Euro-Argo key messages from EuroSea Deliverables 7.1 & 7.2

D7.1 (GEOMAR) Report on demo mission and dissemination pathways of obtained data
D7.2 (GEOMAR) Development of BGC-Argo data quality validation based on an integrative multi-platform approach

To improve our understanding of the ocean's role in global climate change, and to assess long-term changes in the oceanic carbon cycle, sustained, high-quality *in situ* measurements are needed. Defined as an essential ocean variable (EOV) by the Global Ocean Observing System (GOOS; Tanhua et al., 2019), pH is a relevant parameter for assessing many critical questions regarding ocean evolution in response to current global changes. However, this carbonate system's high spatial and temporal variability requires sustained observations to decipher trends and one-time events.

Recently, to estimate carbon fluxes in the tropical Atlantic, and to capture its temporal and spatial variability, many autonomous observation tools such as a Wave Glider, a Saildrone, or BGC-Argo floats have been deployed in the framework of the EuroSea project (European ocean observing and forecasting systems, 2019-2023). This short document provides the take-home messages from EuroSea deliverables 7.1 and 7.2 (https://eurosea.eu/deliverables/).

In response to the growing and critical need for accurate and precise float pH data to better constrain ocean acidification and derive ocean carbon data and its variability to current climate change, the correction of pH data acquired by floats is essential. To correct the pH data from the 5 BGC-Argo floats deployed in the project (WMO 6903874 to 6903878), the depth correction from reference data, developed and provided in the SAGE tool, was used. However, some modifications were required.

The key messages are:

- When floats do not regularly sample until 2000 db, modifying the **reference pressure depth** or the temperature at depth used to correct the data in this ocean region is necessary,
- While **deep profiles are always to be preferred**, the choice of the reference depth changes the pH correction negligibly in this region since the resulting uncertainty is on the order of a few thousand pH units (0.0008 pH units), which is tolerable (Fig. 1),
- There remains a crucial need for **corrected and accurate** auxiliary data, especially **dissolved oxygen**, to adjust the pH values acquired by the floats due to the use of this variable in the calculation of the reference data,
- In addition, special attention needs to be paid to the choice of the **routine used as a reference** to correct float-pH data, especially given the variability of the pH values obtained (between -0.001 and -0.002 pH units depending on the input variables), at intermediate depths, when, for example, the ESPER-Mixed routine is used (Carter et al., 2021).

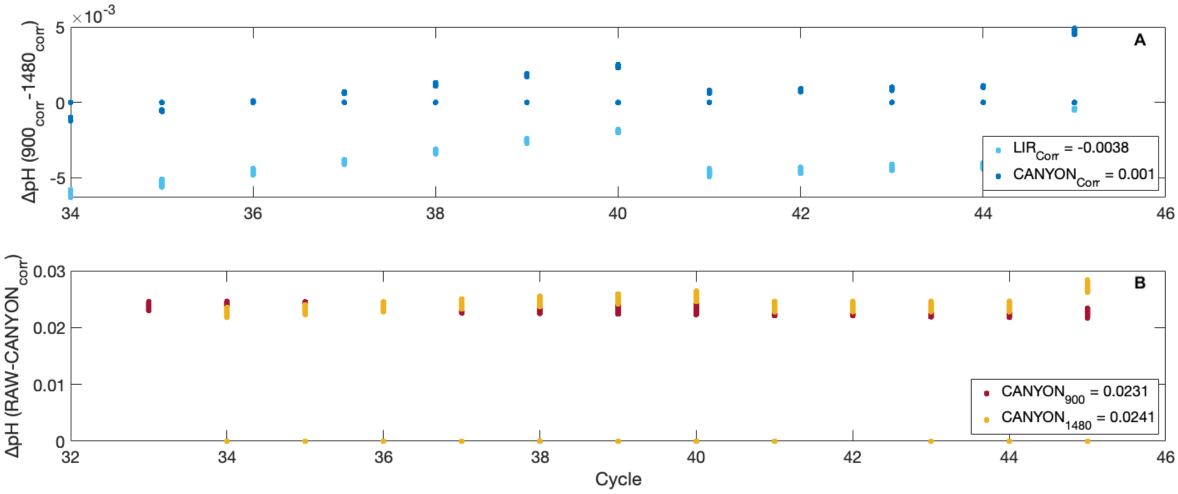

Figure 1. (A) Differences between float pH data (from cycles 33-45; WMO 7901001) corrected using the 900-940 db pressure range minus float pH data corrected using the 1480-1520 db pressure range, for each correction method (LIR or CANYON-B). (B) Differences between the raw float pH data (from cycles 33 to 45; WMO 7901001) minus the float pH data corrected using the CANYON-B method and the 900-940 and 1480-1520 db pressure ranges.

An independent evaluation of the quality of the corrected pH data acquired by the floats was carried out with comparisons to pH data calculated and/or measured *in situ*.

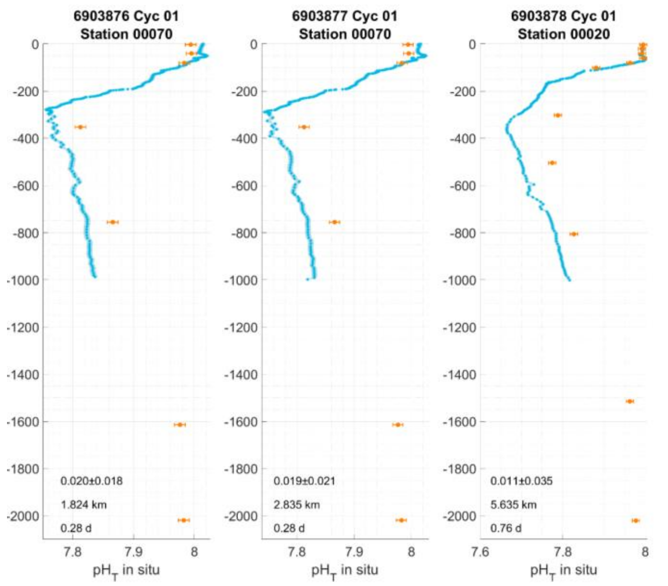

Figure 2. First adjusted pH profiles from BGC-Argo floats (blue) and recalculated pH from TA and DIC (orange) sampled near the profile's location during the PIRATA-FR31 cruise. In the lower left corner of each panel are the mean absolute difference at the comparison depths and the difference in space and time.

Thanks to this inter-comparison work of pH data acquired via various platforms, and in addition to the evidence of the undoubted need to continue the classical sampling strategies (CTD casts during oceanographic campaigns, SOOP lines, autonomous pCO$_2$ measurements via sensors on drones or moorings) to obtain reference data, these comparisons allowed to reveal global differences of *ca*. 0.02 pH units, which corresponds to an uncertainty of about 20 µatm in *p*/*f*CO2, *i.e.*, twice the inclusion limit of the SOCAT database. While this result is in agreement with the literature, the robustness of the conclusions to be drawn is also limited by the small amount of data. Indeed, this study suffered from numerous problems related to dysfunctional pH sensors, particularly concerning some of the failures of the reference electrodes of the pH sensors resulting in a considerable reduction in sensor life and an increase in drift characteristics variability.

This observation underlines the urgency to improve the quality of manufacturing of these sensors and encourages the continuation of work on alternative pH sensors, both at the level of the manufacturers and the sensors' principles.

Thus, from the work done in the framework of the EuroSea project, based on this regional focus (even with our limited dataset), we propose some suggestions that the scientific community could explore in a systematic way to harmonize both the way of measuring but also of correcting pH data from BGC-Argo floats. The joint drafting of **reference guides**, such as standard operating procedures or best practices, by the entire community of users of these tools could help answer these questions. Finally, this study illustrates the **notable uncertainty** and **lack of additional reference data** to compare and possibly correct pH data sets from BGC-Argo floats.

Carter, Brendan R., Bittig, H. C., Fassbender, A. J., Sharp, J. D., Takeshita, Y., Xu, Y., et al. (2021). New and updated global empirical seawater property estimation routines. L*imnology and Oceanography: Method*s, 19(**12**), 785–809. https://doi.org/10.1002/lom3.10461.

Tanhua, T., McCurdy, A., Fischer, A., Appeltans, W., Bax, N., Currie, K., et al. (2019). What we have learned from the framework for ocean observing: evolution of the global ocean observing system. *Frontiers in Marine Sciences*, 6: 471. https://doi.org/10.3389/fmars.2019.00471.