Delayed Mode Quality Control of Argo float 6903556

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DMQC summary

Float number 6903556 was deployed on 17/05/2020
This float is still active and further monitoring is required.

Contents

1 Introduction

This report concerns the delayed mode analysis performed for Argo-float number 6903556. For more information about this float use, for instance, the following link:

http://www.ifremer.fr/argoMonitoring/float/6903556.

Before the analysis, real-time QC flags were visually inspected and modified if necessary. In addition, a few stricter tests necessary before the salinity calibration were applied (and flags modified if necessary). Then, the satellite altimeter comparison plot between the sea surface height and dynamic height anomaly, constructed for this float by Ifremer, was analysed. Part of this analysis are plots of temperature and salinity time series, and surface pressure.

The salinity calibration has been performed using the configuration and objective mapping parameters included in Section 3.2.1. The Argo float data were compared to nearby CTD and Argo profiles from the following reference databases:

`ARGO_for_DMQC_2020V03, CTD_for_DMQC_2021V01_1, and CTD_for_DMQC_2021V01_7`

Reference data are distributed by Ifremer. A simple visual check on the reference data is done prior to analysis (see Appendix B).

The OWC toolbox version 3.0.0 (https://github.com/ArgoDMQC/matlab_owc) was run to estimate a salinity offset and a salinity drift (Cabanes et al., 2016).

Note that only ascending profiles are included in this DMQC.

Technical info on the float is given in Table 1 and an overview of the float trajectory and T&S data is shown in Figure 1.

Table 1: Technical information about float 6903556.

WMO float-number	6903556
DAC	Coriolis
Float SNR	AD2700-18NO001
Platform type	ARVOR-D
Transmission system	IRIDIUM
CTD Sensor model	SBE41CP
CTD Sensor SNR	10980
Other sensors	CTD-PRES and OPTODE-DOXY
Other sensor models	KISTLER-10153PSIA and AANDERAA-OPTODE-4330
Other sensors SNR	5276541 and 3021
Deployment	17/05/2020
Dep. Lat	67.001
Dep. Lon	-0.506
Park Depth	1000 m
Profile depth	3500 m
Cycle time	10 days
Ship	R/V Kristine Bonnevie
PI	Kjell Arne Mork
Float Status	Active
Age	1.51 yrs
Last Cycle	56
Grey list	

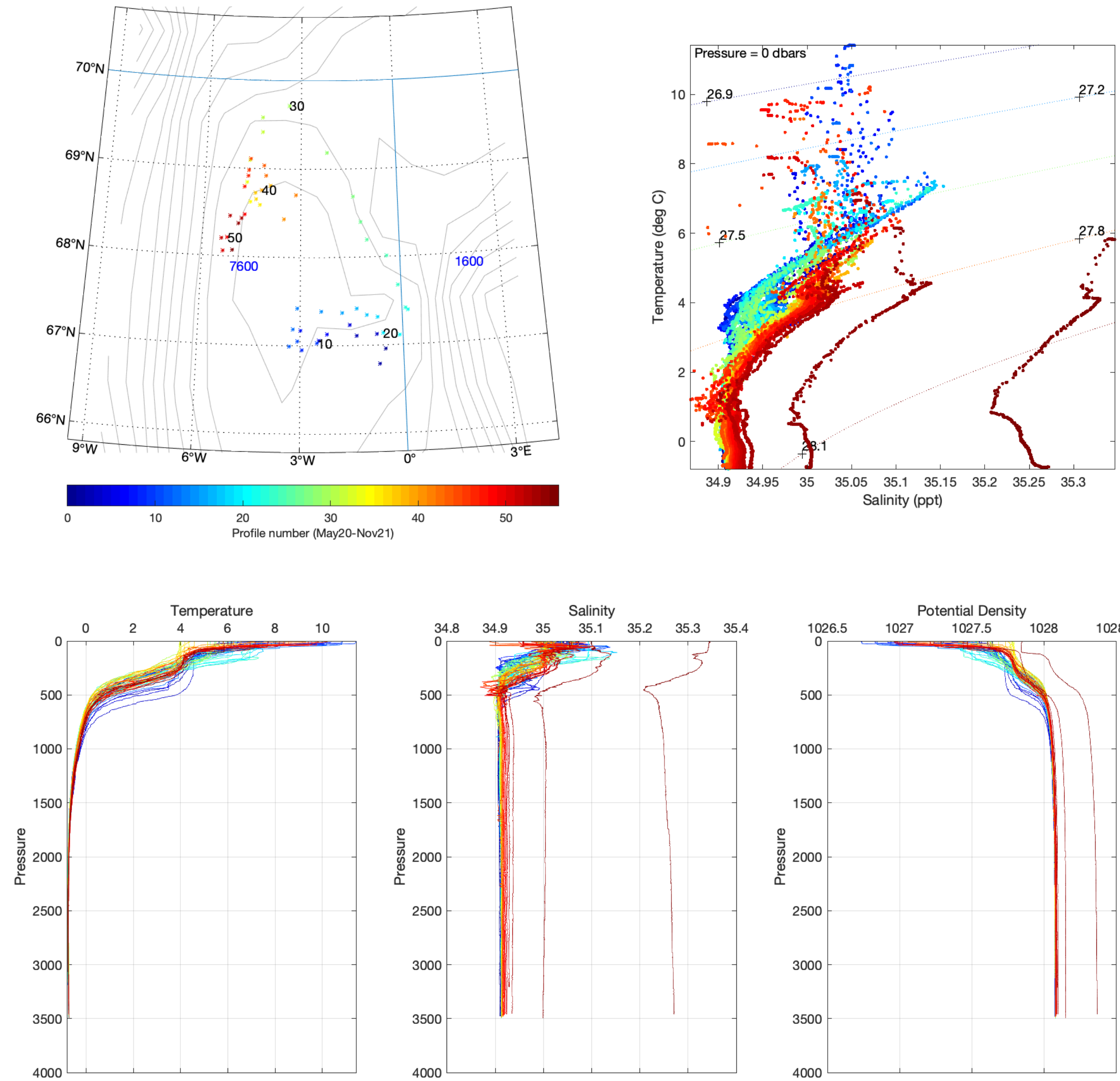


Figure 1: Float 6903556. Map shows the locations of float profiles (numbers in black are every 10th profile number and numbers in blue with corresponding squares/lines show WMO-squares). The grey contours in map indicate bathymetry. The following plots are TS-diagram, temperature profiles, salinity profiles, and density profiles for all profiles. The profiles shown have undergone pre-OWC analysis DMQC (as described in Section 2). Colour shading in all panels indicate profile number (see colorbar under map).

2 Quality Check of Argo Float Data

The DMQC prior to OWC is performed in four phases, after each the found erroneous data are removed before the following phase:

1. Delayed-mode procedures for coordinates
2. Correction of pressure dependent conductivity bias (deep ARVOR only)
3. Visual verification of Real-time mode QC flags
4. Selected automated tests necessary for OWC
5. Visual DMQC of the variables

The tests are described in the following subsections and all results are shown in Table 2. New flags are due to: double-pointed salinity spike(s); salinity spike(s).

Table 2: Results for Float 6903556 in terms of number of flags for each variable, from both RTQC and DMQC.

Variable	RTQC flags ('4')	reversed flags ('1')	new flags ('4')	Affected cycles (cycle numbers)
POS	0	0	0	
JULD	0	0	0	
PRES	0	0	0	
PSAL	43	0	5	28 and 45
TEMP	0	0	0	

2.1 Delayed-mode procedures for coordinates

First the coordinates JULD, LATITUDE, LONGITUDE were checked as prescribed in Section 3.2 of Wong et al. (2021). Chronology of JULD was tested by a simple automated test and any missing or erroneous values replaced by linear interpolation. Position outliers were checked for visually in a map such as in Figure 1 but based on original data, and any positions replaced by 2D linear interpolation.

2.2 Visual verification of Real-time mode QC flags

In the case of RTQC flags in a profile, such profiles are compared to temporally close profiles from same float, as well as surrounding reference data. Each individual plot is inspected interactively in detail and flags are removed or new flags assigned when judged necessary (to both RTQC flagged data as well as any new findings). Examples are shown in Figure 2.

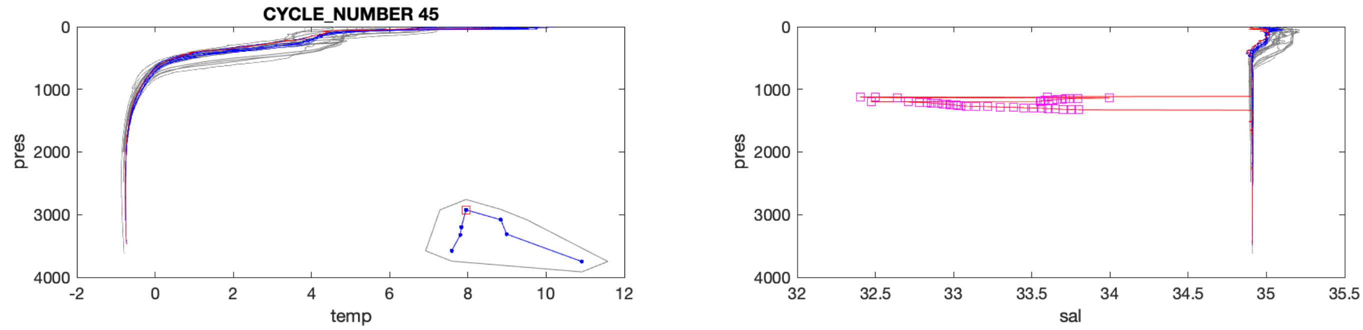


Figure 2: Float 6903556. Profiles flagged by RTQC (red) compared to float profiles before and after (blue) and nearby reference data (grey). Temperature in left and salinity in right panels. Flagged data are marked with magenta squares. If pressure is the flagged variable, the circle is put on both the temperature and salinity profile. The inlays in left panels show the piece of float track shown in blue and the areas of origin of reference data used, as grey enclosures. These are the first flagged profiles for this float (or all; see Table 2). For geography, refer to Figure 1 Panel 1.

2.3 Selected automated tests necessary for OWC

In addition to RTQC, the following automated tests are necessary before OWC as double checks using same critera as RTQC (see Wong et al., 2021) and in some aspects stricter based on experience in the region:

- Pressure increasing test / monotonically increasing pressure test in waters deeper than 400 m.
- Double-pointed spike tests on PSAL and TEMP (see Section 2.3.1).
- Spike tests on PSAL and TEMP (with 0.02 PSU criterion for pressures greater than or equal to 500 dbar, and 0.01 PSU deeper than 1000 dbar; and the addition of temperature criterion 1°C deeper than 1000 dbar).
- Gradient test on TEMP and PSAL (declared obsolete from RTQC in 2019, but implemented here nevertheless).
- Density inversion test.

2.3.1 The double-pointed spike test

The double-pointed spike tests the deviation of subsequent pairs of values instead of single points, from the neighbouring values in a profile, as this is not an uncommon form of spikes. The test values are formed according to

$$TV = \left| \frac{V_i + V_{i+1}}{2} - \frac{V_{i-1} + V_{i+2}}{2} \right| - \left| \frac{V_{i+2} - V_{i-1}}{2} \right|, \tag{1}$$

where TV is the test value and V_i are the subsequent points in a profile. As the test values are assigned to the i-th point in the profile (i.e., the upper point of the pair forming the spike), any testvalues exceeding the criteria results in flagging of both V_i and V_{i+1}. The double-pointed spike test uses the same criteria as the single-point spike test. It is applied before the single-point spike test, since the latter may remove one of the values in a double-point spike and render the double-pointed spike test useless.

2.4 Visual DMQC of the variables

As prescribed in Section 3.3–3.5 of Wong et al. (2021), PRES, TEMP, and PSAL were checked visually by comparing to other cycles from the float (using versions of Figures 1 and 6 from this stage), as well as in relation to reference data in the vicinity of the float (Figure 3). Trends in salinity in the same reference data are also compared to float data (Figure 4) in order to aid interpretation of the calibration results in Section 3.2.2.

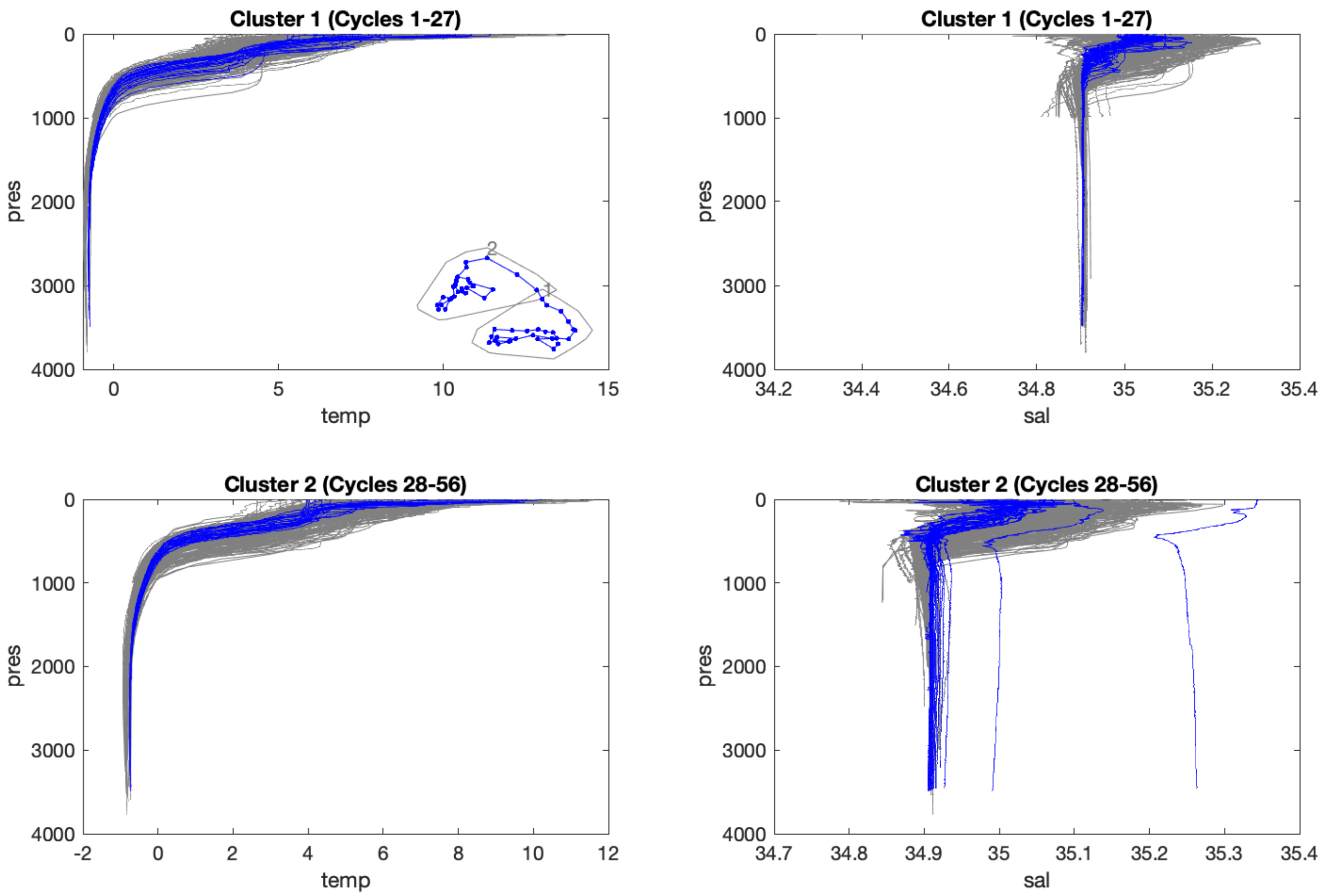


Figure 3: Float 6903556 compared to nearby reference data. Float profiles (blue lines) are divided into clusters based on positions, and compared to nearby profiles from the reference data set (grey lines). Temperature in left and salinity in right panels, and one row per cluster. The inlay in first panel shows areas of origin of reference data used as grey enclosures around the clusters of positions on the blue float track. For geography, refer to Figure 1 Panel 1.

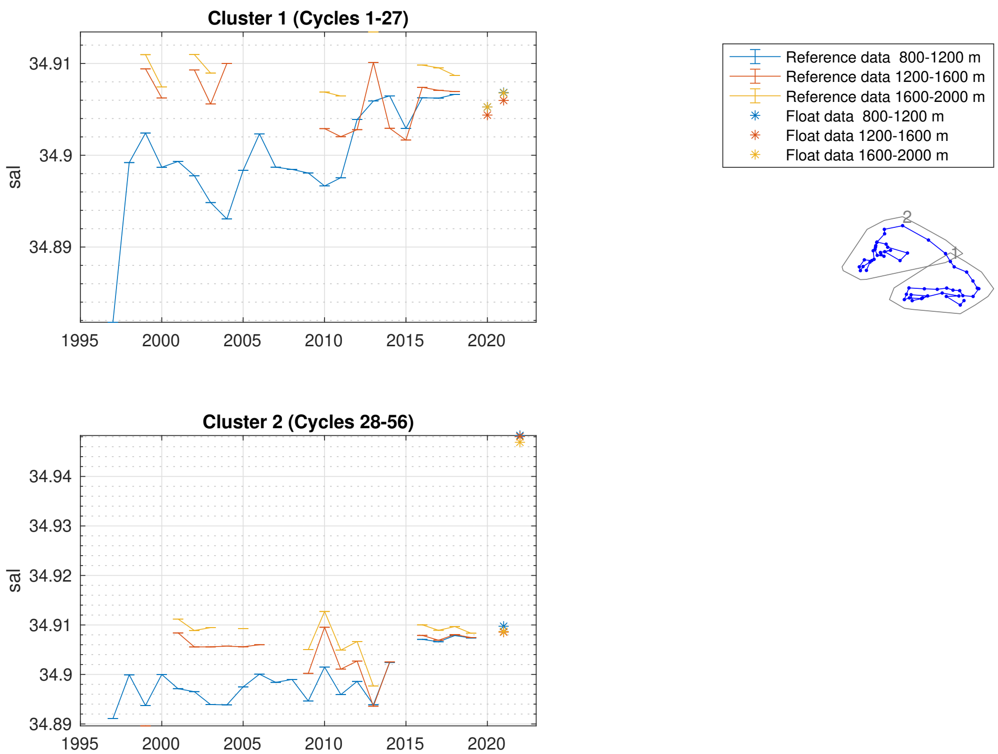


Figure 4: Temporal evolution of data from Float 6903556 and reference data (by cluster as in Figure 3). Time series of annual means of reference data in depth bins (see legend) are plotted as coloured lines with error bars representing the error of the mean (usually very small due to large ensembles), and annual bin means of float data by the same method plotted with asterisks. Annual bins are centered around new year (i.e., winter). The sketch under the legend shows areas of origin of reference data used as grey enclosures around the clusters of positions on the blue float track. For geography, refer to Figure 1 Panel 1.

2.5 Satellite Altimeter Report

Figure 5 shows the comparison with altimetry.

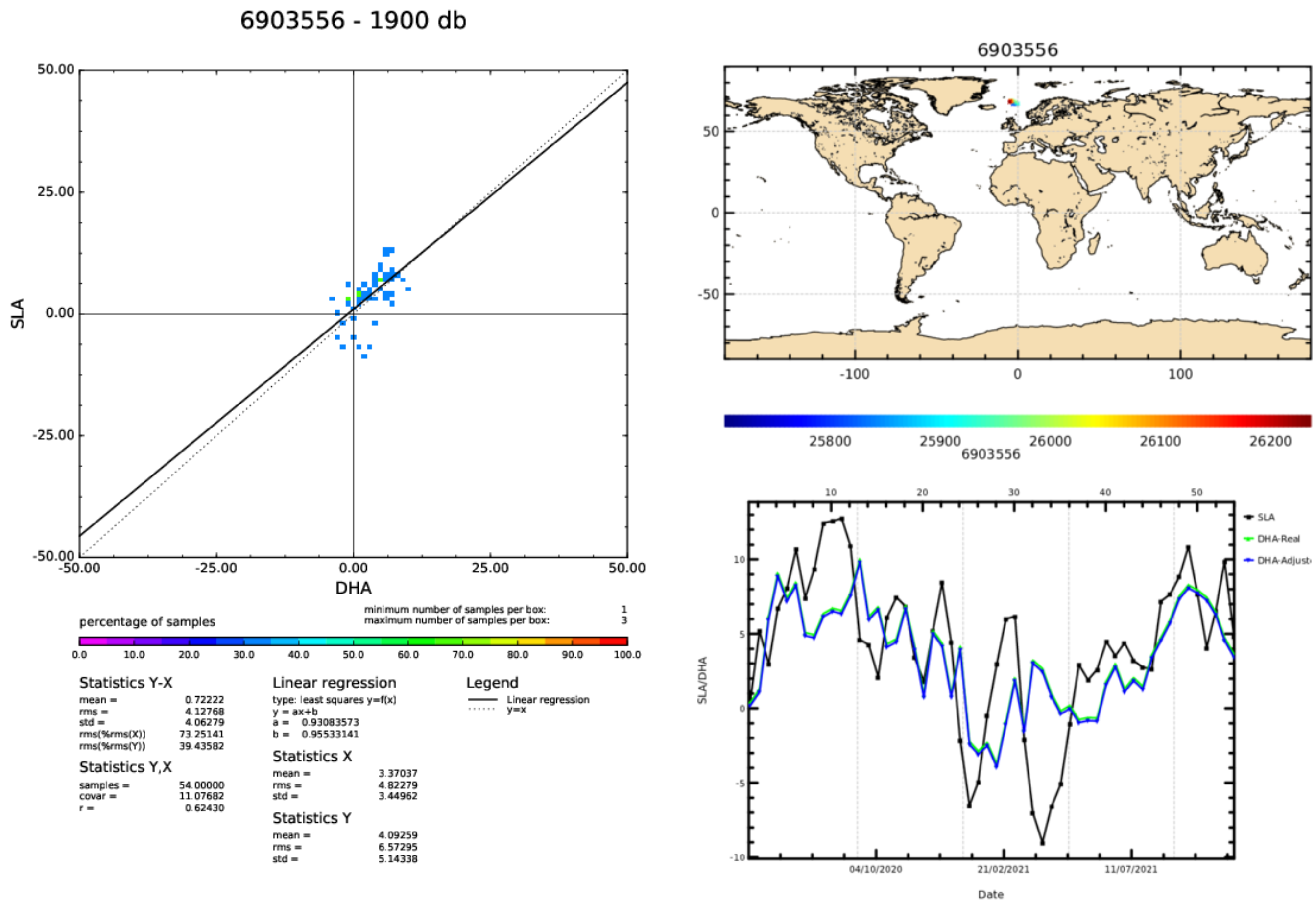
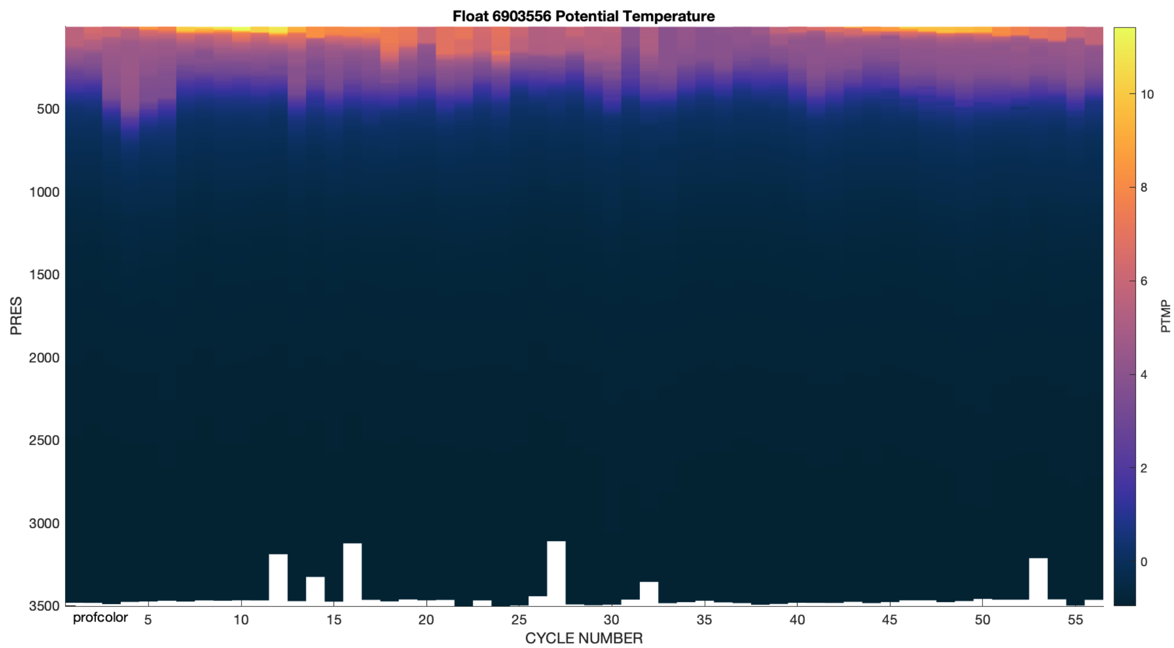


Figure 5: Float 6903556. The comparison between the sea level anomaly (SLA) from the satellite altimeter and dynamic height anomaly (DHA) extracted from the Argo float temperature and salinity. The figure is created by the CLS/Coriolis, distributed by Ifremer (ftp://ftp.ifremer.fr/ifremer/argo/etc/argo-ast9-item13-AltimeterComparison/figures/). If graphics are missing, an altimetry report is not available (yet).

2.6 Time Series of Argo Float Temperature and Salinity

Figure 6 shows Hov-Möller plots of temperature and salinty, respectively, disregarding flags but with flagged data marked.

a)



b)

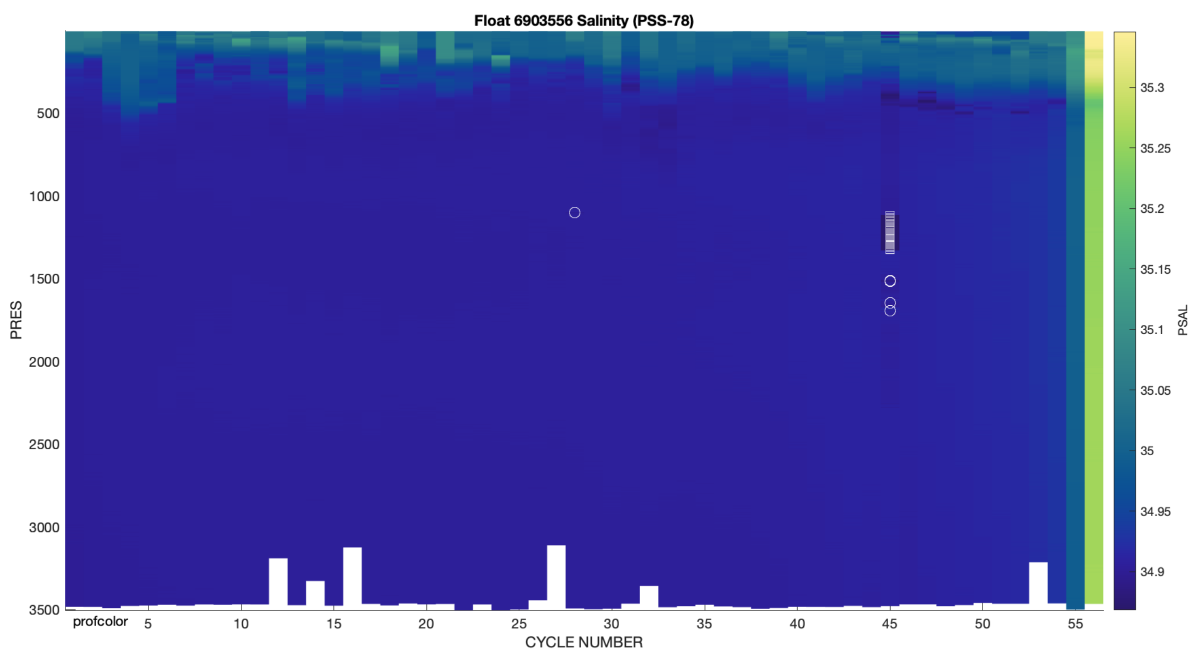


Figure 6: Float 6903556. Time series of Argo float potential temperature (a; ˚C) and salinity (b; PSS-78). Any white squares and circles indicate data that has been flagged '4' by RTQC and DMQC, respectively. A point inside a square indicates the rare occurence of reversal of an RTQC flag to '1'. Pressure flags are marked with the same symbols, in grey.

2.7 Sea Surface Pressure Adjustment

Sea surface pressure adjustments should be done for APEX floats (Wong et al., 2021). This is an ARVOR-D float. Instead, Figure 7 shows the surface pressure from the top of each profile.

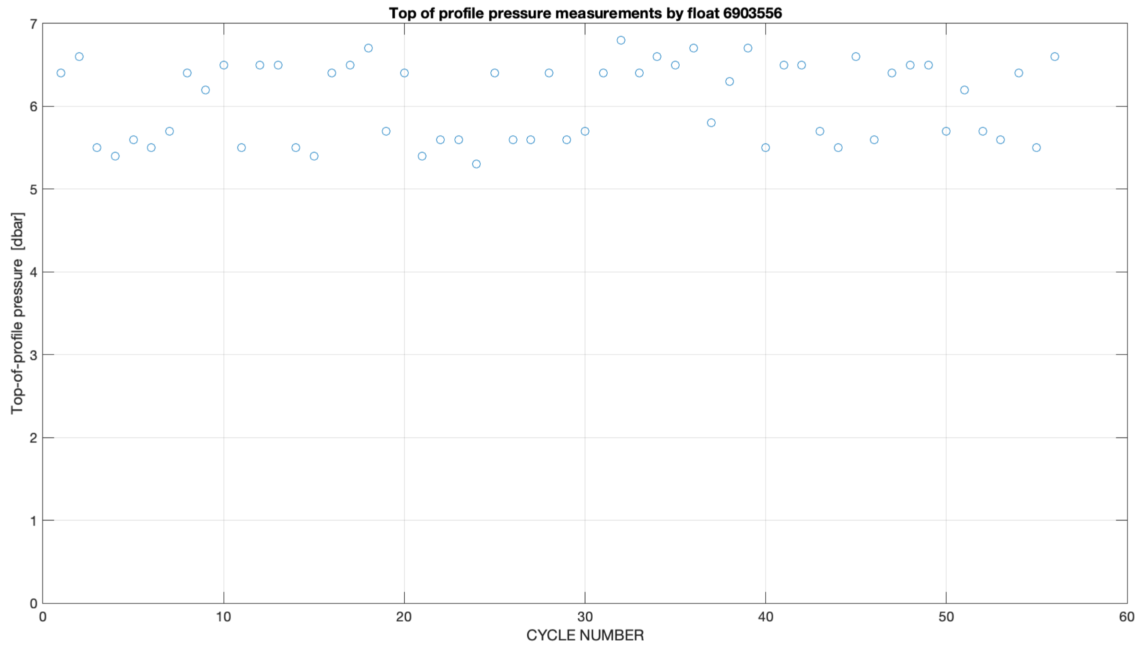


Figure 7: Float 6903556. Top of profile pressure series. Blue circles indicate pressure value in the real-time.

3 Correction of Salinity Data

3.1 Correcting deep ARVOR float pressure dependent conductivity bias

For ARVOR-D floats, conductivity has to be corrected due to a too small conductivity cell compressibility term ($CPcor$) in the manufacturer calibration of the SBE CTDs. For this float the operator has determined CPcor_new based on a near-deployment ship CTD profile. Figure 8 shows the uncorrected and corrected salinities from the 1st cycle compared to a near-deployment ship CTD profile. If the first cycle is not used it is probably because it is too shallow (see Figure 6b).

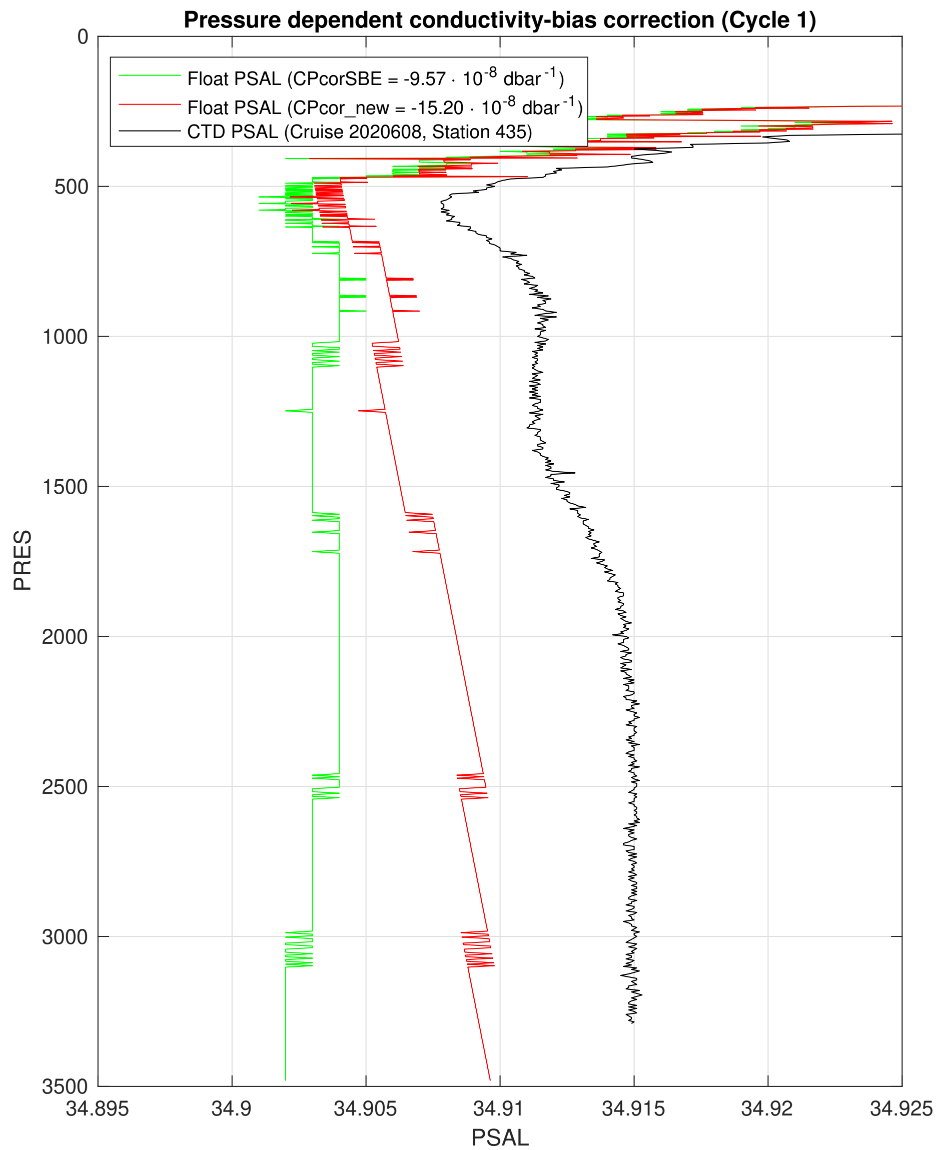


Figure 8: Float 6903556. Salinity profiles from the 1st cycle using the manufacturer calibration ($CPcor_{SBE}$ = -9.57 $\cdot 10^{-8}$ $dbar^{-1}$; i.e., raw data; green) and using the operator's compressibility term ($CPcor_{new}$ = -15.20 $\cdot 10^{-8}$ $dbar^{-1}$; red). The ship CTD profile used is from Cruise 2020608, Station 435 (black).

3.2 Comparison between Argo Float and CTD and Argo Climatology

The OWC-toolbox uses reference data in order to investigate potential salinity drift and calculate calibration offsets. Figure 9 shows the positions of reference data actually used in mapping. In Appendix B profile plots of reference data from the WMO squares (1600 and 7600) traversed by the float, can be found.

3.2.1 Configuration

The following are the mapping configuration parameters set in `ow_config.txt` file of the OWC toolbox with the parameters set for the final correction:

```
      CONFIGURATION_FILE: ow_config.txt
    HISTORICAL_DIRECTORY: ~/Arkiv/data/matlab_owc/climatology
   HISTORICAL_CTD_PREFIX: /historical_ctd/ctd_
HISTORICAL_BOTTLE_PREFIX: /historical_bot/bot_
  HISTORICAL_ARGO_PREFIX: /argo_profiles/argo_
  FLOAT_SOURCE_DIRECTORY: ~/Arkiv/data/matlab_owc/float_source/
    FLOAT_SOURCE_POSTFIX: .mat
  FLOAT_MAPPED_DIRECTORY: ~/Arkiv/data/matlab_owc/float_mapped/
     FLOAT_MAPPED_PREFIX: map_
    FLOAT_MAPPED_POSTFIX: .mat
   FLOAT_CALIB_DIRECTORY: ~/Arkiv/data/matlab_owc/float_calib/
      FLOAT_CALIB_PREFIX: cal_
  FLOAT_CALSERIES_PREFIX: calseries_
     FLOAT_CALIB_POSTFIX: .mat
   FLOAT_PLOTS_DIRECTORY: ~/Arkiv/data/matlab_owc/float_plots/
        CONFIG_DIRECTORY: ~/Arkiv/data/matlab_owc/constants/
       CONFIG_COASTLINES: coastdat.mat
        CONFIG_WMO_BOXES: wmo_boxes.mat
              CONFIG_SAF: TypicalProfileAroundSAF.mat
        CONFIG_MAX_CASTS: 250
              MAP_USE_PV: 1
             MAP_USE_SAF: 0
MAPSCALE_LONGITUDE_LARGE: 1.6
MAPSCALE_LONGITUDE_SMALL: 0.4
 MAPSCALE_LATITUDE_LARGE: 1
 MAPSCALE_LATITUDE_SMALL: 0.3
      MAPSCALE_PHI_LARGE: 0.5
      MAPSCALE_PHI_SMALL: 0.1
      MAPSCALE_AGE_SMALL: 5
      MAPSCALE_AGE_LARGE: 10
           MAP_P_EXCLUDE: 400
             MAP_P_DELTA: 100
```

The scaling parameters are typical for use in the Lofoten Basin.

The calseries parameters are set in `set_calseries.m` file as follows:

```
          breaks: []
      max_breaks: -1  0  1
       calseries: 1-46, 47-54, and 55-56
calib_profile_no: [1x56 double]
    use_theta_lt: []
    use_theta_gt: []
     use_pres_gt: 1000
     use_pres_lt: []
  use_percent_gt: 0.25
```

3.2.2 Results

Figures 9 through 16 show the results of the comparison and correction of the salinity data. Notes made about this float during the different rounds of DMQC, can be found in Appendix A.

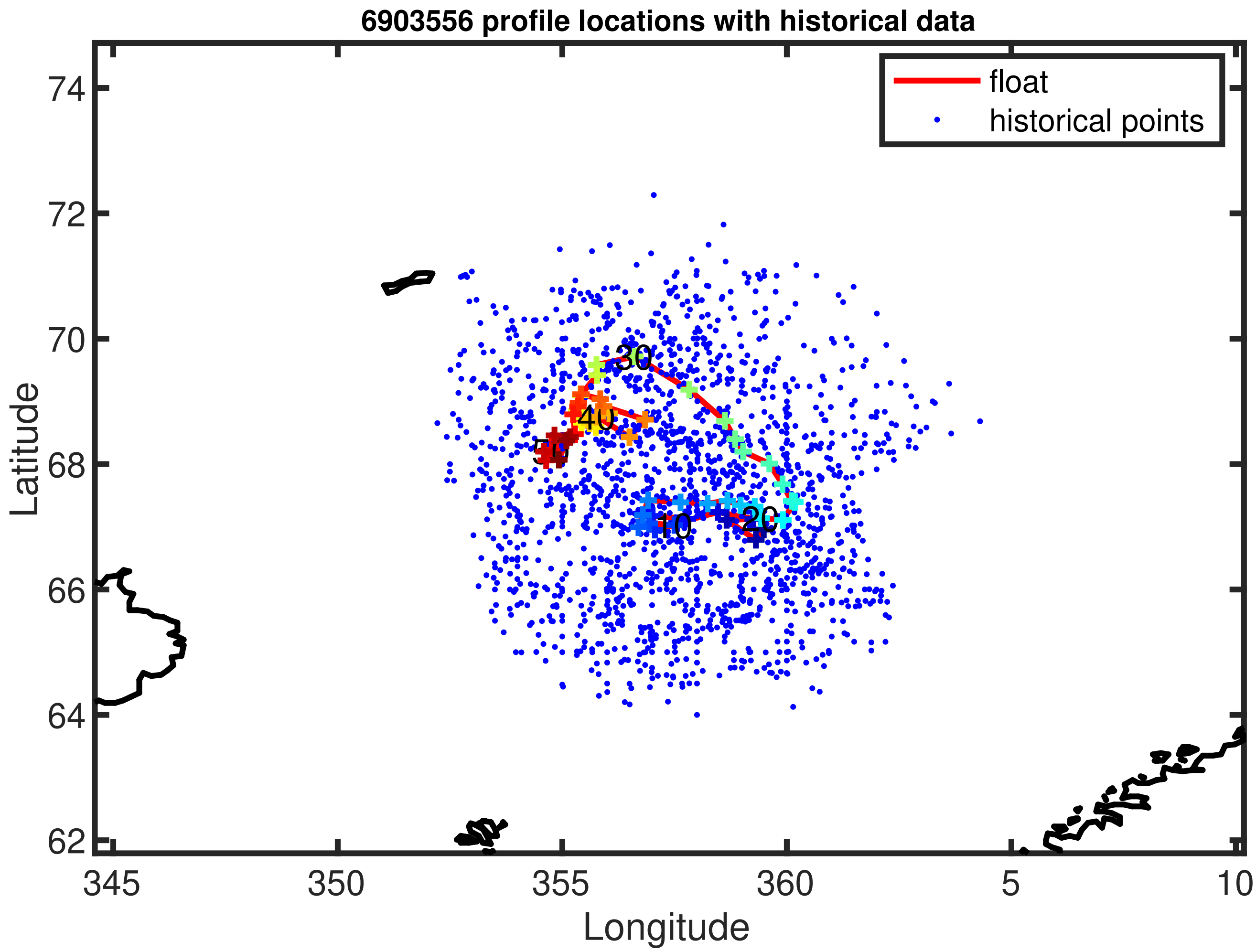


Figure 9: Float 6903556. Location of the float profiles (red line with black numbers) and the reference data selected for mapping (blue dots).

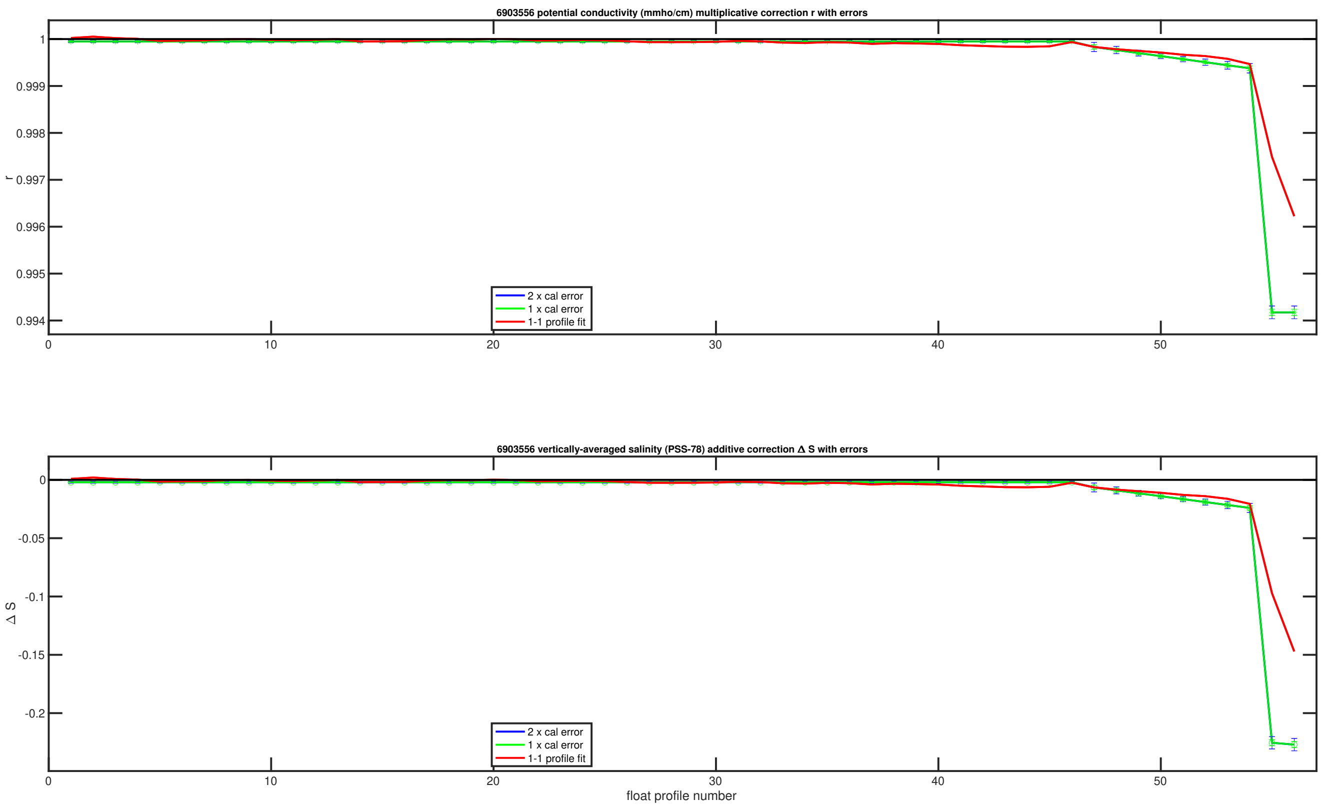


Figure 10: Float 6903556. Evolution of the suggested adjustment with time. The top panel plots the potential conductivity multiplicative adjustment. The bottom panel plots the equivalent salinity additive adjustment. The red line denotes one-to-one profile fit that uses the vertically weighted mean of each profile. The red line can be used to check for anomalous profiles relative to the optimal fit.

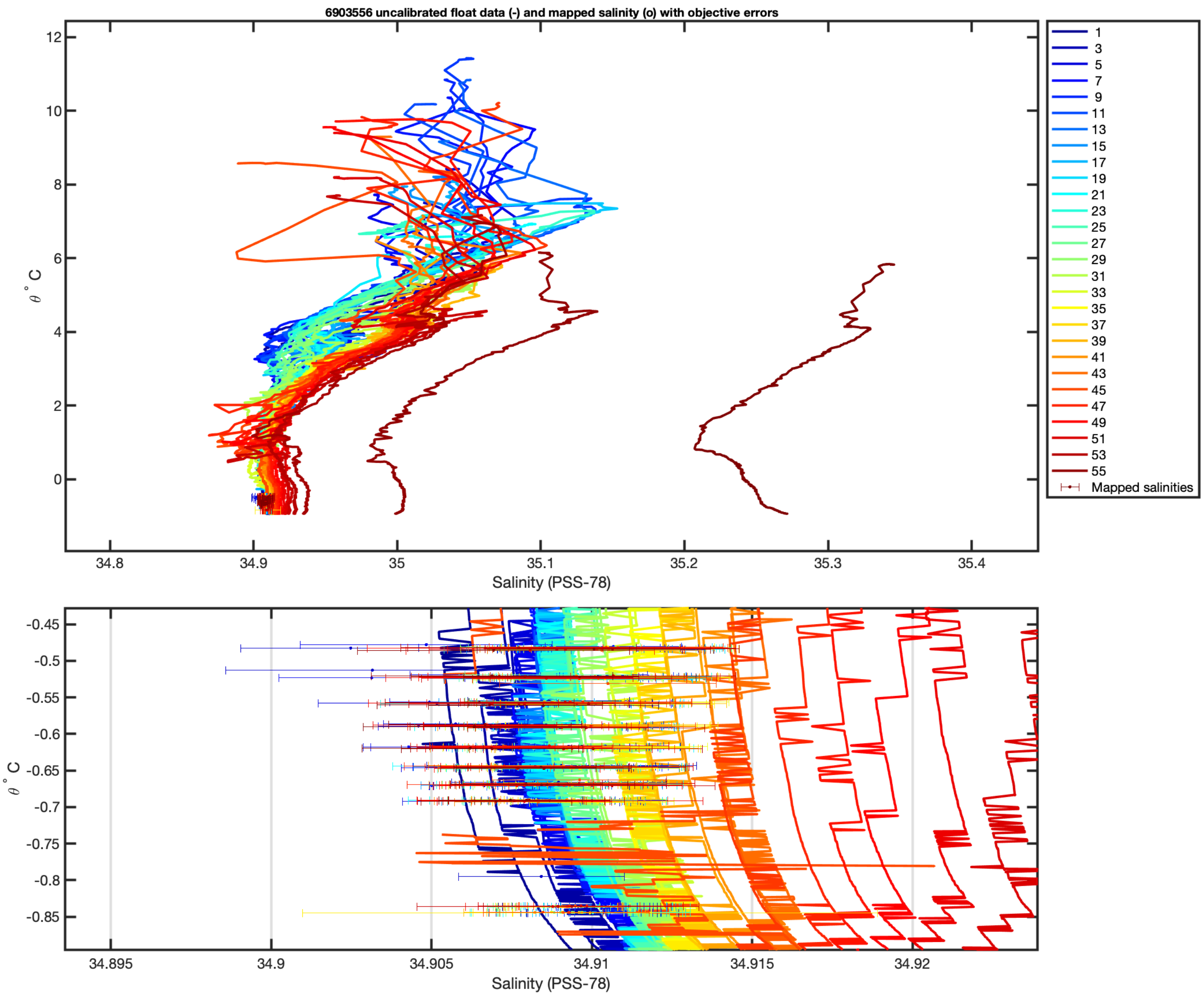


Figure 11: Float 6903556. The original float salinity and the objectively estimated reference salinity at the 10 float theta levels that are used in calibration as errorbars. Lower panel is a zoom to the latter.

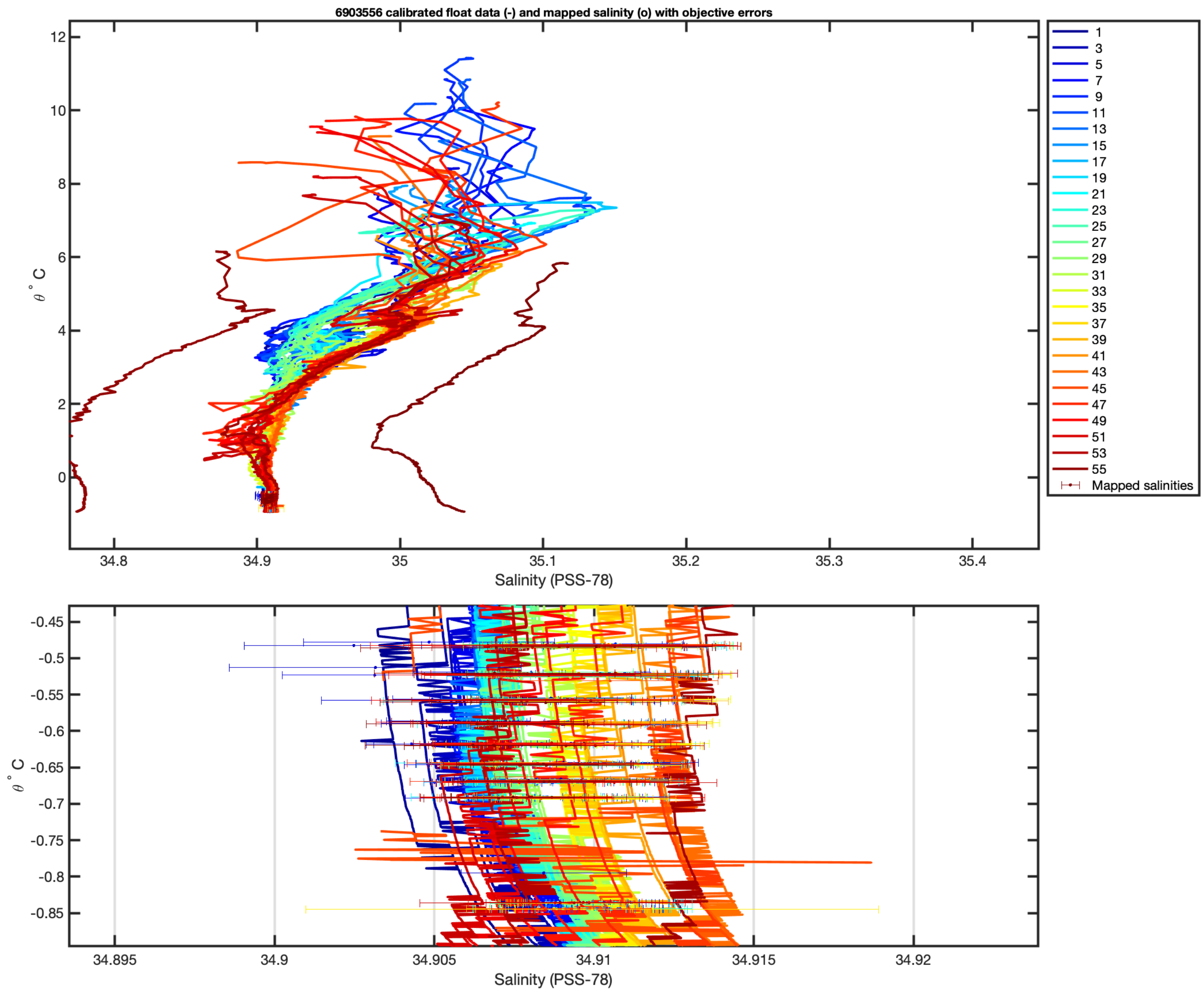


Figure 12: Float 6903556. Plots of calibrated float salinity and the objectively estimated reference salinity at the 10 float theta levels that are used in calibration as errorbars. Lower panel is a zoom to the latter.

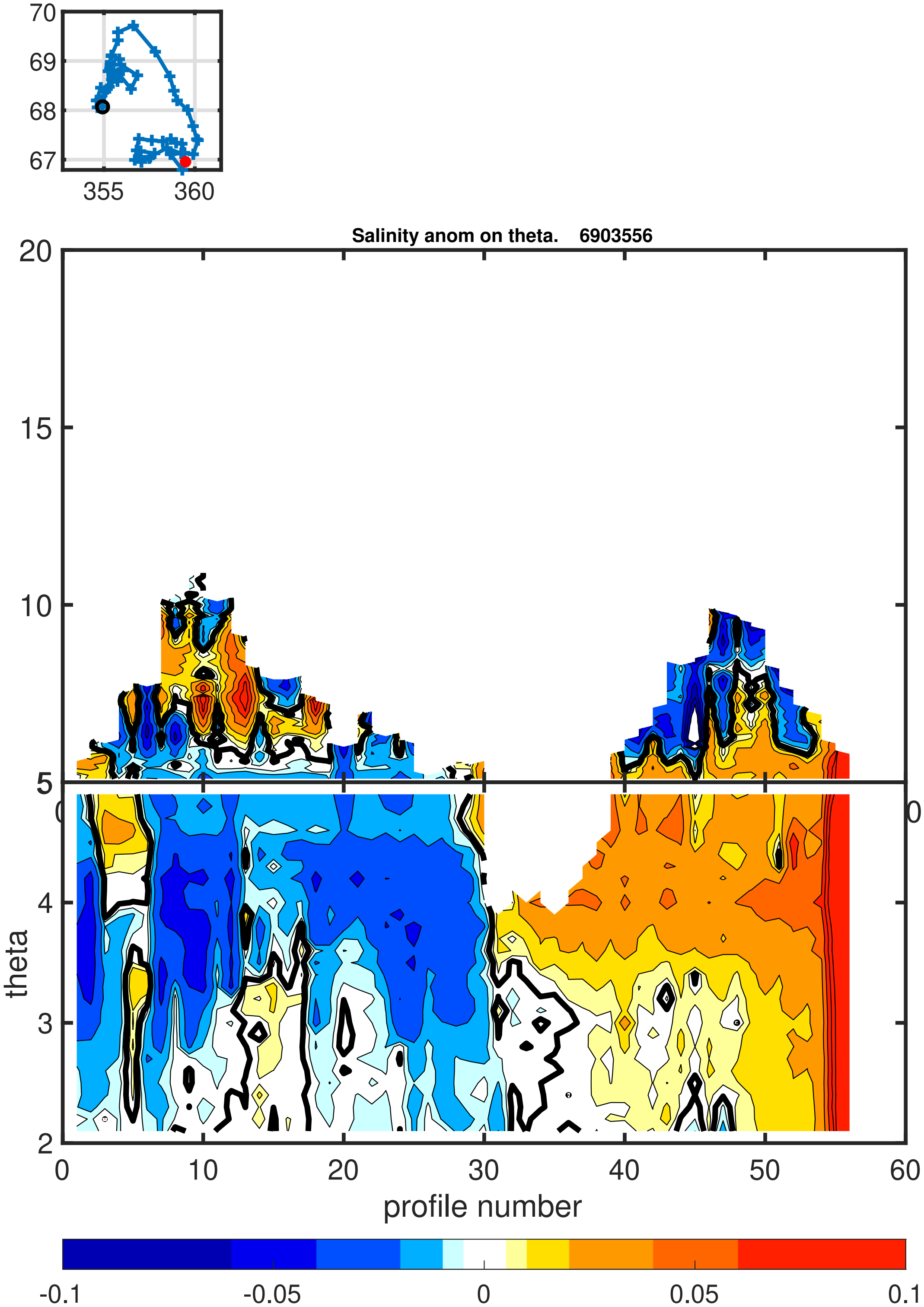


Figure 13: Float 6903556. Salinity anomaly on theta levels.

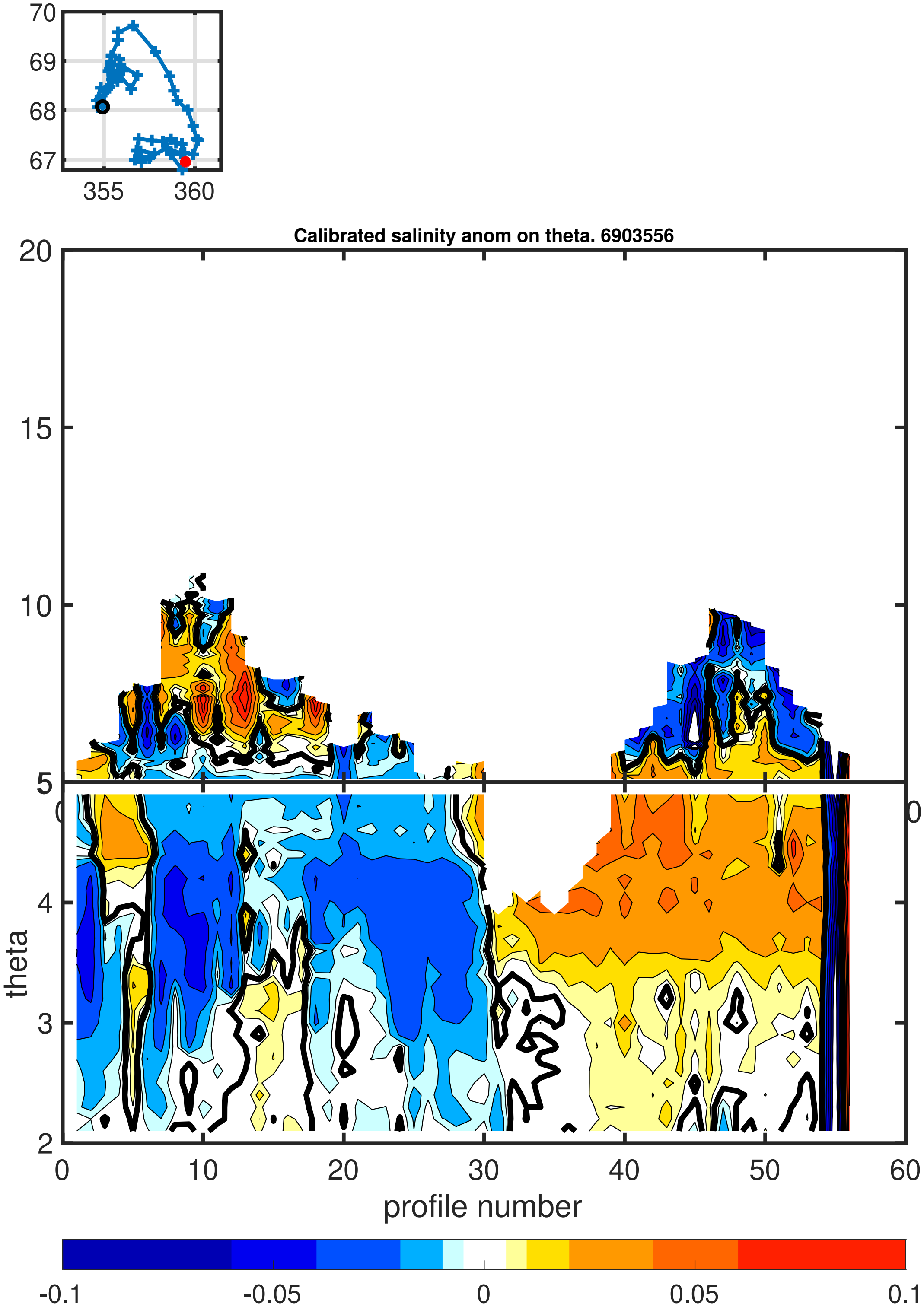


Figure 14: Float 6903556. Calibrated salinity anomaly on theta levels.

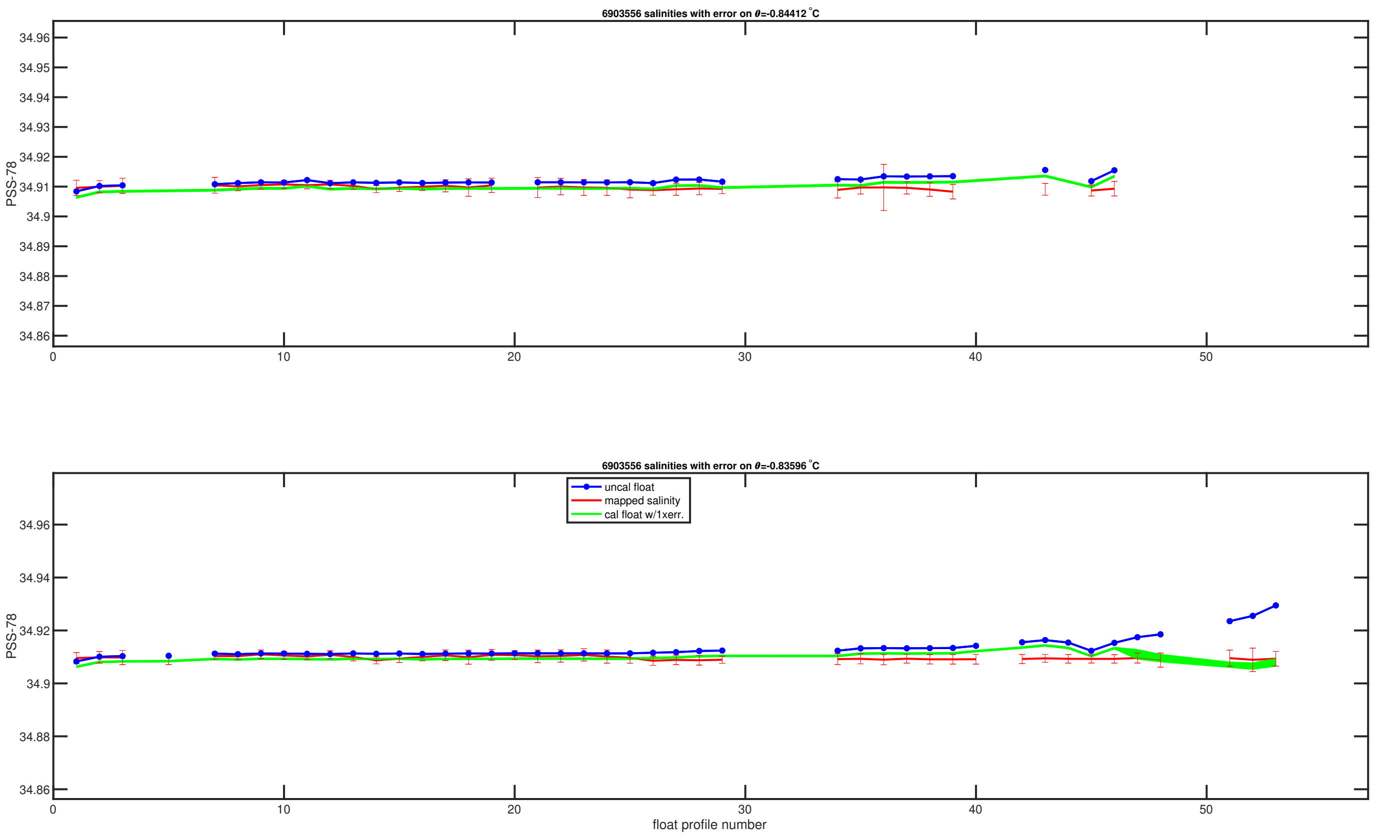


Figure 15: Float 6903556. Plots of the evolution of salinity with time along with selected theta levels with minimum salinity variance.

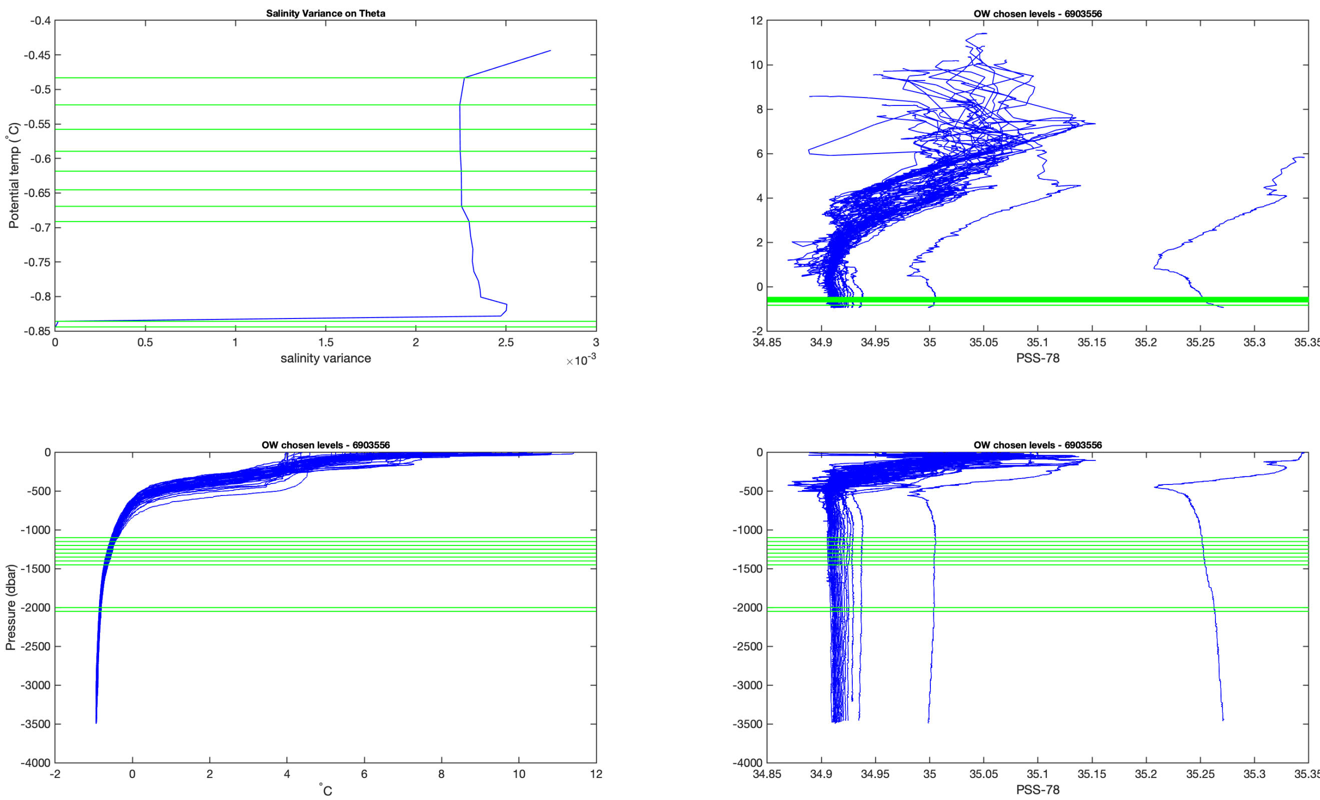


Figure 16: Float 6903556. Plots include the theta levels chosen for calibration: Top left: Salinity variance at theta levels. Top right: T/S diagram of all profiles of Argo float. Bottom left: potential temperature plotted against pressure. Bottom right: salinity plotted against pressure.

4 Discussion and conclusions

Float number 6903556 was deployed on 17/05/2020

This float is still active and further monitoring is required.

Acknowledgments

This report is based on the template given in the DM-REPORT-TEMPLATE Matlab/LaTeX toolbox provided at https://github.com/euroargodev/dm-report-template.git and adapted to own needs (this version is provided in https://github.com/imab4bsh/DMQC-fun.git). Calibration of conductivity sensor drift was done using the Matlab OWC toolbox provided at https://github.com/ArgoDMQC/matlab_owc. The map in Figure 1 was made using the M_MAP toolbox (Pawlowicz, 2020; `http://www.eoas.ubc.ca/~rich/map.html`). Supporting functions can be found in the author's own distribution at https://github.com/evenrev1/evenmat.git.

References

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.

Johnson, G. C., Toole, J. M., & Larson, N. G. (2007). Sensor corrections for Sea-Bird SBE-41CP and SBE-41 CTDs. Journal of Atmospheric and Oceanic Technology, 24(6), 1117–1130. https://doi.org/10.1175/JTECH2016.1.

Pawlowicz, R., 2020. "M_Map: A mapping package for MATLAB", version 1.4m, [Computer software], available online at `http://www.eoas.ubc.ca/~rich/map.html`.

Wong, A., Keeley, R., Carval, T., and the Argo Data Management Team (2021). Argo Quality Control Manual for CTD and Trajectory Data. http://dx.doi.org/10.13155/33951.

5 Appendix A: File information and notes

Operator's notes

The following notes have been made about this float:

```
'6903556'

-- 20211124 --
There are no new profiles from this float since 11-Sep-2021. Has Float 6903556 been decommissioned after pro
All 56 profiles mapped w/o warning. LBmap, KAMage, KAMphi. Ref data reasonably confined.
From center of NB towards east to p20, then fast along Helgelandsryggen to northernmost NB to p30,
then south a bit and now stays in the NW part of the deep NB.
Some levels close to thermocline; use_pres_gt = 1000 => all under.
Cal warnings. Severe salinity deviation in the end. Splitting series in 3 parts.
Still cal warnings on the last parts, but can be ignored.
Ignore 1-46 OK; linear correction for 47:54; ignore the BAD rest

%%% Local Variables:
%%% mode: plain-tex
%%% TeX-master: "DMQCreport_float"
%%% End:
```

Scientific calibration information

The scientific calibration information written to the D-files are summarized in Table 3.

Table 3: Information filled in the SCIENTIFIC_CALIB section for the variables, in the D-files.

Parameter	Field	Cycles/files	Text
PRES	EQUATION	1-56	PRES_ADJUSTED = PRES.
	COEFFICIENT	1-56	none
	COMMENT	1-56	none
	DATE	1-56	20211123172643
TEMP	EQUATION	1-56	TEMP_ADJUSTED = TEMP.
	COEFFICIENT	1-56	none
	COMMENT	1-56	The quoted error is manufacturer specified accuracy with respect to ITS-90 at time of laboratory calibration.
	DATE	1-56	20211123172643
PSAL	EQUATION	1-46	New conductivity = original conductivity * (1 + delta*TEMP + CPcor_SBE*PRES) / (1 + delta*TEMP_ADJUSTED + CPcor_new*PRES_ADJUSTED). PSAL_ADJUSTED = PSAL_ADJUSTED_Cnew.
		47-54	New conductivity = original conductivity * (1 + delta*TEMP + CPcor_SBE*PRES) / (1 + delta*TEMP_ADJUSTED + CPcor_new*PRES_ADJUSTED). PSAL_ADJUSTED = PSAL_ADJUSTED_Cnew + dS.
		55-56	New conductivity = original conductivity * (1 + delta*TEMP + CPcor_SBE*PRES) / (1 + delta*TEMP_ADJUSTED + CPcor_new*PRES_ADJUSTED).
	COEFFICIENT	1-46, 55-56	CPcor_new = -1.52e-07; CPcor_SBE = -9.57e-08; delta = 3.25e-06.
		47	CPcor_new = -1.52e-07; CPcor_SBE = -9.57e-08; delta = 3.25e-06. Vertically averaged dS = -0.004 +/- 0.002.
		48	CPcor_new = -1.52e-07; CPcor_SBE = -9.57e-08; delta = 3.25e-06. Vertically averaged dS = -0.006 +/- 0.001.
		49	CPcor_new = -1.52e-07; CPcor_SBE = -9.57e-08; delta = 3.25e-06. Vertically averaged dS = -0.009 +/- 0.001.
		50	CPcor_new = -1.52e-07; CPcor_SBE = -9.57e-08; delta = 3.25e-06. Vertically averaged dS = -0.011 +/- 0.001.
		51	CPcor_new = -1.52e-07; CPcor_SBE = -9.57e-08; delta = 3.25e-06. Vertically averaged dS = -0.014 +/- 0.001.
		52	CPcor_new = -1.52e-07; CPcor_SBE = -9.57e-08; delta = 3.25e-06. Vertically averaged dS = -0.016 +/- 0.001.
		53	CPcor_new = -1.52e-07; CPcor_SBE = -9.57e-08; delta = 3.25e-06. Vertically averaged dS = -0.019 +/- 0.002.
		54	CPcor_new = -1.52e-07; CPcor_SBE = -9.57e-08; delta = 3.25e-06. Vertically averaged dS = -0.021 +/- 0.002.
	COMMENT	1-46	New conductivity computed by using a different CPcor value from that provided by Sea-Bird. No significant salinity offset or drift detected. The quoted error is max[0.01, statistical uncertainty] in PSS-78.
		47-54	New conductivity computed by using a different CPcor value from that provided by Sea-Bird. Significant salinity sensor offset or drift detected. OW least squares fit adopted. The quoted error is max[0.01, statistical uncertainty] in PSS-78.
		55-56	New conductivity computed by using a different CPcor value from that provided by Sea-Bird. Salinity data are bad and unadjustable.
	DATE	1-56	20211124093743

6 Appendix B: Reference data

Here follows overview plots of the reference data in the WMO-squares traversed by Float 6903556.

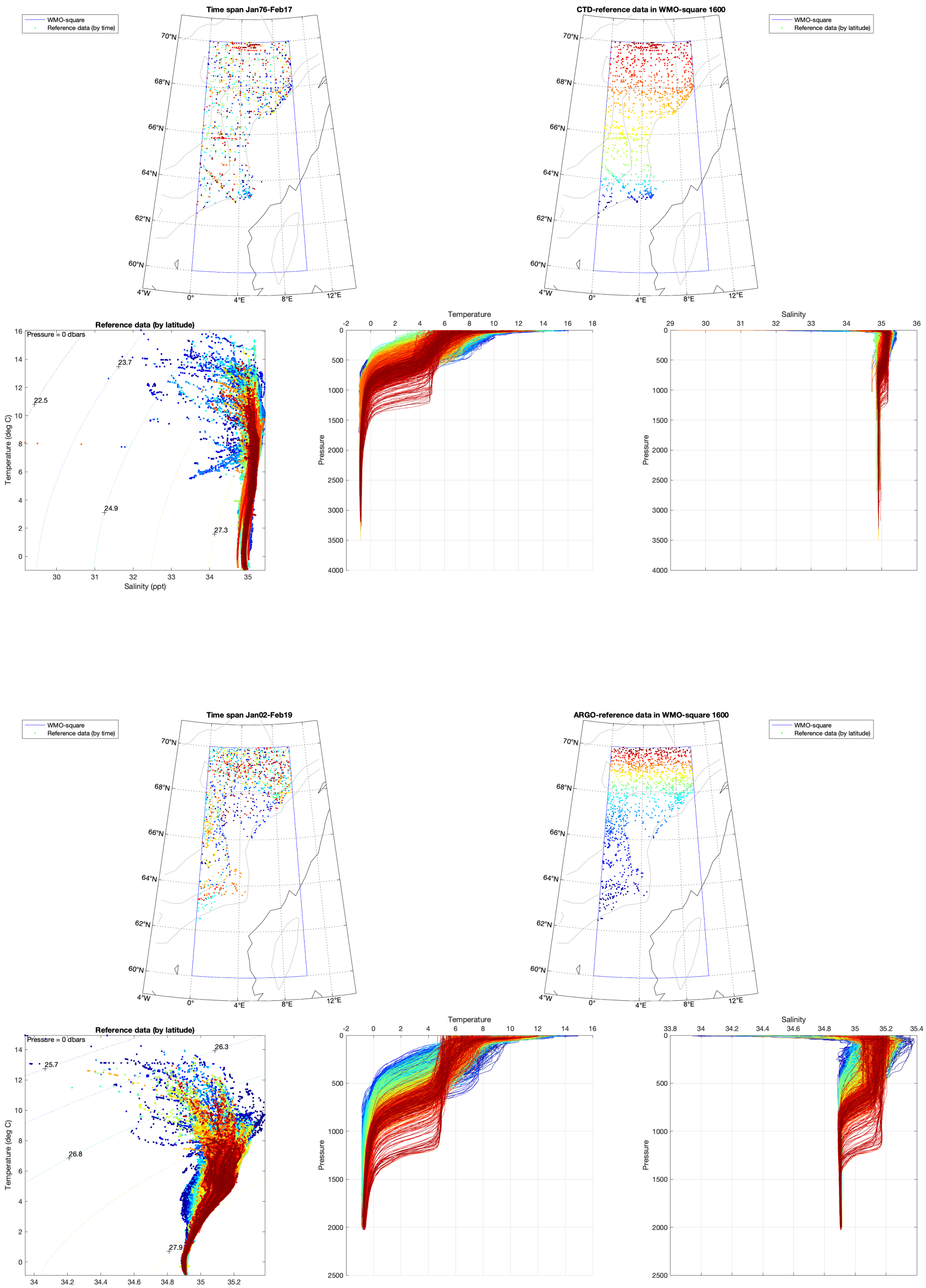


Figure 17: Overview of reference data in WMO square 1600 which is traversed by Float 6903556. Upper set of graphs are for CTD reference data, and lower set is for historical ARGO data. Colouring of positions in map pairs illustrate temporal coverage and latitude, respectively. The following TS and profile plots use the latter colormap.

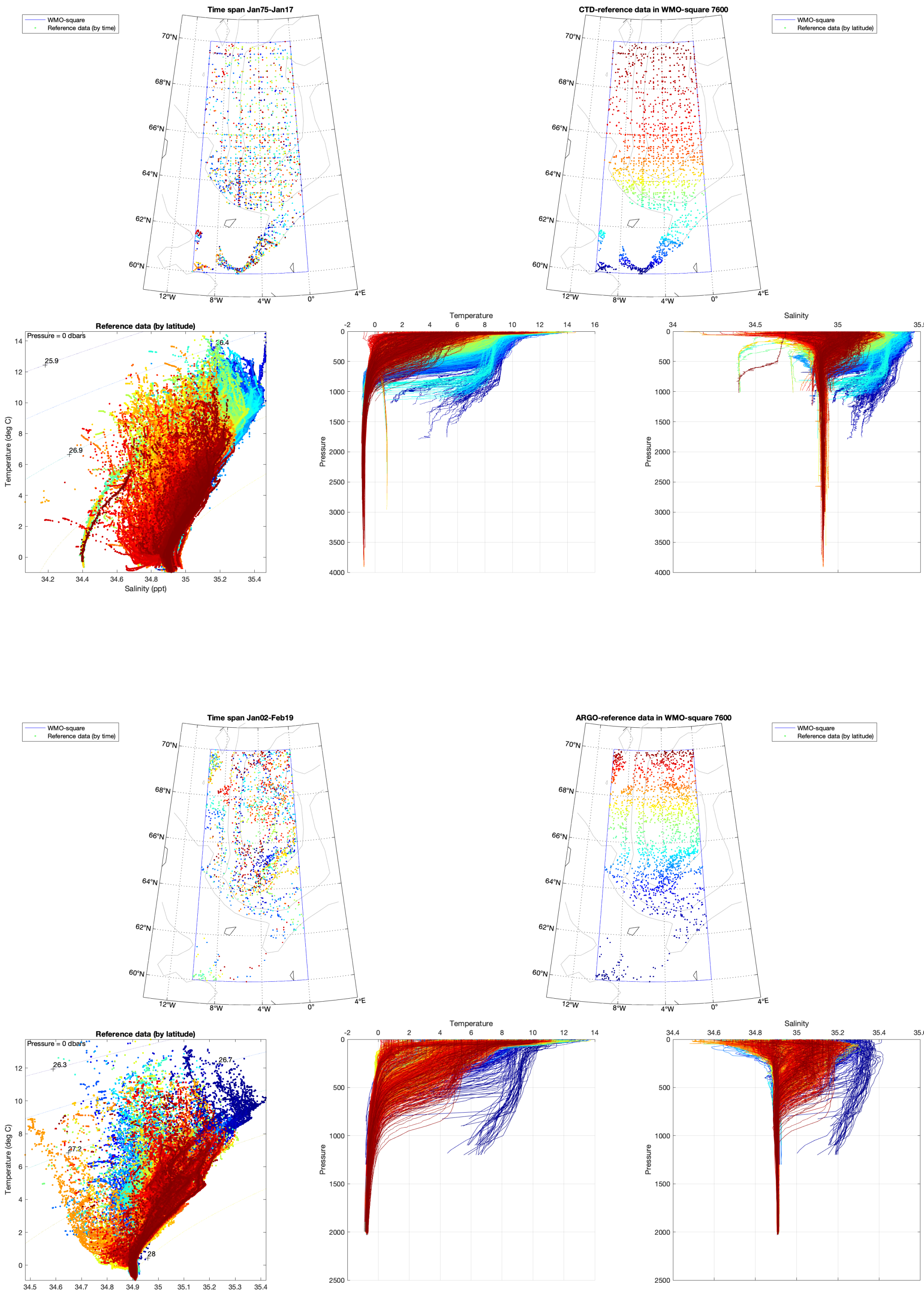


Figure 18: Overview of reference data in WMO square 7600 which is traversed by Float 6903556. Upper set of graphs are for CTD reference data, and lower set is for historical ARGO data. Colouring of positions in map pairs illustrate temporal coverage and latitude, respectively. The following TS and profile plots use the latter colormap.