Report on use of remote sensing to improve delayed mode quality control

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Executive Summary

Ocean colour data from Earth Observation (EO) by satellite can be useful for the BGC-Argo quality control in delayed mode (DM). Several methods and investigations have been carried out in the frame of Euro-Argo RISE to derive the best complementary use of BGC and Ocean Colour data for the qualification of Chlorophyll-a estimates from both sources. In the following, we describe the final methodology which should be put in place for the best use of remote sensing. In short, the work has been focused on how to build a sound comparison between the two sources of data and how to qualify the results of the comparison (knowing that both sources are potentially unperfect). Here the terminology "delayed mode" is related to the (re)processing of the BGC-argo which is then compared in a sound way to satellite, and "delayed mode" is not related to a specific (re)processing of the Ocean Colour products but more to a refined qualification of their quality.

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1 Introduction

BGC-Argo floats are useful instrument to document different parameters within the ocean water column. In synergy with satellite observations, they make feasible 3D observations of the ocean. This is notably the case for the chlorophyll concentration, which is an essential variable to monitor the health of the ocean. Indeed, the concentration in chlorophyll concentration give an overview on the phytoplankton health. This is an important parameter because phytoplankton is first level of the marine food web. Information on the chlorophyll concentration could therefore be used for sustainable aquaculture. In addition to aquaculture purposes, the chlorophyll concentration can be used to monitor the water quality. Elevated chlorophyll concentration can indicate eutrophication event due to inflow of nutrients. Conversely, low chlorophyll concentration indicates water contamination by pollutant, from industrial processes for example, making the marine environment inhospitable. Follow the evolution of the chlorophyll concentration is also important for studies on climate change. Indeed, thanks to the photosynthesis, the ocean is often considered as the second lung of our planet as phytoplankton uses inorganic carbon and emit oxygen toward the atmosphere. Among the amount of carbon hence uptake within the marine food-web and transformed in particulate organic carbon, a part will be exported toward the sediment and stored there for decades, or even centuries. However, due to the global warming, some uncertainties remain on the efficiencies of the biological carbon pump. This is partly due to rising temperature and the induced stratification of the ocean which may lead to a reduction of nutrient supply in the euphotic layer, where photosynthesis occurs.

Regular documentation of the chlorophyll concentration is therefore more than required. Satellite observations and BGC-Argo floats suit well with this objective as they make available data in different place of the global ocean, even where acquire in situ measurement is traditionally challenging. BGC-Argo present the advantage to document the water column, from the surface up to 2000 m. Also, as these data are accessible soon after their acquisition and as the BGC-Argo network is continuously expending, BGC-Argo data appear to be particularly adapted for data assimilation in model.

However, data assimilation required to pay particular attention to the data selection. The data used for the assimilation should be carefully selected in function of their quality. But how can we rely on autonomous platforms, deployed here and there for years, drifting with the currents, in salty and sometimes productive environments? To detect any potential sensor drift or anomaly, BGC-Argo data required a conscientious quality control. During the quality control processes (QC), general corrections are first applied in near real time (NRT-QC) and are then refined for the delayed mode (DM-QC). The delayed mode corrections are adapted to each float. Satellite observations can provide support to the BGC-Argo float DM-QC thanks to their synoptic view. Ocean colour data can be used during the QC processing itself in supplying information not directly measurable by the BGC-Argo float. Also, ocean colour data can be used for the qualification and the validation of BGC-Argo data, before and after QC procedures.

The present report aims to define the procedure which should be put in place for the best use of remote sensing in support of delayed mode quality control of BGC-Argo floats. This includes, but is not limited to the matchup strategy, the uncertainty estimated, the qualification of the BGC-Argo data and the generation of metrics to be used at GDAC level.

2 Matchup strategy – how to build a reliable matchup

Thanks to their large coverage, spatially as well as temporally, ocean colour data is very useful for validation purpose, and notably for the validation of chlorophyll estimates. However, for the comparison between in situ data and ocean colour observation, one should follow the specific procedure described below.

To consider a matchup (i.e. the spatio-temporal correspondence of EO and BGC-Argo products) as suitable for the QC, in situ measurements and satellite observation shall be observed the same day. From a spatial point of view, two approaches can be considered.

- One approach considers only the pixel collocated with the in situ measurement. If the pixel is valid (without any cloud, glint, etc…), the ocean colour data is compared with the *integrated*[1] BGC-Argo measurement.
- The second approach considers a macro-pixel, centred on the in situ measurement, with different sizes (3x3, 5x5, 7x7, etc…). A matchup is considered as valid and suitable for comparison with in situ data when at least 50% of the pixels within the macro-pixel are valid, and when the coefficient of variation is equal or below 15%. When such conditions are met, the median value of the macro-pixel data is compared with the *integrated* BGC-Argo measurement.

Also, one should consider that there are several chlorophyll *a* algorithms derived from ocean colour data. In this study, we consider the two main chlorophyll algorithms that are widely used at global scale; the GSM (Maritorena et al., 2002) and the OC5 algorithm (Gohin et al., 2002). The corresponding chlorophyll values are respectively noted CHL-GSM and CHL-OC5 in the following.

In order to define the best strategy to use to compare BGC-Argo chlorophyll data with satellite observations, the performance of the different macro-pixel size and chlorophyll algorithms have been analysed and are documented in the following.

2.1 Macro-pixel size

The largest number of matchups used for the validation is obtained with CHL-OC5 algorithm, with a number of matchups comprised between 7107 and 5801 among 10235 profiles available. As anticipated, the number of usable matchups is decreasing with the increasing macropixel size because of the increasing constraint induced by the matchup selection criterion. For the GSM, the number of matchups available for the validation is reduced by approximately 45% compared to CHL-OC5 algorithm (down to 2655 available pixels for the validation). The reduction of available pixels is directly explainable by the better spatial coverage of CHL-OC5 algorithm.

After several tests, it appears that the macropixel size does not significantly affect the validations, even if the number of pixels satisfying the matchup requirement decreases with the increasing macropixel size. Results from the analysis of the macropixel size appears to indicate that increasing the macropixel does not improve the validation results.

[1] The ocean colour information represents the upper layer of the ocean and is therefore, representative of optical properties within a marine layer whose depth is known as the "optical depth". To be comparable with ocean colour products, BGC-argo profile needs to be integrated over this optical depth. This vertical integration is described below.

Nevertheless, following the most commonly used strategy, a **macro-pixel size of 3x3** will stand as a step forward.

2.2 Vertical integration

To be comparable with satellite data, one should consider the vertical integration of surface values of the BGC-Argo profile to be comparable to the surface depth sensed by the optical sensors aboard satellite. There are several protocols often used to consider in situ profiles comparable with satellite observation. First, here is recalled what is seen by a satellite. This corresponds to the first optical depth Z_{opt} which is derived from the coefficient of diffuse attenuation (Kd), itself derived from the chlorophyll surface concentration (Morel et al., 2007):

$$Kd = 0.01660 + 0.077298 * CHL^{0.67155}$$

And

$$Z_{opt} = \frac{1}{Kd}$$

One of the easiest ways is to consider that any value between the surface and Zopt, or even 10 m depth, can be compared with satellite observations. Other methods require an integration over Z_{opt}, or an average over Z_{opt} (weighted or not).

For this exercise, four integration techniques have been considered (AVW: weighted average of the BGC samples over Z_{opt} ; AV:simple average of the BGC samples over Z_{opt} ; Int: Integrated value (by trapezoids) ; Surf: the first available value of the profil starting from surface down to -10m)

Results of the comparison between BGC-Argo data and satellite observations using these vertical integration techniques are summarized in the Table 1 below.

Table 1:Validation metrics of the BGC-Argo floats compared with two ocean colour algorithms (GSM and OC5).

Globcolour	GSM				OC5			
Method	**AVW**	**AV**	**Int**	**surf**	**AVW**	**AV**	**Int**	**surf**
N	912	912	912	910	1656	1656	1656	1652
slope	0.96	0.94	0.81	0.97	1.08	1.07	0.97	1.11
offset	0.09	0.04	0.11	0.15	0.10	0.06	0.17	0.17
R^2	0.74	0.74	0.61	0.66	0.68	0.69	0.54	0.65
RMSE	0.28	0.27	0.43	0.34	0.3	0.32	0.46	0.36

These results indicate that there is no significant difference between the definition of surface value, for the two tested chlorophyll algorithms (GSM and OC5). The coefficient of determination is included between 0.6 and 0.7 for the GSM algorithm, and between 0.5 and 0.7 of OC5. The lowest correlation between satellite and in situ measurements is observed for the chlorophyll concentration integration over the first optical depth. In addition to a low coefficient of correlation, this integration method is also characterised by the slope the furthest away from 1 compared to the other methods.

These results point out that the simple average of the chlorophyll profile over Z_{opt} is a good approach. **This approach is the one selected for the QC Delayed Mode with Ocean Colour.**

2.3 Chlorophyll algorithm selection

As explained earlier, several algorithms are available, from the GlobColour dataset (https://hermes.acri.fr/) for the Chlorophyll estimation. We have selected OC5 and GSM algorithms that are the most common and applicable, in principle, to a large range of water types. Disposing of several algorithms is also a chance for the quality control of BGC-Argo data as it could reinforce or weaken the assessment of the BGC product quality.

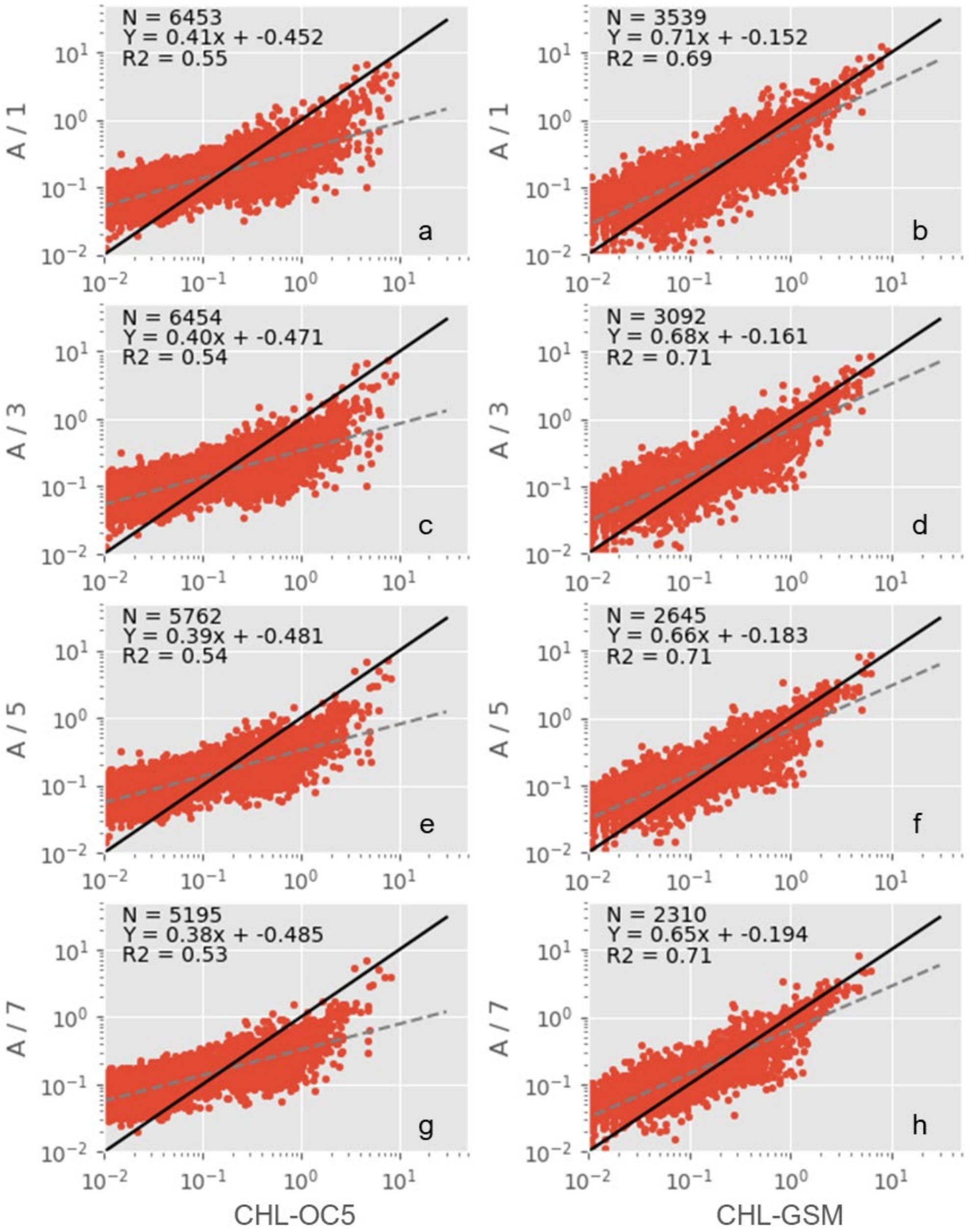

Figure 1:BGC-Argo validation plots in function of the macro-pixel size and satellite algorithm

The best correlation between satellite observations and in situ measurements is noticeable with the GSM algorithm, whatever the macro-pixel size. Indeed, the coefficient of determination is about 0.5 with the OC5 algorithm while it is around 0.7 with the GSM algorithm. In addition to the correlation, the slope is closer than 1 for GSM than OC5 (Figure 1).

For both algorithms, BGC-Argo floats appear to overestimate low chlorophyll concentrations. For concentration above 0.5 mg.m^{-3}, GSM and BGC-Argo data seem to be in line, while BGC-Argo data appears to be underestimated compared with OC5 observations.

Despite its greater discrepancy with BGC-Argo floats, the OC5 algorithm presents a number of valid matchups twice as high as the GSM algorithm. The coverage of the OC5 algorithm is improved thanks to a revision of the flagging strategy (Garnesson et al., 2019).

It is therefore not easy to argue against one algorithm or the other, but these results underline the advantage to use both algorithms to support the BGC-Argo DM-QC.

The strategy for Euro-Argo RISE project is therefore to use both algorithms

2.4 BGC-Argo products in Delayed Mode

The DM-QC procedure concerns mainly 3 points: the dark correction before the conversion of the electronical count to fluorescence signal, the quenching correction, and the correction of the slope (calibration curve from the manufacturer, allowing to pass from fluorescence to Chl- *a* concentration). Further details on DMQC procedure for Chl*a* can be found in the related deliverable (D4.2).

Three datasets were available for the evaluation (seeTable 2) : the dataset A which is the outcome of the QC in real time, the dataset C which proposes a correction for the dark offset and for the quenching and the dataset D which proposes in addition an estimate of the slope based on radiometry measurements. It is important to note that :

1. Only floats equiped with relevant measurement of radiometry could initially be used for such slope correction
2. AI methods are being deployed in the project to rebuilt the radiometry data from other parameters and then to be able to compute this slope correction with such artificial radiometry.

At the time of this report, the second step above is still prototypal so the dataset C has been mainly used to derive the methodology (which remain fully applicable once the dataset D will be become available).

These datasets and corresponding QC steps are summarized in the Table 2.

Table 2 Quality control steps applied to BGC-Argo profiles for the three datasets

Dataset	« A » Adjusted in real time	« C » Partial delayed mode	« D » Full delayed mode
Dark correction	Basic	Advanced	Same as « C »
Quenching	Xing et al. 2012	Terrats et al. 2020	Same as « C »
Slope	0.5 applied	0.5 to apply	Xing et al. 2011

As a first gain, the passage from NRT-QC (dataset A) to DM-QC (dataset D) makes more profiles available for matchup. For both chlorophyll algorithms (OC5 and GSM), the number of available matchups is increased by 10% (Figure 2).

Then, the corrections applied to BGC-Argo floats with the DM-QC procedures lead to improve their correlation with satellite observations. After the corrections, there is a better fit with satellite observations, especially for low chlorophyll concentrations. Indeed, BGC-Argo surface concentrations appear to be less over-estimated than the "A" profiles, compared to satellite observations. In addition, the slope of correlation is getting closer to 1, from 0.4 to 0.6 for OC5 and from 0.7 to 0.9 for GSM (Figure 2). The coefficient of determination is also improved after the DM-QC (from 0.5 to 0.6 for OS5, and from 0.7 to 0.8 for GSM).

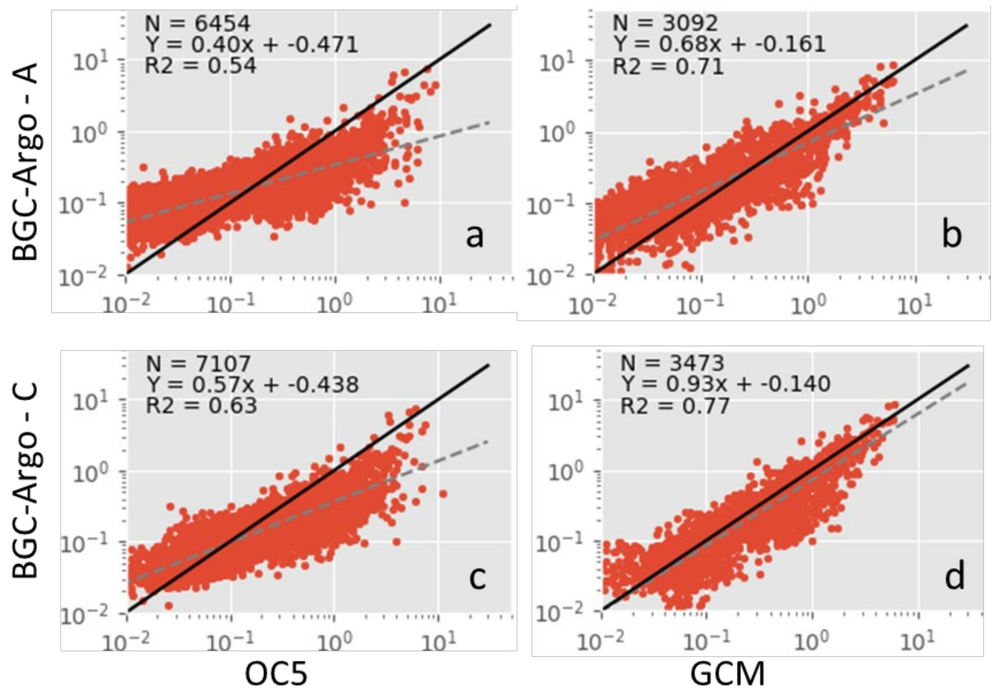

Figure 2:Validation plots of the BGC-Argo floats as a function of the QC procedures and the satellite algorithm, for a macro-pixel size of 3x3

3 Global estimation of the products uncertainty

While comparing two datasets, one key aspect is to be able to use an estimate of the natural uncertainty of each dataset in order to assess if the discrepancy between the two dataset lies into explainable or suspect variability. Indeed, when BGC-Argo chlorophyll data are compared with satellite observations (or any other source of chlorophyll data), the latter data are often (and wrongly) considered as a golden value. It is therefore required to estimate this error without considering any measurement as the truth. This can be achieved thanks to the triple collocation method which is based on the covariance of three independent sources of data.

It is to be underlined (even if obvious) that the resulting estimates of uncertainty depends on the choice of dataset used as input. Here, as an illustration, we use the dataset C for BGC-Argo and OC5 algorithm for the satellite. In case the dataset D is used and/or some adjustements are brought to ocean colour data, then the whole computation below will have to be updated.

3.1 Triple collocation method

The three sources of data required by the triple collocation technique shall be spatially colocalized and temporally coincident. They also have to be fully independent (non-correlated). In this approach, we consider as sources of chlorophyll: satellite observations (GlobColour, OC5 algorithm), BGC-Argo floats measurements (dataset C) and BGC modelling output (from CMEMS products and without assimilation to preserve the independence of each dataset, GLOBAL_REANALYSIS_BIO_001_029).

Outliers have to be removed before using the triple collocation method. The analysis of the BGC-Argo dataset reveals some chlorophyll concentrations below 10^{-3} mg.m^{-3} and even down to 8.10^{-4} mg.m^{-3}. These minimal values encountered in the BGC-Argo floats dataset might be explained by the computation of the chlorophyll-α. With regard to the float sensor accuracy, chlorophyll concentrations below 2.10^{-3} mg.m^{-3} are considered as suspect values and are removed from the dataset.

Still, to eliminate potential outliers, the data out of the range between the 1st quartile and the 3rd quartile, are discarded from the dataset (Tukey, 1977).

Note that the triple collocation method requires at least 500 triplets (Zwieback et al., 2012). After the data selection, in case the number of available triplets is not sufficient, data are bootstrapped in order to simulate additional data.

The triple collocation equations used for the RMSE are based on variance (σ_x^2) and covariance ($\sigma_{x,y}$) and are defined as follow for satellite observations:

$$\sigma_{\varepsilon,sat} = \sqrt{\sigma_{sat}^2 - \frac{\sigma_{sat,model} * \sigma_{sat,argo}}{\sigma_{model,argo}}}$$

Thanks to the use of three independent datasets, the results of this triple colocation are an estimate of uncertainty attached to each of the three inputs independently.

3.2 Estimation of the error for the global scale

In the following, BGC-Argo chlorophyll data collected from the Coriolis GDAC (ftp://ftp.ifremer.fr/ifremer/argo) are compared to the chlorophyll concentration estimated from NEMO-PISCES coupled model outputs and the remote sensed chlorophyll concentration with OC5 algorithm to maximize the number of matchups. The in situ data were acquired between the end of March 2008 and end of June 2020. This dataset is composed of 12651 matchups spread in all the oceans with an important proportion of these matchups located in the polar ocean (Figure 3). Despite the high number of matchups, some gaps remain in the Indian South subtropical gyre and the North west Pacific.

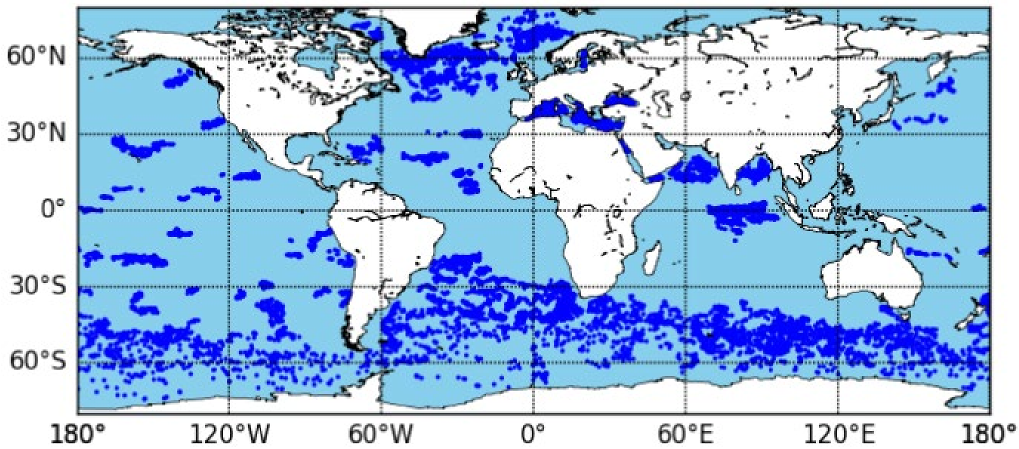

Figure 3: Location of the BGC-Argo profiles used for the triple colocation

At a global scale, chlorophyll concentration average is relatively constant for the three sources of data, with a concentration between 0.18 and 0.20 mg.m^{-3} (Table 3). At this scale, the highest error is estimated for model outputs, with a RMSE of 0.1 mg.m^{-3} and the lowest corresponds to BGC-Argo (0.07 mg.m^{-3}). Compared to the chlorophyll concentration average of each data set, the error estimated by the triple collocation represents 52, 45 and 36 % of the chlorophyll average for modelling, satellite and BGC-Argo data, respectively. This difference in terms of uncertainties for the three sources of data considered here can be explained by the spatial resolution. Indeed, modelling data are extracted with a spatial resolution of 0.25°. If this resolution is not limiting in open ocean, this low resolution can have its importance in dynamic environments, such as coastal regions.

3.3 Estimation of the error at biome scale

Thanks to the large number of matchups available on the period considered, triple collocation can be applied on the triplets located in the four classical biomes usually considered (Longhurst et al., 1995; coastal, polar, trade winds, and westerlies). Therefore, the dataset is split in four subsets and triple collocation is applied to each of them. The lowest number of triplets is found for the coastal region, with 435 available matchups. Therefore, bootstrapping was only applied to this last biome, to artificially increase the number of triplets available. The bootstrapping was applied 1000 times to ensure there is no impact of this step on the RMSE estimate.

The highest uncertainties for model data are observed in polar and coastal environments, with uncertainties between 0.24 and 0.14 $mg.m^{-3}$ (or uncertainties of 55 and 61%, respectively, Table 3). On average, polar region is the biome with a relatively high error. Indeed, for this biome, the error exceeds 50% for the three sources of data. The relatively high error observed for satellite data can be caused by the presence of sea ice, intense winds and the presence of waves with whitecaps, or rich waters in coloured dissolved organic matter (Bélanger et al. 2007, Kahru et al., 2016).

Lowest uncertainties for satellite and model outputs are observed in the biome of the trade winds (0.03 $mg.m^{-3}$ for satellite and for model data). Chlorophyll concentration measured by BGC-Argo in the trade wind biomes is also affected by an error of 0.03 $mg.m^{-3}$ and represents the highest relative error for this source of data. In this biome, where the lowest chlorophyll concentrations are assessed, the relatively high uncertainties for BGC-Argo can be explained by the error induced by the dark correction which is applied to fluorescence profiles (Xing et al., 2018).

The highest chlorophyll concentration is observed in the coastal biome for satellite and BGC-Argo data (0.57 and 0.48 $mg.m^{-3}$, respectively), and in the polar region for model outputs (0.40 $mg.m^{-3}$). This might be explained by the low resolution of model in coastal region. The chlorophyll concentration averaged on the pixel model can encompass data nearshore and offshore (up to 25 km offshore), which can be characterised by a substantially different environment. The relatively high error for model data can also be explained by local events such as riverine outflows, potentially poorly constrained by the model.

Table 3: Validation metrics and triple collocation results for the global ocean and in function of the Longhurst biomes

Source	N	median	mean	stdev	RMSE
	Global ocean				
Sat-OC5	**12651**	**0.153**	**0.176**	**0.097**	**0.080**
BGC-Argo	**12651**	**0.132**	**0.188**	**0.169**	**0.067**
Model	**12651**	**0.141**	**0.197**	**0.131**	**0.103**
	Coastal				
Sat-OC5	**435**	**0.497**	**0.566**	**0.206**	**0.214**
BGC-Argo	**435**	**0.450**	**0.481**	**0.212**	**0.217**
Model	**435**	**0.274**	**0.262**	**0.142**	**0.143**
	Polar				
Sat-OC5	**1938**	**0.220**	**0.278**	**0.168**	**0.164**
BGC-Argo	**1938**	**0.298**	**0.386**	**0.302**	**0.197**
Model	**1938**	**0.335**	**0.401**	**0.245**	**0.244**
	Trade winds				
Sat-OC5	**3488**	**0.082**	**0.092**	**0.047**	**0.029**
BGC-Argo	**3488**	**0.035**	**0.046**	**0.037**	**0.027**
Model	**3488**	**0.084**	**0.091**	**0.035**	**0.029**
	Westerlies				
Sat-OC5	**6896**	**0.125**	**0.139**	**0.077**	**0.057**
BGC-Argo	**6896**	**0.083**	**0.137**	**0.137**	**0.060**
Model	**6896**	**0.099**	**0.161**	**0.116**	**0.079**

4 QC procedure and recommended operations

4.1 Use of the error estimate within the QC procedure

The estimation of the error built by using the triple collocation is now used to perform quality control on the new DM BGC-Argo dataset.

When comparing BGC-Argo and Ocean Colour datasets; since these two datasets are independent; the global uncertainty σ_{tot} is simply given by

$$\sigma_{tot} = \sqrt{\sigma_{sat}^2 + \sigma_{bgc}^2}$$

So when doing the comparison between the two datasets, suspicious situations will be identified when the absolute difference between the two products exceeds N.σ_{tot} , in which N is a threshold to be specified (3 or 4 are usual numbers when looking at exceptions with statistical normal distribution).

The difference between BGC and Ocean Colour has to be built from the linear regression in order to remove slope and bias effects.

Hence,the first step is to estimate the correlation between BGC-Argo and satellite data and estimate the usual validation metrics, and especially the slope (S) of the type 2 regression (or orthogonal regression) as well as the intercept (I):

$$S = \frac{\sum_{i=1}^{N}\left(X_i^E - \overline{X}^E\right)^2 - \sum_{i=1}^{N}\left(X_i^M - \overline{X}^M\right)^2 + \left[\left\{\sum_{i=1}^{N}\left(X_i^E - \overline{X}^E\right)^2 - \sum_{i=1}^{N}\left(X_i^M - \overline{X}^M\right)^2\right\}^2 + 4\left\{\sum_{i=k}^{N}\left(X_k^E - \overline{X}^E\right)\left(X_k^M - \overline{X}^M\right)\right\}^2\right]^{1/2}}{2\sum_{i=k}^{N}\left(X_k^E - \overline{X}^E\right)\left(X_k^M - \overline{X}^M\right)}$$

And

$$I = \overline{X}^E - S \cdot \overline{X}^M$$

Where the *M* exponent indicates in situ chlorophyll measurements, and the *E* exponent indicates chlorophyll estimates from ocean colour.

Here, the orthogonal regression is preferred to the usual type-1 regression because the type-2 regression considers error on both X and Y-axis by minimizing the perpendicular distance between independent variables.

The resulting linear regression law is applied to BGC-Argo data. This allows to put satellite and BGC-Argo data in a same dimension space. Then, these synthetic satellite data are compared to the original ones. A data is considered as good when the difference between the original data and synthetic value is lower than the error estimated with the triple collocation (σ_{tot}). When the difference between both datasets is higher than N times the error (N.σ_{tot}), one can considered this value as suspicious.

However, in case of large difference, one can suspect either the BGC-Argo data or satellite observations as source of deviation. To verify this information, the exercise of comparison is performed with the two different ocean colour algorithms (this was a justification to keep both for the analysis). In case a data is considered as suspicious with both GSM and OC5 algorithms, one can flag this value.

The difference between satellite and BGC-Argo data was plotted on a map, as this could be helpful to identify any regional trend. As an example, one can observe a deviation in the Southern ocean. In this case, the deviations can be attributable to environmental conditions (Figure 4).

The BGC-Argo data was controlled with this technique, before and after the DM-QC procedures (i.e. with dataset A and dataset C) and with N equal to 3. This analysis highlights the improvement of the comparison between BGC-Argo measurement and satellite observation. First, because the number of matchups is increased, then because there is less matchups rejected by the 3σ threshold (Table 4).

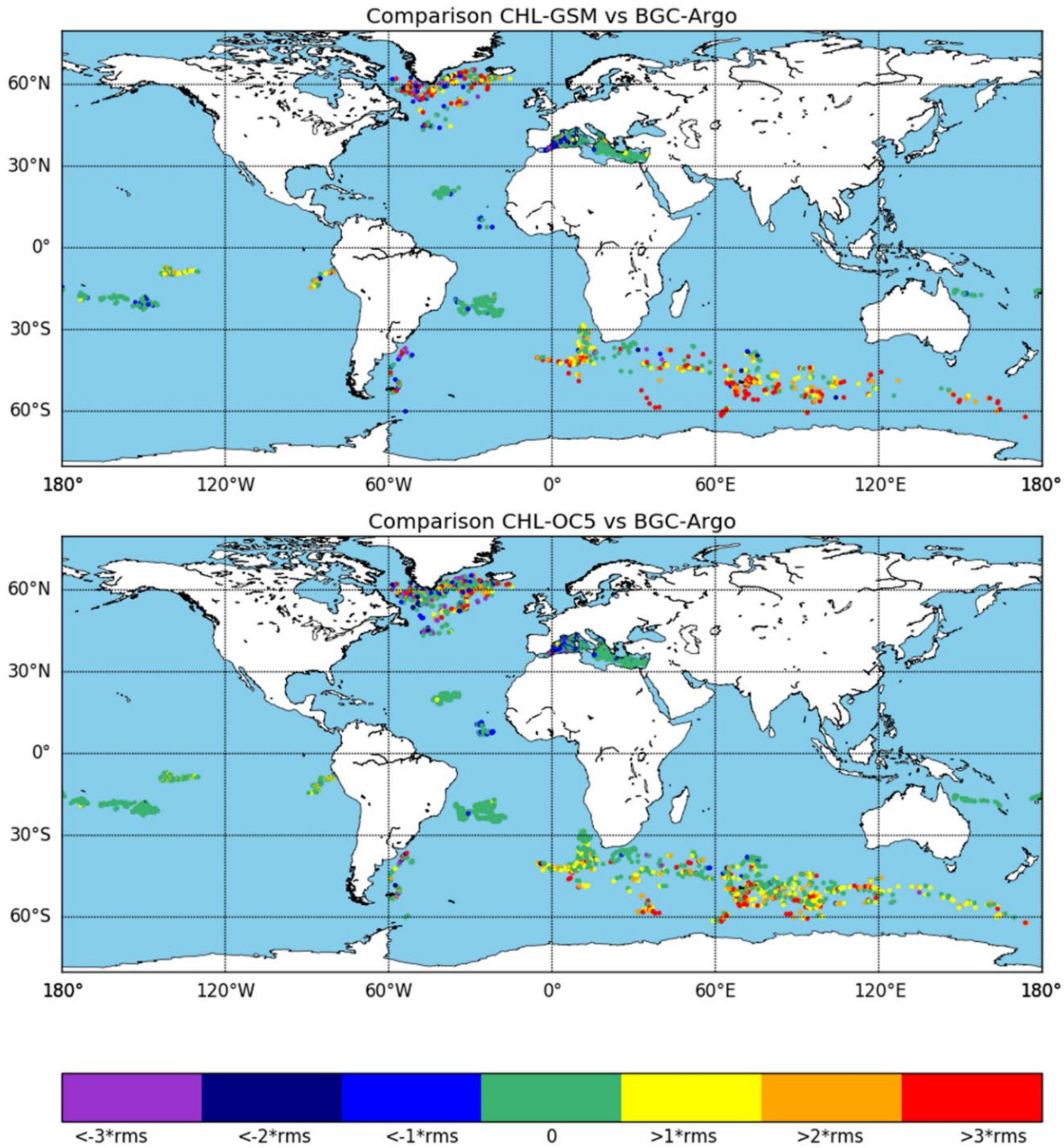

Figure 4: Matchup locations. The colour of the point corresponds to the thresholds of the difference between satellite and BGC-Argo data. Rms is equivalent to σ_{tot}

Table 4:Number of matchups before and after the DM-QC, and number of matchups rejected by the 3 σ threshold biomes

Chl-sat retrieval	BGC-Argo dataset	Nb matchup	Nb Rejected (%)
GSM	A	3539	283 (9.2)
	C	3934	272 (7.8)
OC5	A	6453	372 (5.7)
	C	7167	352 (4.9)

Several profiles are rejected regardless of the Ocean Colour algorithm that is used. In such case, this indicates a high probability of bad quality of the BGC-argo profile. These cases have to be analysed individually. It is therefore proposed to perform the comparison between BGC-Argo DM datasets with Oceanc Colour and to annotate profiles for which the absolute difference is above $N.\sigma_{tot}$ for :

1. GSM only
2. OC5 only
3. GSM and OC5

4.2 Recommended QC operation with Ocean Colour

What is recommended and will be implemented in the frame of Euro-Argo RISE:

1. Every day, computation of matchups between BGC Argo and OC-OC5 and OC-GSM

2. Every month, update of a map of flags for all profiles (as for Figure 4) indicating for which profiles the absolute difference between BGC-Argo and OC is above $N.\sigma_{tot}$ for one or two of the Chla retrieval technique (N is presently taken equal to 3 but can be adapted through offline analyses). A list of flagged profiles per float has also to be prepared and updated to point towards possible problematic floats. A monthly log-file, containing all these information will be prepared and sent to Coriolis/GDAC on a montly basis.

3. When requested/needed, update an histogram of differences (normalised by σ_{tot}) that would help to adjust the value of N

For any update of the BGC-Argo DM datasets (and/or a new update of satellite processing) , the whole method is to be repeated:

1. Application of the triple colocation technique with the updated datasets in order to derive σ_{sat}, σ_{bgc} and then σ_{tot}
2. Application of the point 3 above for the whole datasets to optimise the value of N
3. Activation of the process (point 1 to 3) above

5 Conclusions

In this document, we have reported on the most reliable way to make comparable the chlorophyll surface concentration retrieved from BGC Argo (after DM processing) and from satellite remote sensing (ocean colour).

These comparisons are then conducted following a clear methodology that implies the use of uncertainty of both data sources in order to be able to detect any "abnormal" situation for which BGC-Argo products shall be QC-annotated. The way of deriving uncertainty is also described. This approach allows to use simple and reliable statistics to raise warning on data validity & quality of BGC-Argo products.

Another point of interest is the possible use of two Ocean Colour algorithms that give access to two estimates of surface concentration of Chlorophyll. These two sources of information help the consolidation of the identification of possible troubles either in the satellite data and/or in the BGC-Argo measurements.

Some maps and indicators are proposed to be prepared and used within the frame of the project to check the usefulness of this QC with remote sensing and to possibly optimise data flagging rules on DM products.

Beyond the project, the next steps will be:

- to analyse more precisely :
  - the possible combined use of the two OC algorithms (GSM, OC5) in order to better target which data source is suspect.
  - the sensitivity to the choice of the N value
  - the environmental context for which discrepancies occur
- To support validation of satellite by BGC-Argo within H2020 EuroSea
- To operationalise the process of comparison with OC (under the form proposed section 4.2 above)

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