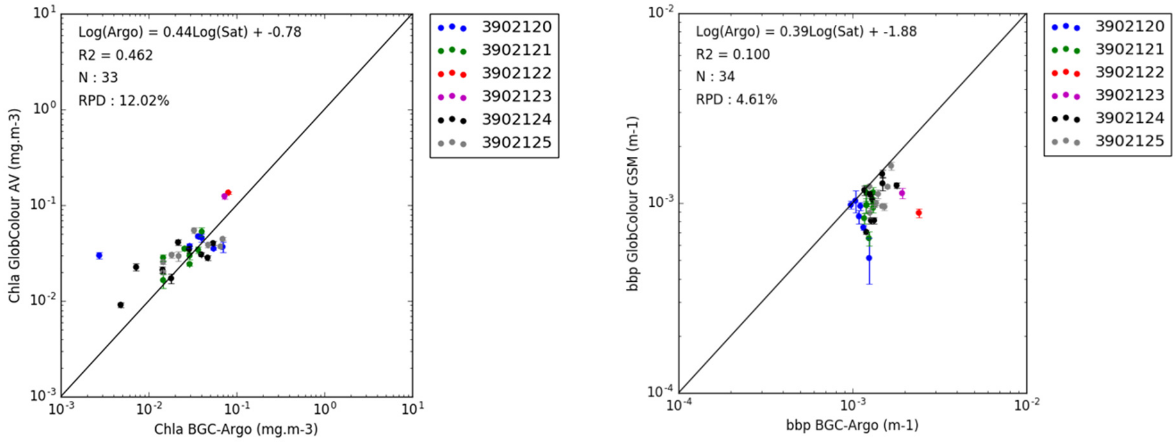


Figure 26. AtlantOS BGC floats : matchup with VIIRS for Chl-a (left) and bbp (right)

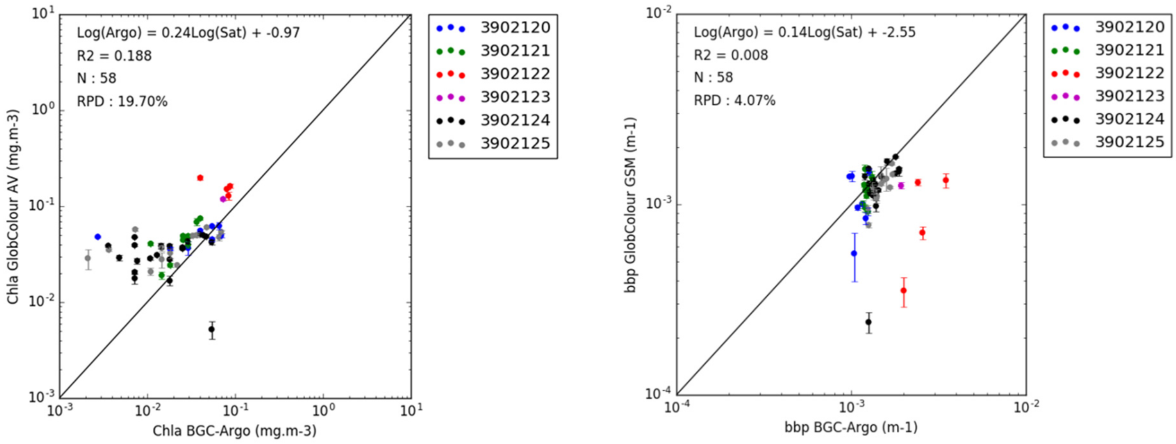


Figure 27. AtlantOS BGC floats : matchup with MODIS for Chl-a (left) and bbp (right)

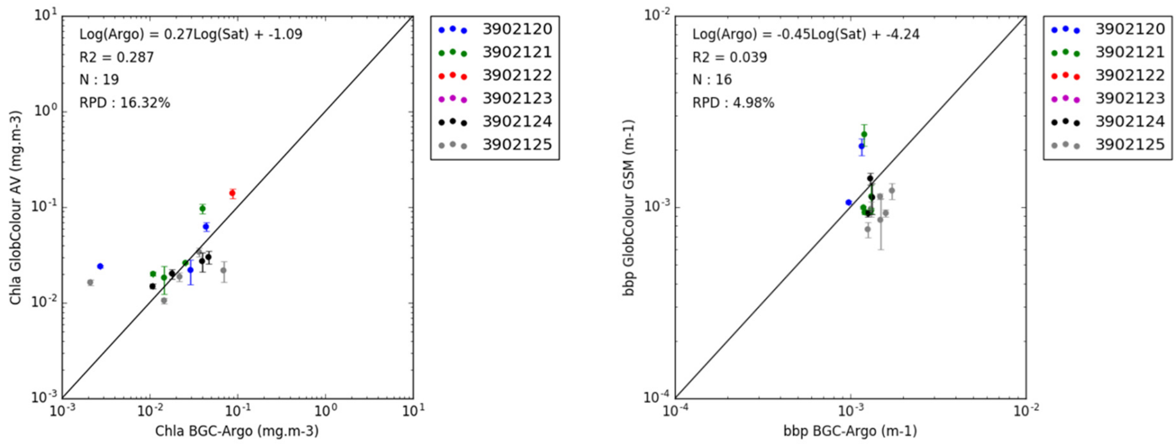


Figure 28. AtlantOS BGC floats : matchup with OLCI-A for Chl-a (left) and bbp (right)

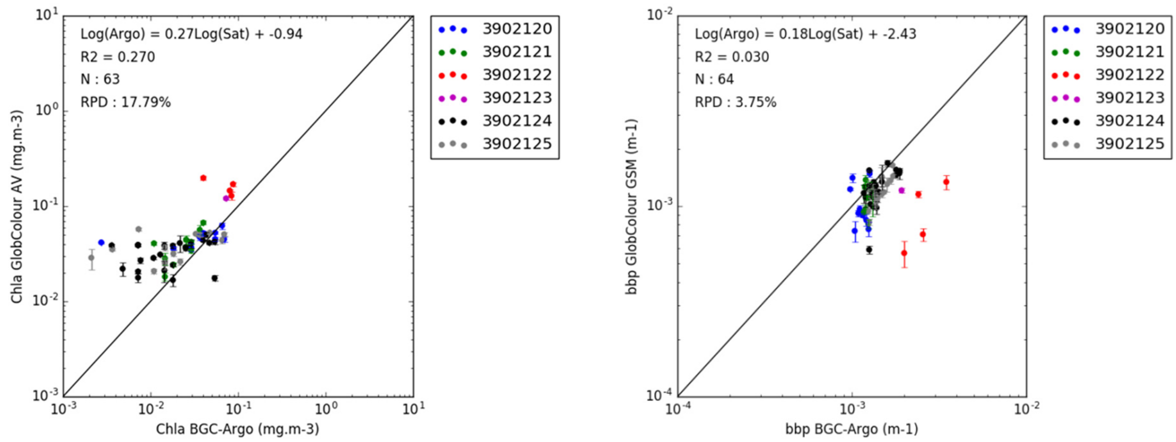


Figure 29. AtlantOS BGC floats : matchup with merging (MODIS+VIIRS+OLCI-A) for Chl-a (left) and Bb_p (right)

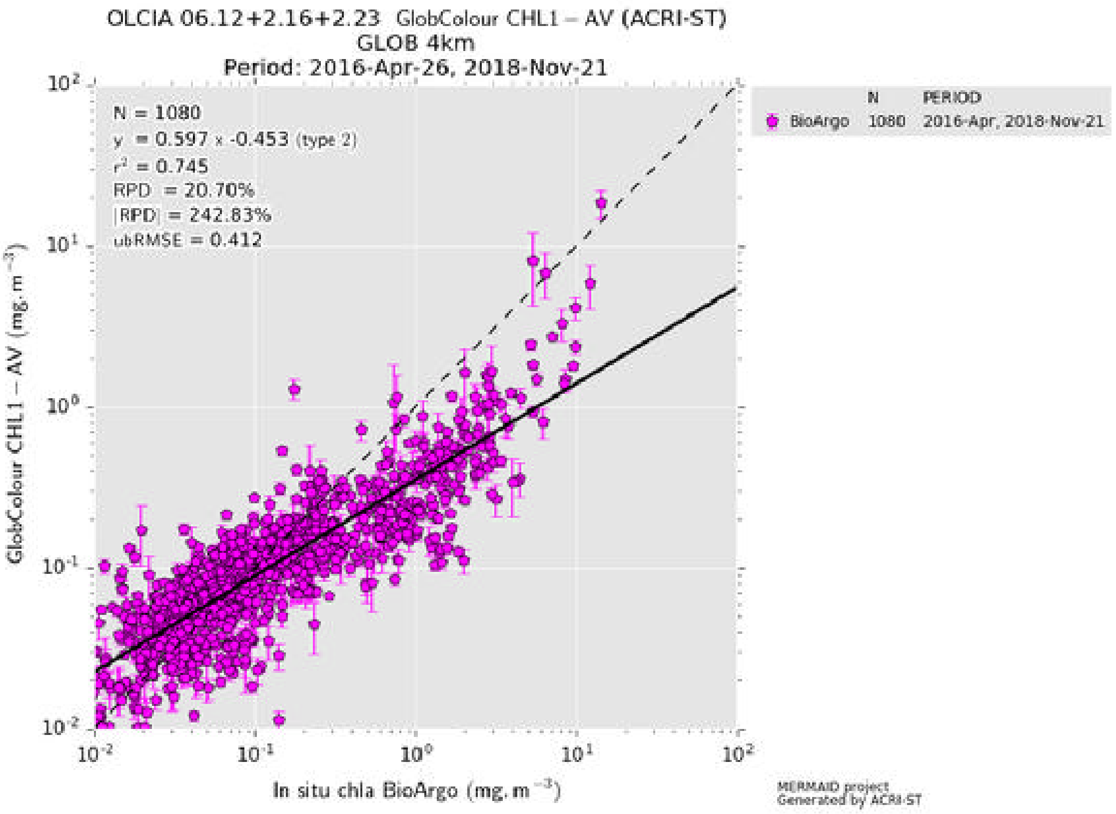


Figure 30. BGC Argo used for CMEMS QC of Chl-a – **BGC is generally larger than Ocean colour for concentration below 10-1 mg/m3**

6.3.4 Perspectives

Comparison of BGC floats measurements with Ocean Colour is always a delicate exercise in the sense that if there are discrepancies between the two sources, it can be due to one of the two, or two of the two. The perspective will be to use the Ocean Colour as "reference" and to clusterise the difference obtained with BGC-Argo. Then a consistency of the clusters with external contextual parameters will be examined. These parameters can be a common bioregion, similar latitude, similar type of waters, etc. If no correlation is found then one might suspect the floats themselves, if correlations are found and, this might also point towards problem of one of the two types of observation (depending on the parameter with which correlation has been found). This study could represent a step forward and open perspectives for the Delayed-Mode QC.

7 Reference documents

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8 List of acronyms

ADMT	Argo Data Management Team
ARC	Argo Regional Centre
AST	Argo Steering Team
BGC	Bio-geochemistry, Bio-geochemical
BODC	British Oceanographic Data Centre
CLS	Collecte Localisation Satellites
CORIOLIS	http://www.coriolis.eu
CTD	Conductivity Temperature Depth Sensor
DAC	Data Assembly Centre
DM	Delayed mode
DMQC	Delayed Mode quality control
DOXY	Dissolved Oxygen
EOV	Essential Ocean Variable
ESA	European Space Agency
FNMOC	Fleet Numerical Meteorology and Oceanography Center
GDAC	Global Data Assembly Centre
GTS	Global Transmission Services
IFREMER	Institut Français de Recherche pour l'Exploration de la Mer
IOC	Intergovernmental Oceanographic Commission
LOCODOX	http://biogeochemical-argo.org/cloud/document/meetings/admt/17/admt17-workshop-5-bgc-argo-d1_16_locodox_thierry.pdf
LOV	Laboratoire d'Oceanographie de Villefranche
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Prediction
NetCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
NRT	Near Real Time
OAO	Oceanographic Autonomous Observations
OC-TAC	Ocean Colour Thematic Assembly Centre
OLCI	Ocean and Land Colour Instrument
OW	Owens, W.B. and A.P.S. Wong, 2009. An improved calibration method for the drift of the conductivity sensor on autonomous CTD profiling floats by θ - S climatology. DeepSea Res. Part I, 56, 450-457. https://doi.org/10.1016/j.dsr.2008.09.008
PAR	Photosynthetically Available Radiation
PI	Principal Investigator
PML	Plymouth Marine Laboratory
QC	Quality Control
RPD	Relative Percentage Difference
RT	Real Time

RTQC	Real Time Quality Control
SCOOP3	Coriolis tool for DMQC
SHOM	Service Hydrographique et Oceanographique de la Marine
VIIRS	Visible Infrared Imaging Radiometer Suite
WMO	World Meteorological Organisation
WOA	World Ocean Atlas