FINAL REPORT PROGRAM LEFE

Program LEFE/CYBER	OBOO From Optics to Biodiversity in the world Open Oceans: application to BGC-Argo floats	Years 2021–2022

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Contribution to the BioGeoChemical-Argo program
Other funding source: 3-year PhD grant (2019–2022) from Sorbonne Université (ED 129) allocated to F. Petit

Context: Developing a capability for global observation of phytoplankton community composition and response to environmental forcing, over a wide range of space and time scales, is fundamental to improve our understanding of biogeochemical cycles in today's oceans and predict their evolution under climate change.

Objectives/Scientific questions: OBOO aims to explore innovative methods for observing phytoplankton community composition from BGC-Argo profiling floats. To this end, we propose a generic approach that can be implemented during field cruises to build an *in-situ* database of optical, biogeochemical and phytoplankton diversity measurements. This database can be used to develop regional or global algorithms to retrieve phytoplankton composition along BGC-Argo float trajectories.

Main results: OBOO considers two approaches for deriving phytoplankton composition from in situ optical measurements , such as could be collected by BGC-Argo floats: (1) the first is based on the use of a multispectral fluorometer (MSF, Proctor & Roesler 2010), each of whose excitation channels targets a specific region of the phytoplankton light absorption spectrum, corresponding to distinct accessory pigments used as biomarkers of phytoplankton taxonomic groups; (2) proposed by Rembauville et al. (2017) for the Southern Ocean (SO), the second approach derives the relative contribution of phytoplankton groups to the stock of particulate organic carbon (POC) from standard BGC-Argo measurements.
We first investigated the MSF approach using measurements from lab experiments in collaboration with SBR, in addition to data collected over an annual cycle in the northwestern Mediterranean Sea (NW-Med; BOUSSOLE long-term observation site). HPLC-determined pigments collected in the NW-Med were analyzed using a Hierarchical Ascending Classification (clustering) method. This resulted in 4 clusters representative of the phytoplankton communities encountered during the seasonal cycle. The pigment-based clusters along with the corresponding MSF measurements served as a basis for developing a predictive model (Histogram Gradient Boosting, HGB) enabling to discriminate phytoplankton groups based on MSF. In the perspective of its application to BGC-Argo, we evaluated the response of the HGB model to the bio-optical data used as input (Fig. 1). This analysis indicates that using the MSF measurements at the 3 excitation channels as input gives a fairly robust phytoplankton group discrimination (65-70% accuracy), which can be improved when combined with measurements from additional bio-optical sensors.
Secondly, we explored the Rembauville approach and its potential for regions other than the SO. The principle is to use measurements of temperature and salinity (T/S), (non-multispectral) fluorescence, and the particle backscattering (b_{bp}) and beam attenuation (c_p) coefficients to infer the relative contribution (%) of plankton classes to POC using a multivariate regression model. Here we analyzed 3 datasets collected in different regions: the SO (SOCLIM), the NW-Med (BOUSSOLE), and the Eastern Mediterranean (PERLE cruises), and developed an XGBoost (Extreme Gradient Boosting) algorithm. This algorithm uses T/S and bio-optical measurements as input to estimate the bulk POC as well as the POC contribution of distinct plankton groups, thus providing quantitative POC information rather than relative (%) contributions as was the case with Rembauville method. We also analyzed the sensitivity of the XGBoost algorithm performance to the input datasets, i.e. the combined cruise datasets, or individual cruise datasets. The model robust performances in predicting the contribution of phytoplankton groups to total POC under contrasting conditions, such as those encountered in the SO or NW Mediterranean Sea, suggests that it could be implemented on larger datasets to quantitatively predict POC and phytoplankton composition in a wide variety of regimes. The potential of the XGBoost model is illustrated by an application to a BGC-Argo float time series in the NW Mediterranean Sea (Fig. 2). The proposed model adds important quantitative information on POC stocks, photoacclimation status (Chla/POC ratio) and community composition to the standard BGC-Argo measurements.

Figure 1

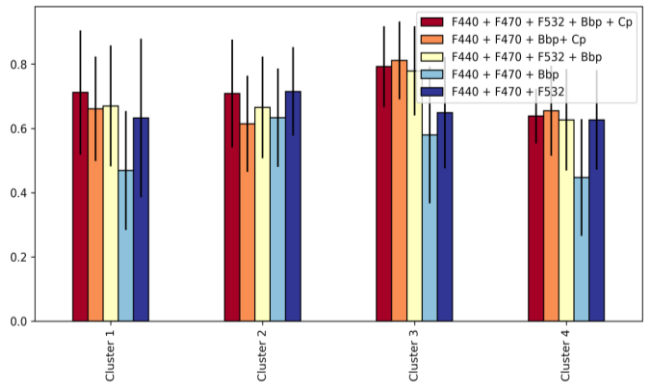

Figure 2

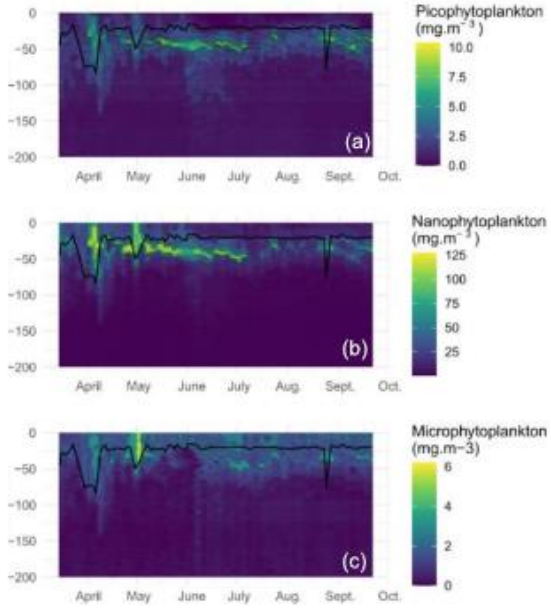

Figure 1. *Accuracy of the HGB model in predicting the occurrence of distinct phytoplankton clusters in the NW-Med, using different sets of bio-optical measurements considered as BGC-Argo sensor packages as input.*
Figure 2. *Vertical distribution of the POC stock associated with (a) pico-, (b) nano- and (c) microphytoplankton, derived from T/S and bio-optical data acquired by a BGC-Argo profiling float in 2014 in the NW-Med Sea; the black line is the depth of the mixed layer derived from the T/S measurements.*

Future of the project:

The results of the OBOO project, obtained by Flavien Petit as part of his PhD thesis at LOV, are highly relevant to the international BGC-Argo programme. Petit et al. (2022) highlight the strong regional variability of the fluorescence signal and challenge its calibration in Chla equivalents. This result was followed by the implementation of a fluorescence sensor with two excitation channels (instead of just one) on a portion of the BGC-Argo fleet, a question being actively discussed at the international level as part of the BGC-Argo Technological Task Team. We will pursue the investigations initiated within OBOO in order to obtain critical information that will complement the standard BGC-Argo variables, making them truly multidisciplinary platforms.

Nombre de publications, de communications et de thèses :

Publication: Petit F, Uitz J, Schmechtig C, Dimier C, Ras J, Poteau A, Golbol M, Vellucci E, Claustre H (2022). Influence of the phytoplankton community composition on the in-situ fluorescence signal: Implication for an improved estimation of the chlorophyll-a concentration from BioGeoChemical-Argo profiling floats. *Frontiers in Marine Science*, https://doi.org/10.3389/fmars.2022.959131.

Communications:

Petit F, Uitz J, Claustre H (2023). Enhancing phytoplankton biomass and community structure observation from BGC-Argo floats using machine learning. *ASLO Aquatic Science Meeting*, 4–9 June 2023, Palma de Majorqua, Spain.

Petit F, Uitz J, Claustre H (2023). From Optics to biodiversity in the world open ocean: Application to BGC-Argo floats (project OBOO). *Journées du Groupe Mission Mercator Coriolis (GMMC)*, 31 May-2 June 2023, Brest, France.

Petit F, Uitz J, Claustre H (2022). Variability in the fluorescence signal in relation to phytoplankton community composition and implications for the retrieval of the chlorophyll a concentration from BGC-Argo floats, *7th Argo Science Workshop*, 11-13 October 2022, Brussels, Belgium.

Petit F, Uitz J, Claustre H (2022). Influence of the phytoplankton community composition on the fluorescence signal: Implication for a better estimation of chlorophyll a concentration from BGC-Argo profiling floats. *Ocean Sciences Meeting*, virtual event, February 27-March 4 2022.

Thèse: Petit F. (2023). Development and exploitation of new methods for observing phytoplankton community composition from BGC-Argo profiling floats in the open ocean. PhD Thesis, Sorbonne University.

Data availability

BOUSSOLE: http://www.obs-vlfr.fr/Boussole/html/boussole_data/collected.php
SOCLIM: https://doi.org/10.17882/71768
BGC-Argo data: https://argo.ucsd.edu, https://www.ocean-ops.org,
https://www.seanoe.org/data/00311/42182/#90179