Preliminary results of shallow coastal Argo floats data DMQC activity in the North Adriatic Sea

by

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Table of Contents

1. Introduction

This report includes the delayed mode analysis of salinity data performed on two shallow coastal Argo floats: WMO 6903783 and WMO 6903800. These two float were deployed in the North Adriatic Sea (https://fleetmonitoring.euro-argo.eu/dashboard?Status=Active,Inactive). This DMQC analysis is part of the work planned in the WP6 of the H2020 Euro-Argo RISE project and also in the framework of the MedArgo program. In general, the quality control of Argo salinity data is based on the OWC procedure (Cabanes et al., 2016) that is a statistical method that relies on accurate reference datasets. The method is developed mainly for floats deployed in open ocean. The accuracies of float data are assessed by comparison of Argo salinity profiles with calibrated reference measurements in the deep waters (> 700 dbar in the Mediterranean Sea) where theta-salinity (θ-S) relationship become more uniform. The investigation of profiling floats that operate in shallow coastal waters is complicated due to the high variability of the surface layers. In shallow waters, profiles are not deep enough for OWC method that could provide unreliable estimates, with large uncertainties, useless for quality control. Furthermore, in the North Adriatic Sea, the reference dataset which is mandatory to obtain useful statistics, is scarce both in spatial and temporal coverage. The maximal depth reached by both floats is about 80 dbar. In the first meters of the surface layer, the variability is the largest and the OWC method can't be used. Several additional qualitative analyses were computed in order to obtain a more reliable quality control. In this report, the DMQC analysis of these two floats in the northern Adriatic is described.

Plots of density, temperature and salinity profiles and plots of density, temperature and salinity versus nearby historical CTD profiles were generated. The visual analysis can help in detecting sensor salinity outliers and spikes. Qualitative comparisons between floats profiles and CTD at deployment or nearest CTD in time and space were made in order to estimate the sensor accuracy. The reference dataset used is composed of the following CTD and Argo historical datasets:

CTD:

- CMEMS: INSITU_GLO_TS_REP_OBSERVATIONS_013_001_b
- Coriolis: CTD_for_DMQC_2021V01
- Historical CTD profiles provided through personal contact

Argo:

- ARGO_for_DMQC_2020V03

In addition, a comparison between single Argo profiles and model products from CMEMS is done to try to have a picture of the high natural haline variability of this shallow area.
Both floats are Arvor model and surface pressure is auto corrected; hence no adjustment is required.

2. WMO 6903783 float

The Euro-Argo RISE (H2020 project) WMO 6903783 float was deployed in July 2020 and performed 40 cycles (Figure 1). Flags applied are QC=1 to all cycles except for cycles 22 (QC=4) and 33 (QC=3).

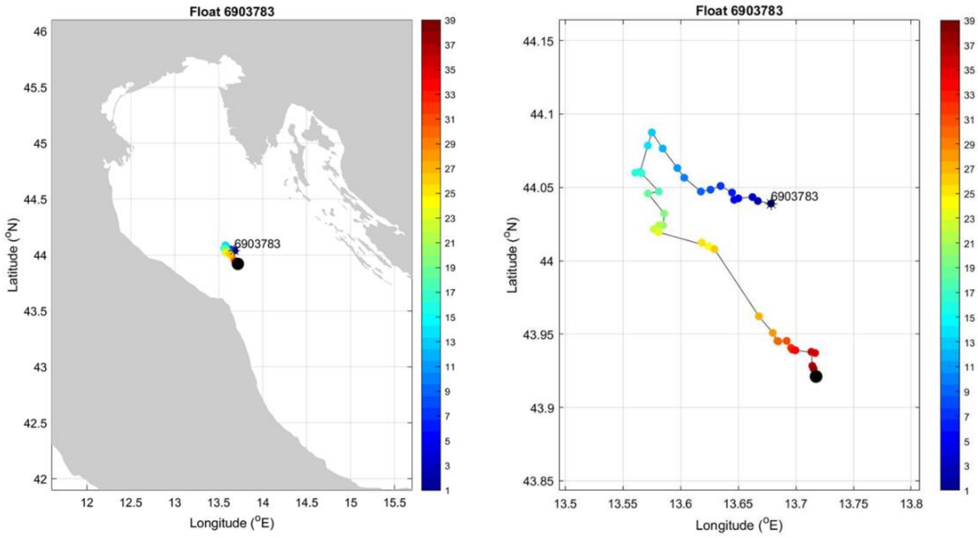

Figure 1: Trajectory of float WMO 6903783, color-coded per cycle number.

2.1 Argo Float Density, Temperature and Salinity measurements

The profiles covered the period between summer and winter, capturing the seasonal variability typical of temperate climates. Density profile (Figure 2) highlights a clear stratification of the water column during the summer months, and the deepening of the mixed layer during autumn and winter; also temperature profiles (Figure 3) evidence this behavior. Instead salinity profiles (Figure 4) show different water masses typical of the investigated area characterized by the advection of LIW, NAdDW and fresh water (Cushman-Roisin, 2001).

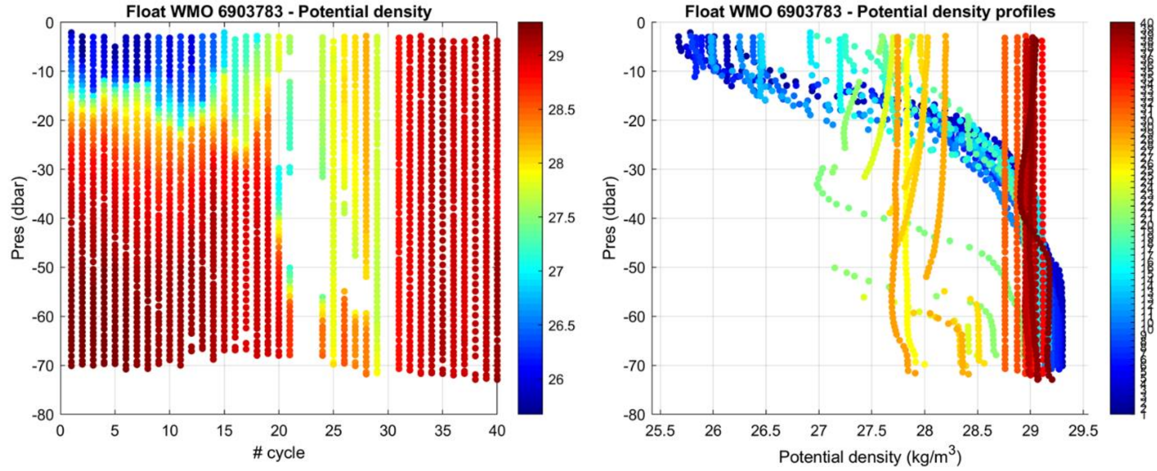

Figure 2: Hovmöller diagram of potential density (left panel), and potential density profiles color-coded per cycle number (right panel) for Argo float WMO 6903783.

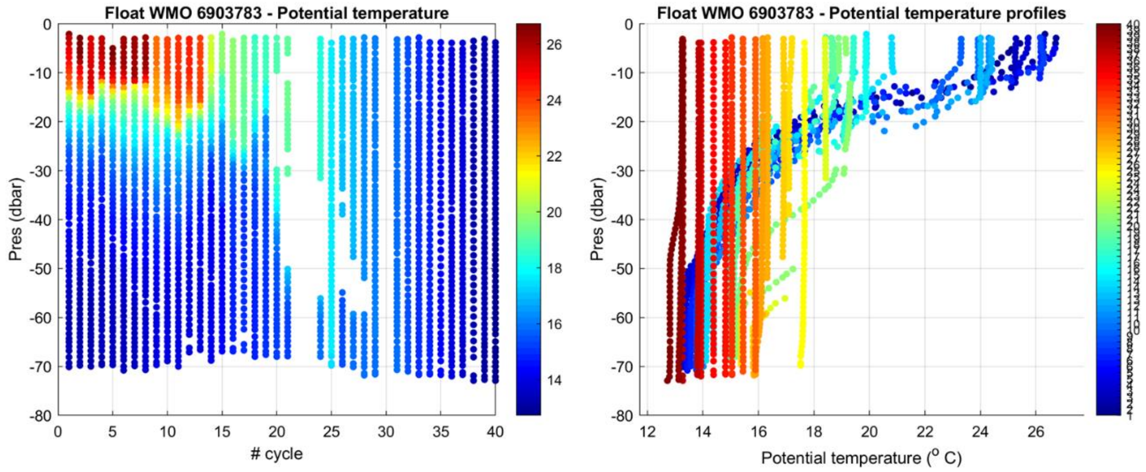

Figure 3: Hovmöller diagram of potential temperature (left panel), and potential temperature profiles color-coded per cycle number (right panel) for Argo float WMO 6903783.

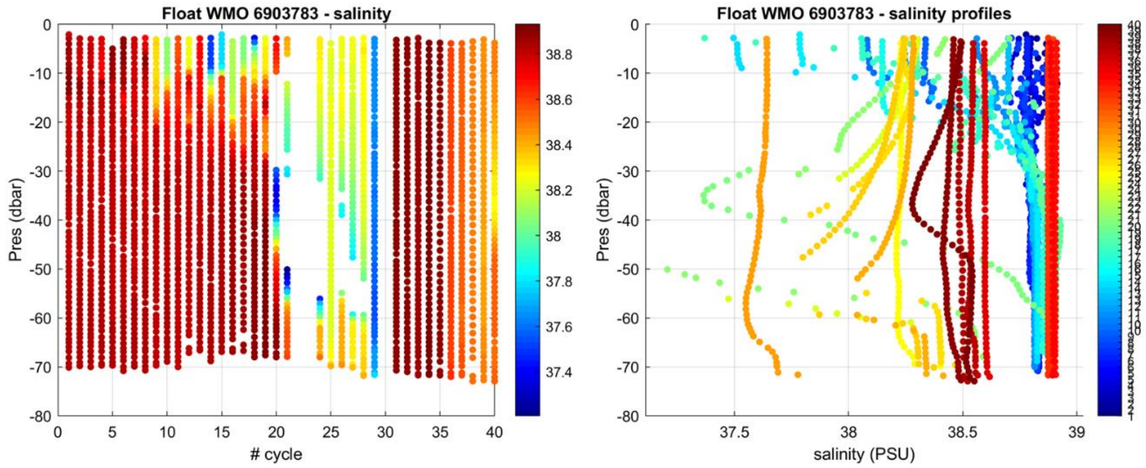

Figure 4: Hovmöller diagram of salinity (left panel), and salinity profiles color-coded per cycle number (right panel) for Argo float WMO 6903783.

The salinity profiles and the theta-salinity (θ-S) diagram of the float is analyzed (Figure 5). A suspect sensor behavior is observed and it is necessary to understand if it is due to a sensor problem or to natural variability.

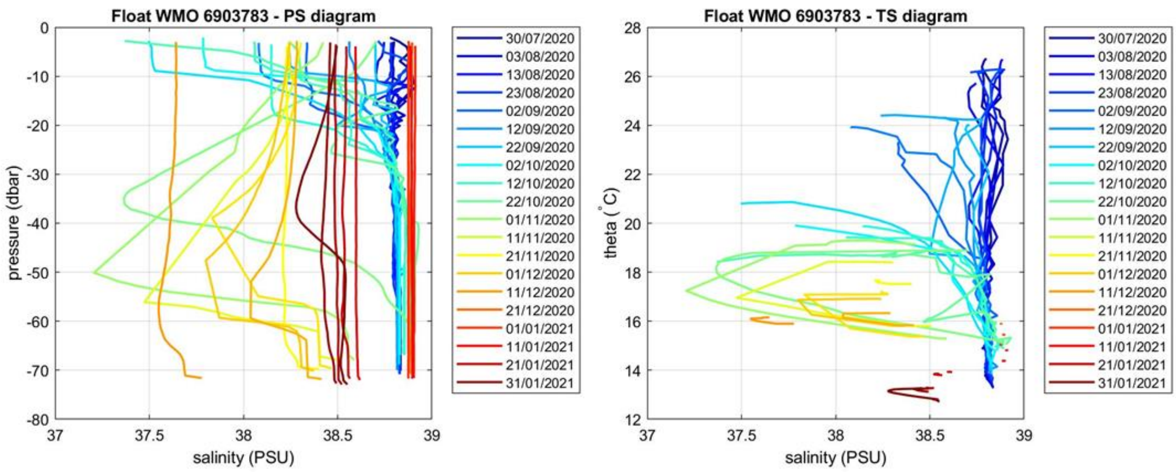

Figure 5: Float WMO 6903783. Salinity profiles and θ-S diagram color-coded per cycle number.

2.2 Comparison between Argo float and reference dataset

The first salinity float profile is selected to perform a comparison (in time and space) with the historical data. In figure 6 the float profile is compared to the most recent reference CTD data used in this analysis that are very close (in space) each other. The salinity float profile is depicted in black while other colors represent the salinity reference profiles. The red color means that the historical data are more recent with respect to the float ones, while magenta states that the float data are more recent than the historical ones (the maximal difference is 1 year).

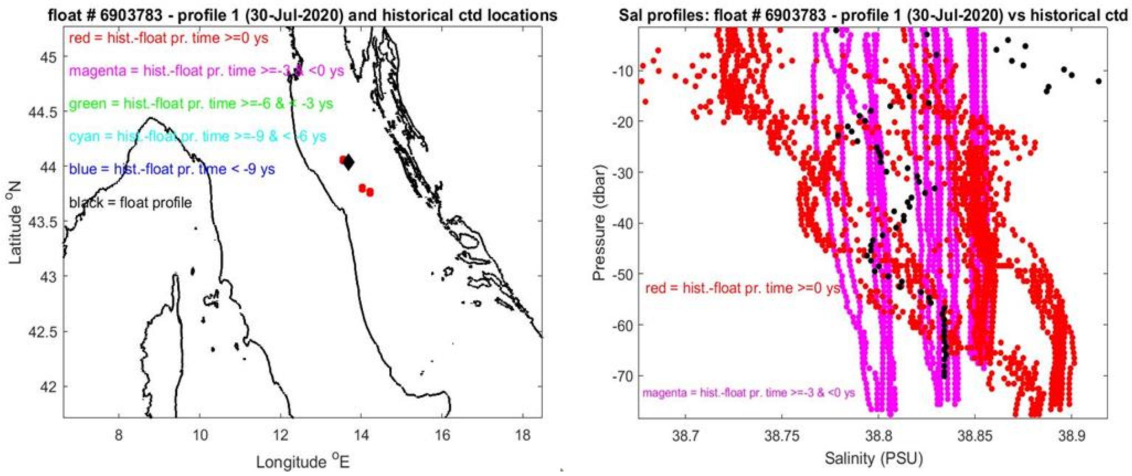

Figure 6: Float WMO 6903783. Locations of the salinity float profile number 1 and historical CTD data (left panel) and the respective salinity profiles (right panel).

The first salinity float profile is compared with the closest (in space and time) salinity reference profile (Figure 7). Figure 8 shows the comparison between 50 and 70 meters (sea bottom). The agreement between the first float salinity profile and the historical salinity profile is quite good. The difference between the salinity data is approximately 0.055 PSU. From the analyses made and as deduced from the historical variability (Figure 11), this difference seems to be well within the natural haline variability of the northern Adriatic.

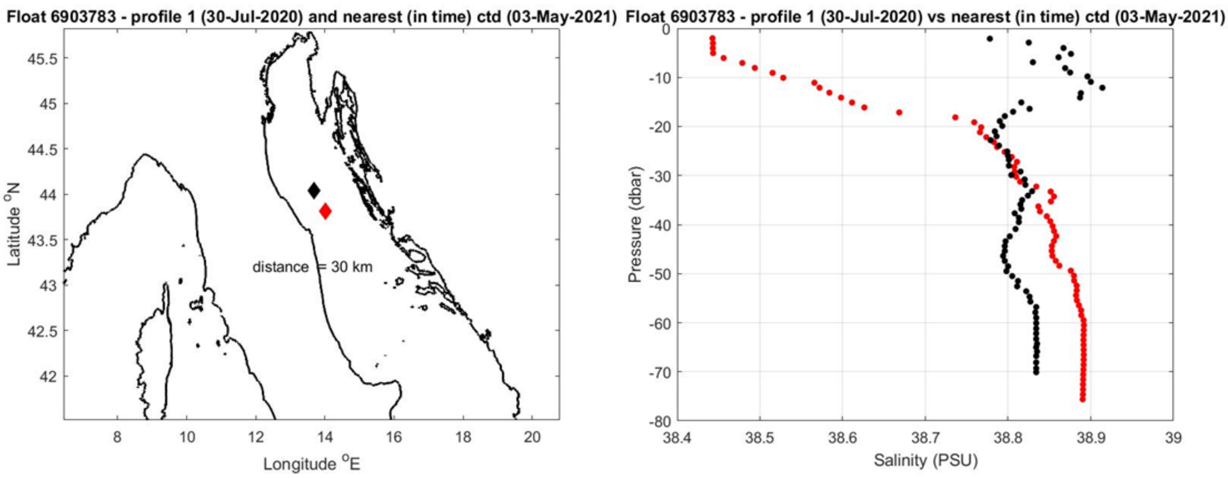

Figure 7: Float WMO 6903783. The salinity float profile number 1 (in black in right panel) is compared to the nearest in time reference profile (red dots). The locations of the two profiles and their distance is given in the left panel.

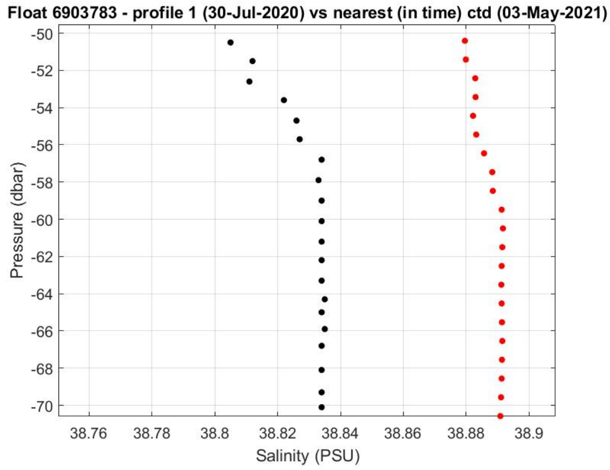

Figure 8: Float WMO 6903783. The salinity float profile number 1 (black dots) compared to the nearest in time reference profile (red dots) at the maximal depth reached by the float.

The analysis of the θ-S diagram of Argo profiles and most recent historical data is made (Figure 9). The comparison shows a good agreement in the deepest layers of the water column.

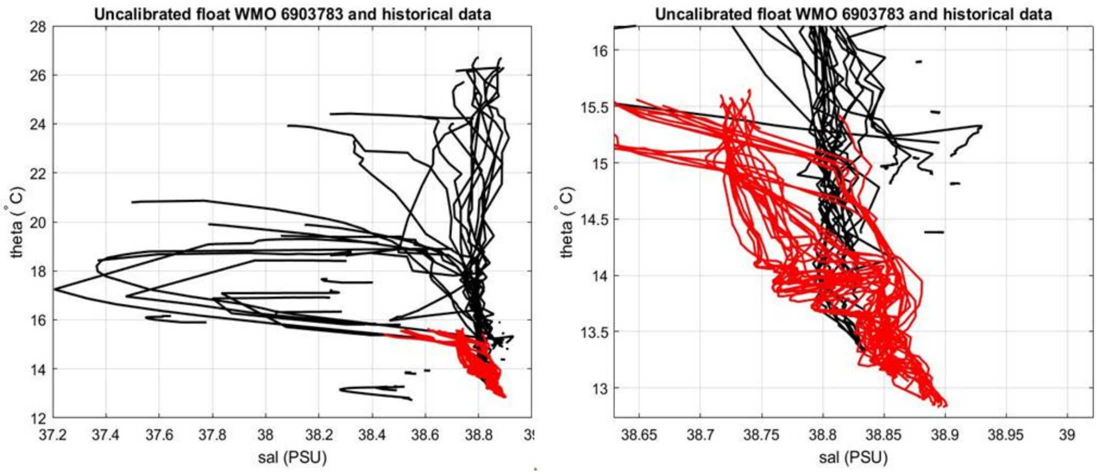

Figure 9: Float WMO 6903783. Uncalibrated float salinity profile (black lines) and historical data (red lines). On the left in the most uniform part of the θ-S curve.

The float salinity and potential temperature data are also compared with the mean of most recent CTDs (Figure 11). To analyzed the variability of float profiles with the historical variability, the standard deviation of all CTDs is used since the most recent CDTs (2019-2021, right panel in figure 10) are scarce and cannot adequately represent the variability of the area. For this analysis CTD profiles within 50km from float profiles are taken in account (Figure 10).

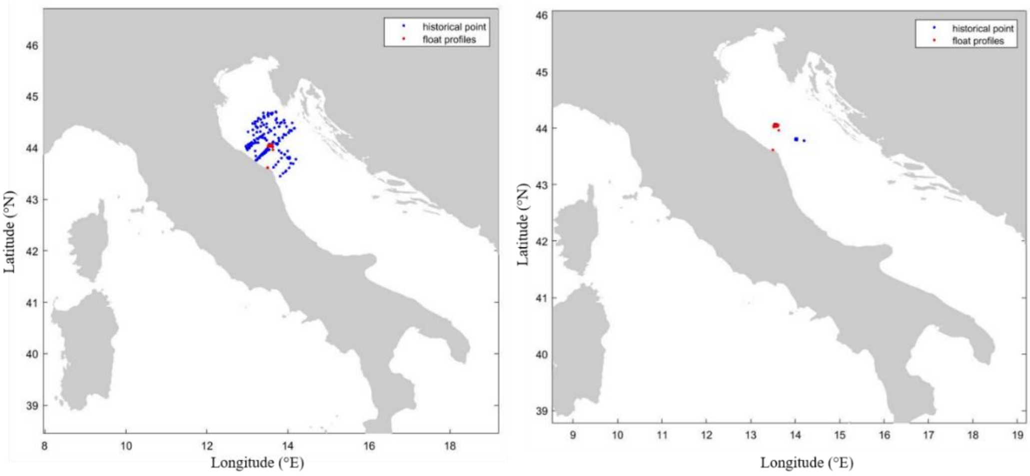

Figure 10: Float WMO 6903783. Locations of float profiles (red dots) and reference profiles selected for statistical comparison (blue dots). Entire CTD reference dataset (left panel), CTD collected from 2019 (right panel).

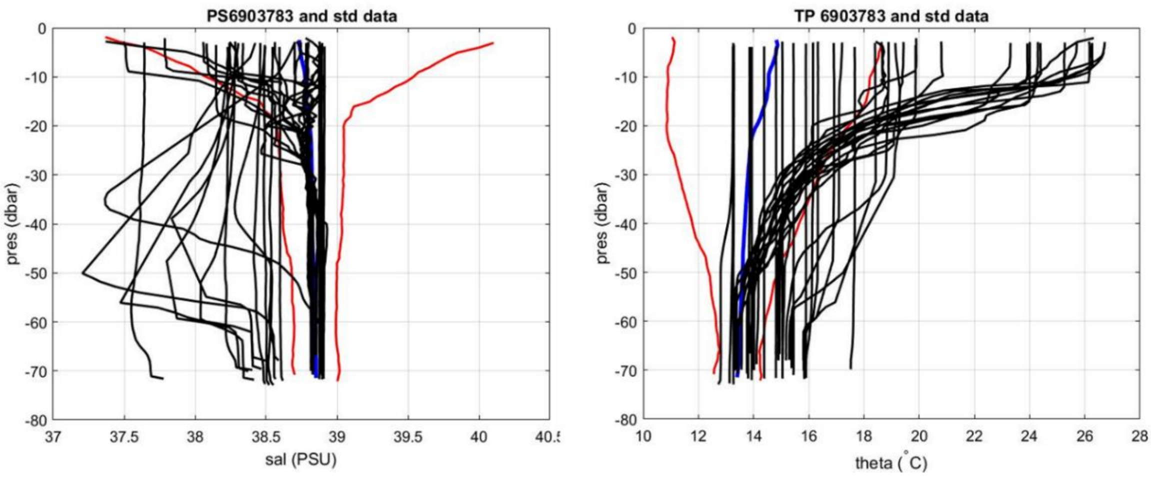

Figure 11: Float WMO 6903783. On the left, uncalibrated float salinity profiles (black lines) and on the right float potential temperature profiles (black lines). The mean of the most recent CTD data is in blue and standard deviation calculated with all CTDs is in red.

The Argo profiles outside the standard deviation range are probably due to some particular convection events and/or some other events that have an important impact on the vertical structure of the water column. Taking in account only the float profiles inside the standard deviation range, the mean of float salinity data and the mean of the recent reference salinity data are compared (Figure 12). The difference between the two salinity means in the deepest layers is less than 0.03.

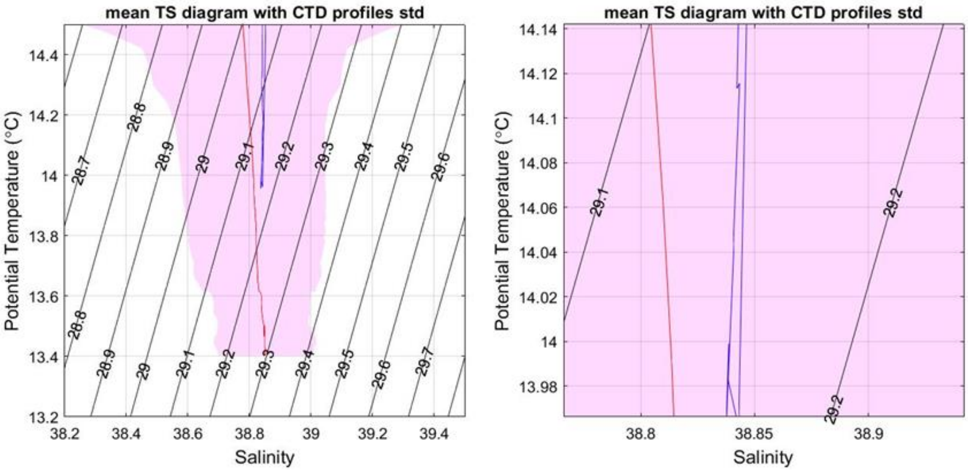

Figure 12: Float WMO 6903783. Mean of float TS diagram (blue lines) and mean of the most recent reference TS diagram (red line). The standard deviation (magenta area) is calculated using the entire reference dataset.

Figure 12 shows that the natural variability of the water column is very high and that there is not a tight relation between temperature and salinity. Salinity variations on specific theta levels are at least about 0.15 near the bottom.

3. WMO 6903800 float

The WMO 6903800 float was deployed in May 2021 and performed 33 cycles (Figure 13). The flags applied in near-real time are QC=1 to all cycles. QC=4 is applied to several levels in some cycles.

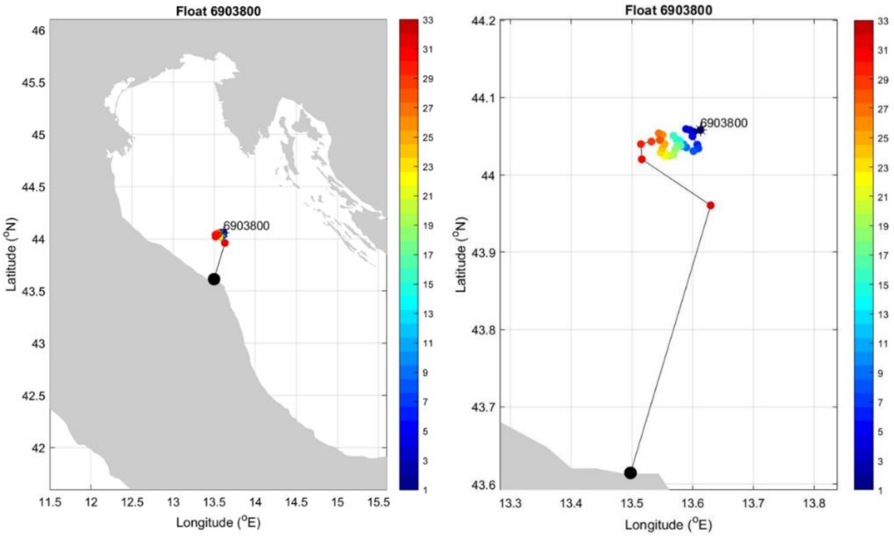

Figure 13: Float WMO 6903800. Trajectory color-coded per cycle number.

3.1 Argo Float Density, Temperature and Salinity measurements

The float operated between the late spring and the early autumn, in this period the warm up generated stratification allowing the formation of a stable pycnocline/thermocline (Figures 14, 15). As observed for the other float (Figure 4), salinity profiles (Figure 16) show great variability due to the different water masses present in the area.

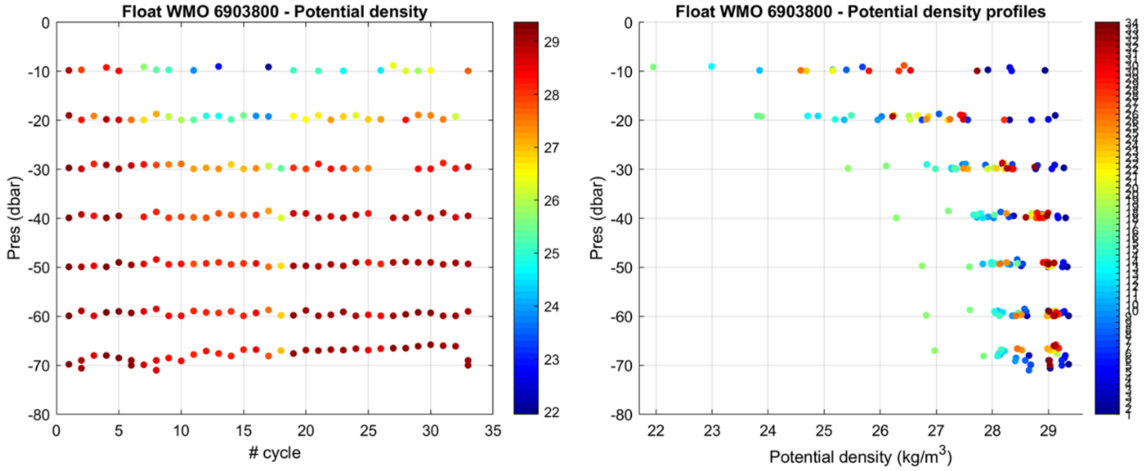

Figure 14: Hovmöller diagram of potential density (left panel), and potential density profiles color-coded per cycle number (right panel) for Argo float WMO 6903800.

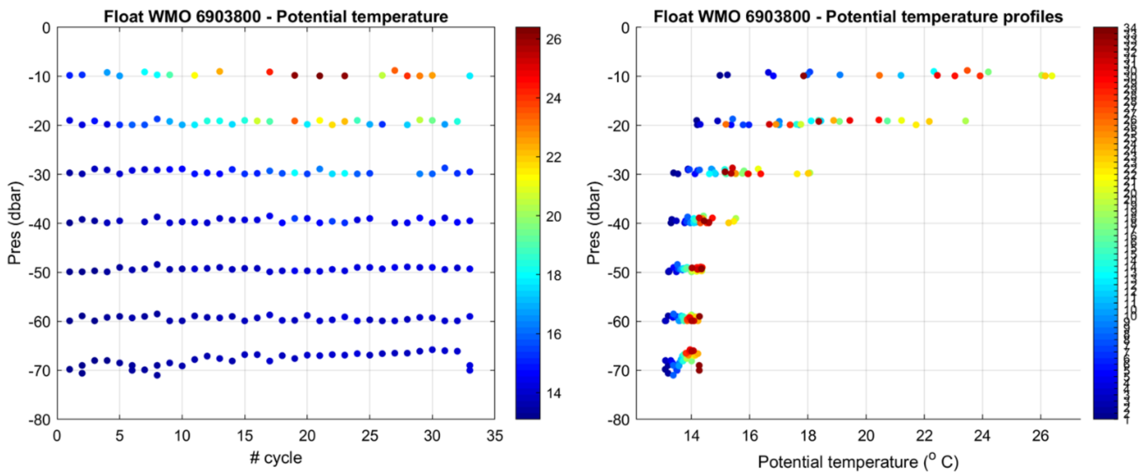

Figure 15: Hovmöller diagram of potential temperature (left panel), and potential temperature profiles color-coded per cycle number (right panel) for Argo float WMO 6903800.

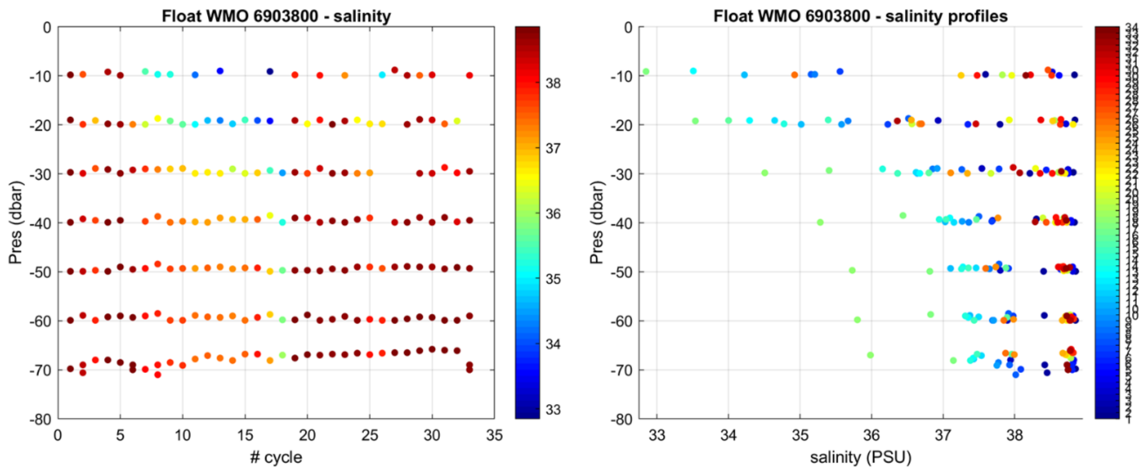

Figure 16: Hovmöller diagram of salinity (left panel), and salinity profiles color-coded per cycle number (right panel) for Argo float WMO 6903800.

The salinity profiles and the theta-salinity (θ-S) diagram of the float are analyzed (Figure 17). A high variability is observed and it is necessary to understand if it is due to a sensor malfunctioning or to natural variability.

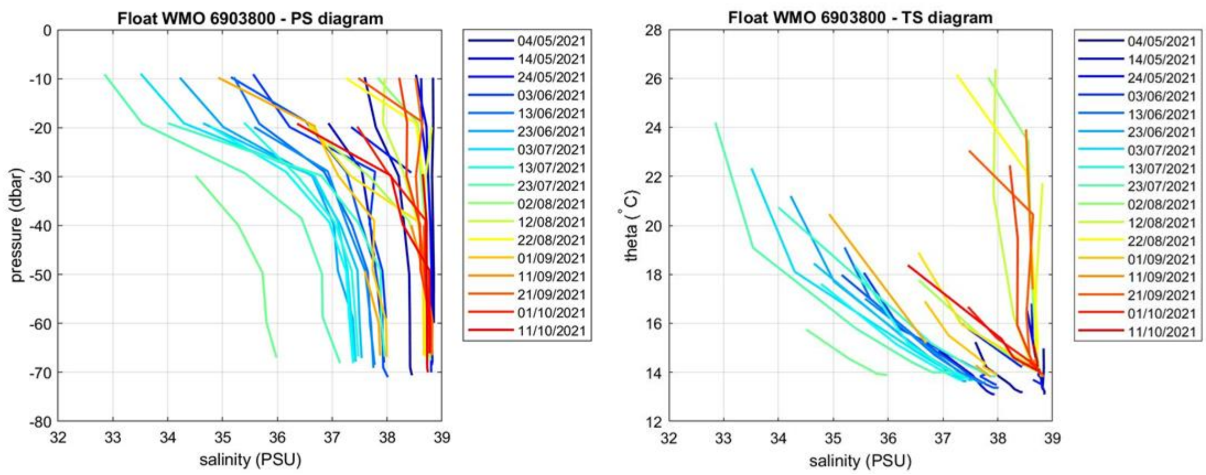

Figure 17: Float WMO 6903800. Float salinity profiles and θ-S diagram color-coded per cycle number.

3.2 Comparison Between Argo Float and reference data

The first salinity float profile is selected to perform a comparison (in time and space) with the historical data. In figure 18 the profile is compared with all recent reference CTD data used in this analysis. The salinity float profile is depicted in black while other colors represent the salinity reference profiles. The red color means that the historical data are more recent with respect to the float ones, while magenta states that the float data are more recent than the historical ones (the maximal difference is 1 year).

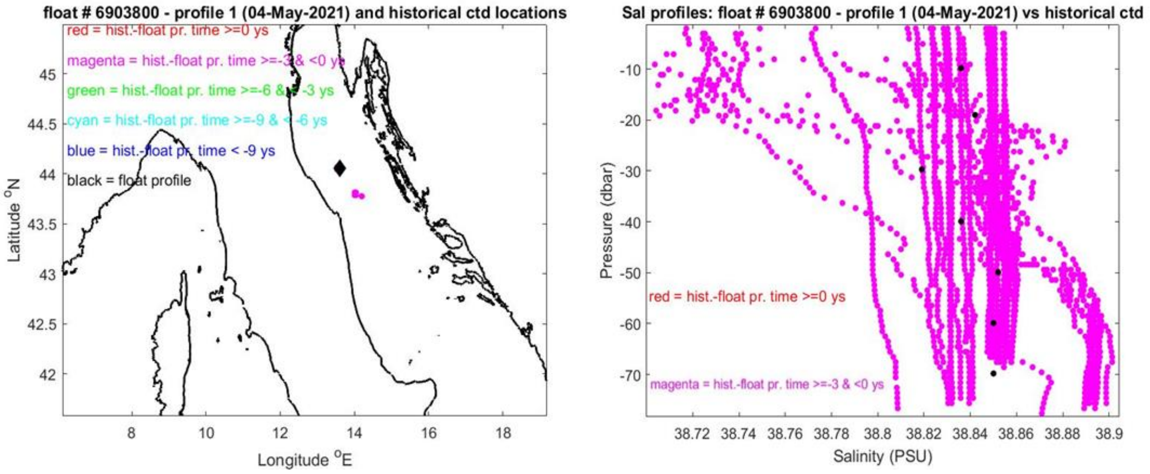

Figure 18: Float WMO 6903800. Locations of the salinity float profile number 1 and historical CTD data (left panel) and the respective salinity profiles (right panel).

The comparison of the first salinity float profile with salinity reference profile at deployment is analysed (Figure 19) and in particular the area where the maximum depth is reached (Figure 20). The agreement between the first float salinity profile and the historical salinity profile is good. The difference between the salinity data is less than 0.01 PSU that is better that the accuracy requested by Argo for floats in open ocean.

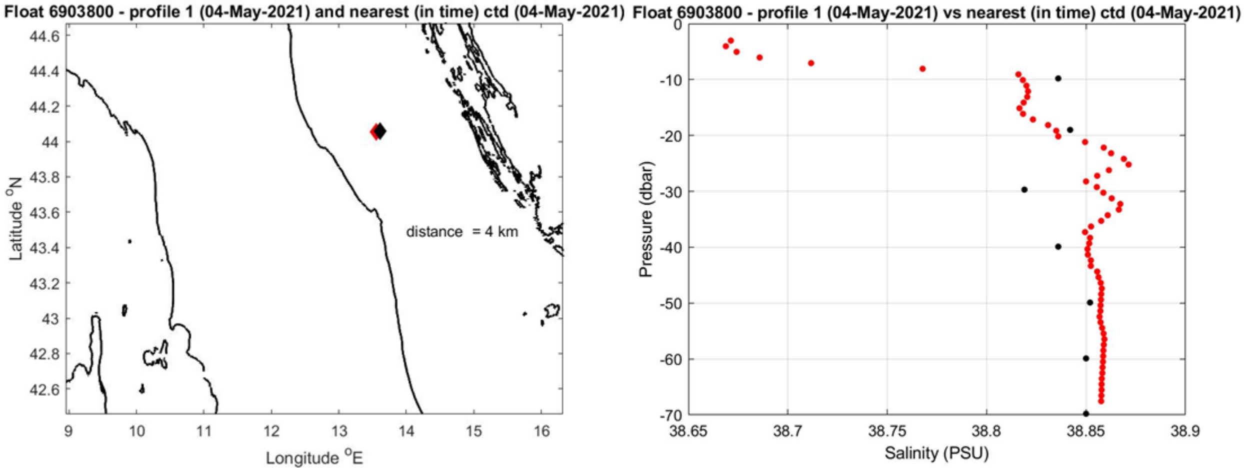

Figure 19: Float WMO 6903800. The salinity float profile number 1 (in black in right panel) is compared to the reference profile at deployment (red dots). The locations of the two profiles and their distance is given in the left panel.

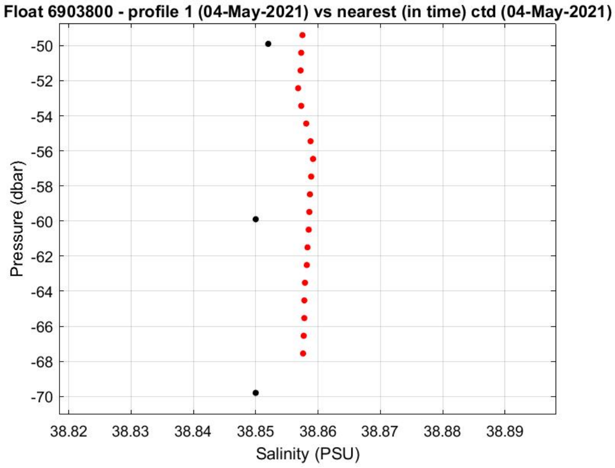

Figure 20: Float WMO 6903800. The salinity float profile number 1 (black dots) compared to the reference profile at deployment (red dots) at the maximum depth reached by the float.

The analysis of the θ-S diagram of profile with most recent historical data is made (figure 21). The comparison shows a good agreement in the deepest layers.

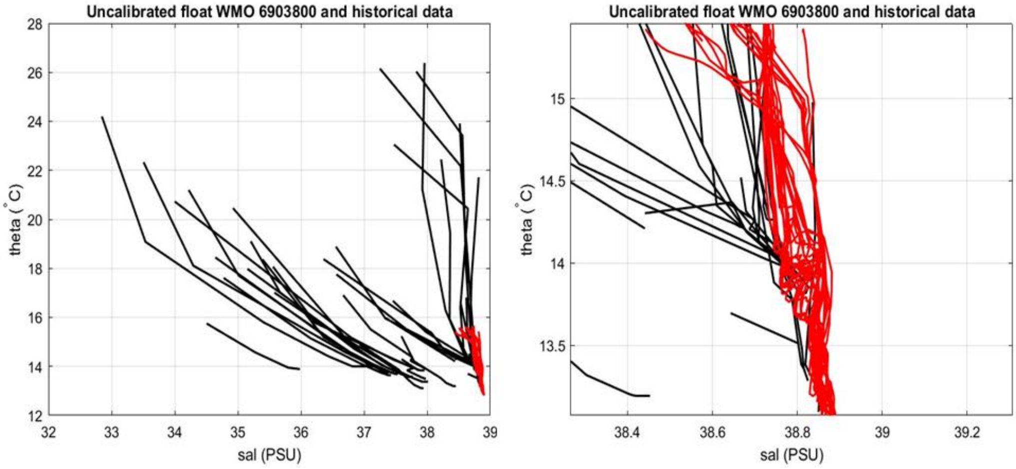

Figure 21: Float WMO 6903800. Uncalibrated float salinity profile (black lines) and historical data (red lines). On the left in the most uniform part of the θ-S curve.

The float salinity and potential temperature data are also compared with the mean of most recent CTD (Figure 22). To analyze the variability of float profiles with the historical variability, the standard deviation of all CTD collected is used. For this analysis only CTD profile near 50 km are taken in account (Figure 10).

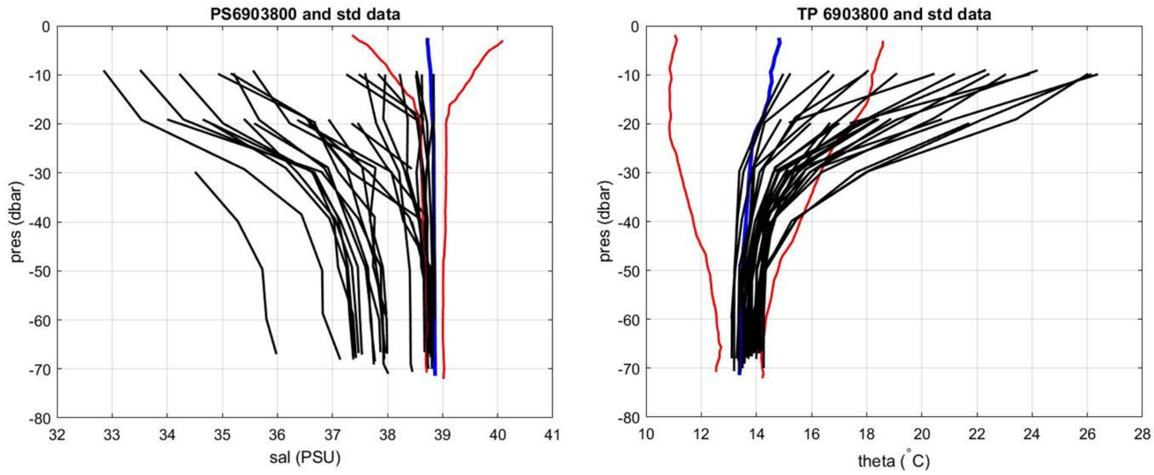

Figure 22: Float WMO 6903800. On the left, uncalibrated float salinity profiles (black lines) and on the right float potential temperature profiles (black lines). The mean of the most recent CTD data is in blue and standard deviation calculated with all CTDs is in red.

Figure 22 shows the potential temperature profiles are comparable with the variability of historical profiles. Regarding the salinity profiles, there are several float profiles that are not in a good agreement with the reference dataset. Taking in account only the float profiles inside the standard deviation range, a comparison between the mean of float salinity data and the mean of the recent CTD salinity data is analyzed (Figure 23). The difference between the two salinity means in the deepest layers is less than 0.05.

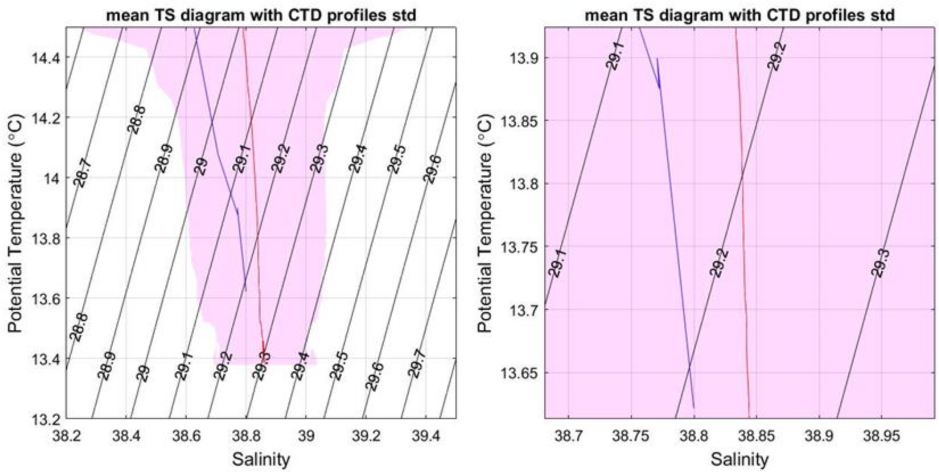

Figure 23: Float WMO 6903800. Mean of float TS diagram (blue lines) and mean of the most recent reference TS diagram (red line). The standard deviation (magenta area) is calculated using the entire reference dataset.

3.3 Comparison with model

The variability of the area was investigated using model output data retrieved from the CMEMS catalogue, using the analysis products for the Mediterranean Sea physics (Clementi et al, 2021). Figure 24 shows the Hovmöller diagram of salinity averaged between 40 and 60 meters depth different days close to first cycles of the float. The model clearly highlights a high zonal salinity gradient and natural variability.

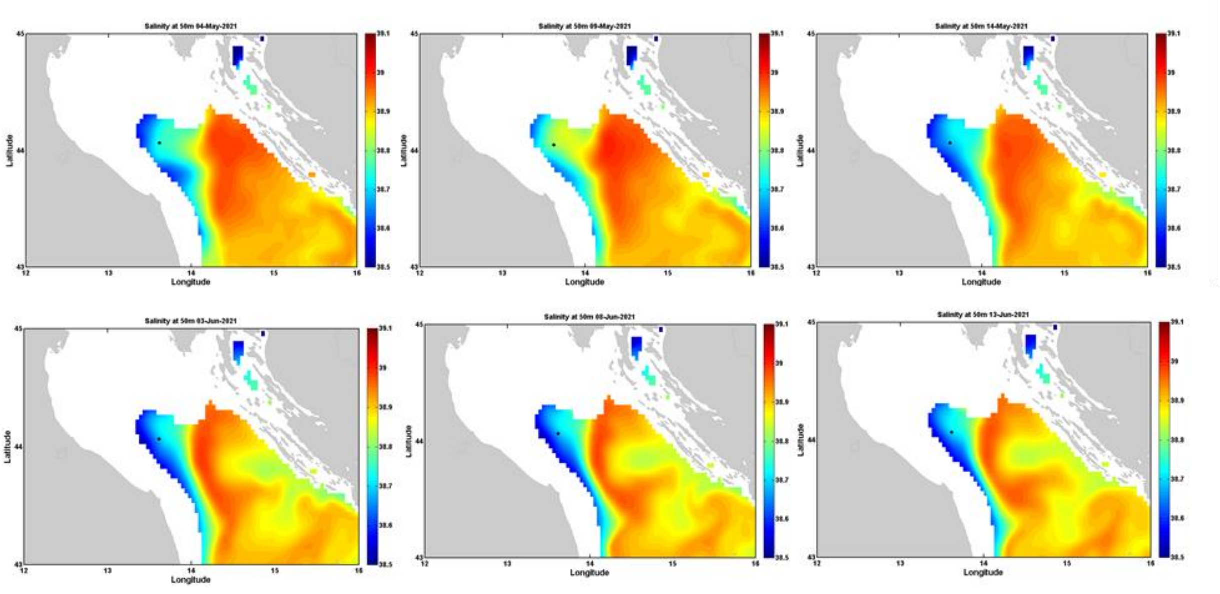

Figure 24: Hovmöller diagram (y-latitude/x-longitude) of Salinity in different days close to the first cycles of the float WMO 6903800. The black dot is the location of the float surfacing.

3.4 Comparison between floats

A comparison between the two floats under analysis is performed (Figure 25), to obtain additional qualitative results. Both floats operate in the same area quite close in time but in different seasons (autumn-winter for WMO 6903783 and spring-summer for 6903800). The two TS curves are quite in agreement where the TS relationship is tighter (difference is about 0.02).

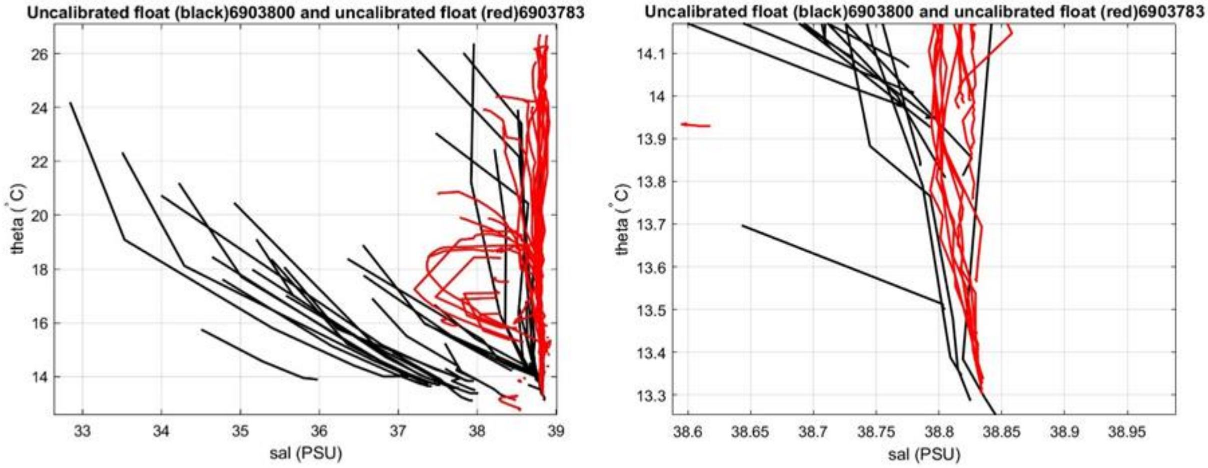

Figure 25: Float WMO 6903800. Comparison between float 6903800 (black line) and 6903783 (red line), on the left, in the most uniform part of the θ-S curve on the right.

4. Conclusions

The delayed mode analysis of salinity data performed for two shallow coastal Argo floats deployed in the North Adriatic Sea is performed. This sea is shallow and with high natural variability. For this reason, an accurate DMCQ is difficult to achieve. The profiles are not deep enough to apply the OWC method and to obtain reliable results. Moreover, the reference dataset in this area is scarce both in spatial and temporal coverage. Several qualitative analyses are performed to try to obtain a more reliable DMQC analysis of these two floats. For the float WMO 6903783, the theta-salinity (θ-S) diagram highlights events that provides dramatic changes in the vertical structure of the water column. There is a quite good agreement between salinity float profiles and most recent reference profiles salinity. The differences between the first salinity float profile and the closest (in space and time) salinity historical profile in the deepest layers is about 0.055 PSU. Most of float salinity profiles ranges within the historical variability (± 0.15 PSU) calculated with the entire CTD dataset, whist some other Argo salinity profiles are outside that range and are probably acquired during specific events that strongly affected the hydrographic characteristics of the water column. For this reason, the difference between the salinity mean of the closest reference salinity profiles and the float salinity that takes into account only the float profiles inside the standard deviation range is computed. This difference is less than 0.03 PSU. For the float WMO 6903800, the theta-salinity (θ-S) diagram shows a high variability of salinity profiles. The comparison between the first Argo salinity profile and the CTD reference profiles closest in time and space is less than 0.01 PSU. The float salinity profiles show a similar behavior as observed for float 6903783, with profiles that depict consistent and rapid changes of the water column properties. Numerical model provided by CMEMS highlights a high zonal salinity gradient and high natural variability. When Argo salinity profiles within the natural variability as described by the historical dataset are considered, there is a quite good agreement between the means of profiles salinity and of reference profiles in the deepest layers (the difference is about 0.05 PSU). The comparison between the theta-salinity (θ-S) diagram of the two floats is good in the deeper layers. After these several analyses, both floats' conductivity sensors appear to work correctly, hence salinity data of the two floats doesn't need to be corrected. The accuracy of Argo salinity in shallow waters of the North Adriatic Sea (maximal depth 80 m) can be estimated in the range of 0.05-0.1 PSU. However, further analysis is required with an updated reference dataset to have a more robust estimate of the conductivity sensor behavior.

5. References

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