Preliminary work on DMQC activity of Deep Argo data in the Mediterranean Sea

by

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Table of Contents

1. INTRODUCTION

Deep-Argo are a new generation of floats that play an important role in the systematic sampling of the deep layers of the ocean (between 4000 and 6000 m). In the framework of the MedArgo Regional Center, 6 deep floats (4000 m model) have been deployed in the Mediterranean Sea (figure 1). OGS has started to perform the DMQC of temperature and salinity data of deep floats, as responsible for the DMQC activity of Argo data in the Mediterranean and Black seas. The DMQC analysis is also part of the work planned in tasks 2.4 and 3.2 of the H2020 Euro-Argo RISE project. The DMQC analysis of deep floats requires a different approach with respect to the core floats, due to the pressure dependent salinity bias. Hence, a correction has to be applied before using the OWC procedure (Cabanes et al., 2016). In order to do this quality control, an adequate reference database is required. OGS reviews and improves on a regular basis the high-quality ship-based CTD reference data deeper than 2000 m. It collects CTD data in complement of the official CTD reference dataset, provided by the Coriolis Global Data Assembly Center (GDAC), from the main European Marine Services and several research institutes at regional level. It is also very important to collect a reference profile during the deployment of the float to compute a consistent pressure dependent correction on salinity. This report describes the DMQC analysis on two deep floats.

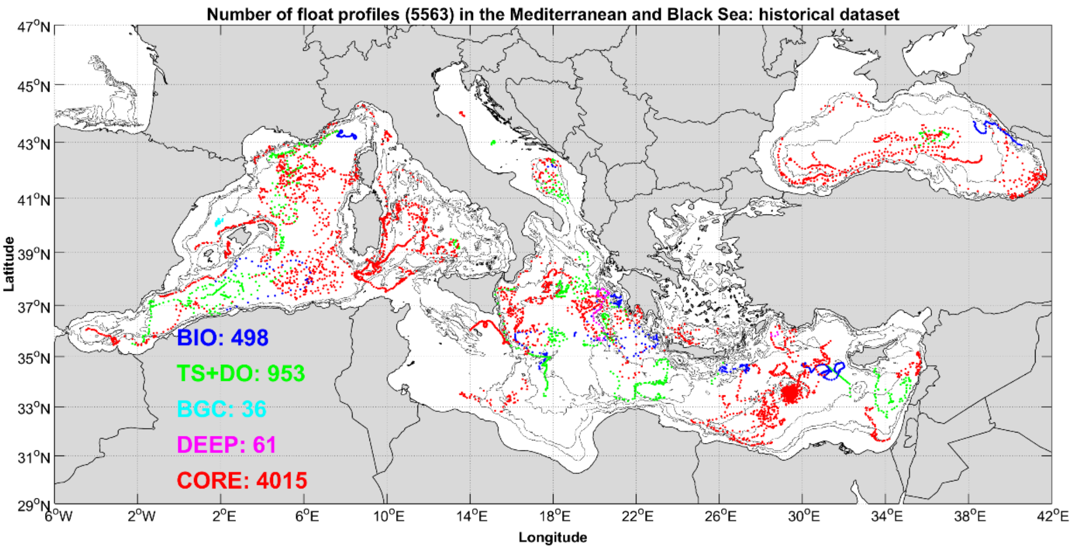

Figure 1. Spatial distribution of profiles collected by Argo floats in 2021 (January-September) in the Mediterranean and Black Seas: locations are color-coded per float type (Deep-Argo are in magenta).

2. REFERENCE DATASET

The official CTD reference dataset is provided by the Coriolis Global Data Assembly Center (GDAC) that is updated on a regular basis. Other CTD reference datasets are used and consists of CTD data collected worldwide by several research institutes and by the main European Marine Services. A second reference dataset is built using the Argo CTD profiles that respect a set of predefined criteria as stated in the Argo quality control manual for CTD and trajectory data, version 3.6 (Wong et al, 2022). OGS, as responsible of QC activities, has reviewed and improved the availability of high-quality ship-based CTD reference data for QC of Argo float data in the Mediterranean and Black seas (Gallo et al, 2021). For the DMQC analysis of Deep-Argo only CTD reference dataset is used because at the moment there is no Deep-Argo climatology in Mediterranean Sea and also because the reliability of the deep data (below 2000 m) is not yet well known. CTD data from Copernicus Marine Environment Monitoring System (CMEMS) and CTD profiles acquired by European colleagues from different research institutes during regular cruises or in the framework of projects are integrated to the CTD reference dataset provided by Coriolis. In this way, a high-quality ship-based CTD reference data is obtained. Figures 2 and 3 shows the spatial and temporal distribution of the CTD dataset deeper than 2000 m.

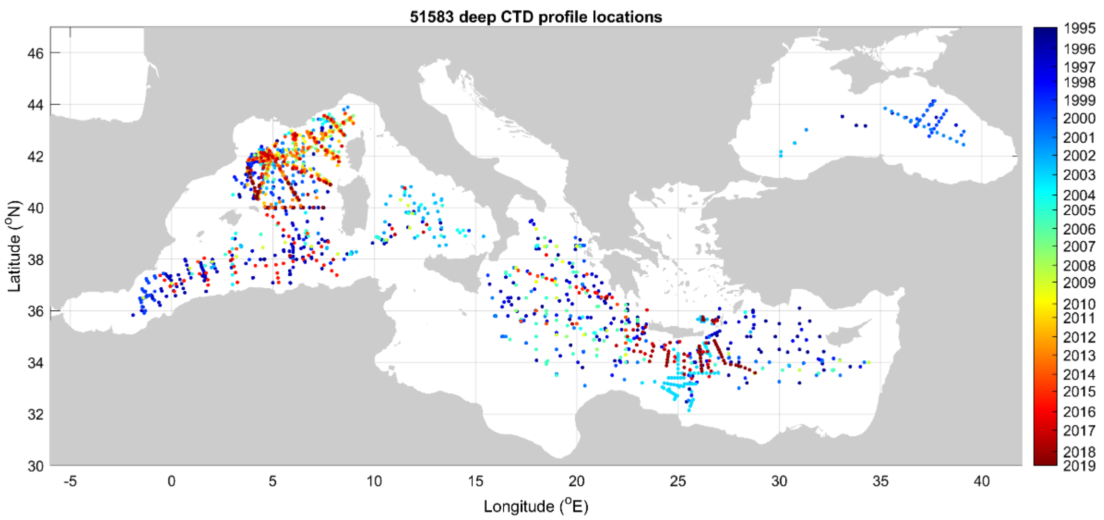

Figure 2. Spatial distribution, color-coded for time, of the CTD profiles deeper than 2000m in the final version of the CTD reference dataset of the Mediterranean and Black Seas.

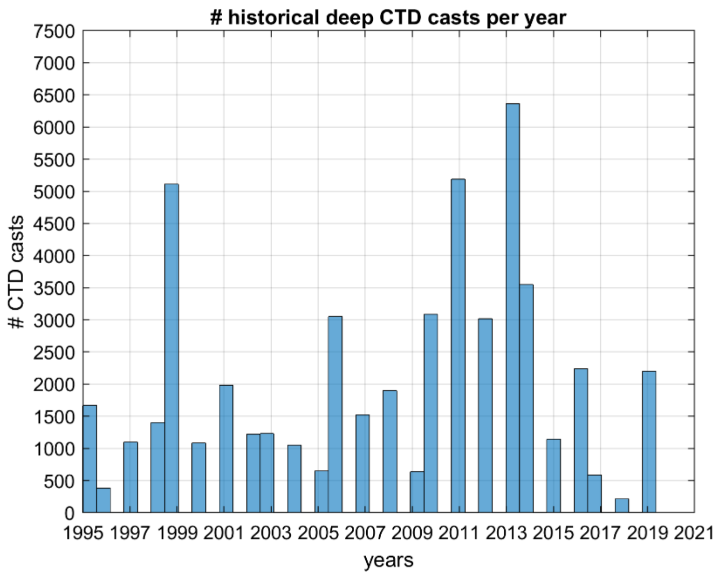

Figure 3. Temporal distribution of the CTD profiles in the final version of the CTD reference dataset of the Mediterranean and Black Seas.

3. DMQC ANALYSIS – CPCOR CORRECTION

Following the Deep Argo team's recommendations, OGS has done the DMQC analysis of two deep floats. The salinity of deep floats shows a bias that is dependent on pressure. Before applying the QC procedure, the correction for pressure effects on conductivity is necessary. This correction is called CPcor. Three CPcor values are used:

- the nominal CPcor value from Sea-Bird that the Deep Argo team consider to high;
- the CPcor_new default value obtained by Argo deep team and raccomanded;
- the optimazed CPcor value obtained in delayed-mode by comparing a deep float profile to a reference profile.

To obtain the optimized value is important to use the CTD done at the float deployment location in order to have a reliable comparison between the profiles. As recommended by Deep Argo Team, the robustness of the refined optimized CPcor_new value is defined by the difference from the reference levels which must be within +/- 0.5 e–08 $dbar^{-1}$ (Wong et al, 2022).

The CPcor correction is applied to original conductivity. From the new conductivity new salinity is computed. After this correction OWC method is used for checking salinity sensor calibration drift or offset.

4. EXAMPLE 1 – WMO 6903268 FLOAT

The WMO 6903268 float was deployed in Ionian sub basin in the Hellenic trench (figure 4) in October 2019 and performed 140 cycles. The quality flags applied are QC=1 to cycles from 1 to 39 and QC=3 to cycles from 40 to 140. Float 6903268 is an Arvor model and the surface pressure offset is auto corrected.

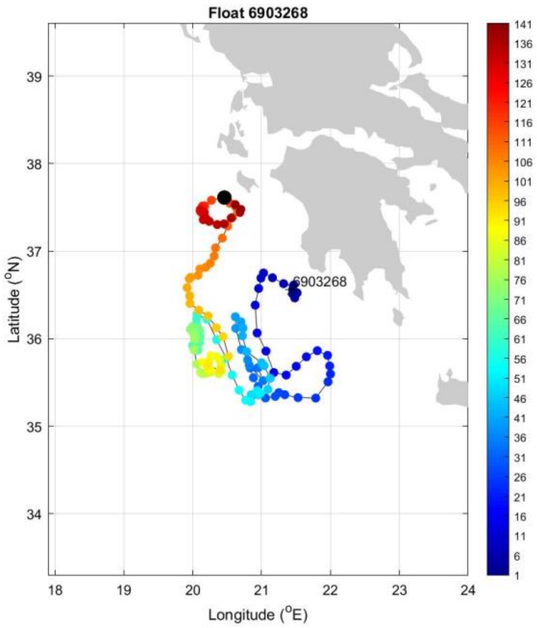

Figure 4: Float WMO 6903268. Profile trajectory color-coded per cycle number.

The theta-salinity (θ-S) diagram of the float was analyzed and in particular the area where the θ-S relationship is the tightest (figure 5). A significant positive salinity drift was observed.

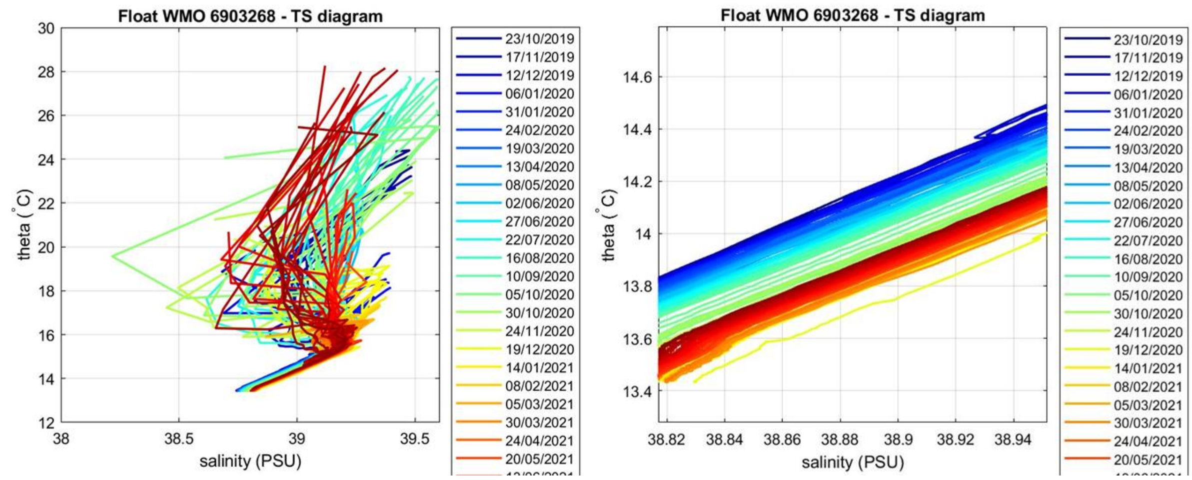

Figure 5: Float WMO 6903268. θ-S diagram color-coded per cycle number. On the right where the θ-S relationship is more uniform.

Before applying the OWC method, CPcor corrections were applied and compared. The CTD profile used to estimate the optimized CPcor correction is shown in figure 6. This CTD cast was done few months before the deployment and it can be considering quite close in time to the float deployment.

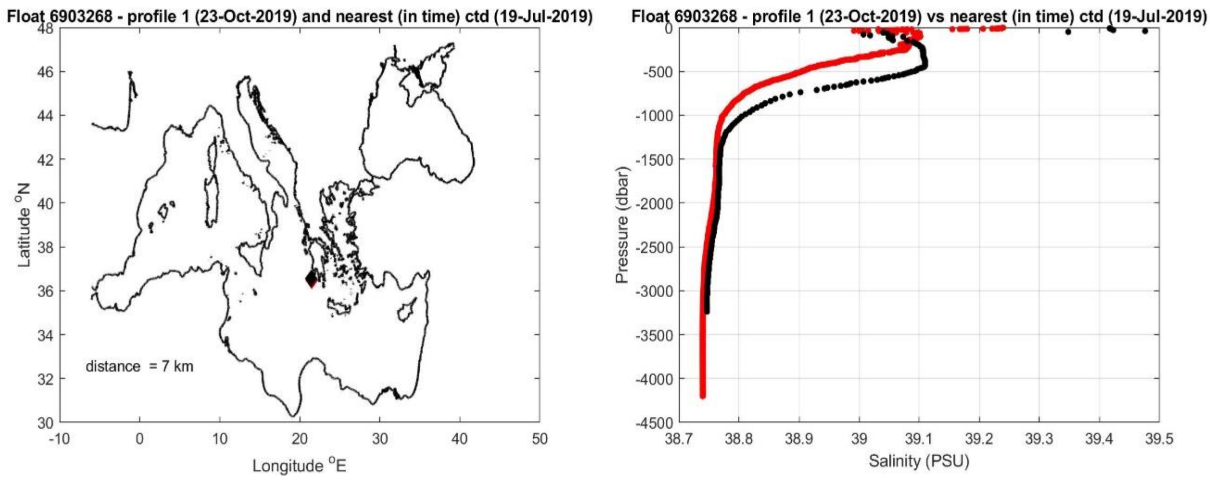

Figure 6: Float WMO 6903268. The salinity float profile number 1 (black dots) are compared to the nearest in time reference profile (red dots). The locations of the two profiles and their distance is given in the left panel.

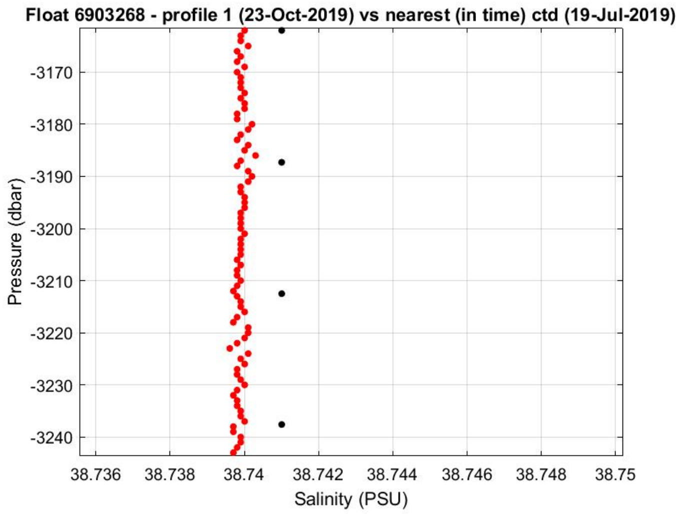

Figure 7. Float WMO 6903268. The salinity float profile number 1 (black dots) are compared to the nearest in time reference profile (red dots) in the deeper layers.

Figure 8 shows the comparison between the effect of CPcor corrections to salinity profiles. Both CPcor correction with default and optimized value leads to the positive deviation from CTD. The positive deviation already starts at surface layers (figure 9). The best result was obtained applying the nominal CPcor value.

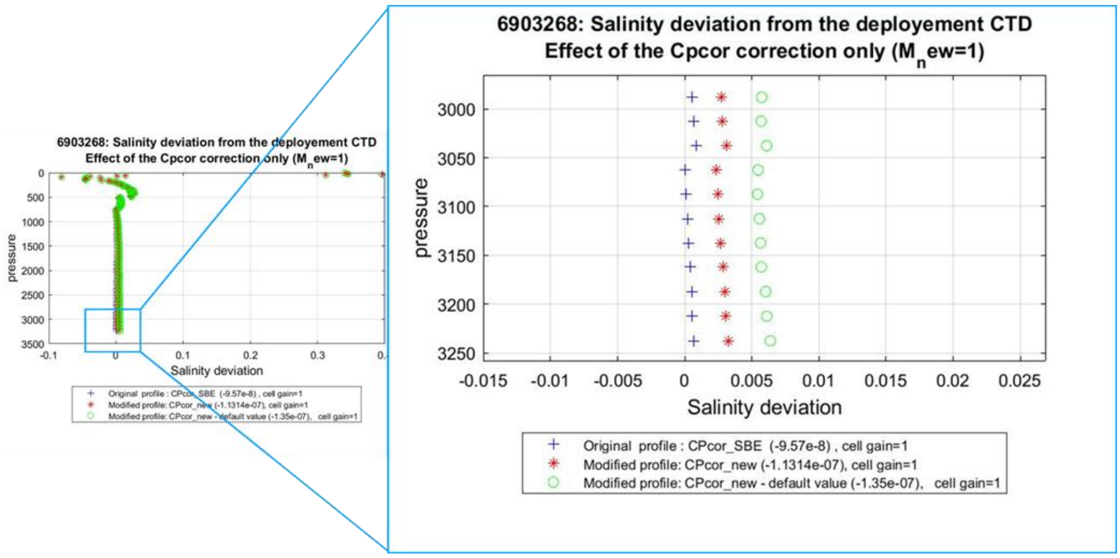

Figure 8: Float WMO 6903268. Salinity deviation from the deployment CTD due to the CPcor correction using three values: the nominal CPcor value from SeaBird, the CPcor_new default value obtained by Argo deep team and optimized CPcor value obtained in delayed-mode by comparing a deep float profile to a reference profile.

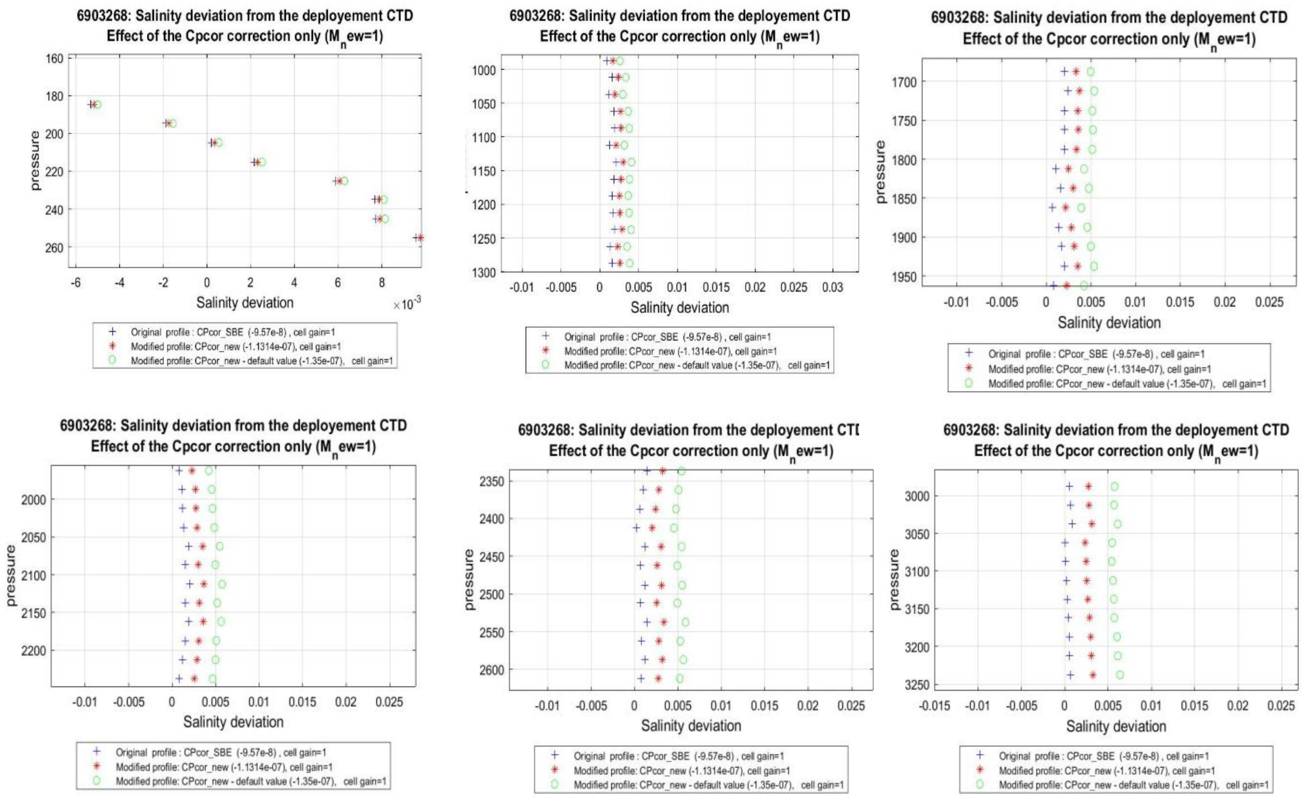

Figure 9: Float WMO 6903268. Salinity deviation from the deployment CTD due to the CPcor correction using the three values, along depth.

In the figure 10, the theta-salinity (θ-S) diagram after applying the three CPcor and the OWC adjustments in the area where the θ-S relationship is more uniform, is shown. The delayed-mode adjusted salinity obtained with nominal CPcor (blue profiles) agrees better with nearby CTD reference data (red profiles).

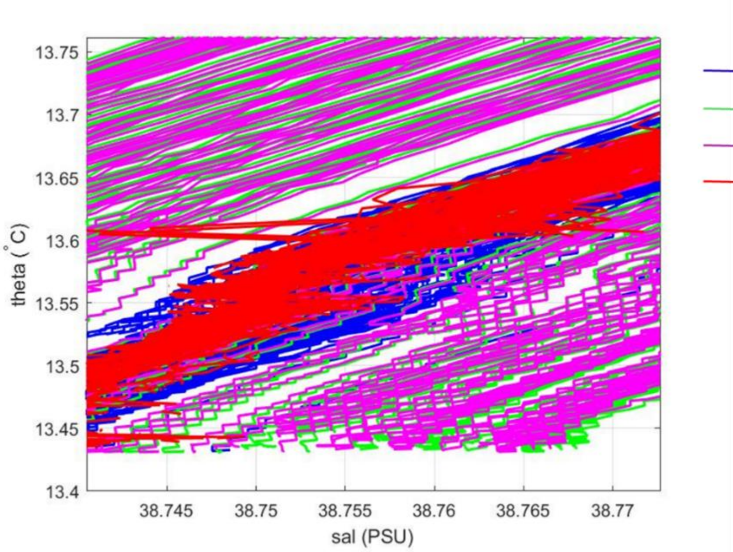

Figure 10: Float WMO 6903268. CTD reference dataset (red) compared with θ-S diagram obtained used the three CPcor correction plus OWC correction: original data with nominal CPcor (blue), Psal adjusted with CPcor new with default CPcor, Psal adjusted with CPcor new with default CPcor optimized obtained using Brian procedure.

The OWC results are presented in figures 11 and 12.

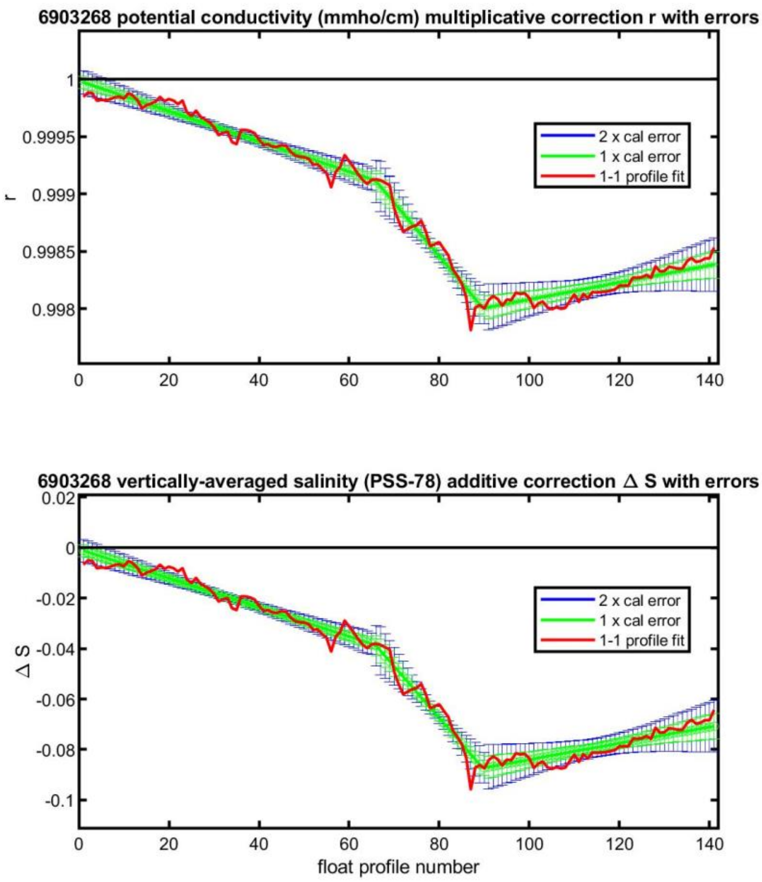

Figure 11: Float WMO 6903268. Evolution of the suggested adjustment with time. The top panel plots the potential conductivity multiplicative adjustment. The bottom panel plots the equivalent salinity additive adjustment. The red line denotes one-to-one profile fit that uses the vertically weighted mean of each profile. The red line can be used to check for anomalous profiles relative to the optimal fit.

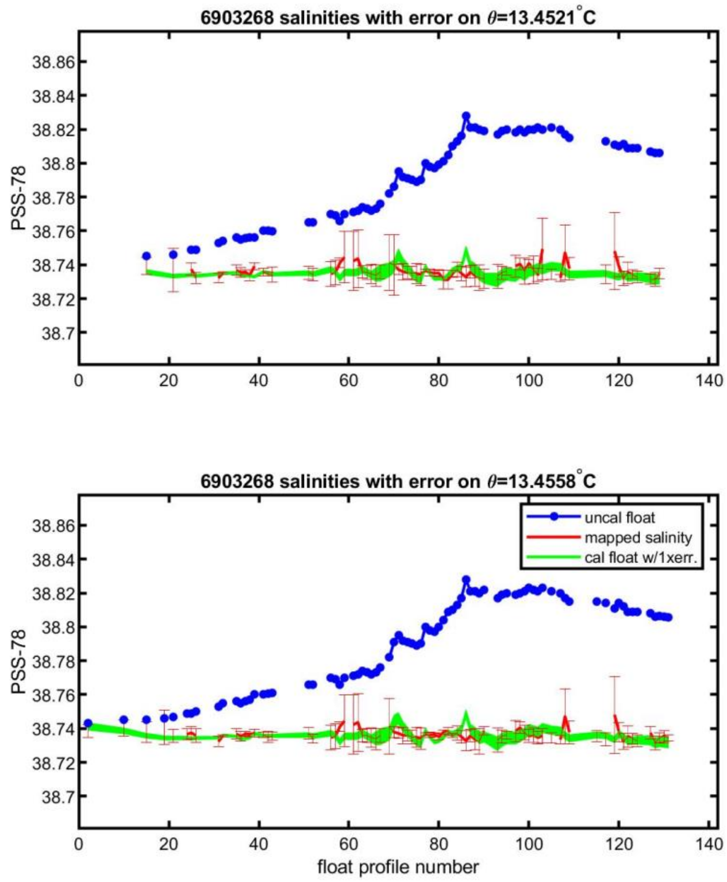

Figure 12: Float WMO 6903268. Plots of the evolution of salinity with time along with selected theta levels with minimum salinity variance.

The OWC analysis showed a potential positive salinity drift. Figure 11 reveals that the least square fit is good. Figure 12 shows a salinity drift on selected θ-levels. The correction proposed by OW is larger than the Argo requested accuracy (0.004). The salinity data of deep float WMO 6903268 needs a delayed mode correction for cycles from 1 to 64. QC 1 is applied. Cycles from 65 to 140 are bad and not adjustable (correction exceed 0.05). QC 4 is applied.

5. EXAMPLE 2 – WMO 6903203 FLOAT

The WMO 6903203 float was deployed in Ionian sub basin near Hellenic trench (figure 13) in December 2016 and after performed 81 cycles, died. Before the analysis, real-time QC flags were visually inspected. The list of flags applied is QC=1 to all cycles. Float 6903244 is the Arvor float, where the pressure sensor is auto corrected and no adjustment is required.

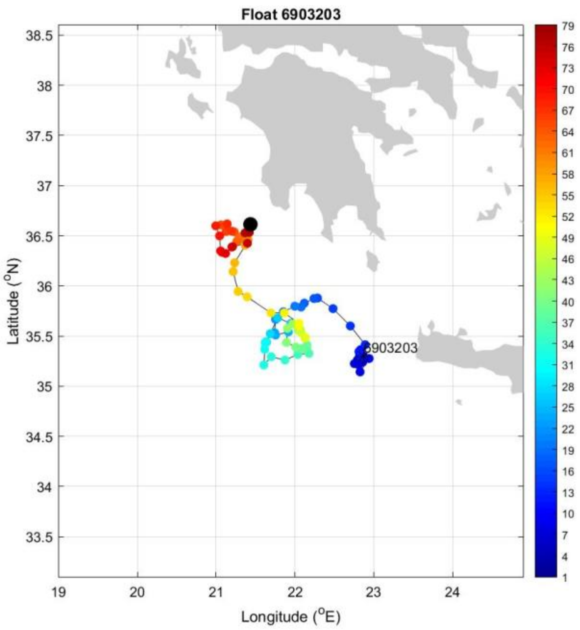

Figure 13: Float WMO 6903203 Profile trajectory color-coded per cycle number.

The theta-salinity (θ-S) diagram of the float was analyzed and in particular the area where the θ-S relationship is the tightest (figure 14). A potential salinity drift/offset was observed.

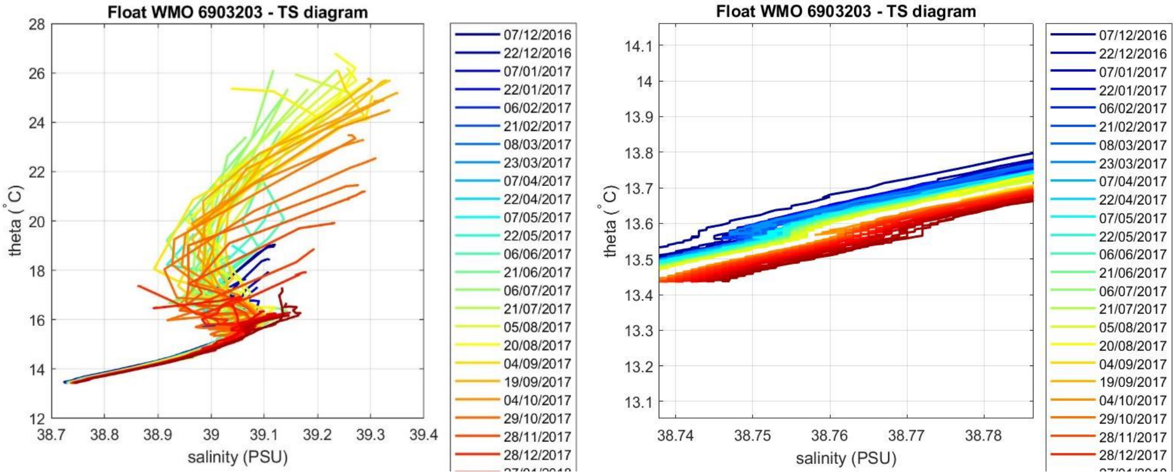

Figure 14: Float WMO 6903203. θ-S diagram color-coded per cycle number. On the right where the θ-S relationship is more uniform.

Before apply the OWC method, CPcor corrections are applied and compared. For this float there isn't the CTD at deployment. CTD nearest in time and space (figures 15, 16) was used to estimate optimized CPcor.

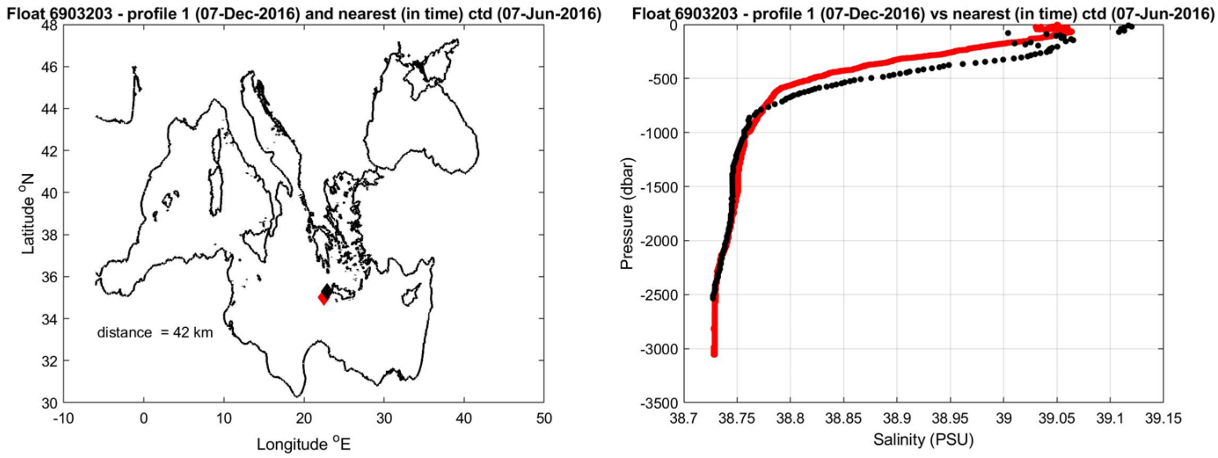

Figure 15: Float 6903203. The salinity float profile number 1 (black dots) are compared to the nearest in time reference profile (red dots). The locations of the two profiles and their distance is given in the left panel.

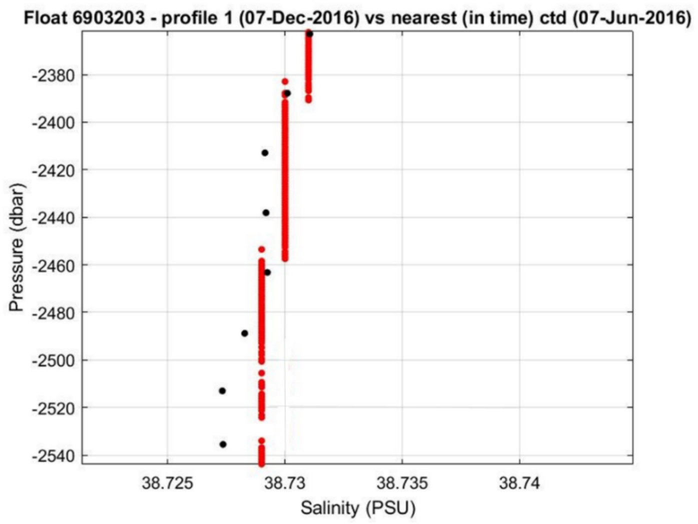

Figure 16. Float WMO 6903268. The salinity float profile number 1 (black dots) are compared to the nearest in time reference profile (red dots) in the deeper layers.

Compared the deviation from CTD obtained using the different CPcor correction (figure 17), the best result was obtained using CPcor_new default value.

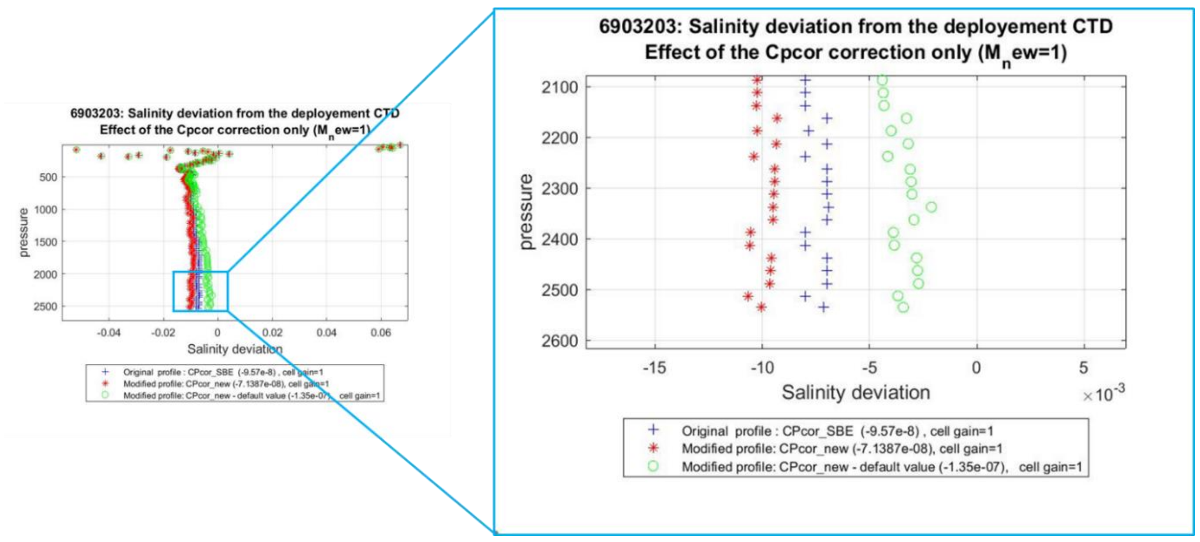

Figure 17: Float WMO 6903203. Salinity deviation from the deployment CTD due to the CPcor correction using three values: the nominal CPcor value from Sea-Bird, the CPcor_new default value obtained by Argo deep team and optimazed CPcor value obtained in delayed-mode by comparing a deep float profile to a reference profile.

In the figure 18, the theta-salinity (θ-S) diagram after applying the CPcor correction and the OWC adjustments in the area where the θ-S relationship is more uniform, is shown. The optimized value is not reliable for the lack of the CTD at deployment and the use of CTD nearest in time and space. For this reason, was not taken in account in that comparison. The delayed-mode adjusted salinity obtain with CPcor default value (green profiles) agrees better with nearby CTD reference data (red profiles).

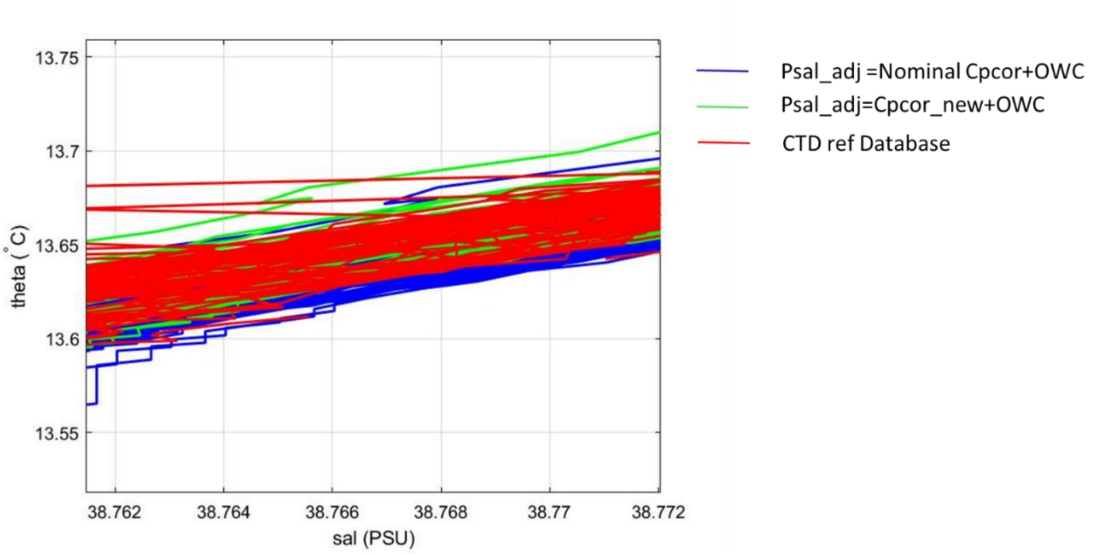

Figure 18: Float WMO 6903203. CTD reference dataset (red) compared with θ-S diagram obtained used the three CPcor correction plus OWC correction: original data with nominal CPcor (blue), Psal adjusted with CPcor new with default CPcor.

The OWC results are shown in figures 19 and 20.

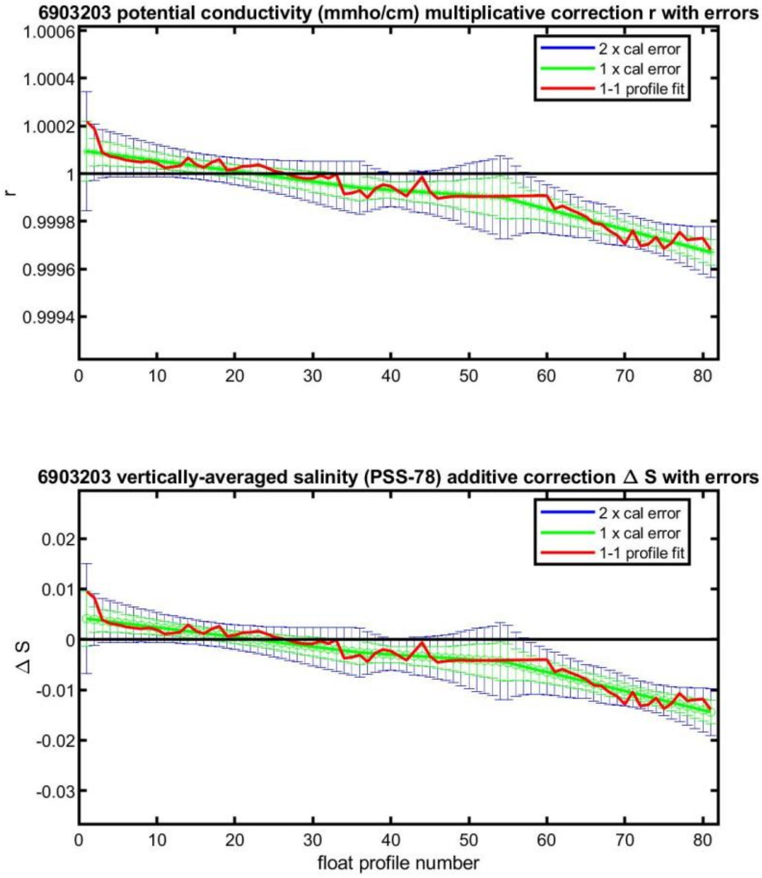

Figure 19: Float WMO 6903203. Evolution of the suggested adjustment with time. The top panel plots the potential conductivity multiplicative adjustment. The bottom panel plots the equivalent salinity additive adjustment. The red line denotes one-to-one profile fit that uses the vertically weighted mean of each profile. The red line can be used to check for anomalous profiles relative to the optimal fit.

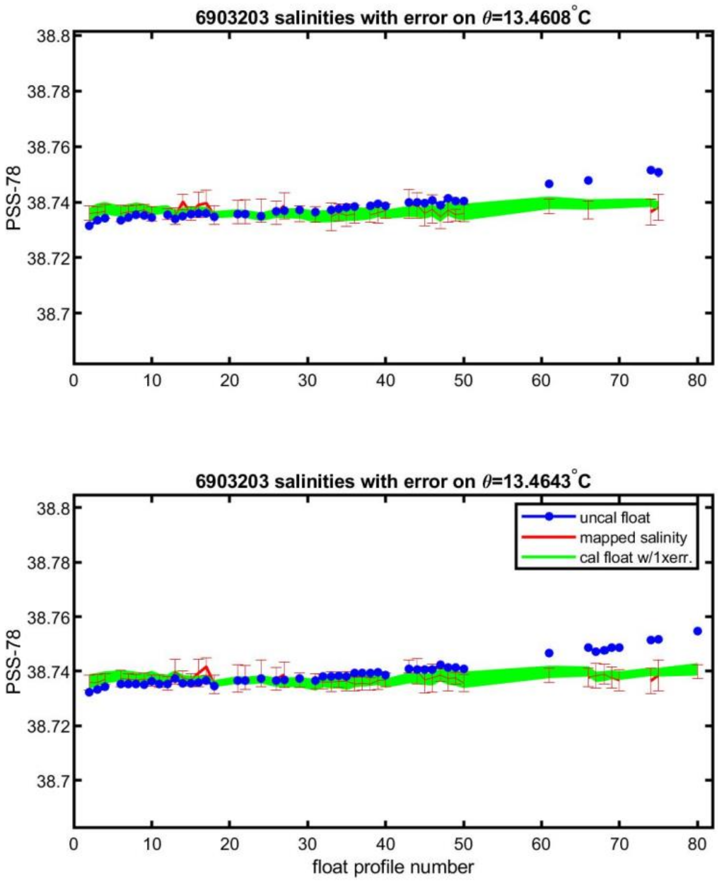

Figure 20: Float WMO 6903203. Plots of the evolution of salinity with time along with selected theta levels with minimum salinity variance.

The OWC analysis showed a small positive salinity drift after cycle 30. Figure 19 reveals that the least square fit is good. Figure 20 shows a salinity drift on selected θ-levels. The correction proposed by OWC is a larger than the Argo requested accuracy (0.004). The salinity data of deep float WMO 6903203 needs a delayed mode correction for all cycles. QC 1 is applied.

6. CONCLUSIONS

The DMQC analysis has been conducted on two deep floats deployed in the Hellenic Trench (Eastern Ionian Sea). For this type of floats, the salinity data show a bias that is dependent on pressure. Before applying the OWC procedure is necessary to correct for pressure effects on conductivity. This correction is called CPcor and it has three possible values: provided by the manufacturer, by the Deep-Argo team, and a refined and optimized estimate of CPcor_new obtained in delayed-mode by comparing a deep float profile to a reference profile. Two examples of CPcor correction application are shown in this report. Both floats show a significant positive salinity drift. For the WMO 6903268 float, the CPcor correction with default and optimized value resulted in a positive deviation of salinity from CTD. The best result was obtained using the CPcor value by manufacturer. After the CPcor correction (float salinity is recomputed), OWC was applied. The correction proposed by OWC was applied to salinity data to cycle from 1 to 64. QC =1 is applied. Cycles from 65 to 140 are bad and not adjustable. QC 4 is applied. For the second deep float, WMO 6903203, there wasn’t the CTD at deployment and a CTD nearest in time and space was used to estimate CPcor optimized value. The best result was obtained using CPcor_new default. After the OWC application, the salinity data of deep float WMO 6903203 was corrected in a delayed mode to all cycles. QC 1 is applied.

Recently, other two deep floats are deployed in Med Sea. OGS will continue to implement the delayed-mode procedures for adjusting salinity data from Deep-Argo floats with the SBE CTDs in Mediterranean Sea, applying the CPcor corrections to estimate the most robust value that provide the best results.

7. REFERENCES

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