DMQC ON FOUR MOCCA-EU FLOATS DEPLOYED IN THE SOUTHERN PACIFIC OCEAN

M. Pacciaroni, G. Notarstefano, A. Gallo

Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS), Trieste, Italy

Table of Contents

1. Introduction

Four Arvor-I were released in the Southern Pacific sector in December 2018 from R/V RENE DESCARTES as part of the ORANGE Transit cruise, in the framework of MOCCA (Monitoring the Oceans and Climate Change with Argo) project.
https://www.euro-argo.eu/EU-Projects/Completed-projects/MOCCA-2015-2020

This report provides details about the delayed mode quality control (DMQC) of floats 3901993, 3901994, 3901995, 3901996 operating for about 3.5 years in the Southern Pacific and providing about 125 cycles at the time of this work.
The quality control is mainly performed on salinity and is based on the OWC method (Cabanes et al., 2016) that is a statistical method that relies on accurate reference datasets. The reference dataset is provided by the Coriolis GDAC (Global Data Assembly) and is based on CTD casts and Argo profiles.

2. Float deployments

The deployments (Table 1) occurred between 20 and 30 December 2018 and these instruments are all alive at the moment of this analysis. Floats trajectory and the last fix positions are shown in Figure 1.

Float type	WMO	Deployment date	Lat.	Lon.	Cycles	Last date	Lat.	Lon.
Arvor-I	3901993	28-Dec-2018	-48.32	-104.31	125	23-May-2022	-45.38	-97.30
Arvor-I	3901994	30-Dec-2018	-51.11	-91.99	125	23-May-2022	-49.24	-31.48
Arvor-I	3901995	20-Dec-2018	-24.93	-142.46	126	25-May-2022	-23.38	-155.32
Arvor-I	3901996	26-Dec-2018	-42.92	-117.99	125	21-May-2022	-39.35	-116.11

Table 1. Status information for the four Arvor-I floats deployed in the Southern Pacific Ocean.

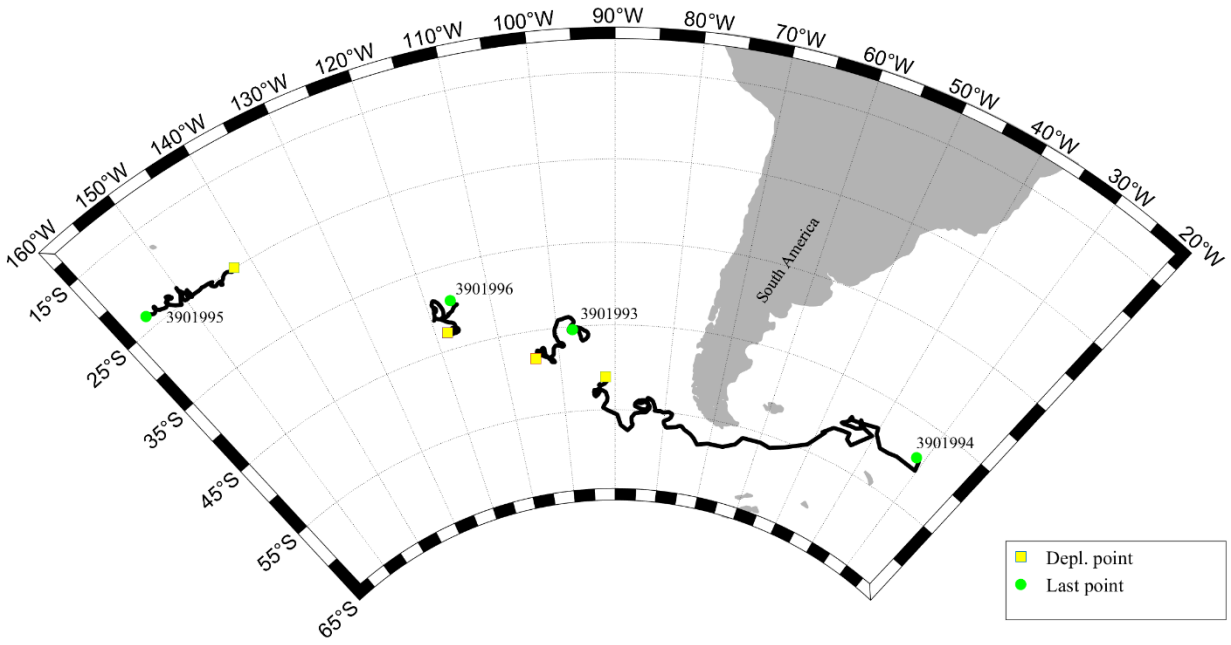

Figure 1. Trajectories and last positions at the end of May 2022.

3. OWC initial setup

The OWC procedure allows the editing of a configuration text file. This file contains the paths that are necessary to run the analysis and a list of parameters used in the initial phase of the method.

Some of these parameters are listed hereafter:

- The maximum number of historical casts

  CONFIG_MAX_CASTS=300

- The spatial decorrelation scales, in degrees

  MAPSCALE_LONGITUDE_LARGE=5

  MAPSCALE_LONGITUDE_SMALL=0.5

  MAPSCALE_LATITUDE_LARGE=4

  MAPSCALE_LATITUDE_SMALL=0.5

- The temporal decorrelation scale, in years

MAPSCALE_AGE_LARGE=50

MAPSCALE_AGE_SMALL=10

- Excluding part of the upper water column, dbar

  MAP_P_EXCLUDE=700

- Using only historical data that are within a range (+/- delta) from float data, dbar

  MAP_P_DELTA=250

Concerning the reference dataset, both CTD and Argo float data are used in this study:
CTD and ARGO for_DMQC: CTD2021V02 & ARGO2021V03

The files are available at ftp.ifremer.fr

4. Arvor-I 3901993

Figure 2 shows the selected dataset distribution with respect to the chosen configuration.

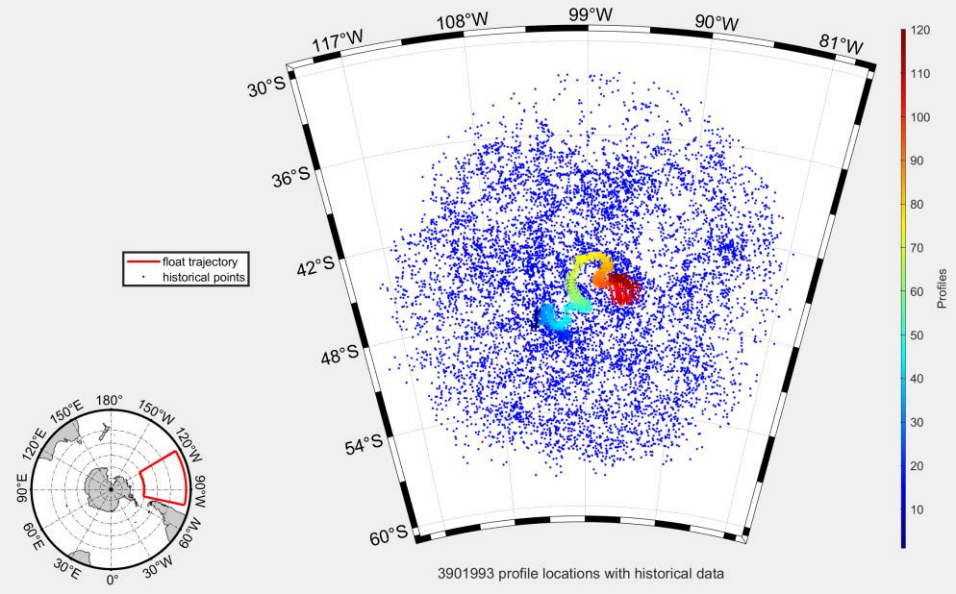

Figure 2. Float trajectory (color coded cycles) and the historical data points (blue).

Θ-S diagram and temperature and salinity profiles are reported in Figures 3, 4, 5, showing the seasonal variability in the upper 100 m and no presence of fronts. In general, a quite uniform Θ-S relation is observed in the deep layers suggesting no potential drift. Hence the analysis can be conducted in this deep zone below 1500 dbar.

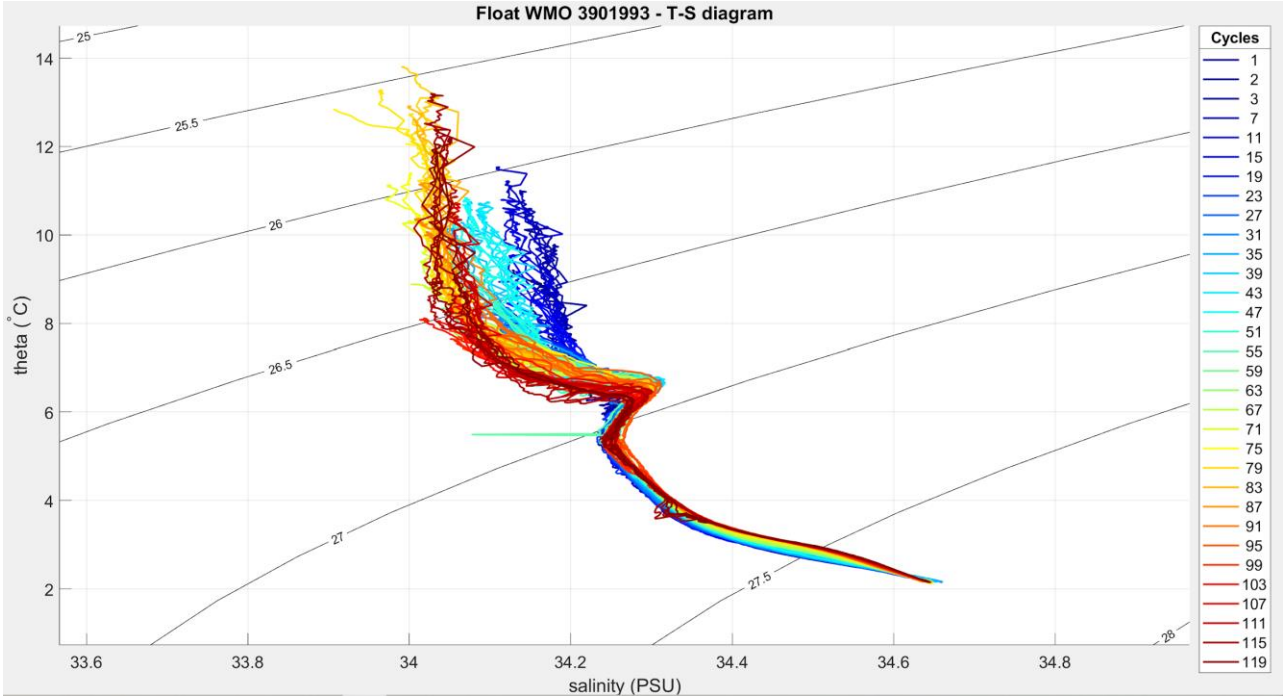

Figure 3. Θ-S diagram with color coded cycles.

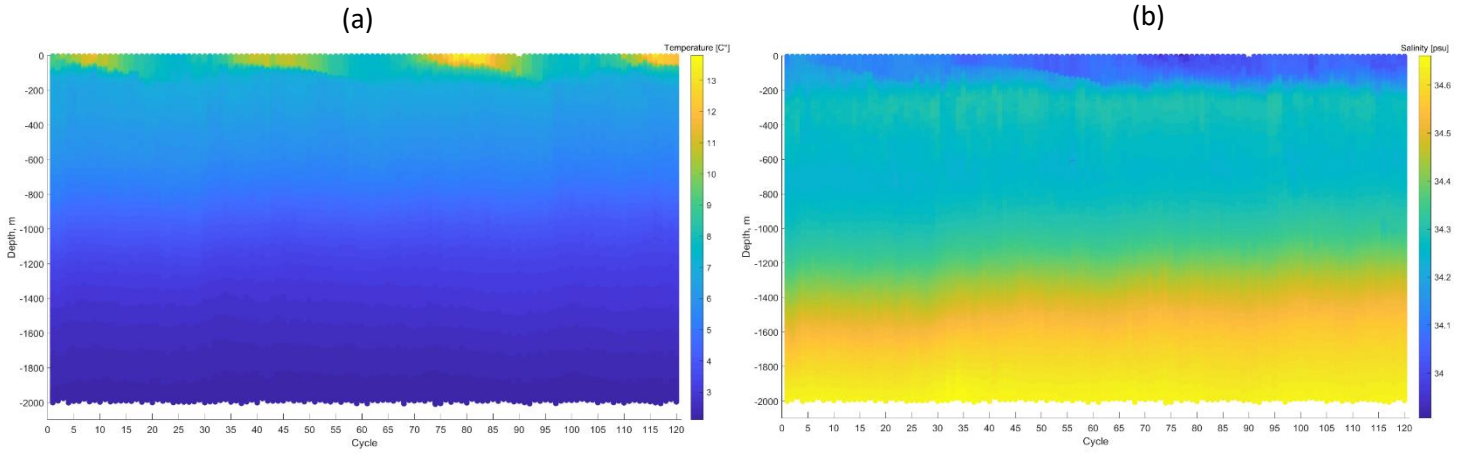

Figure 4. Hovmöller diagrams of (a) temperature and (b) salinity.

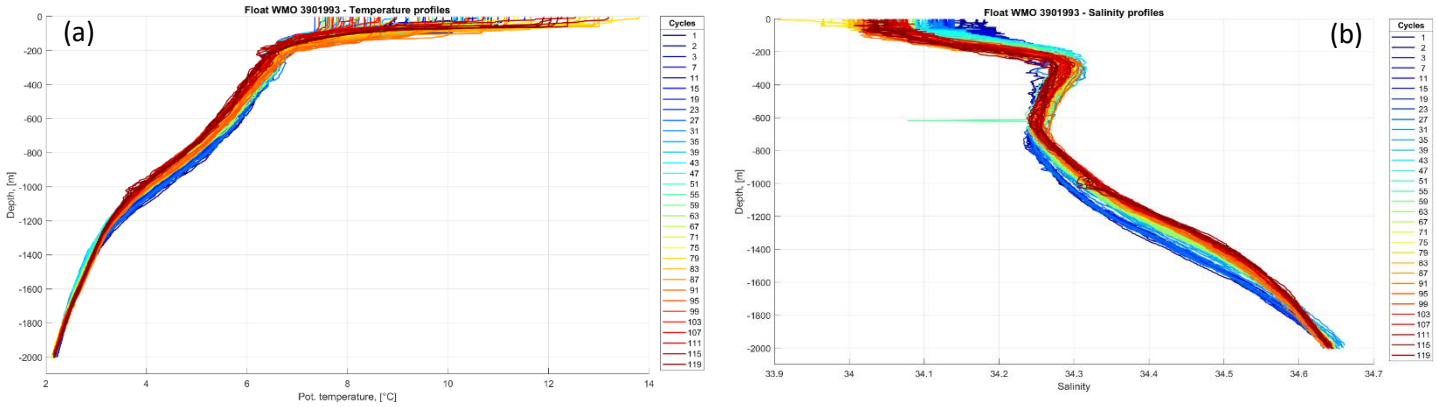

Figure 5. Temperature (a) and salinity (b) vertical profiles with color coded cycle number.

Before running the OWC method, it is possible to select a potential temperature Θ range as well as a depth range and set other parameters in order to optimize the calibration. This is done in the Matlab routine 'set_calseries'.

For this float, 'set_calseries' was configured to select data below 1500 dbar and no Θ constraint (Table 2).

Description	Parameter	Value
specify the cycle(s) to break the series	breaks	[ ]
maximum number of breaks	max_breaks	3
sequence of numbers that characterize the cycle series	calseries	[ones(1,num_cycles)]
sequence of profile numbers	calib_profile_no	PROFILE_N°
use theta less than	use_theta_lt	[ ]
use theta greater than	use_theta_gt	[ ]
use pressure less than	use_pres_lt	[ ]
use pressure greater than	use_pres_gt	[1500]
percentage of good data on a level to consider it included in the analysis	use_percent_gt	0.5

Table 2. Parameters used in 'set_calseries' file.

The fitting results are shown in Figure 6, in which the green lines and bars represent the calibrated data and the relative error (green for one time, blue for two times the standard deviation). The red line refers to the "one to one" profile fit and gives an estimation of how variable the float data are relative to the historical data.The more noisy is the curve, the more uncertain is the fit (it could depend on the local natural variability or not a good selected representative dataset). In this case a good fit is observed.

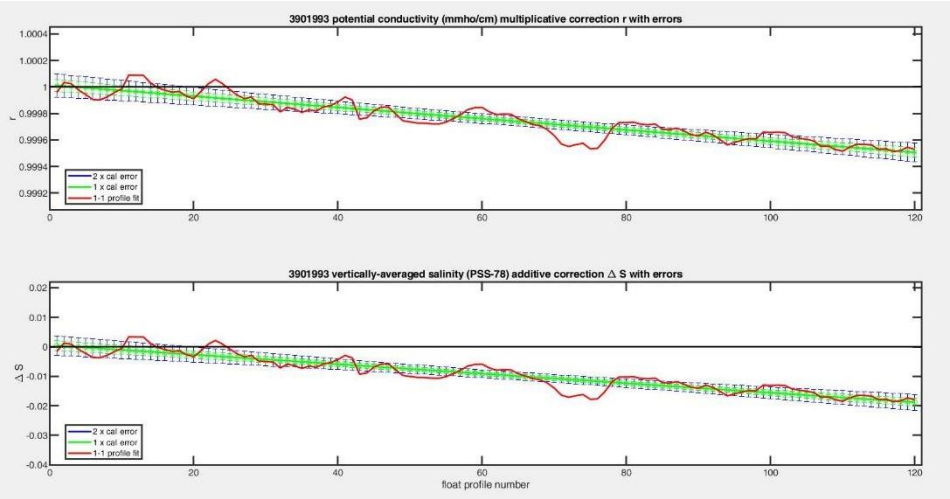

Figure 6. Potential conductivity multiplicative term (upper panel), vertically averaged salinity corrections (lower panel).

In Figure 7, the entire time series provides information on drift presence since cycle 34 and Figure 8 shows better this behavior. Anyway, the error in the mapped field (red bars) is lower than the suggested correction and the OWC fit is reliable. Hence, the correction can be applied (Table 3).

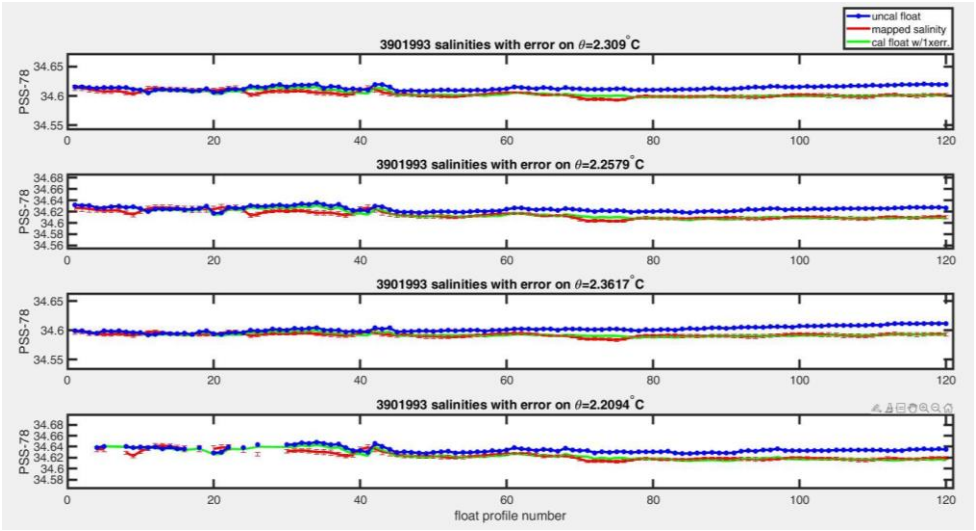

Figure 7. Source (blu), calibrated (green) and mapped (red) salinity data when considering a specific theta level.

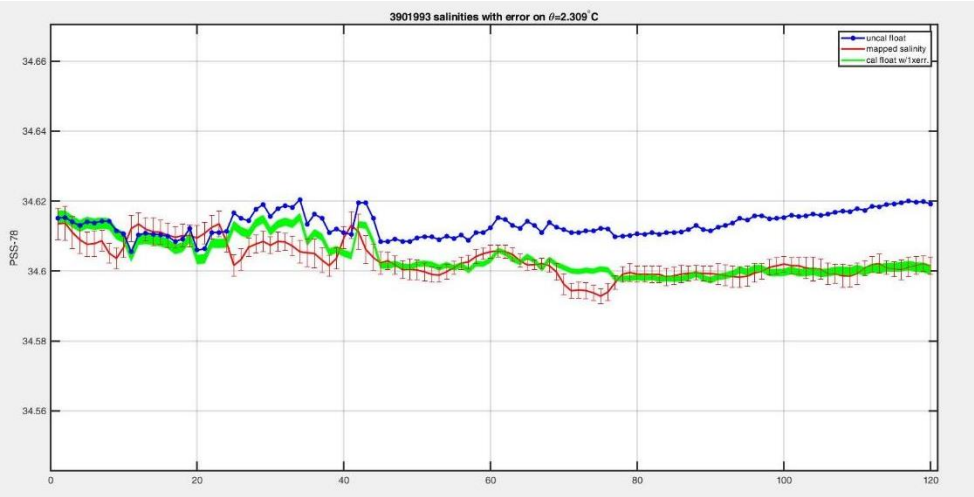

Figure 8. Source (blu), calibrated (green) and mapped (red) salinity data on the 2.309 °C theta level.

In Figure 9, the range of depth and temperature where OWC works can be appreciated; in particular the green lines represent the potential temperature (theta) levels chosen (by the system) to perform the analysis.

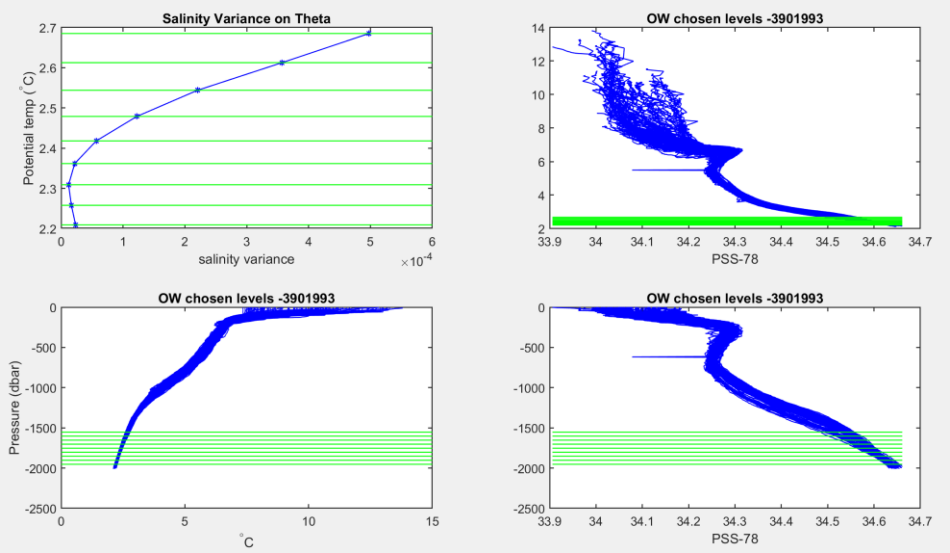

Figure 9. The 10 selected theta levels (green lines) are related to the minimal salinity variance on theta and to the Θ-S diagram and the vertical temperature and salinity profiles.

In Figure 10 the DMQC summary graphs for salinity are reported. The upper plot represents the vertically averaged difference between the calibrated and source salinity. The two plots in the middle refer to the QC associated to the adjusted and source salinity, respectively. The last plot shows the averaged adjusted error.

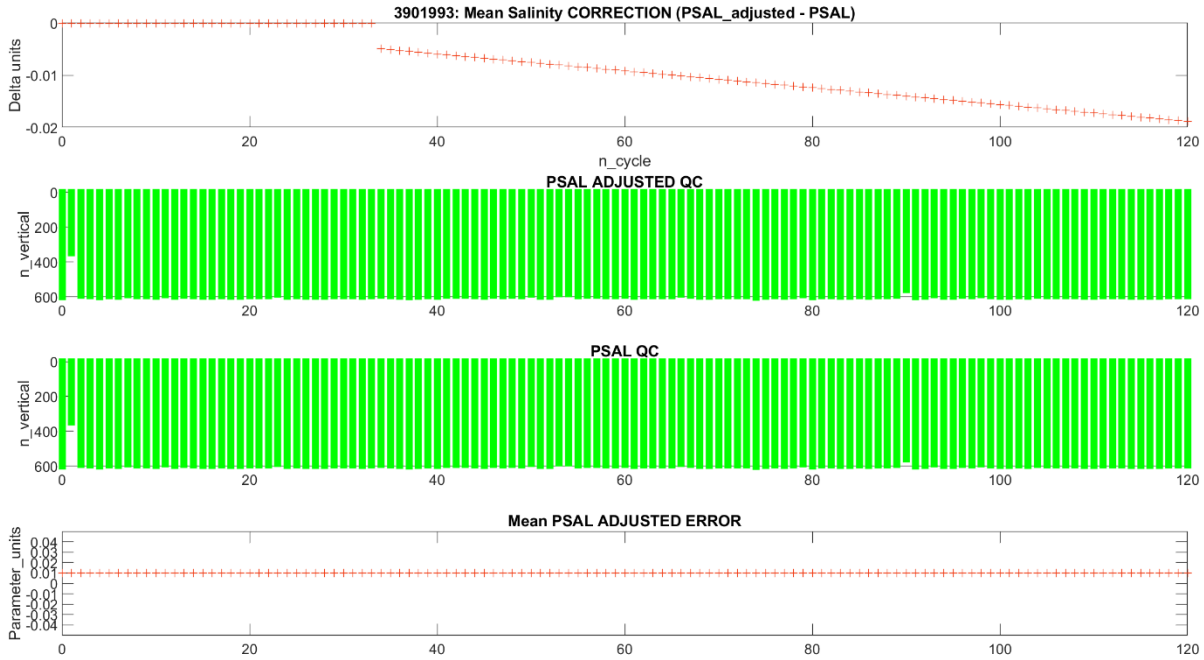

Figure 10. Summary of DMQC decisions on the salinity parameter: upper plot for corrections, the two in the middle for QC (adjusted and source, green means QC 1) and one plot below for the averaged adjusted salinity error.

Float WMO	Status	Correction on salinity	Flag applied to PSAL_ADJUSTED
3901993	Active	not required	Profiles 1 to 33 →QC 1
		required	Profiles 34 to 120 →QC 1

Table 3. Actions for this float.

5. Arvor-I 3901994

For the WMO 3901994 float, the configuration file was modified in the spatial and temporal decorrelation scales, the longitudinal mapping scale being more than two times the latitudinal one and searching for more recent reference data; this was done after suggestion from colleagues that work on DMQC in similar areas. The float in fact was deployed in the southern Pacific but, unlike the other three floats, traveled many miles reaching the southern Atlantic area (see map in Figure 11).

MAPSCALE_LONGITUDE_LARGE=5

MAPSCALE_LONGITUDE_SMALL=0.5

MAPSCALE_LATITUDE_LARGE=2

MAPSCALE_LATITUDE_SMALL=0.5

MAPSCALE_AGE_LARGE=10

MAPSCALE_AGE_SMALL=2

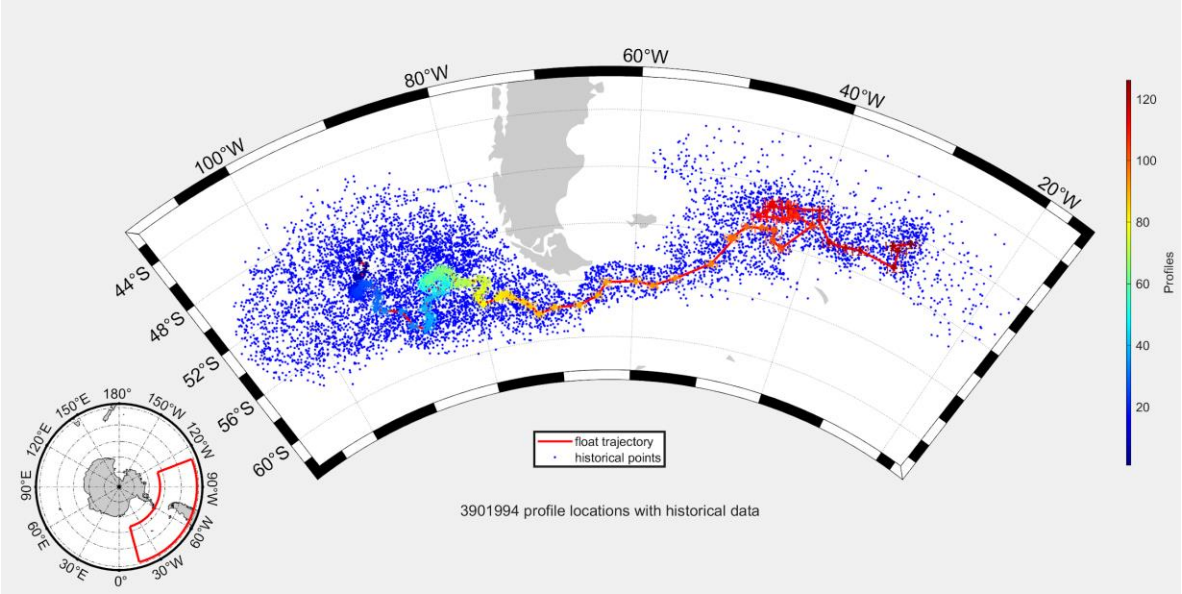

Figure 11. Float trajectory (color coded cycles) and the historical data points (blue).

The Θ-S diagram in Figure 12 and the Hovmöller graphs in Figure 13 reveal strong changes after cycle 90 in the water column, both in temperature and salinity. The float in fact entered in an area with high natural variability (see also Figure 15).

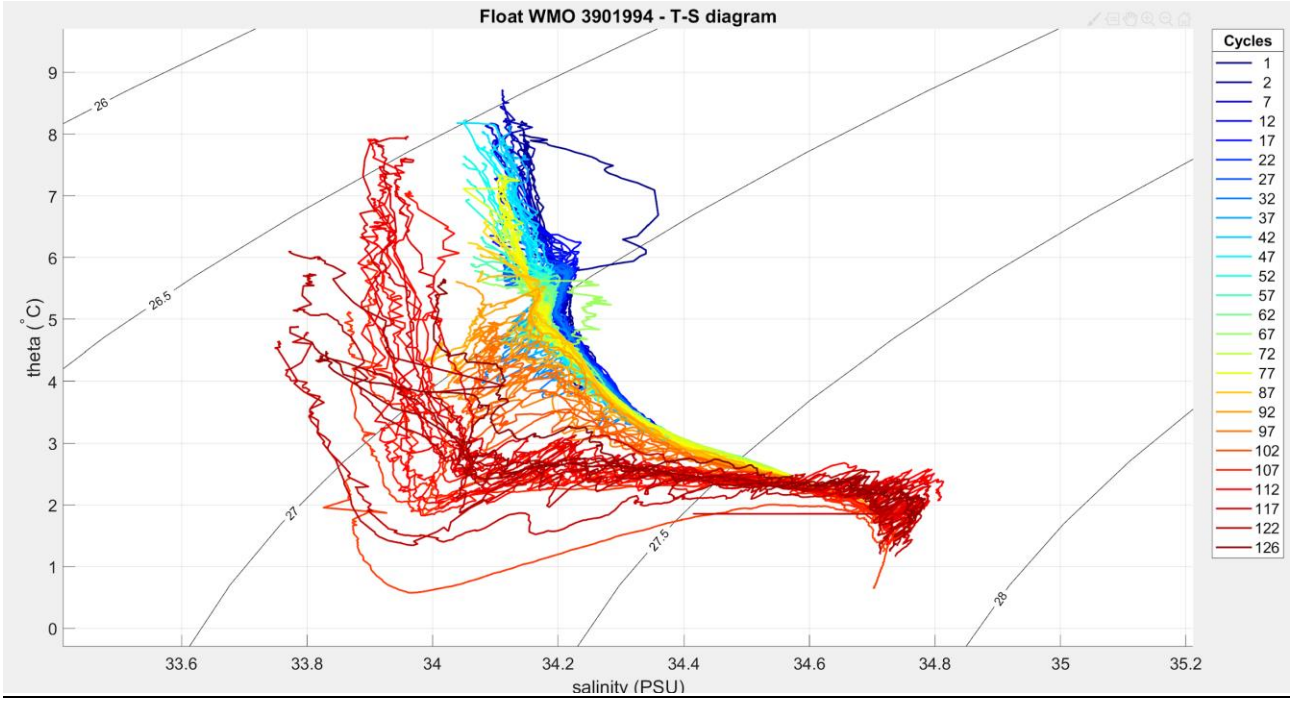

Figure 12. Θ-S diagram with color coded cycles.

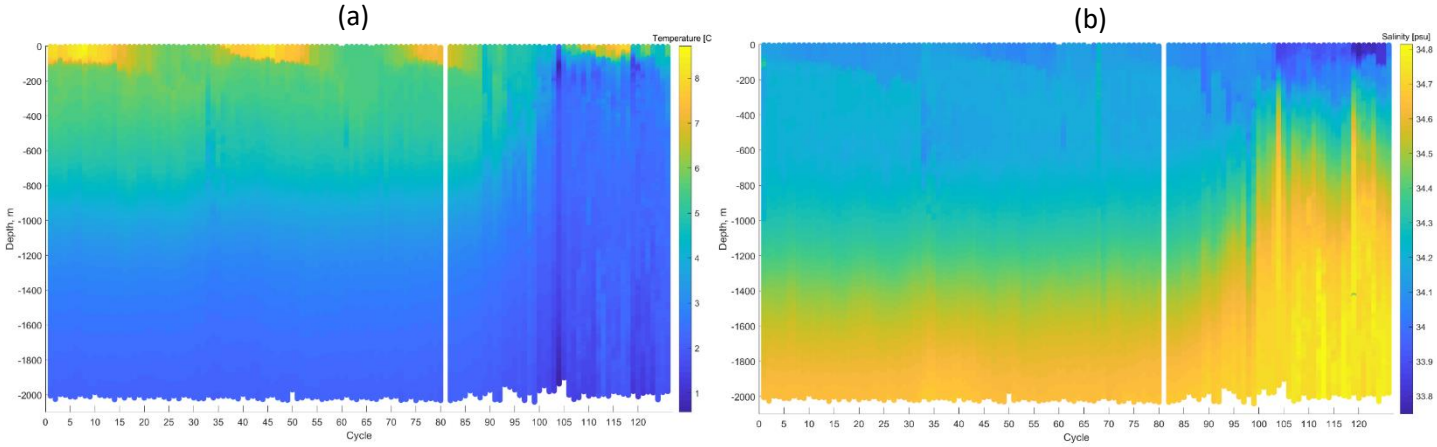

Figure 13. Hovmöller diagrams of (a) temperature and (b) salinity.

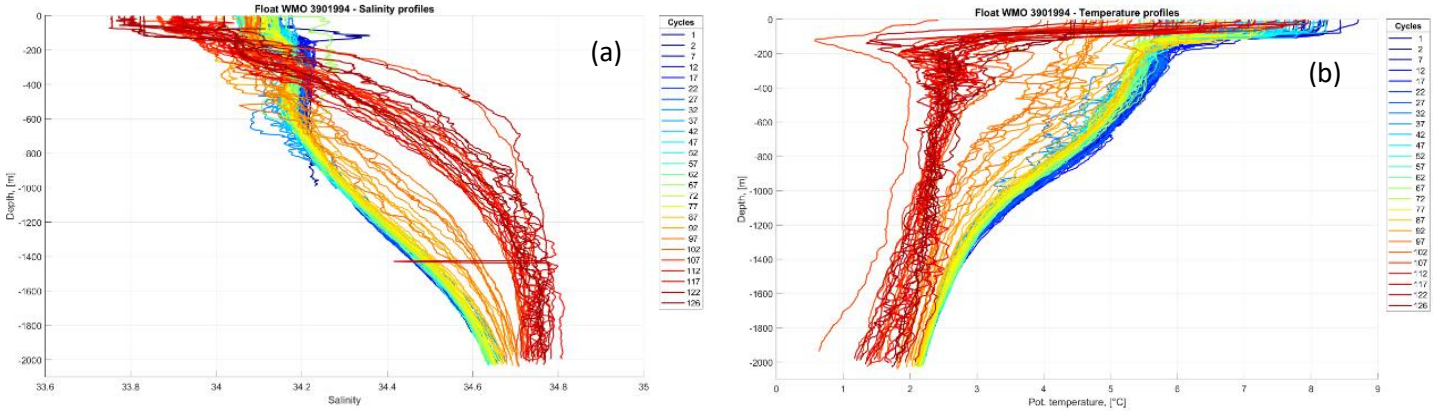

Figure 14. Temperature (a) and salinity (b) vertical profiles with color coded cycle number.

The 'set_calseries' routine was configured with a split of the series in 2 parts at cycle 89, when the float crossed the Drake Passage; a range of temperature was also defined and the pressure was set greater than 1200 dbar (Table 4).

Description	Parameter	Value
Specify the cycle(s) to break the series	breaks	[ ]
Maximum number of breaks	max_breaks	3
sequence of numbers that characterize the cycle series	calseries	[ones(1,89) 2*ones(1,n-89)]
sequence of profile numbers	calib_profile_no	PROFILE_N°
use theta less than the specified value	use_theta_lt	[2.4]
use theta greater than the specified value	use_theta_gt	[1.9]
use pressure less than the specified value	use_pres_lt	[ ]
use pressure greater than the specified value	use_pres_gt	[1200]
percentage of good data on a level to consider it included in the analysis	use_percent_gt	0.5

Table 4. Parameters used in 'set_calseries' file.

The OWC results, reported in Figure 15, show that the float is working fine from the beginning up to about cycle 102 and the suggested corrections are below the instrument accuracy. On the other hand, many spikes are detected after cycle 102 in the "one to one" profile fit (red line). Indeed, the red line appears very noisy and this behavior most likely depends on high local natural variability. In this case a qualitative comparison with CTD or Argo profiles could help to overcome this issue.

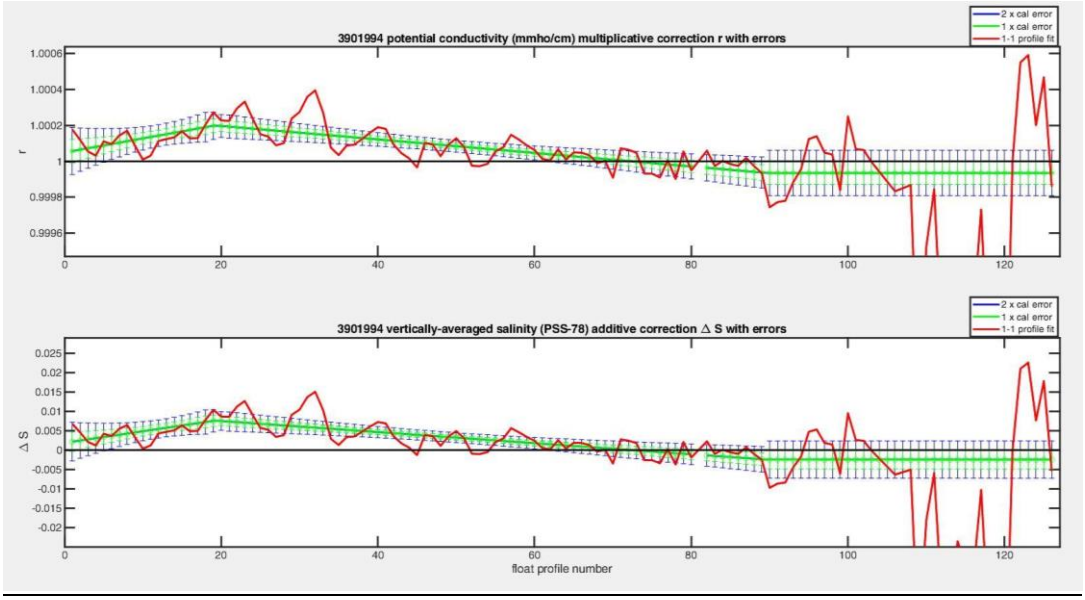

Figure 15. Potential conductivity multiplicative term (upper panel), vertically averaged salinity corrections (lower panel).

Results on four specific potential temperatures are shown in Figure 16 and provide information on any potential salinity drift. One of these selected theta levels is shown in detail in Figure 17.

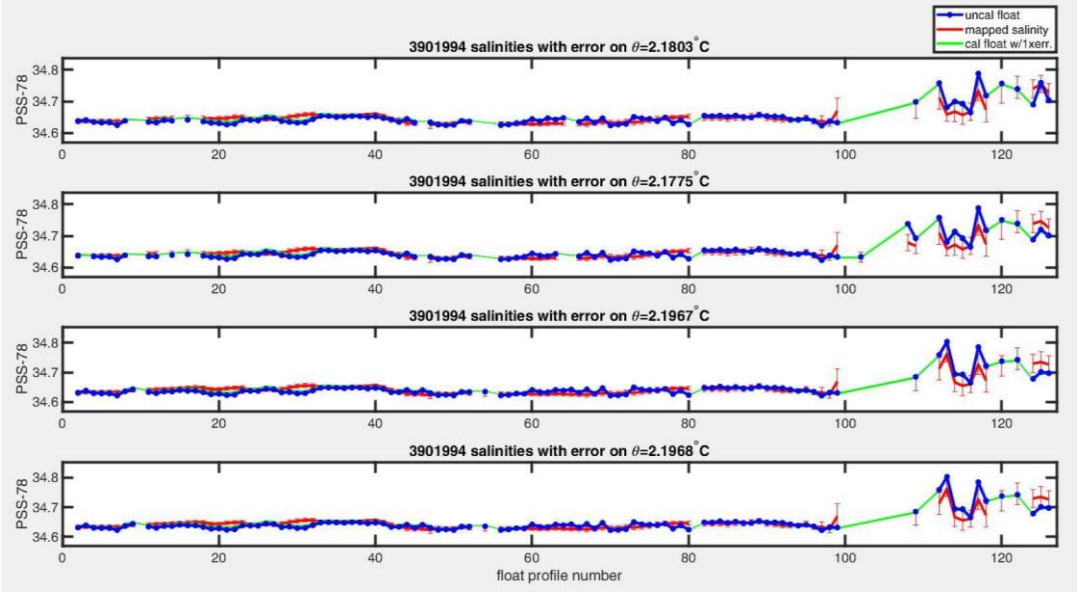

Figure 16. Source (blu), calibrated (green) and mapped (red) salinity data when considering a specific theta level.

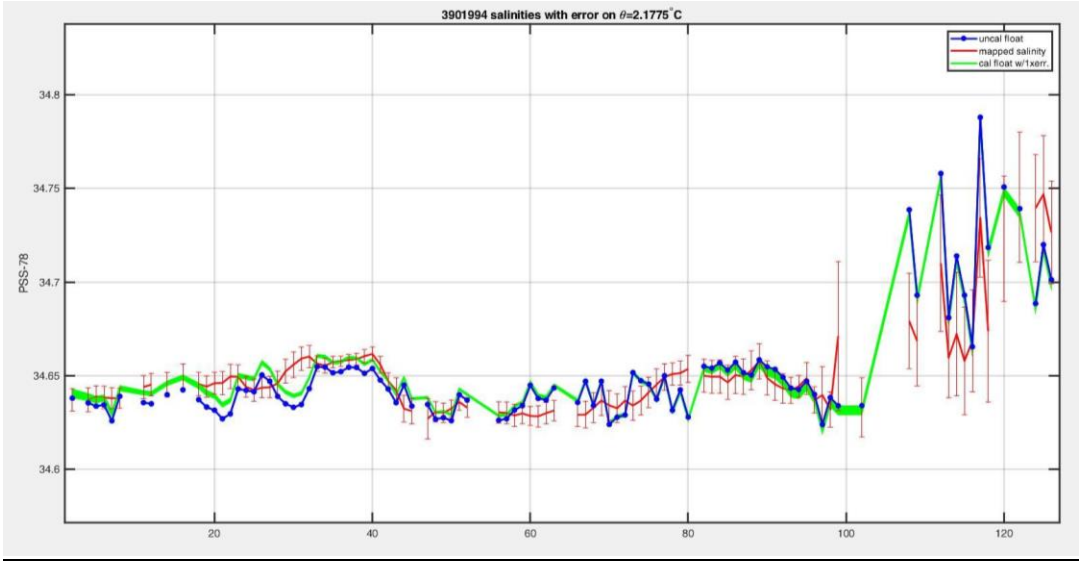

Figure 17. Source (blu), calibrated (green) and mapped (red) salinity on the 2.1775 °C theta level.

The 10 selected theta levels are shown in Figure 18.

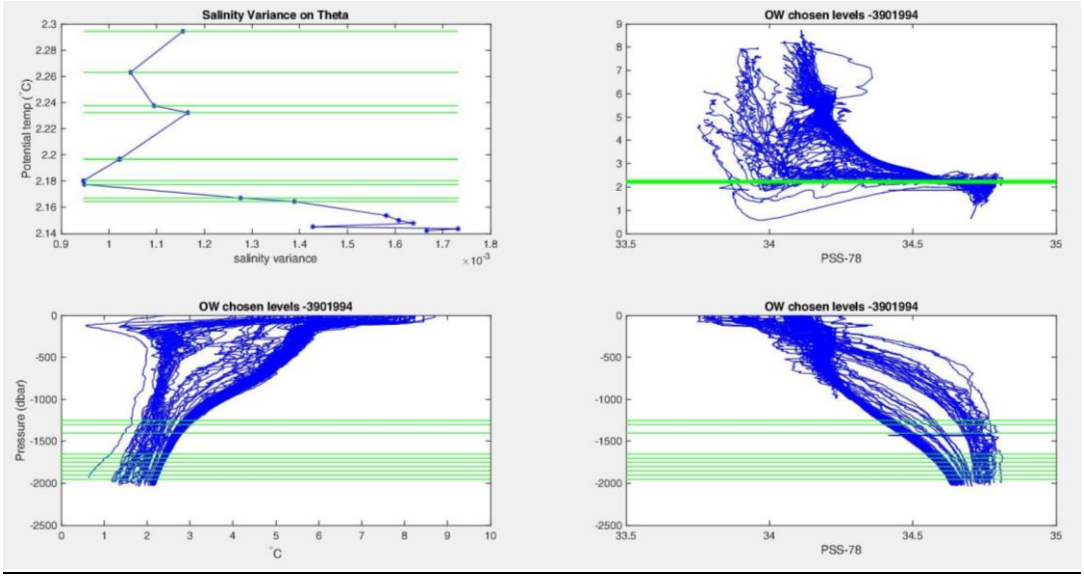

Figure 18. The 10 selected theta levels (green lines) are related to the minimal salinity variance on theta and to the Θ-S diagram and the vertical temperature and salinity profiles.

In Figure 19 the DMQC summary graphs for salinity are reported. In this case no corrections are applied. The adjusted salinity QC was changed from 1 to 2 starting from cycle 102. This decision is taken after the comparison with other data, CTD casts and mainly Argo profiles (the data selection tool used is available at https://dataselection.euro-argo.eu/), performed in the area around the float

trajectory from cycle 98 to 119 in the same period (Figure 20). The plots in Figure 20 show a good agreement between measurements especially in the deep zone; there is no evidence of drift or offset. This flag (QC 2) will be reviewed when the float will reach an area with normal thermohaline variability, which will help to understand the presence or not of salinity drift.

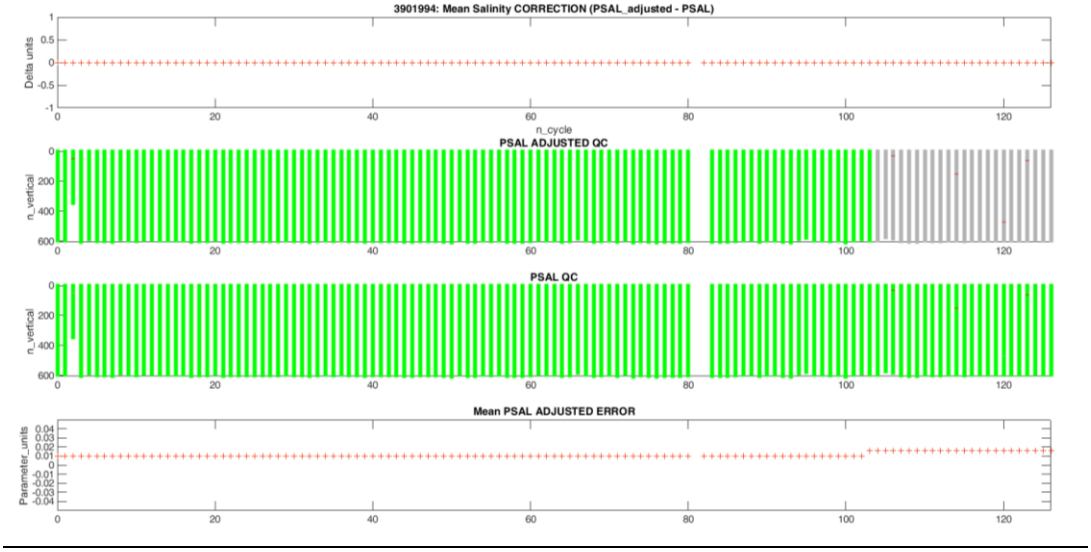

Figure 19. Summary of DMQC decisions on salinity parameter: upper plot for corrections, the two in the middle for QC (adjusted and source, green means QC 1, red QC 4, grey QC 2) and one plot below for the averaged adjusted salinity error.

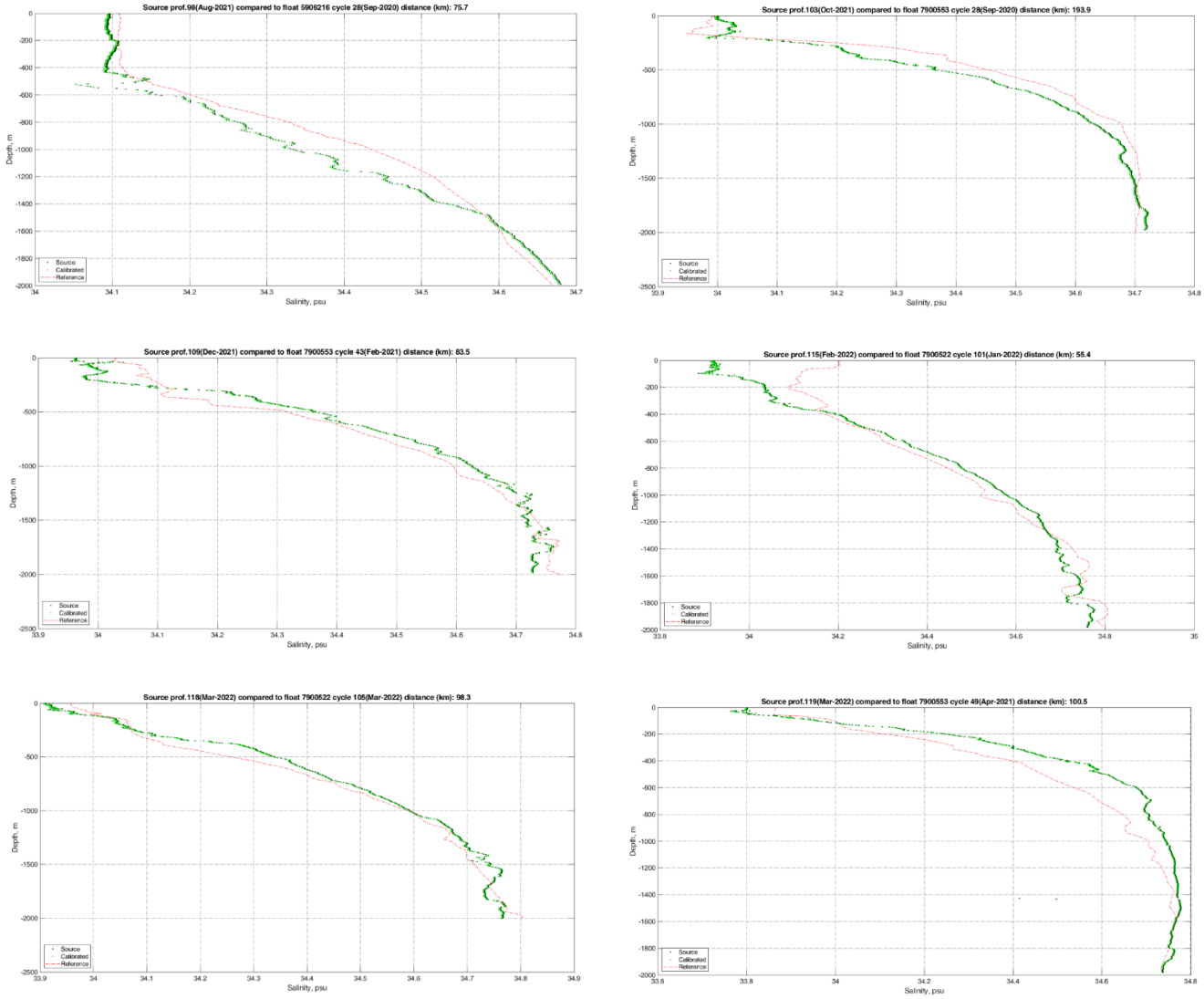

Figure 20. Arvor-I 3901994 profiles (black uncalibrated and green calibrated) comparison with respect to the selected Argo floats (red) in the area to be investigated.

Float WMO	Status	Correction on salinity	Flag applied to PSAL_ADJUSTED
3901994	Active	not required	Profiles 1 to 102 →QC 1
		not required	Profiles 103 to 126 →QC 2

Table 5. Actions for this float.

6. Arvor-I 3901995

Float trajectory and the selected reference dataset distribution is reported in Figure 21.

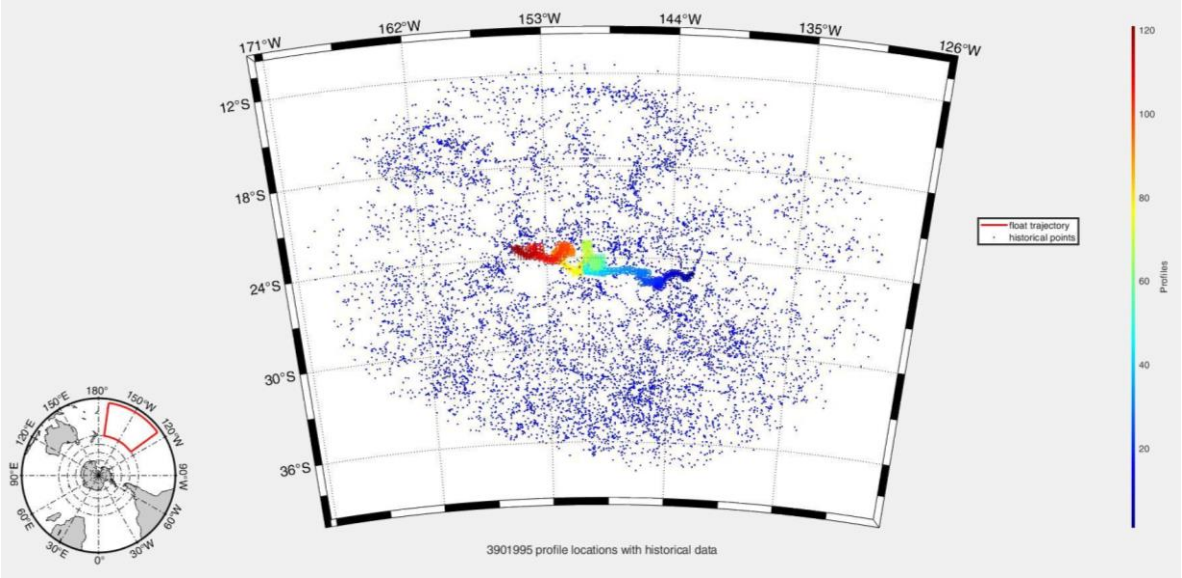

Figure 21. Float trajectory (color coded cycles) and the historical data points (blue).

The Θ-S diagram in Figure 22 shows a uniform relation between temperature and salinity in the deep zone. An anomalous salinity profile is observed at cycle 54 between 400-600 dbar which could be most likely a false spike.

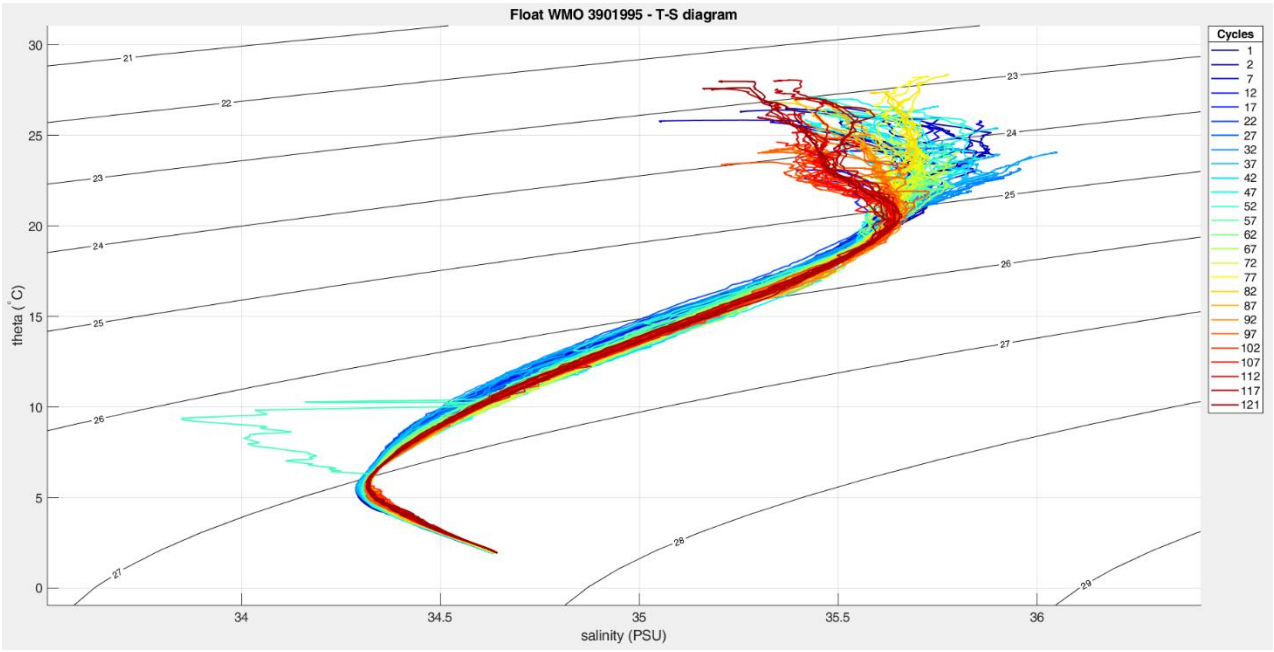

Figure 22. Θ-S diagram with color coded cycles.

The Hovmöller graphs and the vertical profiles shown in Figures 23 and 24, confirm homogeneity both in temperature and salinity below 1500 dbar. Hence the analysis can be conducted in this deep zone.

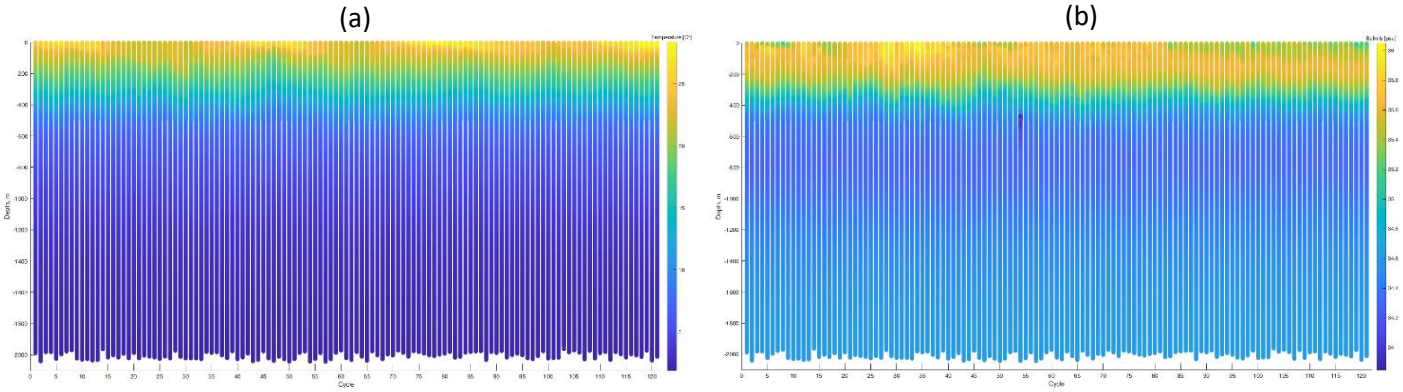

Figure 23. Hovmöller diagrams of (a) temperature and (b) salinity.

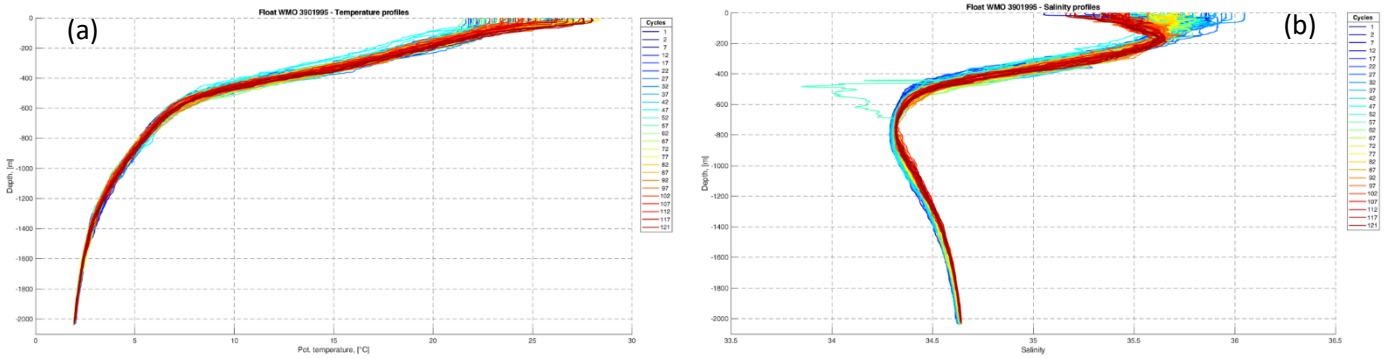

Figure 24. Temperature (a) and salinity (b) vertical profiles with color coded cycle number.

The ‘set_calseries’ procedure was configured as reported in Table 6.

Description	Parameter	Value
specify the cycle(s) to break the series	breaks	[ ]
maximum number of breaks	max_breaks	3
sequence of numbers that characterize the cycle series	calseries	[ones(1,num_cycles)]
sequence of profile numbers	calib_profile_no	PROFILE_N°
use theta less than	use_theta_lt	[ ]
use theta greater than	use_theta_gt	[ ]
use pressure less than	use_pres_lt	[ ]
use pressure greater than	use_pres_gt	[1500]
percentage of good data on a level to consider it included in the analysis	use_percent_gt	0.5

Table 6. Parameters used in ‘set_calseries’ file.

The corrections proposed by OWC are reported in Figure 25. The "one to one" fit between float potential conductivity and reference dataset potential conductivity is quite regular and smooth (red line). In this case the vertically averaged additive corrections stay below the 0.01 psu threshold until cycle 84. After this profile a salty drift is observed.

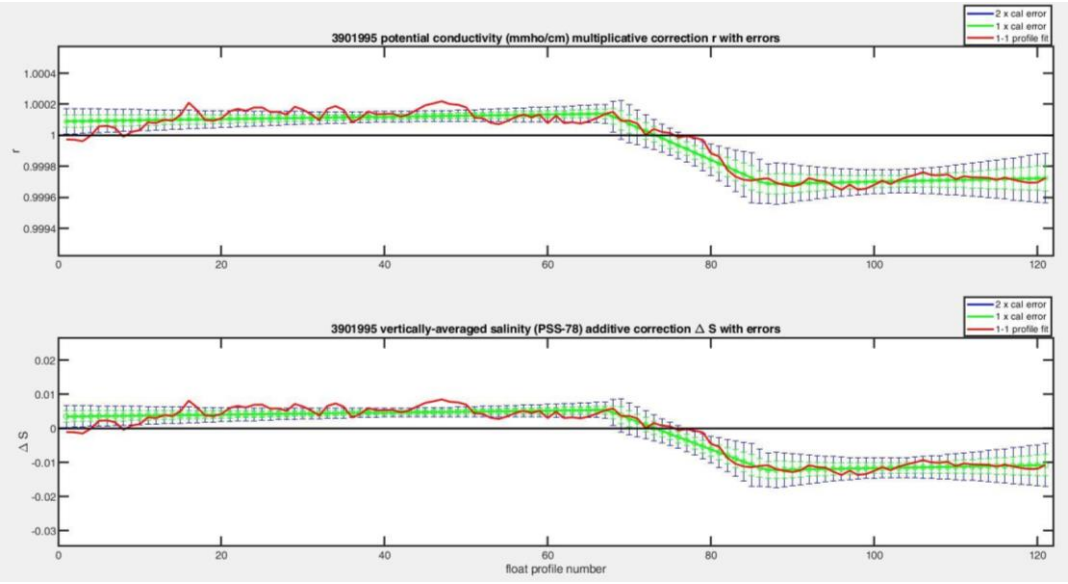

Figure 25. Potential conductivity multiplicative term (upper panel), vertically averaged salinity corrections (lower panel).

The uncalibrated, calibrated and the mapped salinity on four selected theta levels are reported in Figure 26 and in more detail in Figure 27.
Looking at Figure 27, the float calibrated salinity data (green lines) lie within the variability of the reference data (red vertical bars) especially after the detected sensor drifting.

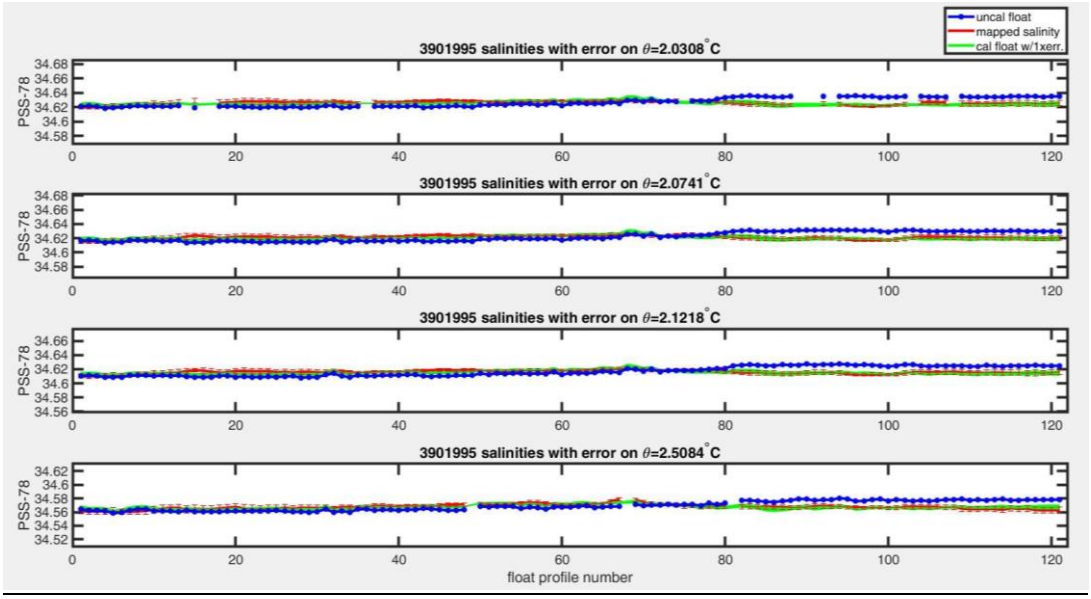

Figure 26. Source (blu), calibrated (green) and mapped (red) salinity data when considering a specific theta level.

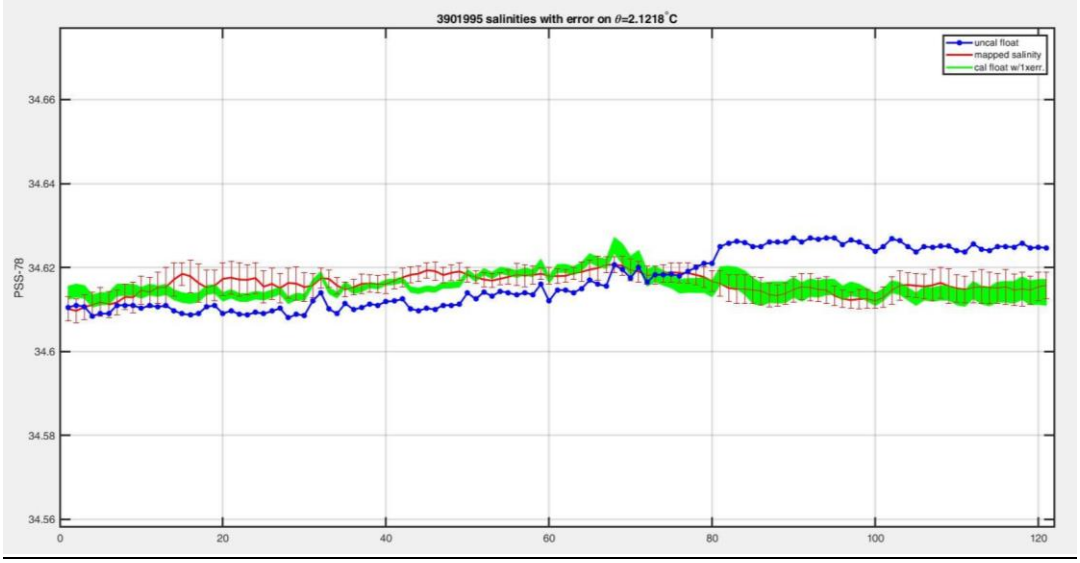

Figure 27. Source (blu), calibrated (green) and mapped (red) salinity data on the 2.1218 °C theta level.

The automatically selected theta levels used to compute the corrections are shown in Figure 28.

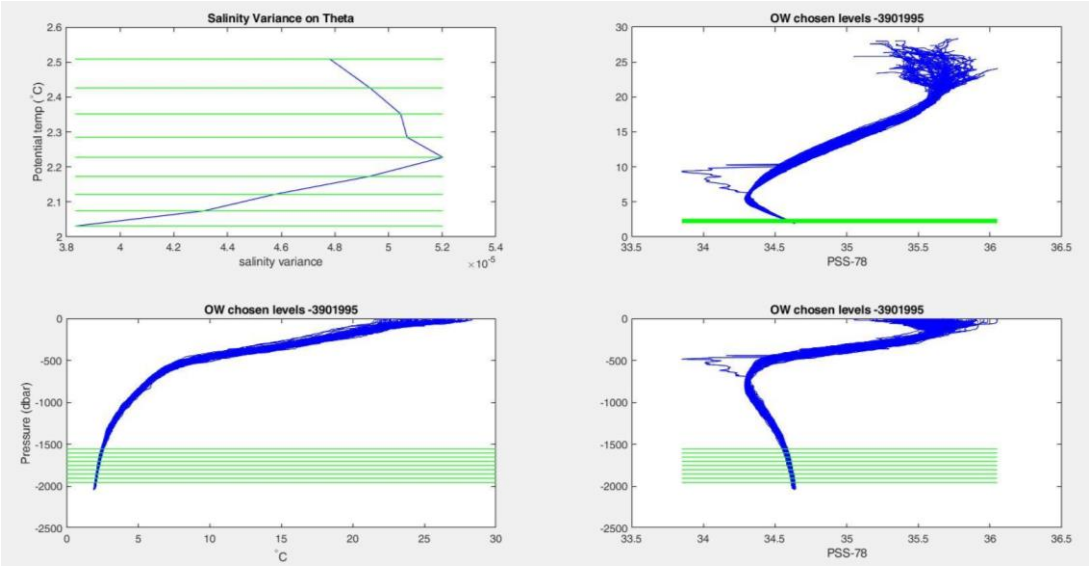

Figure 28. The 10 selected theta levels (green lines) are related to the minimal salinity variance on theta and to the Θ-S diagram and the vertical temperature and salinity profiles.

In Figure 29 the DMQC summary graphs for salinity are reported. The corrections are applied since cycle 78 and the QC is set 1 to all cycles.

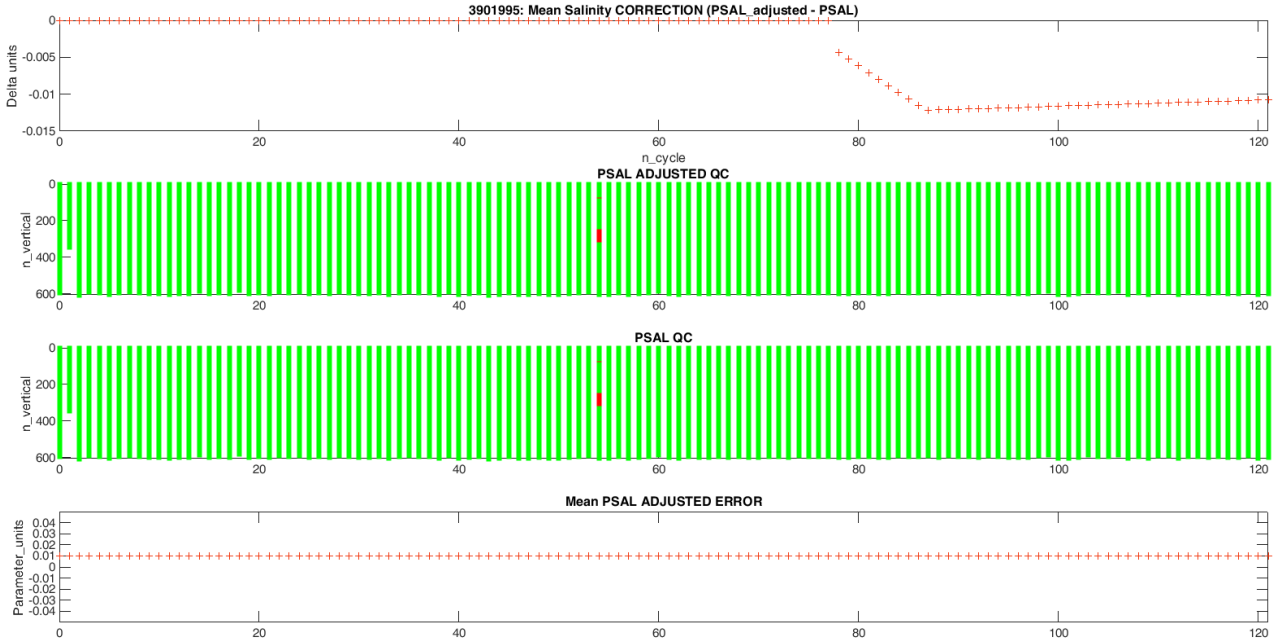

Figure 29. Summary of DMQC decisions on salinity parameter: upper plot for corrections, the two in the middle for QC (adjusted and source, green means QC 1, red QC 4) and one plot below for the averaged adjusted salinity error.

Float WMO	Status	Correction on salinity	Flag applied to PSAL_ADJUSTED
3901995	Active	not required	Profiles 1 to 77 →QC 1
		required	Profiles 78 to 121 →QC 1

Table 7. Actions for this float.

7. Arvor-I 3901996

Float trajectory and the selected reference dataset distribution is reported in Figure 30.

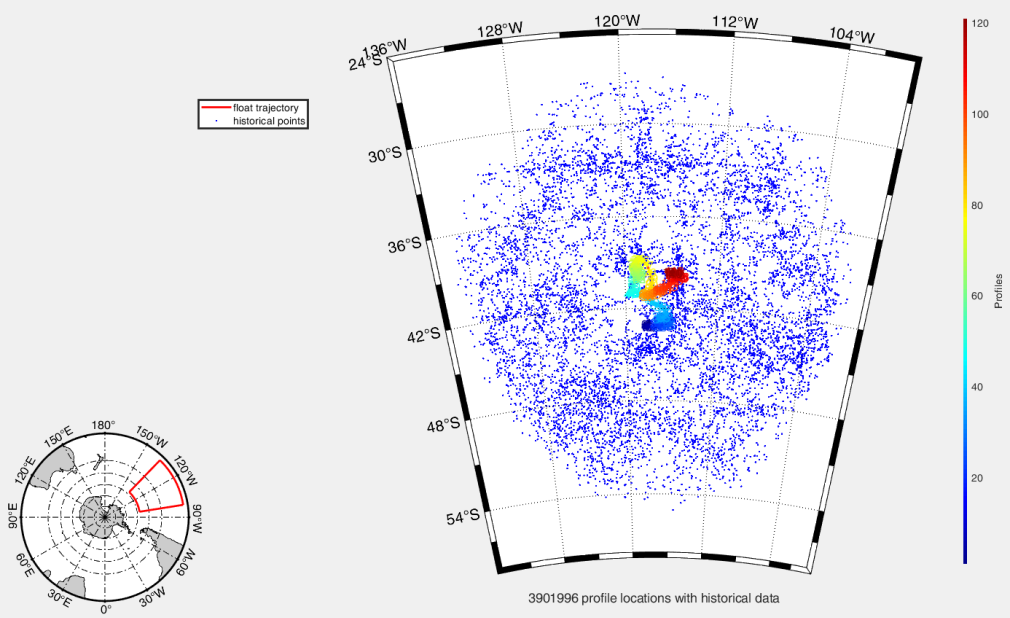

Figure 30. Float trajectory (color coded cycles) and the historical data points (blue).

The Θ-S diagram in Figure 31 shows tightly grouped lines in the deep layers. An anomalous salinity minimum is observed at cycle 54 around 950 dbar, most likely a false spike. In general, a uniform relation between temperature and salinity is observed in the deepest zone. Hence the analysis can be conducted below 1500 dbar.

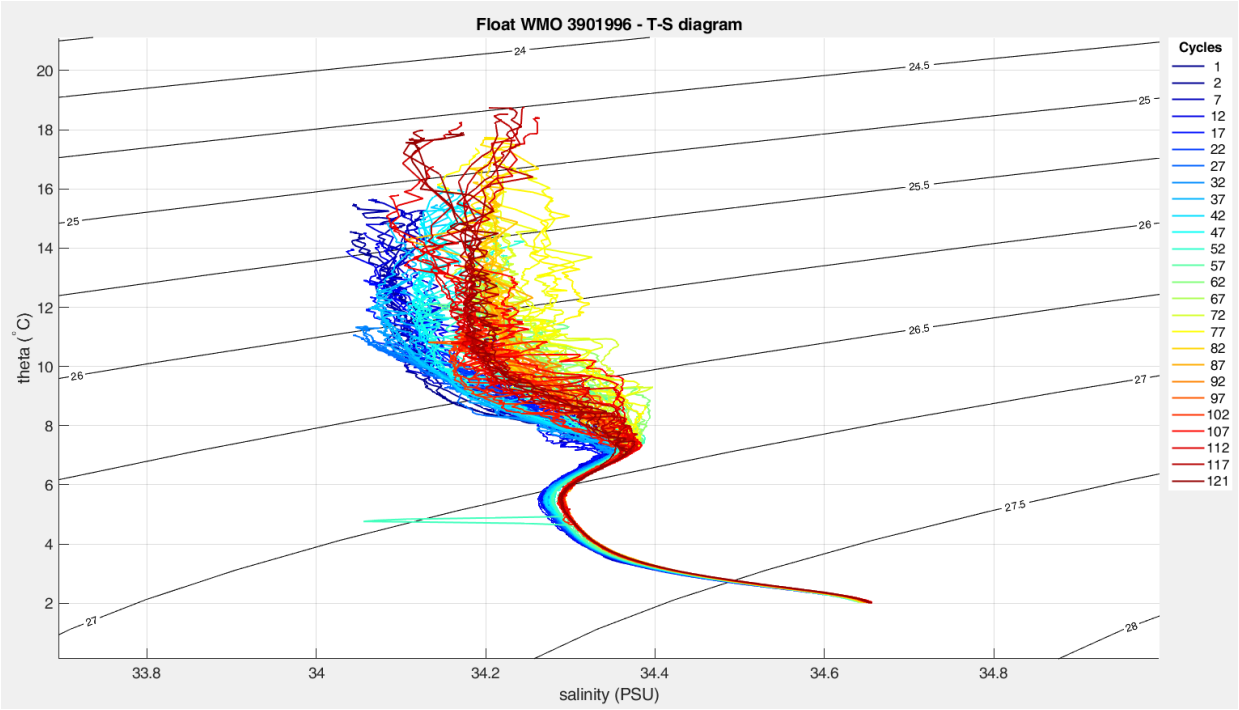

Figure 31. Θ-S diagram with color coded cycles.

An homogeneous temporal evolution of both temperature and salinity is observed in the investigated zone, below 1500 dbar (Figures 32 and 33).

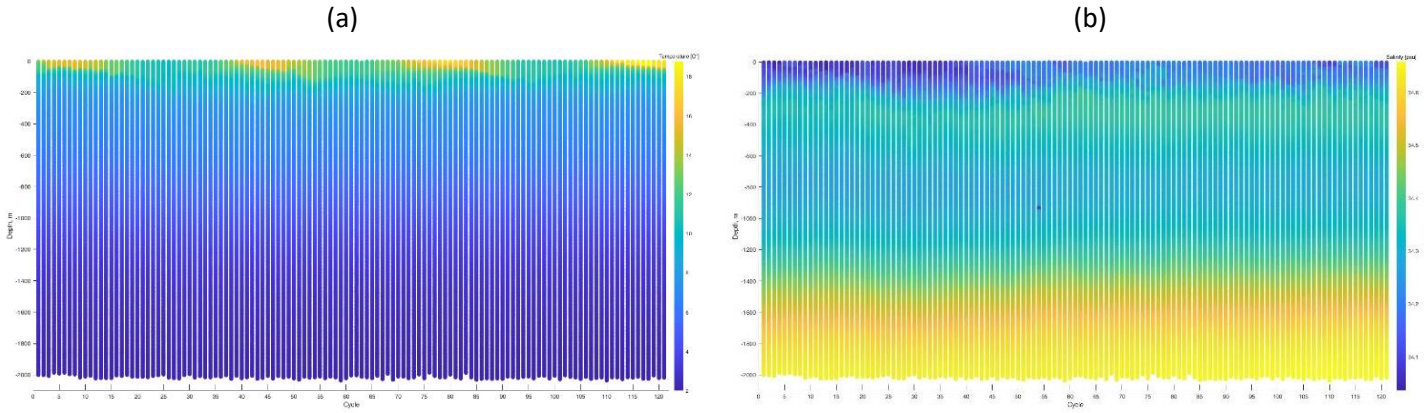

Figure 32. Hovmöller diagrams of (a) temperature and (b) salinity.

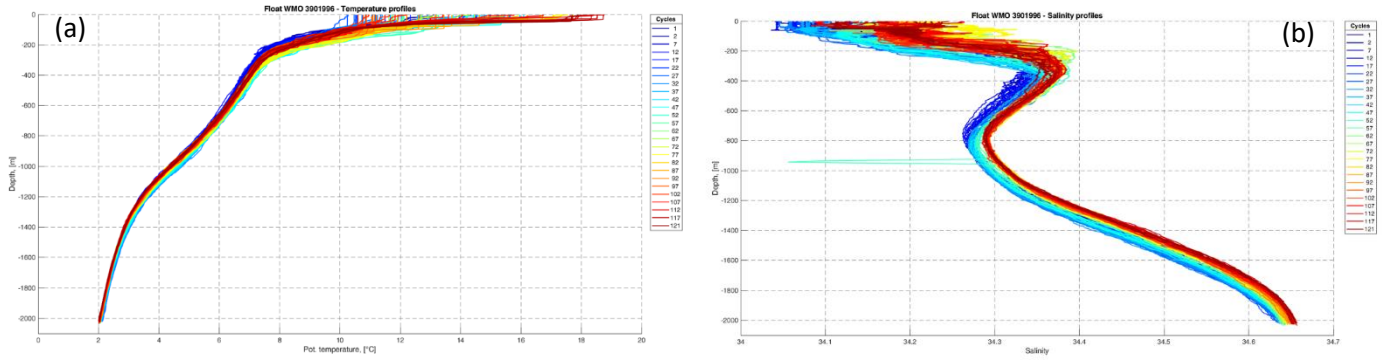

Figure 33. Temperature (a) and salinity (b) vertical profiles with color coded cycle number.

The 'set_calseries' routine was configured as in Table 8.

Description	Parameter	Value
specify the cycle(s) to break the series	breaks	[ ]
maximum number of breaks	max_breaks	3
sequence of numbers that characterize the cycle series	calseries	[ones(1,num_cycles)]
sequence of profile numbers	calib_profile_no	PROFILE_N°
use theta less than	use_theta_lt	[ ]
use theta greater than	use_theta_gt	[ ]
use pressure less than	use_pres_lt	[ ]
use pressure greater than	use_pres_gt	[1500]
percentage of good data on a level to consider it included in the analysis	use_percent_gt	0.5

Table 8. Parameters used in 'set_calseries' file.

The OWC results in Figure 34 reveal a good “one to one” profile fit and the proposed corrections do not exceed the instrument accuracy (0.01 psu); hence there is no need to correct the salinity data of this float.

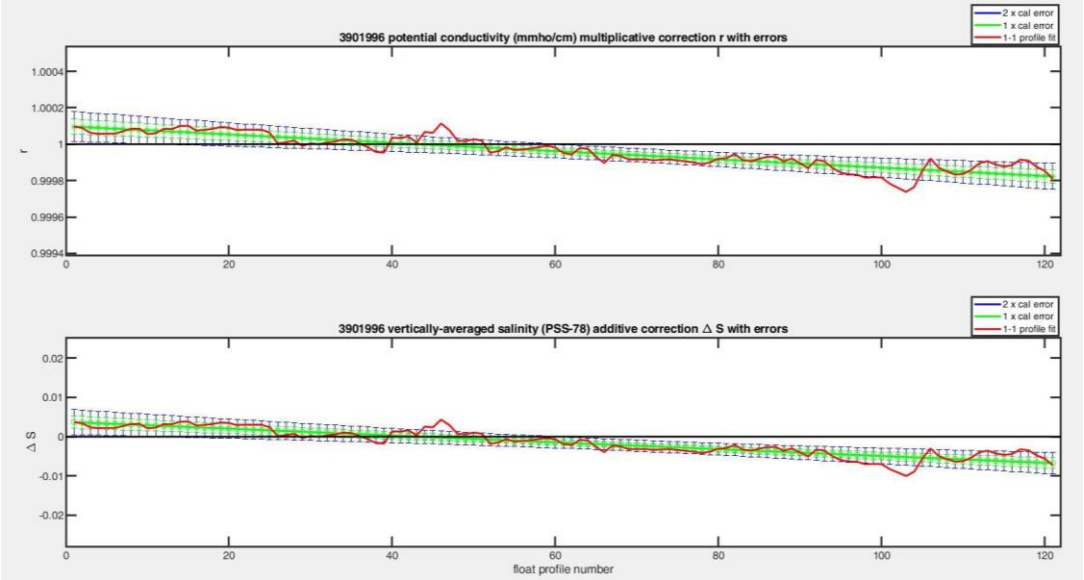

Figure 34. Potential conductivity multiplicative term (upper panel), vertically averaged salinity corrections (lower panel).

Figure 35 and Figure 36 in detail, confirm that this float is behaving well also when considering different theta levels.

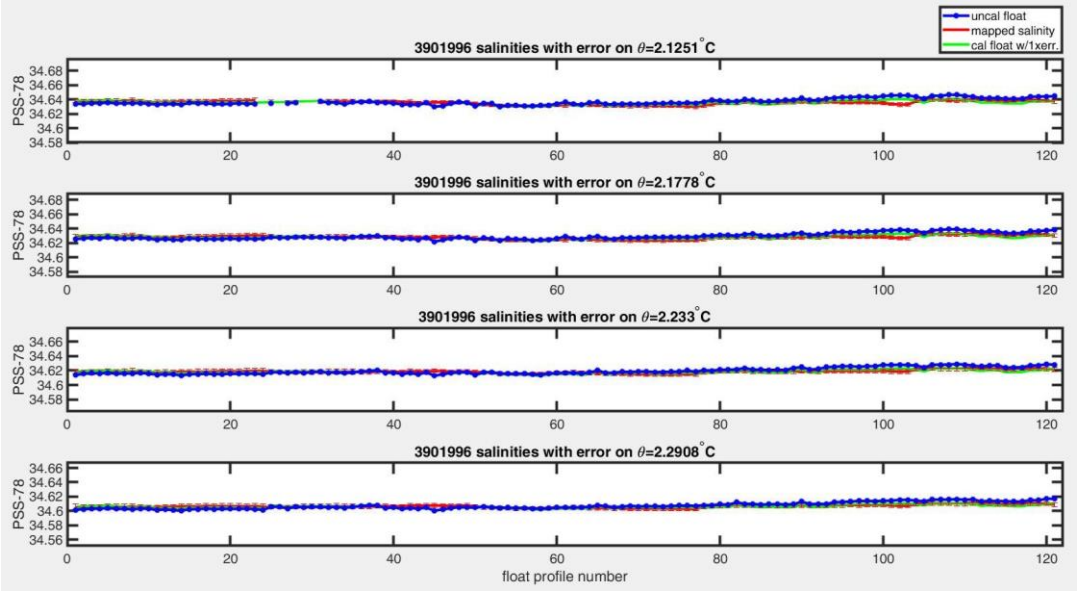

Figure 35. Source (blu), calibrated (green) and mapped (red) salinity data when considering a specific theta level.

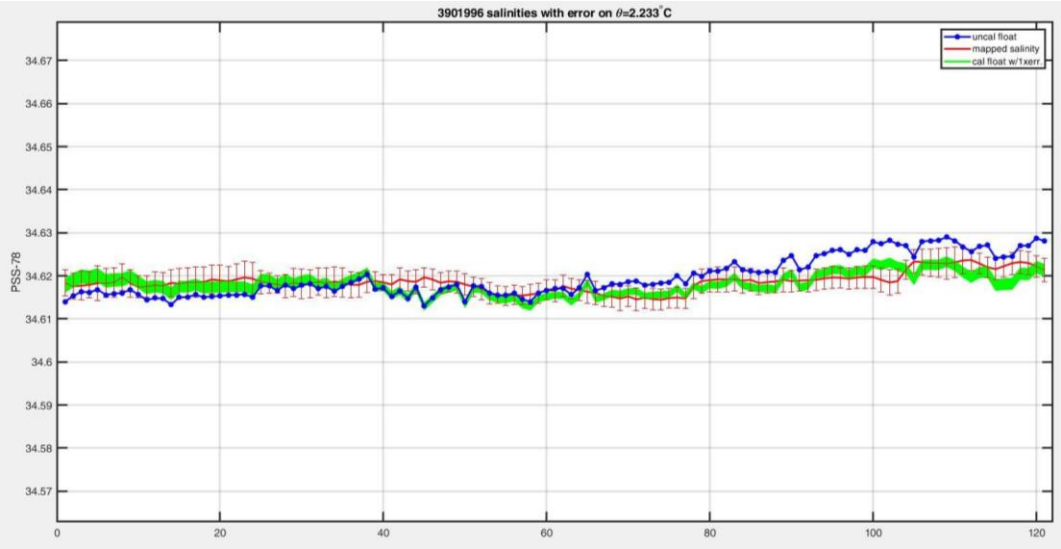

Figure 36. Source (blu), calibrated (green) and mapped (red) salinity data on the 2.233 °C theta level.

The 10 theta levels (green horizontal lines), used to estimate the salinity correction, are reported in Figure 37, in which (upper left) a very low range of salinity variance of about 2-3.5 10^{-5} indicates a very stable Θ-S relation and hence the theta level selection is optimal.

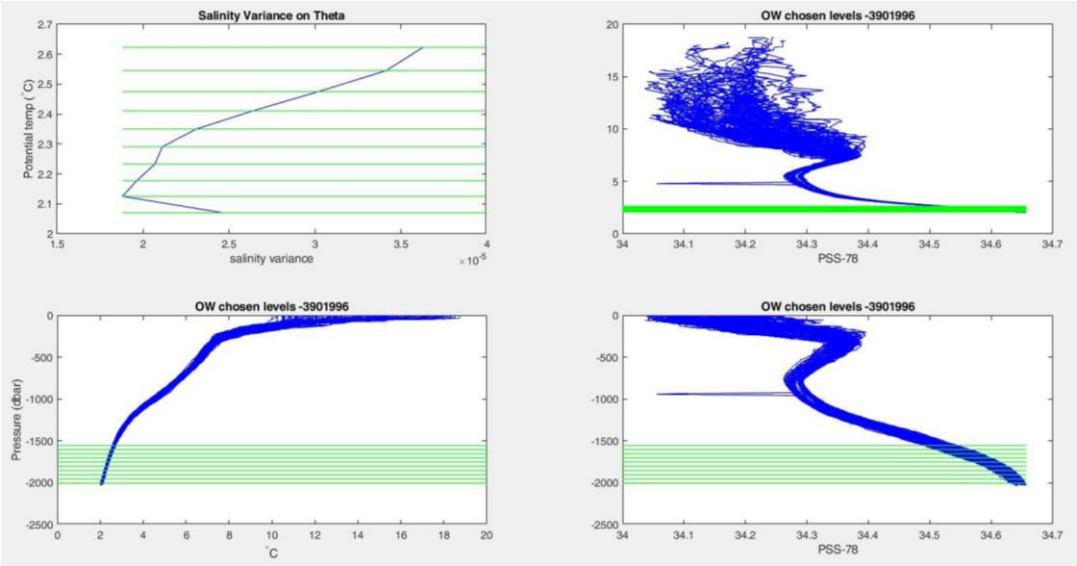

Figure 37. The 10 selected theta levels (green lines) are related to the minimal salinity variance on theta and to the Θ-S diagram and the vertical temperature and salinity profiles.

In Figure 38 the DMQC summary graphs for salinity are reported. There is no need to correct this float. The PSAL_ADJUSTED_QC is therefore set to 1.

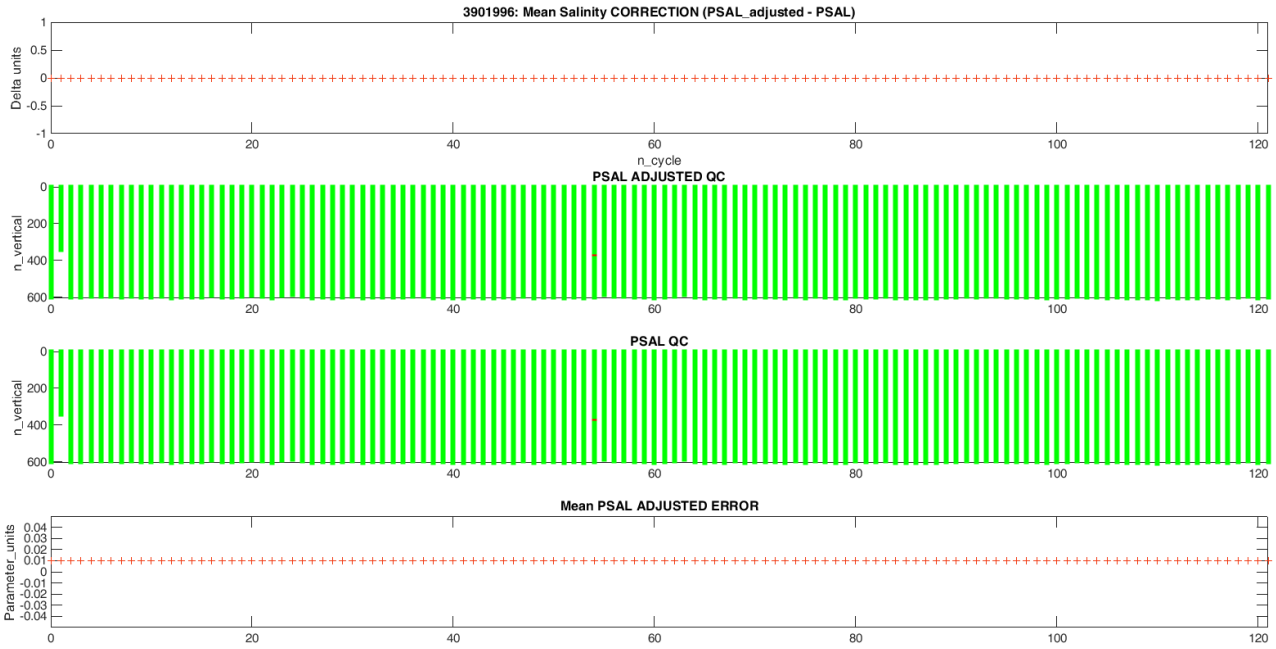

Figure 38. Summary of DMQC decisions on salinity parameter: upper plot for corrections, the two in the middle for QC (adjusted and source, green means QC 1, red QC 4) and one plot below for the averaged adjusted salinity error.

Float WMO	Status	Correction on salinity	Flag applied to PSAL_ADJUSTED
3901996	Active	not required	Profiles 1 to 121 →QC 1

Table 9. Actions for this float.

8. Conclusion

In the framework of the MOCCA project four Arvor-I floats were deployed in the Southern Pacific Ocean and all of them are still alive at the moment of this study performing around 125 cycles.
The delayed quality control on salinity allowed to apply reliable corrections in two cases. On the other hand there was no need to correct the salinity data for the other two floats. In particular, the Arvor-I 3901994 performed correctly, even if it entered in an area with high natural variability that reduced the confidence in the OWC outcomes. In this case, a comparison with CTD reference dataset and suitably selected Argo float profiles was performed, as a qualitative analysis. The adjusted salinity flag was set to 2 (probably good data). If the float escapes that area, a new analysis will be done to check the sensor behavior.

9. References

ARVOR-I FLOAT user manual, DOC33-16-033, rev. 11.

Cabanes, C., Thierry, V., & Lagadec, C. (2016). Improvement of bias detection in Argo float conductivity sensors and its application in the North Atlantic. Deep-Sea Research Part I: Oceanographic Research Papers, 114, 128–136. https://doi.org/10.1016/j.dsr.2016.05.007.

Monitoring the Oceans and Climate Change with Argo (MOCCA). Co-funded by the European Maritime and Fisheries Fund (EMFF). Project No: SI2.709624 | Call reference No: EASME/EMFF/2015/1.2.1.1

Wong Annie, Keeley Robert, Carval Thierry, Argo Data Management Team (2022). Argo Quality Control Manual for CTD and Trajectory Data. https://doi.org/10.13155/33951.