Istituto Nazionale di Oceanografia e di Geofisica Sperimentale

Comparison between ship-based and Argo CTD profiles in the Eastern Mediterranean Sea (April 2006)

by

P.-M. Poulain[1], R. Barbanti[1] & I. Taupier-Letage[2]

[1] OGS, Trieste, Italy

[2] LOB/CNRS, Toulon, France

Partial contribution to the EGYPT and EGITTO projects.

Produced by the Mediterranean Argo Regional Centre (MED-ARC), OGS, Trieste, Italy

Approved for release by: ……………………………………

Dr. Alessandro Crise
Director, Department of Oceanography

Table of contents

1. Introduction

As part of the Eddies and GYre Paths Tracking (EGYPT) and EGITTO projects, whose major objective is to study the circulation of the Eastern Mediterranean Sea, five Argo profiling floats were released in the southeastern Ionian Sea and Cretan Passage areas during the EGYPT-1 oceanographic cruise in April 2006 (Taupier-Letage, 2006). The hydrographic survey conducted during this cruise comprises 125 CTD casts, and care was taken to make one cast prior to each Argo float deployment.

In this report, the temperature and salinity profile data obtained with the Argo floats and with the ship-based CTD are compared using pairs of profiles quasi-collocated in space and quasi-simultaneous in time. The discrepancies found between the profiles are interpreted and discussed.

2. Data and methods

2.1 EGYPT Argo float data

The EGYPT-1 oceanographic cruise was conducted onboard R/V Poseidon between 8 and 26 April 2006 as part of the EGYPT project (Taupier-Letage, 2006). During this cruise, five Argo profiling floats were deployed in the southeastern Ionian Sea and the Cretan Passage to measure and provide temperature and salinity data in near-real time to operational models of ocean forecasting (MERCATOR, GNOO, MOON). All floats were PROVOR CTS3 systems manufactured by Martec (Martec, 2005). They are equipped with Sea-Bird CTD sensors (model 41) with temperature accuracy of 0.002 ºC, conductivity accuracy equivalent to a salinity of 0.005, and pressure accuracy of 2.4 dbars. Numerical resolutions after digitization are respectively 0.001 ºC, 0.001 and 1 dbar (Martec, 2005). The PROVORs were programmed in the “Park and Profile” configuration with a neutral parking depth of 350 m (near the salinity maximum of the Levantine Intermediate Water - LIW) and a maximum profiling depth of 700 m, with a cycling period of 10 days. Every ten cycles, the PROVORs were programmed to profile between 2000 m and the surface in order to sample deep water mass properties. When at surface, the PROVORs were located by, and transmitted data, to the Argos system onboard the NOAA satellites. The sampling intervals for the vertical profiles are 10 m between 5 and 705 m, and 50 m below 750 m.

The PROVOR data were processed and archived in near-real time at the Global Data Assembly Centre (GDAC) of Ifremer in Brest, France (also called the CORIOLIS Operational Oceanography Data Centre) and were distributed on the GTS following the standards of the international Argo program. The data were downloaded from the GDAC and they were considered in this study only if the corresponding quality control (QC) flag was equal to one. More details on EGYPT Argo floats and on the GDAC data management can be found at the following web sites, respectively:

http://poseidon.ogs.trieste.it/sire/medargo/

http://www.ifremer.fr/mfstep/data_management/wp4_medargo/index.html

2.2 EGYPT-1 CTD data

A dense CTD survey of 125 stations (see Figure 1) was carried out during the EGYPT-1 campaign in the southeastern Ionian Sea and in the Cretan Passage area, together with complementary measurements (XBT, surface drifters, deployment of currentmeter moorings, etc.). The sampling interval along the transects was usually set between 5 and 10 nautical miles, in order to sample adequately the mesoscale structures detected from the analysis of the thermal infrared satellite images received on board in near-real time. The CTD casts were made with a Sea-Bird probe SBE 911+ . The probes (temperature SBE 3 and conductivity SBE4) were calibrated prior (13 December 2005) and after the cruise (13 June 2006) at the Seabird facility (reports are included in Appendix 1). The drift of the conductivity sensor was found to be 0.001 per month. This is unusually high, although within the manufacturer's specifications. There was neither need for cleaning nor any failure reported. However, the conductivity probe was sent back for a second recalibration (15 September 2006). It showed no change since the previous calibration. This means that there was no drift in air, and that we must consider that the whole drift intervened during the 125 casts of the EGYPT-1 cruise. The LOB/CNRS team is presently investigating the whole CTD data set to look for a potential sudden drop in conductivity that would allow adjusting at best the drift. If no such sudden signal is found the drift will be considered as linear. Up and down-cast CTD profiles were available but only the down-cast data were considered in this work to save most of the stratification information. Data have been processed according to the manufacturer's recommendations using the SeaSoft software suite, with pressure bins of 1db (see detailed description and parameters used in Appendix 2).

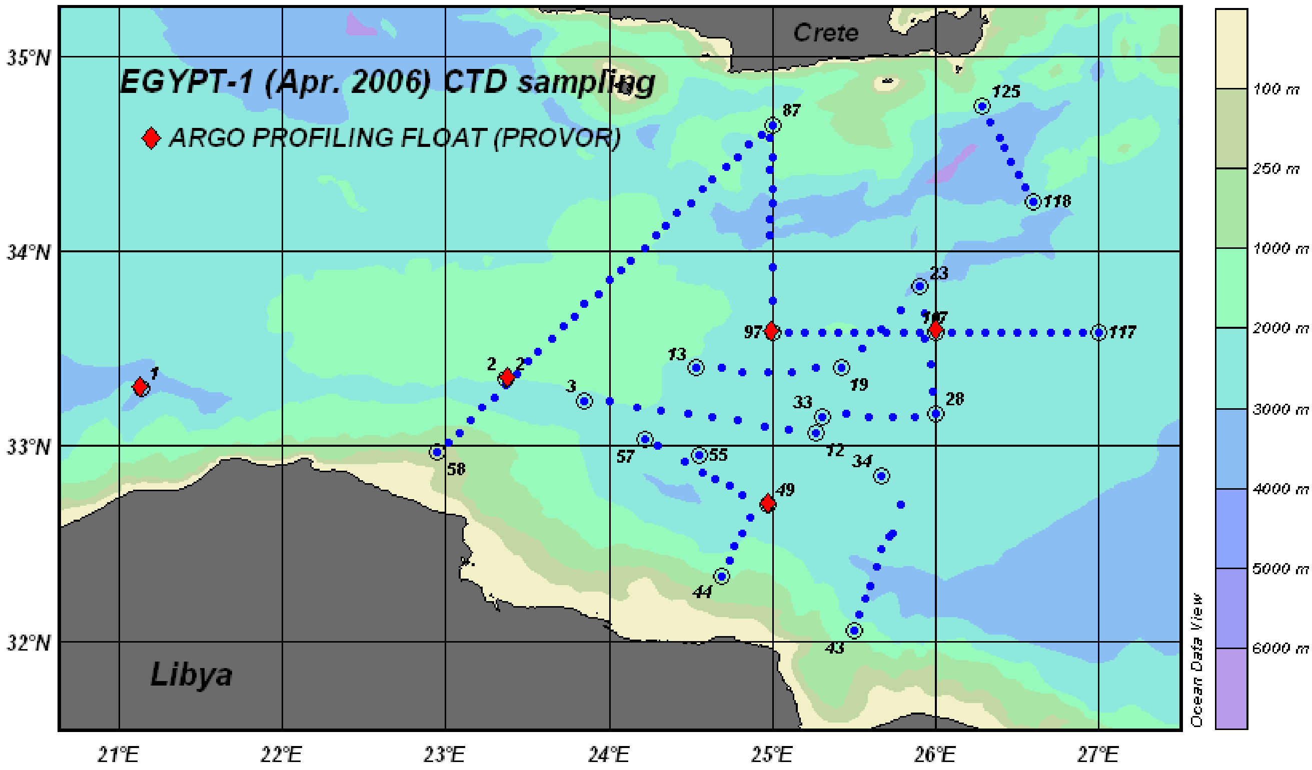


Figure 1. EGYPT-1 CTD survey. The PROVORs were deployed after the CTD casts marked with a red diamond.

2.3 Methods

Five pairs of the PROVOR and ship-based CTD profiles (quasi-collocated and quasi-simultaneous) were considered in this report (see Table 1). For each pair, the distance between the two profiles varies from 3 to 17.4 km and the separation in time spans 26.9-41.9 hours.

PROVOR Profiles					Ship Profiles						
WMO	Argos	Date Time (GMT)	Lat	Lon	CTD Cast	Date Time (GMT)	Lat	Lon	Cast Depth (dbar)	Distance (km)	Time (hours)
1900602	63657	10-Apr-2006 14:54	33.31	21.13	1	10-Apr-2006 16:17	33.30	21.13	1012	4.6	26.9
1900605	63660	11-Apr-2006 04:15	33.31	23.46	2	11-Apr-2006 05:51	33.36	23.37	1016	11.5	39.0
1900604	63659	18-Apr-2006 12:05	32.71	24.97	49	18-Apr-2006 10:31	32.71	24.97	2436	4.4	32.9
1900606	63661	22-Apr-2006 10:20	33.58	25.00	97	22-Apr-2006 08:53	33.58	25.00	2149	3.0	34.4
1900603	63658	23-Apr-2006 04:06	33.60	26.00	107	23-Apr-2006 02:23	33.59	26.00	2421	17.4	41.9

Table 1. Dates/times and positions of the PROVOR and ship-based CTD profiles compared in this report.

The locations of the ship CTD profiles listed in Table 1 are shown in Figure 2a. They are identified with the cast numbers. In Figures 2b to 2f, the same locations are depicted along with those of the closest PROVOR profiles (separated by the minimum time interval) and those of other float profiles in the area for the period 10-24 April 2006.

The CTD profiles were first compared qualitatively by plotting the temperature and salinity data versus depth (pressure). Then, the following statistics were computed for all the pairs:

- Histograms, means and standard deviations of the temperature difference (ship – PROVOR);
- Means and standard deviations of the temperature difference in depth intervals;
- Scatter diagrams with color coding representing depth, time difference and distance;
- Linear regression statistics.

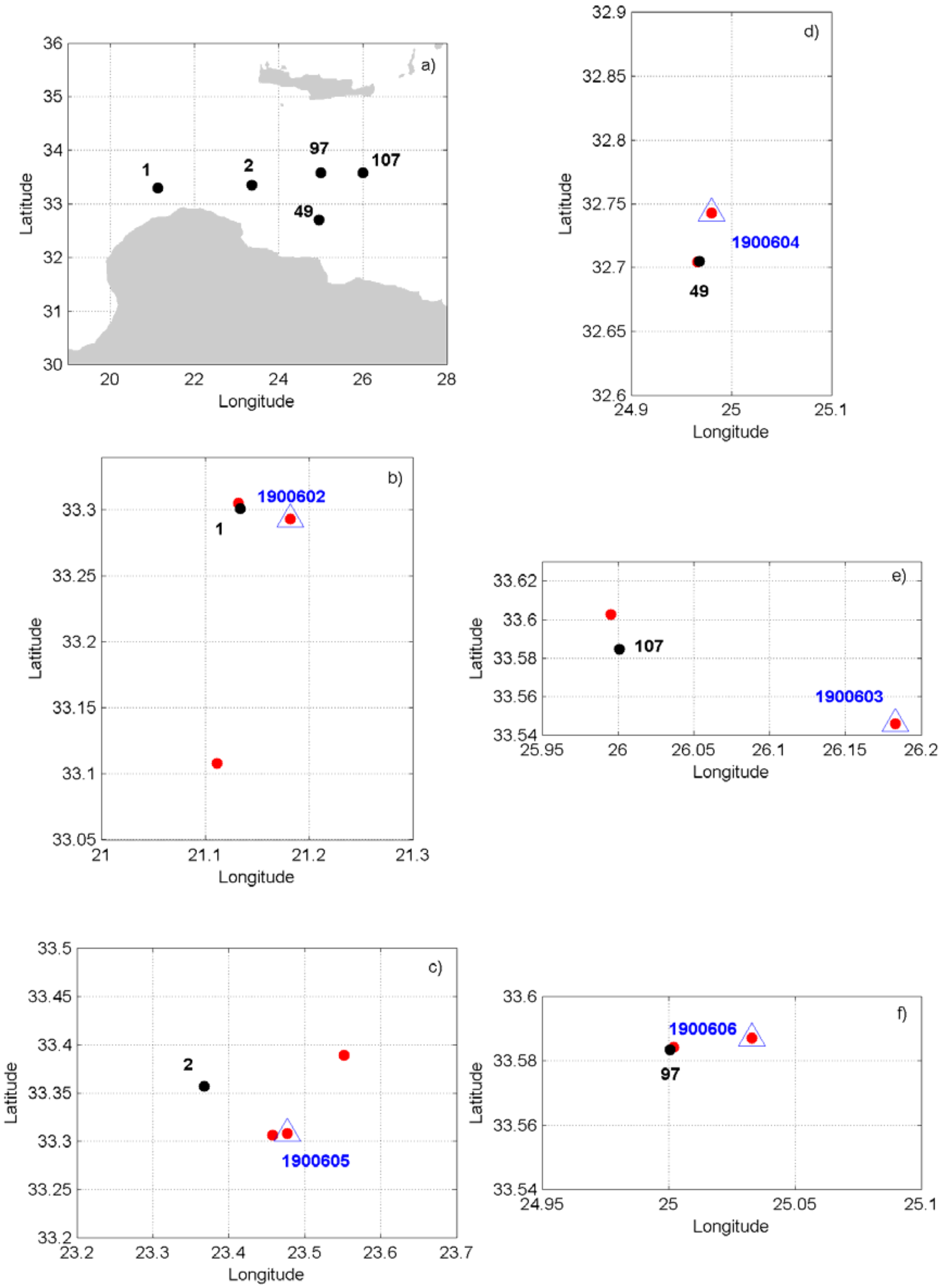


Figure 2. (a): Geographical locations of the ship CTD casts (black dots) identified by their cast numbers; (b) to (f): Positions of the ship and PROVOR profiles (black and red dots, respectively) in the same vicinity over the period 10-24 April 2006. Triangle symbols denote the PROVOR profiles used for the comparison with the ship profiles (corresponding to the minimum time interval).

3. Results

3.1 CTD profiles

Profiles of potential temperature versus depth were plotted for all the PROVOR/ship CTD pairs considered. PROVOR CTD profiles in the period spanning 10 to 24 April 2006 and located in an area delimited by 21-26 °E in longitude and 32-34°N in latitude were are also plotted (in red) to have an indication of the temporal and spatial variability of the thermohaline properties in the area of study. The graphs are shown in Figures 3 to 7.

Most profiles show a mixed layer of nearly homogeneous temperature and salinity and a thermocline/halocline extending from the base of the mixed layer down to depths between 500 and 700 m. In salinity, a sub-surface maximum is prominent at depths ranging in 200 and 600 m, and corresponds to layers of LIW. Values of potential temperature and salinity from the surface to depths between 500 and 1000 m vary substantially with typical ranges of 14-18 °C and 38.4-39.1, respectively. Part of this variability is due to LIW, but is also associated with strong eddies ubiquitous in the southeastern Mediterranean. This is the case for profile #107, which was located in the central part of the wind-induced Ierapetra eddy (generated during summer 2005). At deeper levels the potential temperatures converge to values in 13.44-13.62 °C and the salinities span the limited range 38.72-38.77.

Roughly speaking, below 800 m the differences between the potential temperatures and salinities for the five pairs considered (those with minimal time separation) are bounded by 0.02 °C and 0.02, respectively.

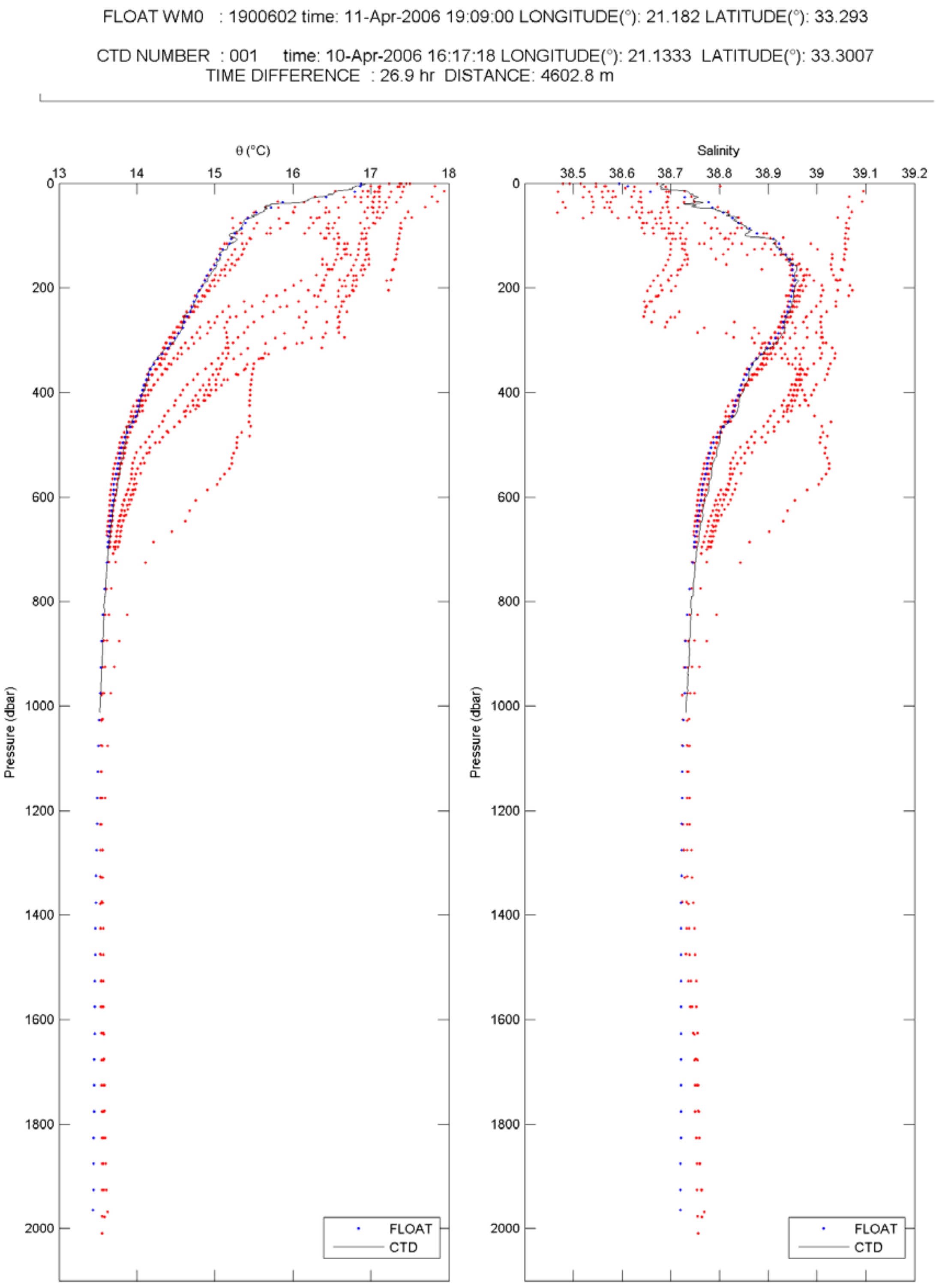


Figure 3. Potential temperature and salinity profiles plotted versus pressure. Profile of PROVOR WMO 1900602 (blue dots), ship CTD profile 001 (black line) and other PROVOR profiles in the area 21-26°E and 32-34°N over the period 10-24 April 2006 (red dots).

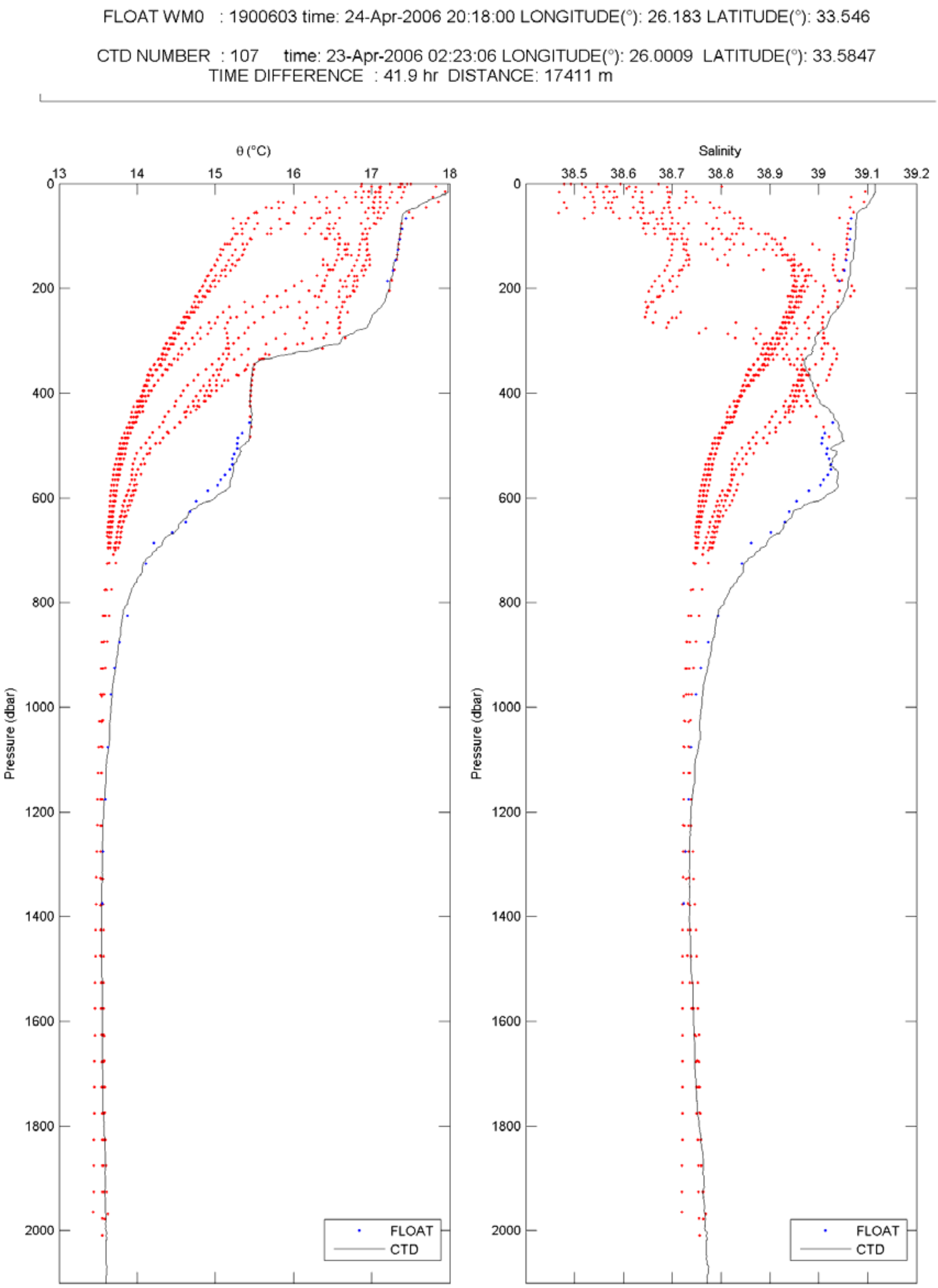


Figure 4. Same as Figure 3 but for profile of PROVOR WMO 1900603 (blue dots) and ship CTD profile 107 (black line).

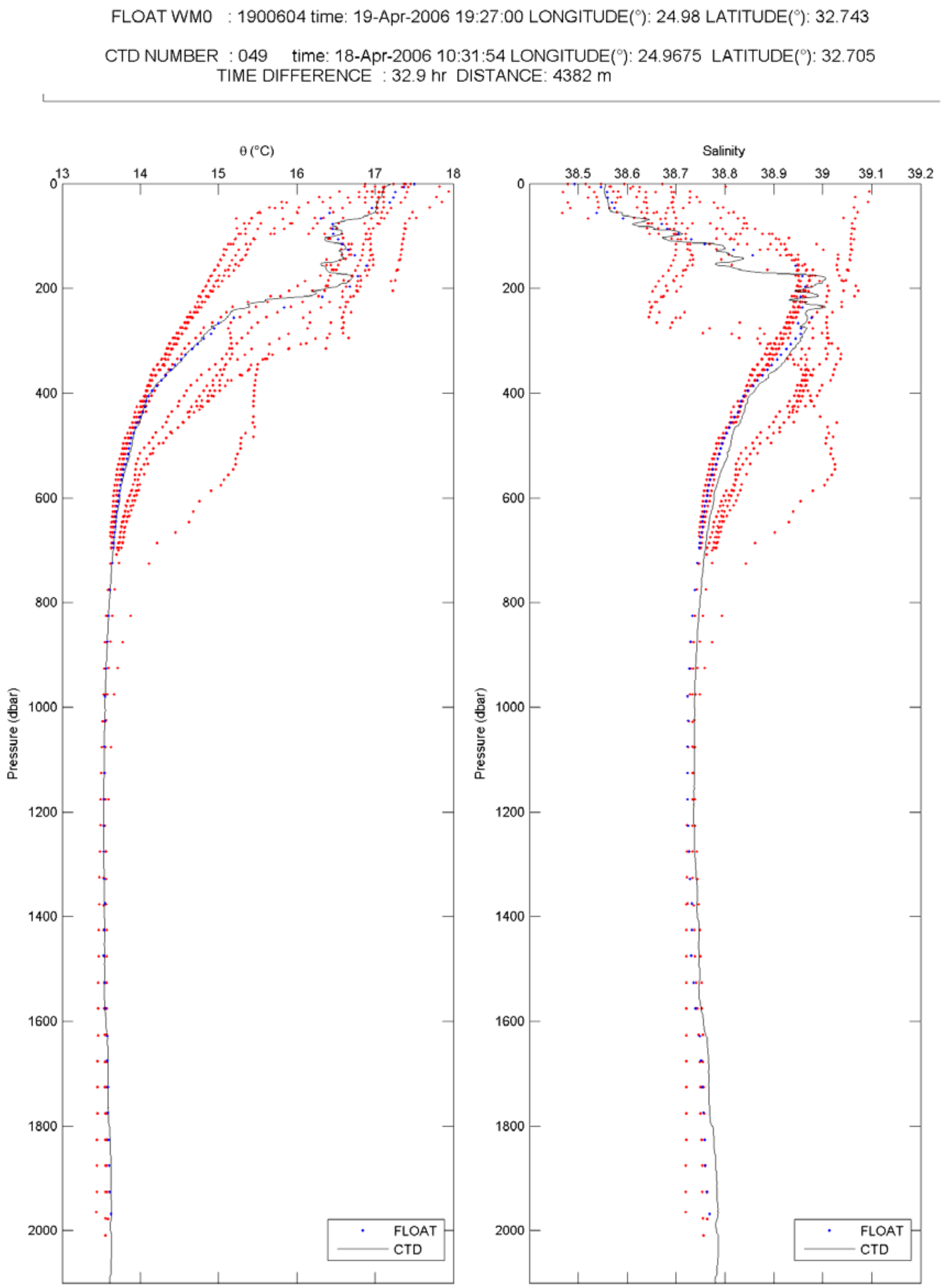


Figure 5. Same as Figure 3 but for profile of PROVOR WMO 1900604 (blue dots) and ship CTD profile 049 (black line).

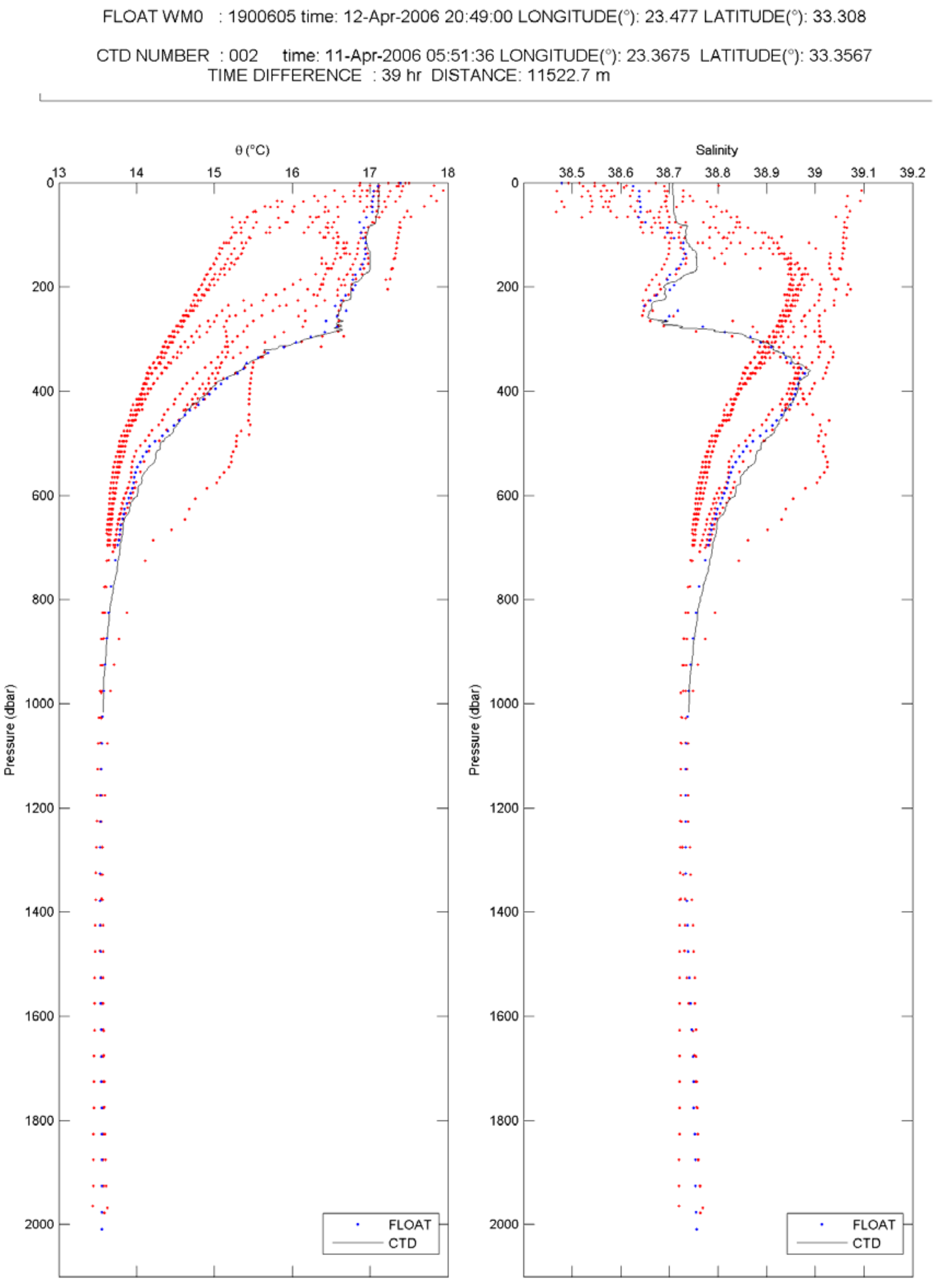


Figure 6. Same as Figure 3 but for profile of PROVOR WMO 1900605 (blue dots) and ship CTD profile 002 (black line).

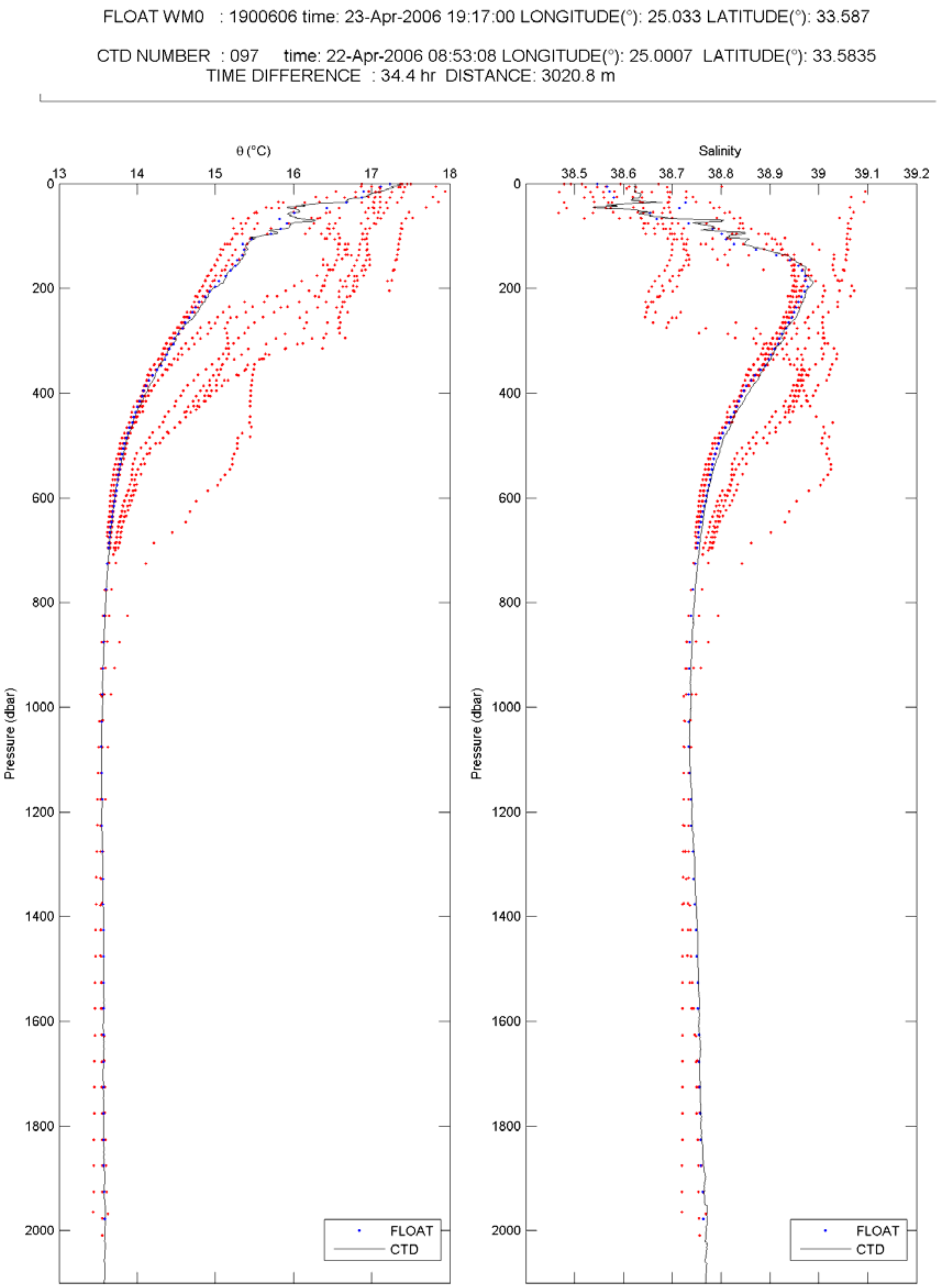


Figure 7. Same as Figure 3 but for profile of PROVOR WMO 1900606 (blue dots) and ship CTD profile 097 (black line).

3.2 Histograms, means and standard deviations

The histograms of the potential temperature and salinity differences (ship-PROVOR) are depicted in Figures 8 to 12, for the pairs analyzed. The mean potential temperature differences vary in -0.01 and 0.04 ºC with standard deviations bounded by 0.13 ºC. In salinity, the mean differences range between 0.006 and 0.017 whereas the standard deviation is less than 0.025.

The comparison pairs were also sorted in depth intervals of 100 m between 0 and 2000 m. The mean and the standard deviation of the temperature differences were calculated for each intervals. The results are plotted in Figures 13 to 22. The numerical results are listed in Tables 2 and 3.

The results show that the potential temperature difference (ship-PROVOR) averaged in the intervals can be as large as +0.06 and -0.03 ºC in the upper layers. At depths below 900 m, this difference becomes bounded by 0.015 ºC. The standard deviation generally decreases with increasing depths because of the reduction of sea water temperature variability with depth. Near the surface it can be as large as 0.26 ºC.

In terms of salinity, the mean differences can be relatively large above 500 m, with values ranging in -0.03 and +0.06. Deeper in the water column, the differences are typically bounded by 0.02 and can be as small as 0.001. Standard deviations are maximal near the surface (up to 0.07).

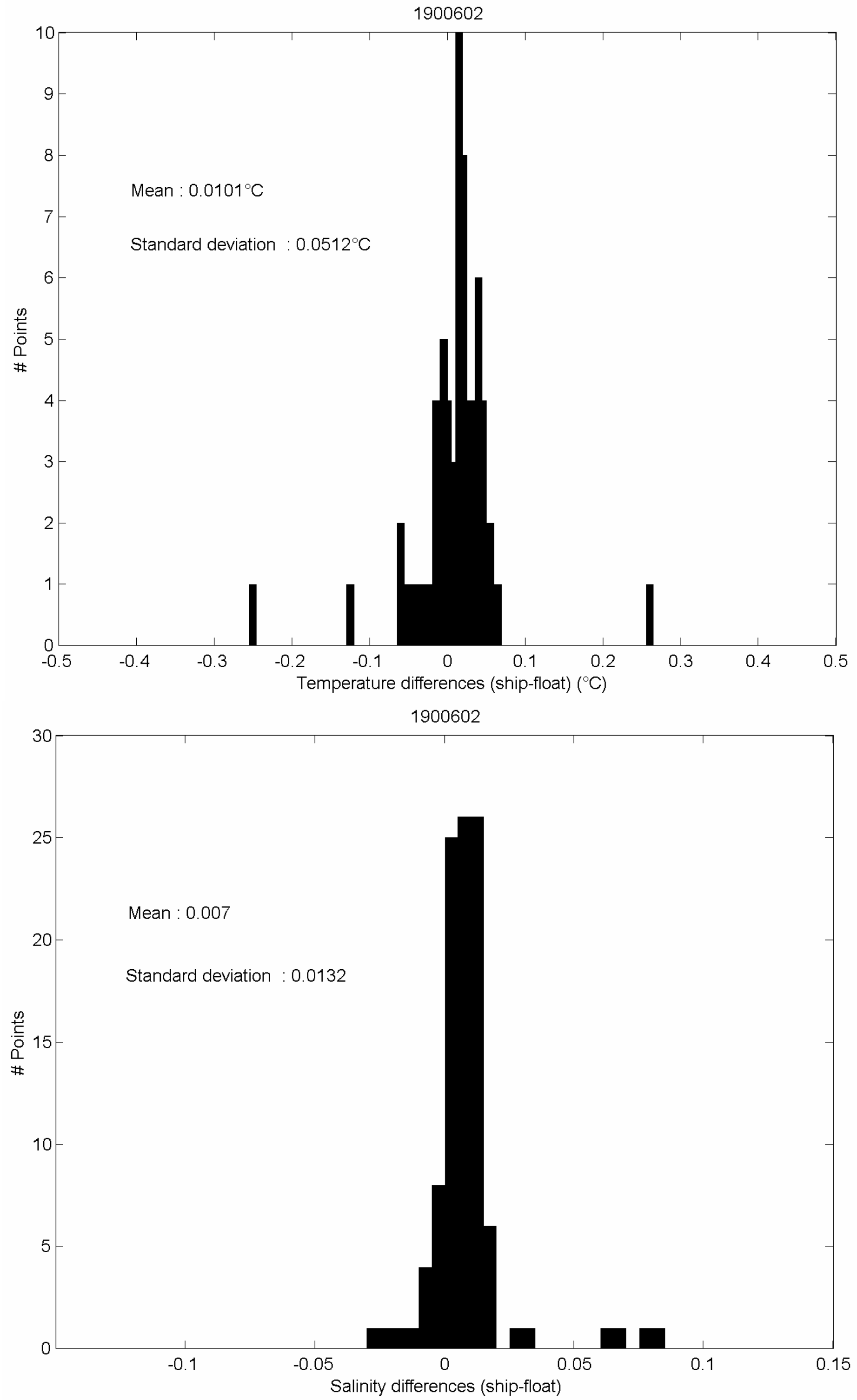


Figure 8. Histogram of the potential temperature (top) and salinity (bottom) differences between ship CTD cast 001 and closest PROVOR CTD (WMO 1900602).

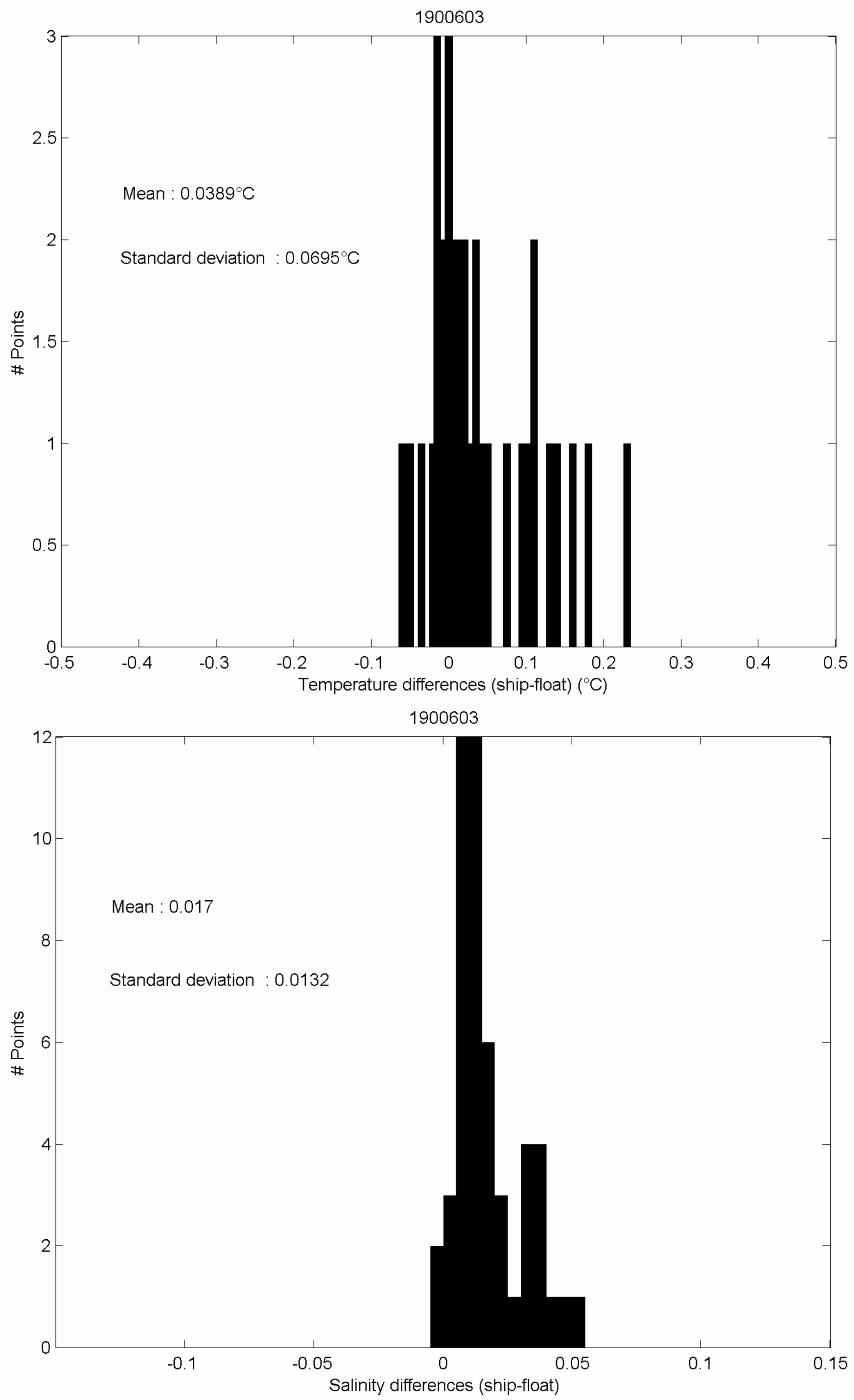


Figure 9. Histogram of the potential temperature (top) and salinity (bottom) differences between ship CTD cast 107 and closest PROVOR CTD (WMO 1900603).

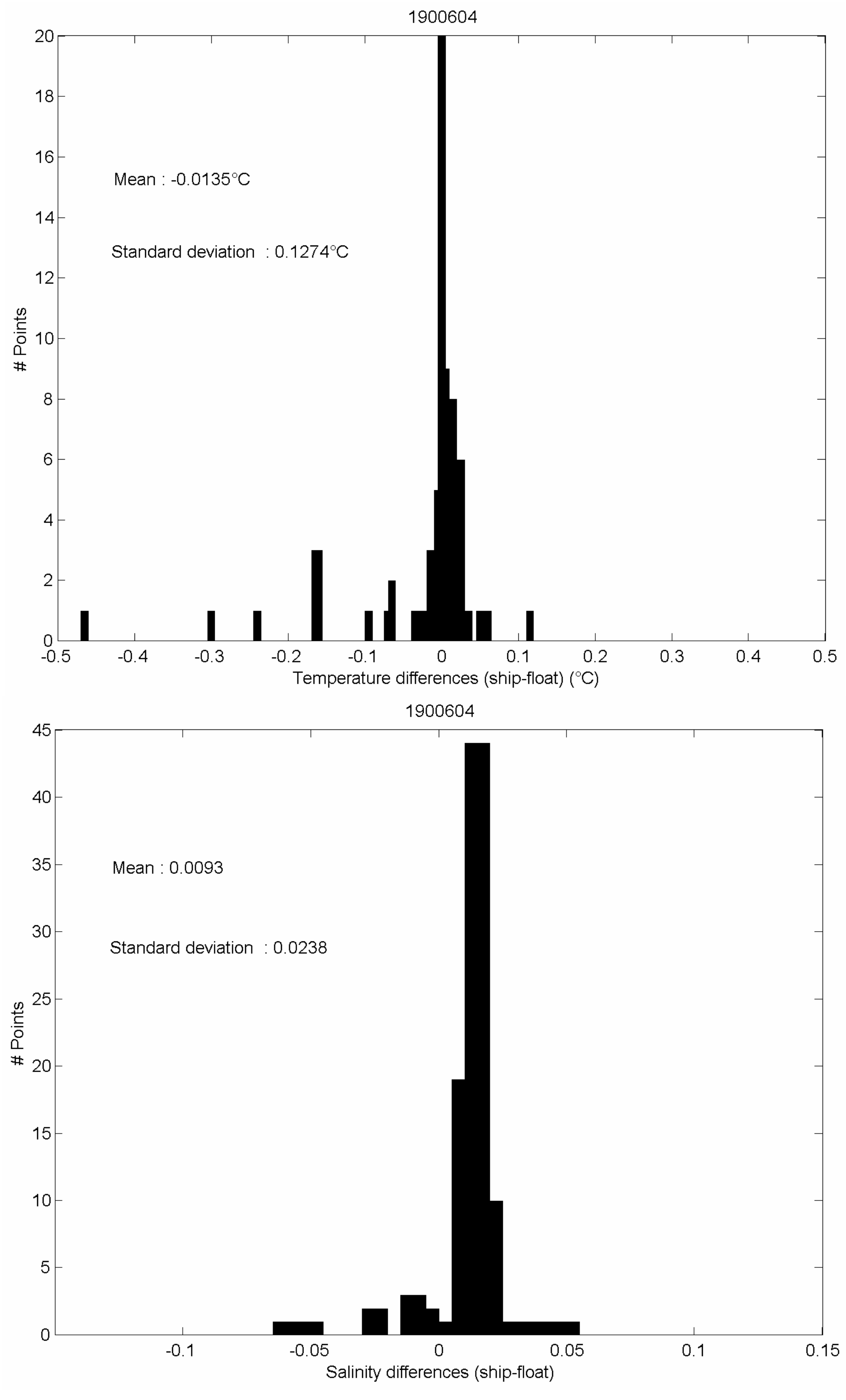


Figure 10. Histogram of the potential temperature (top) and salinity (bottom) differences between ship CTD cast 049 and closest PROVOR CTD (WMO 1900604).

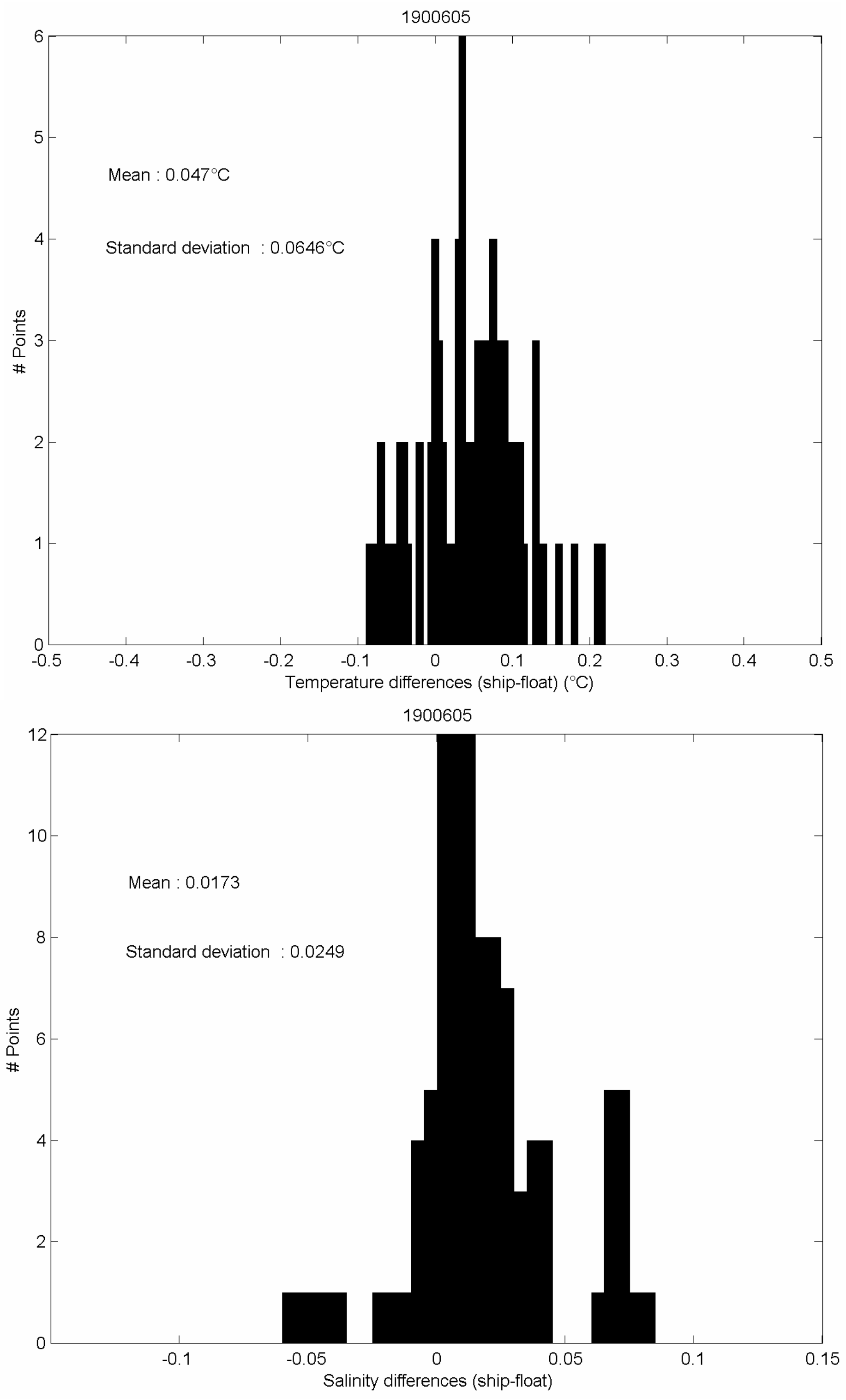


Figure 11. Histogram of the potential temperature (top) and salinity (bottom) differences between ship CTD cast 002 and closest PROVOR CTD (WMO 1900605).

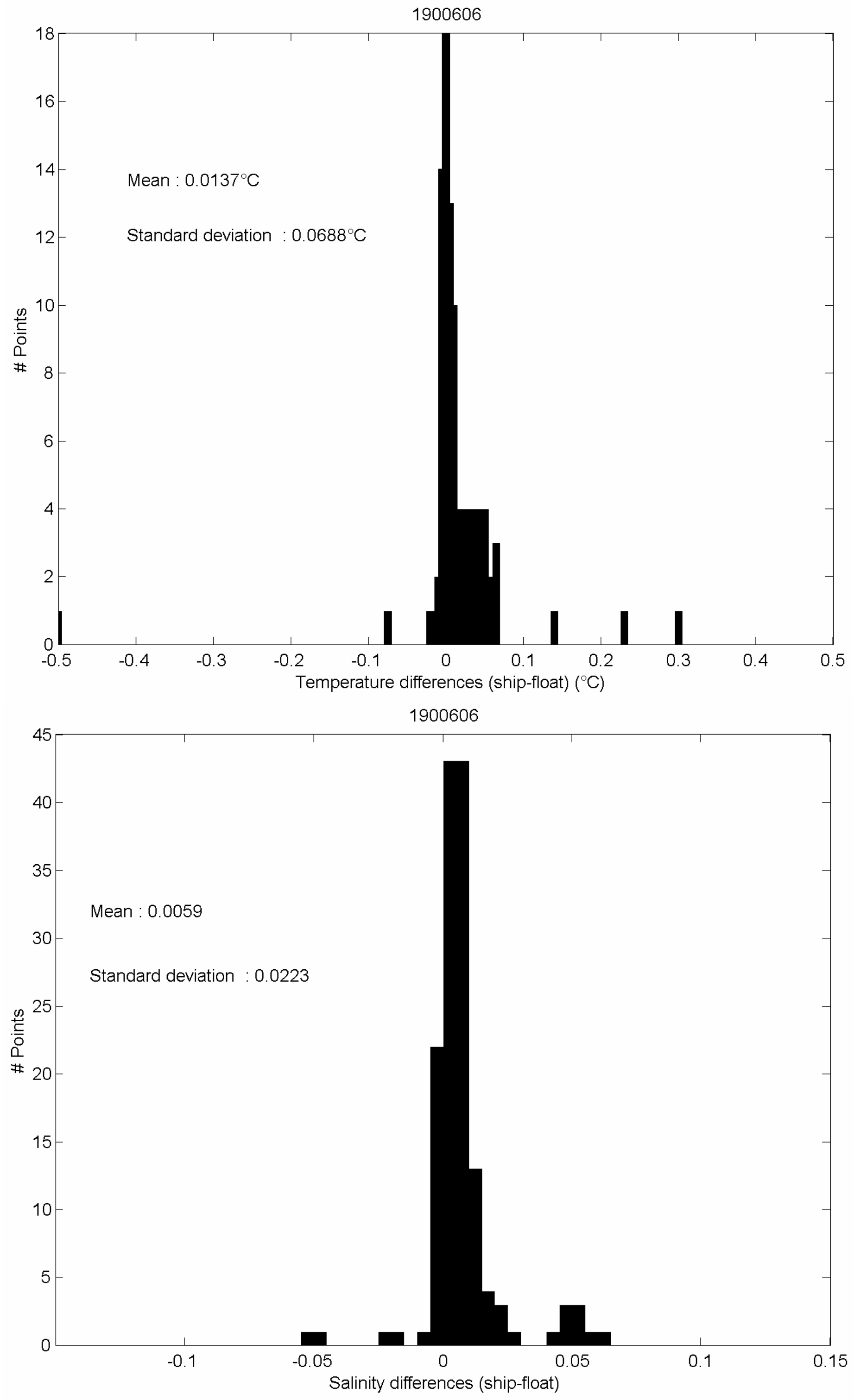


Figure 12. Histogram of the potential temperature (top) and salinity (bottom) differences between ship CTD cast 097 and closest PROVOR CTD (WMO 1900606).

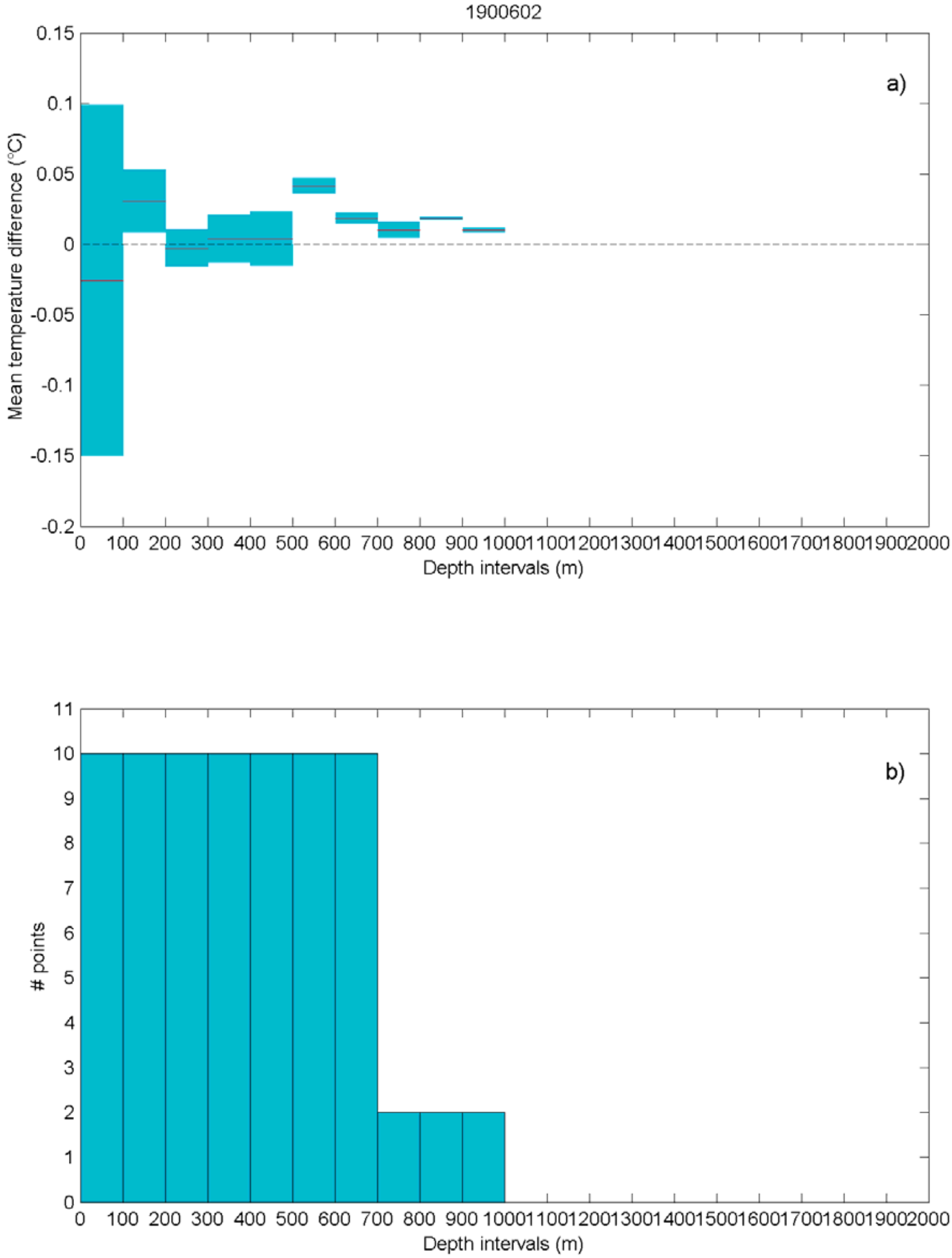
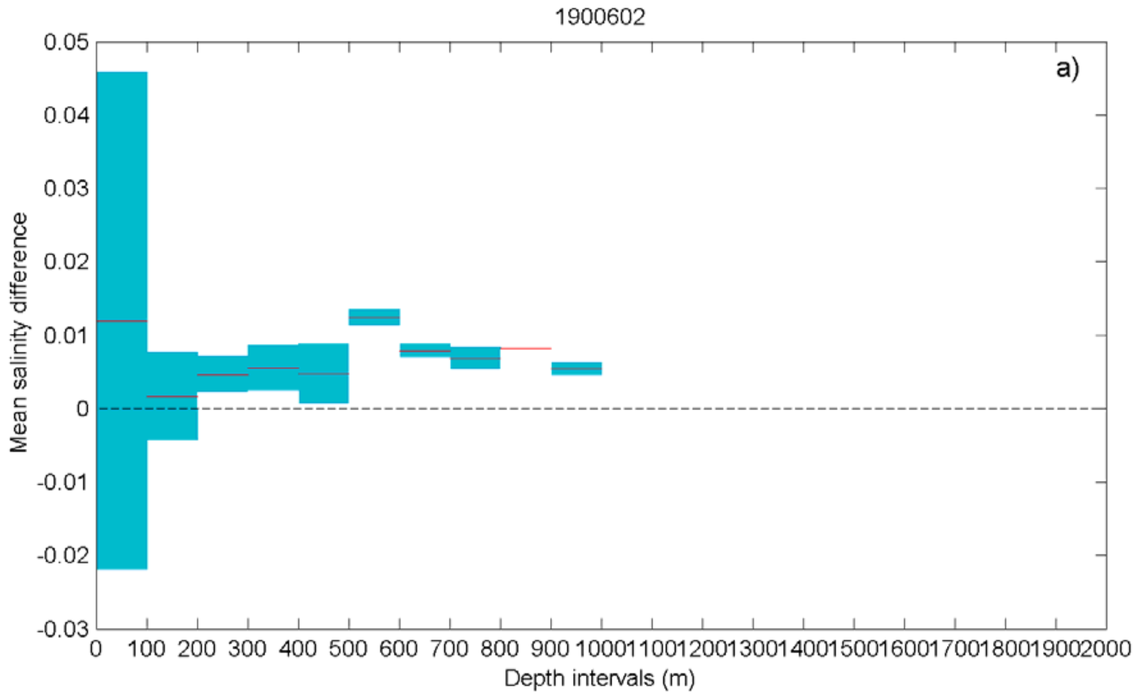


Figure 13. Potential temperature difference statistics in depth intervals of 100 m for PROVOR WMO 1900602 and ship cast 001: (a) mean difference ± standard deviation (shading) versus depth, (b) number of pairs considered in each depth interval.



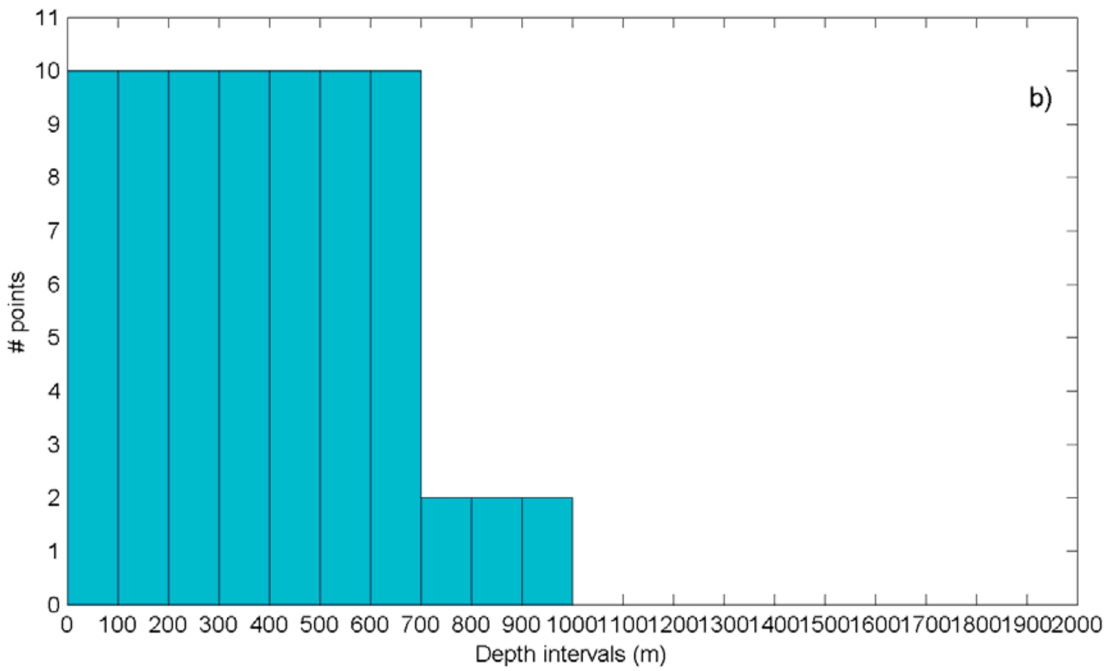
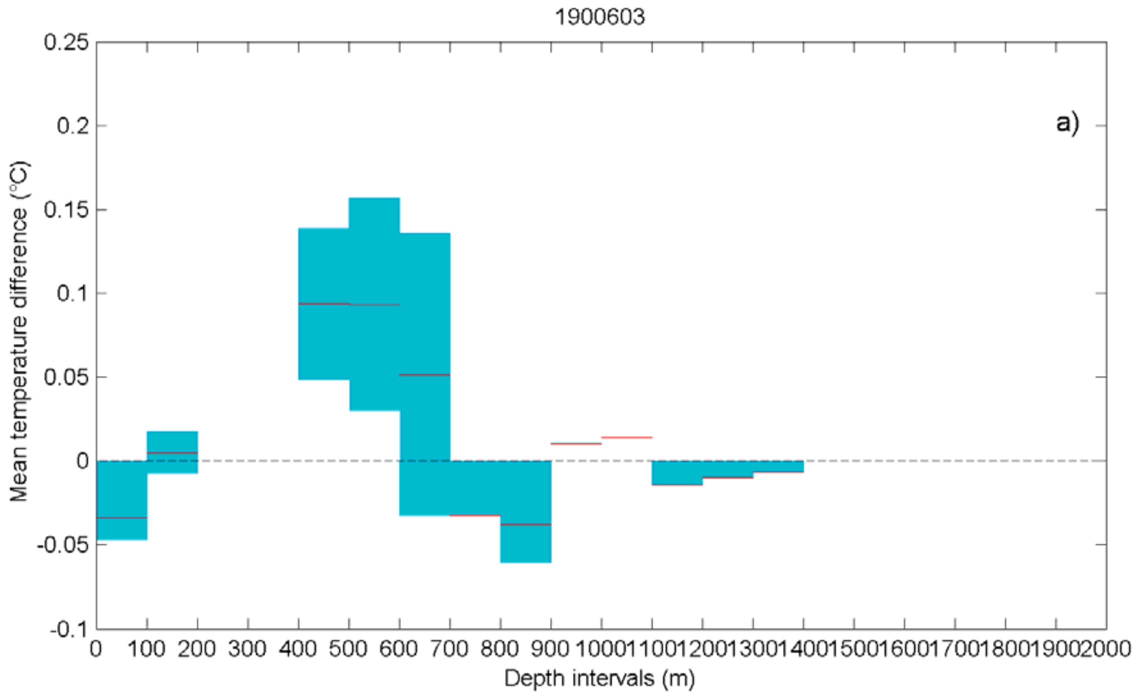


Figure 14. Same as Figure 13 but for salinity.



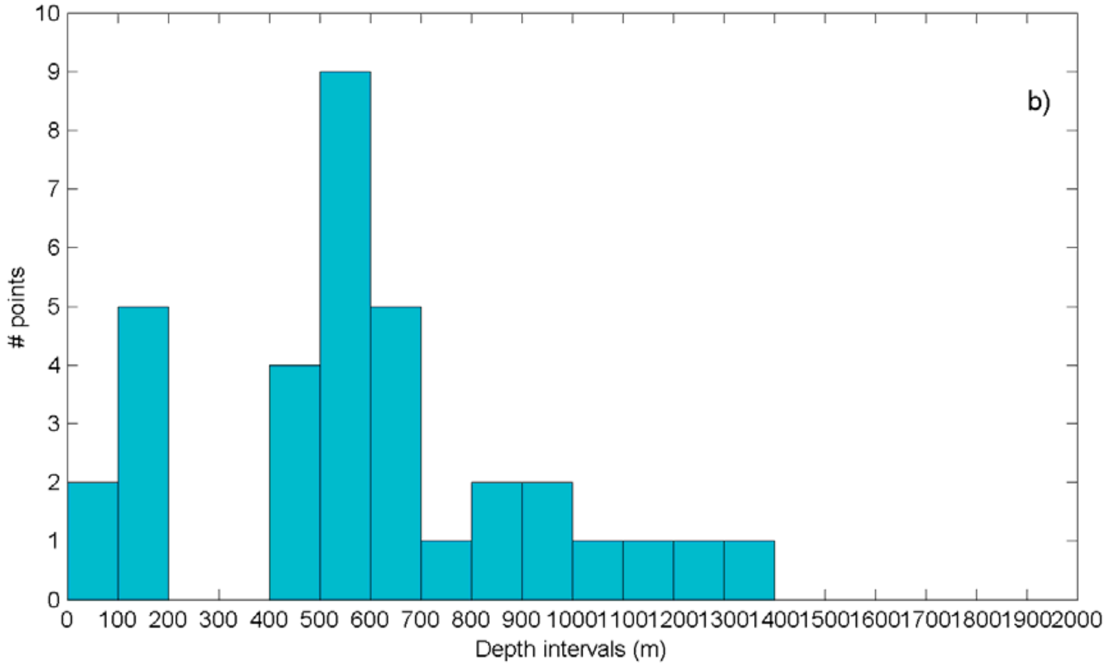


Figure 15. Same as Figure 13 but for PROVOR WMO 1900603 and ship CTD cast 107.

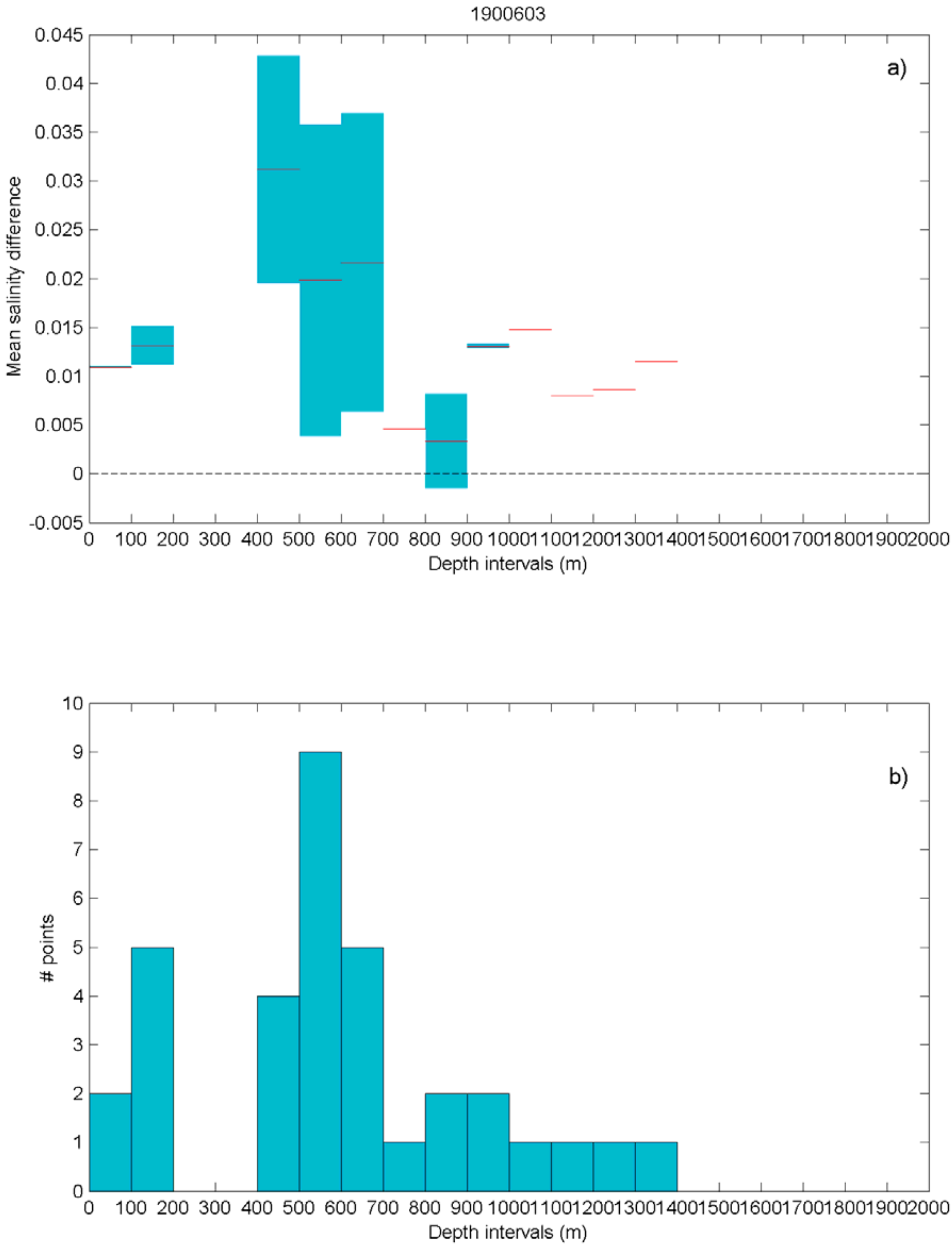
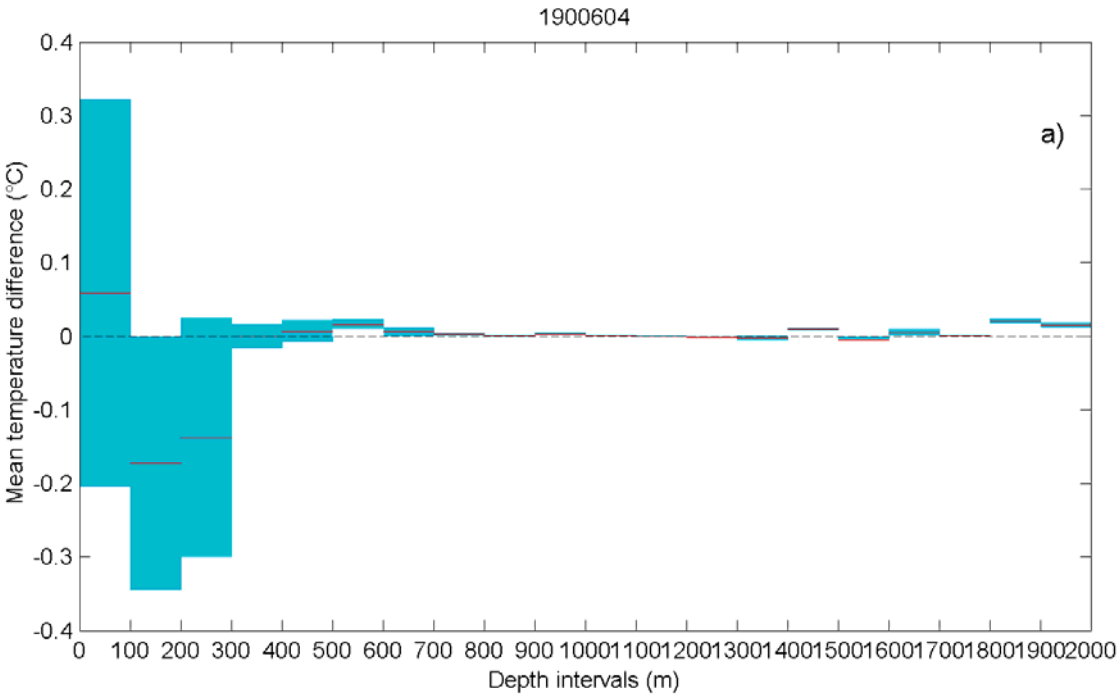


Figure 16. Same as Figure 15 but for salinity.



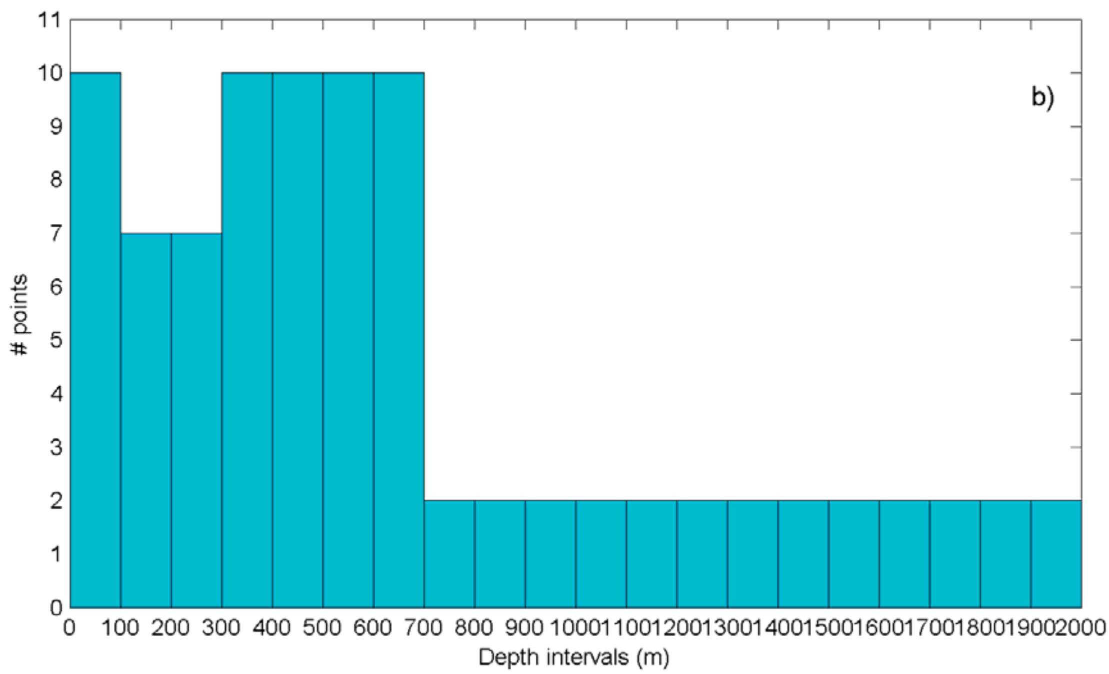


Figure 17. Same as Figure 13 but for PROVOR WMO 1900604 and ship CTD cast 049.

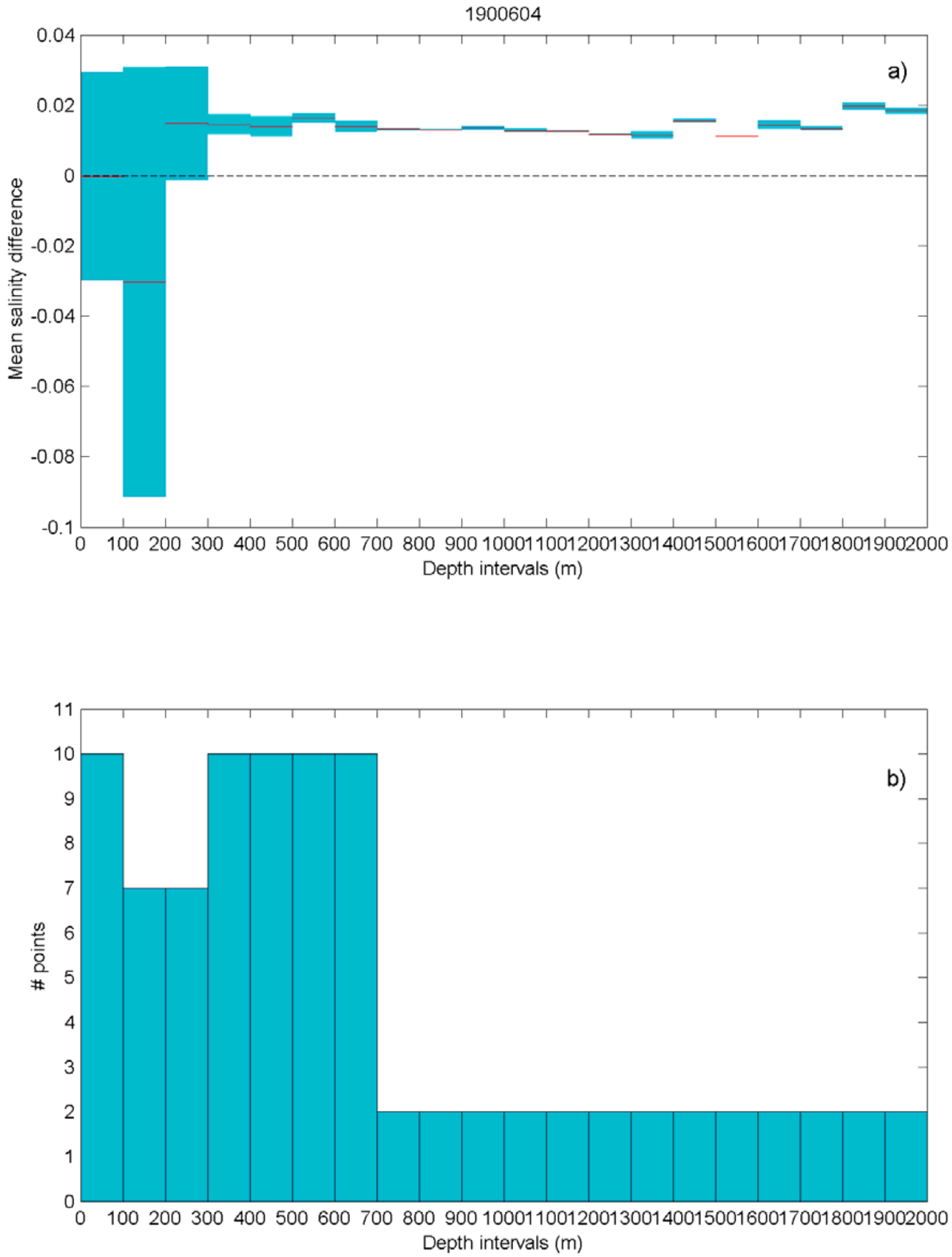


Figure 18. Same as Figure 17 but for salinity.

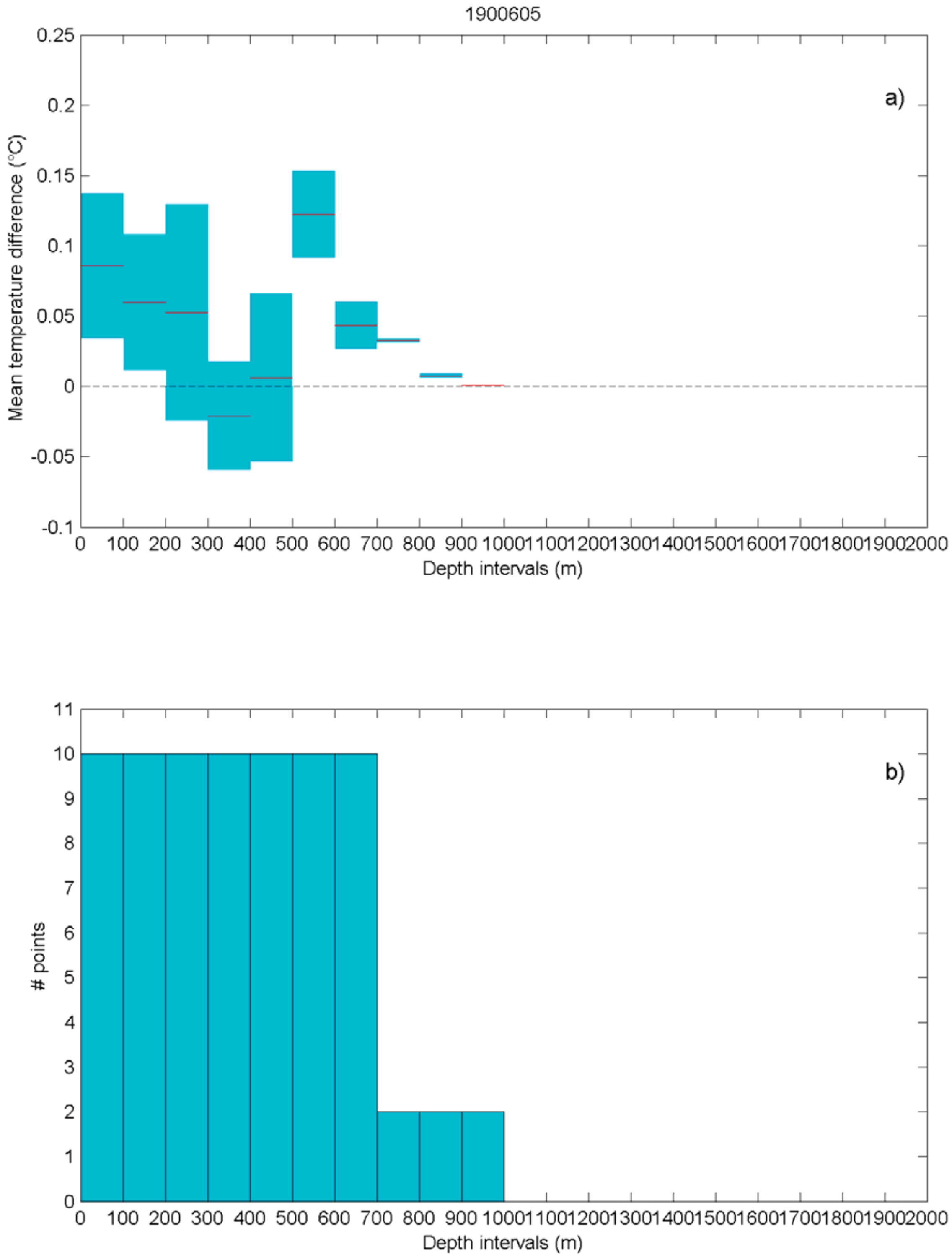


Figure 19. Same as Figure 13 but for PROVOR WMO 1900605 and ship CTD cast 002.

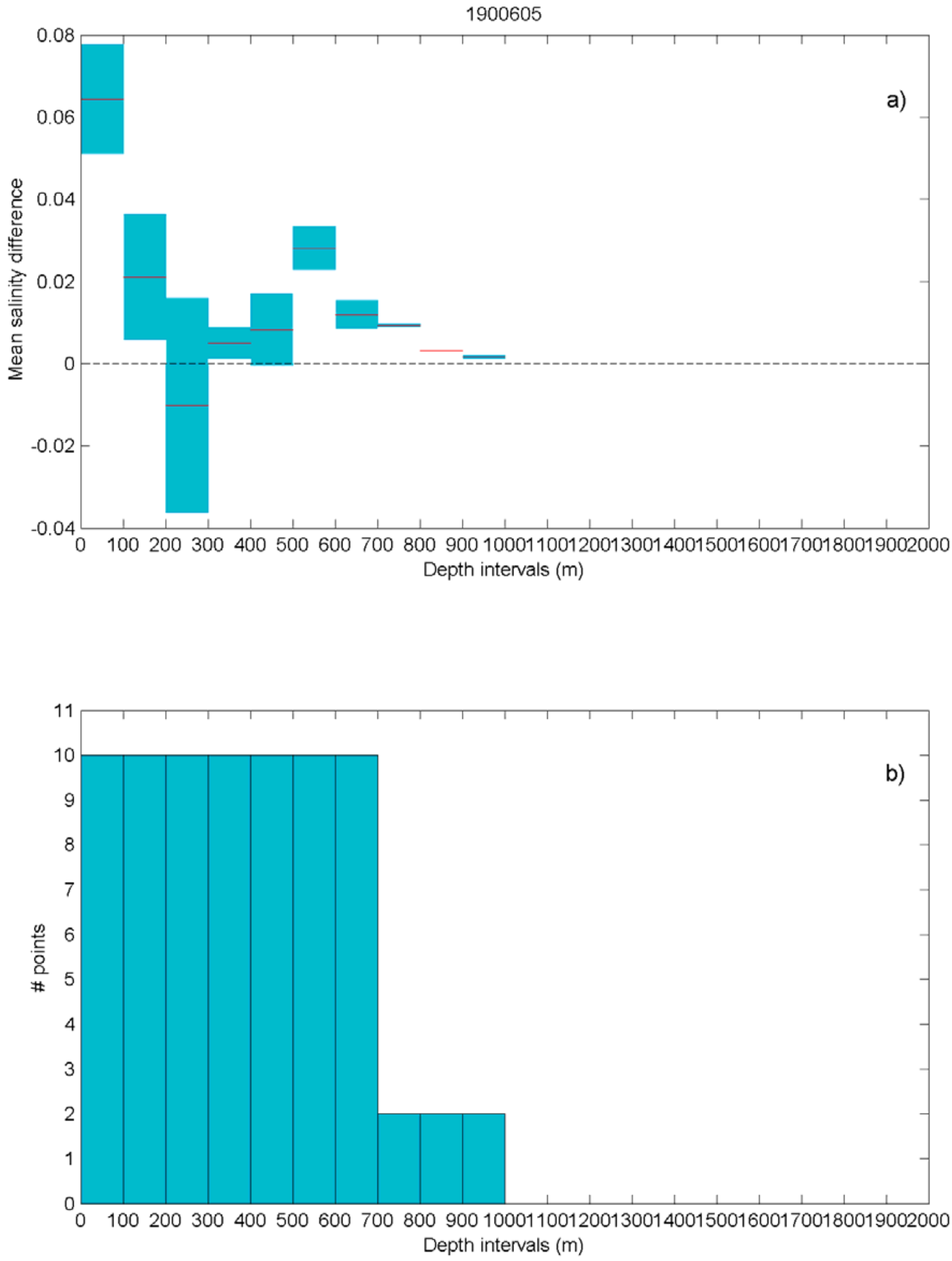


Figure 20. Same as Figure 19 but for salinity.

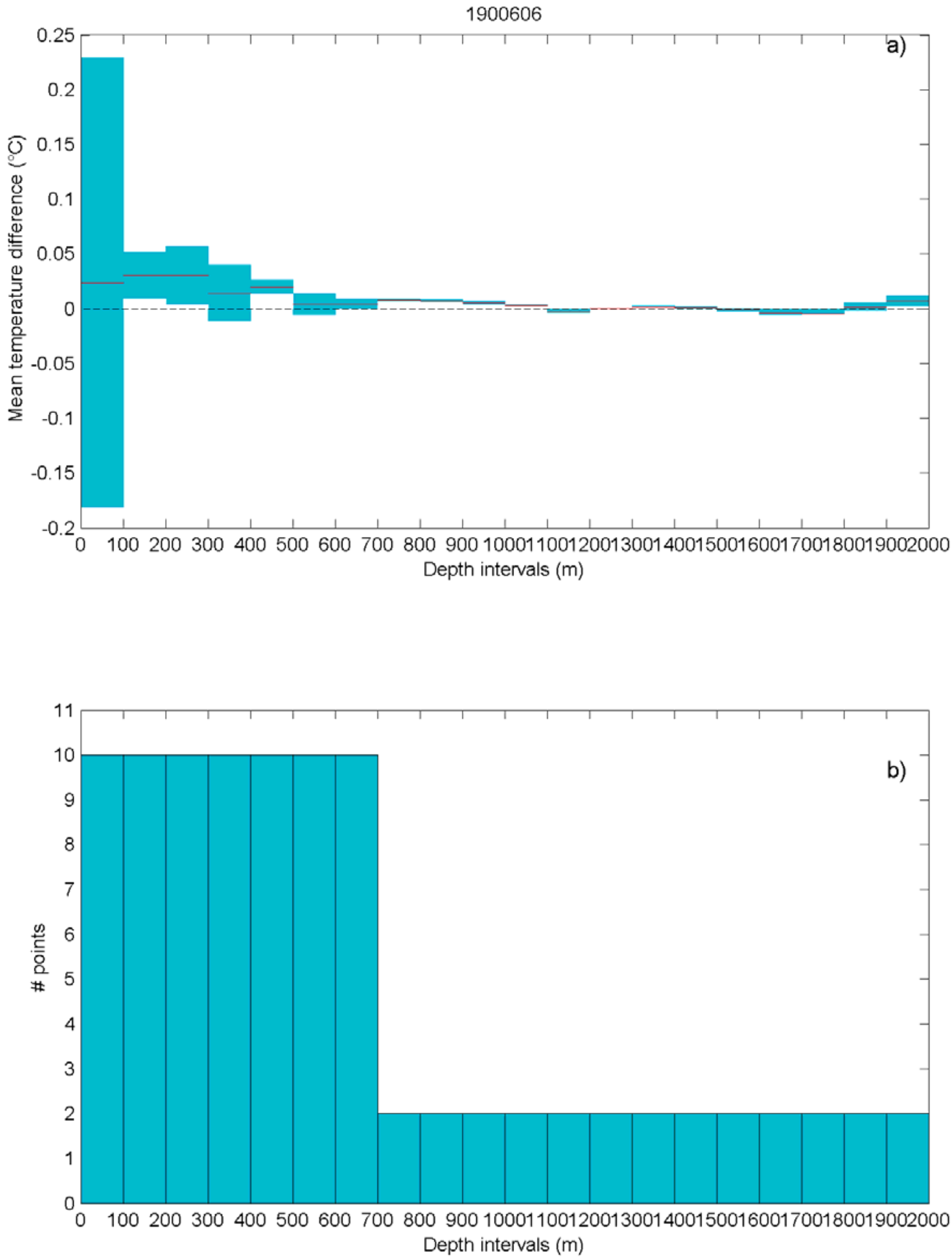


Figure 21. Same as Figure 13 but for PROVOR WMO 1900606 and ship CTD cast 097.

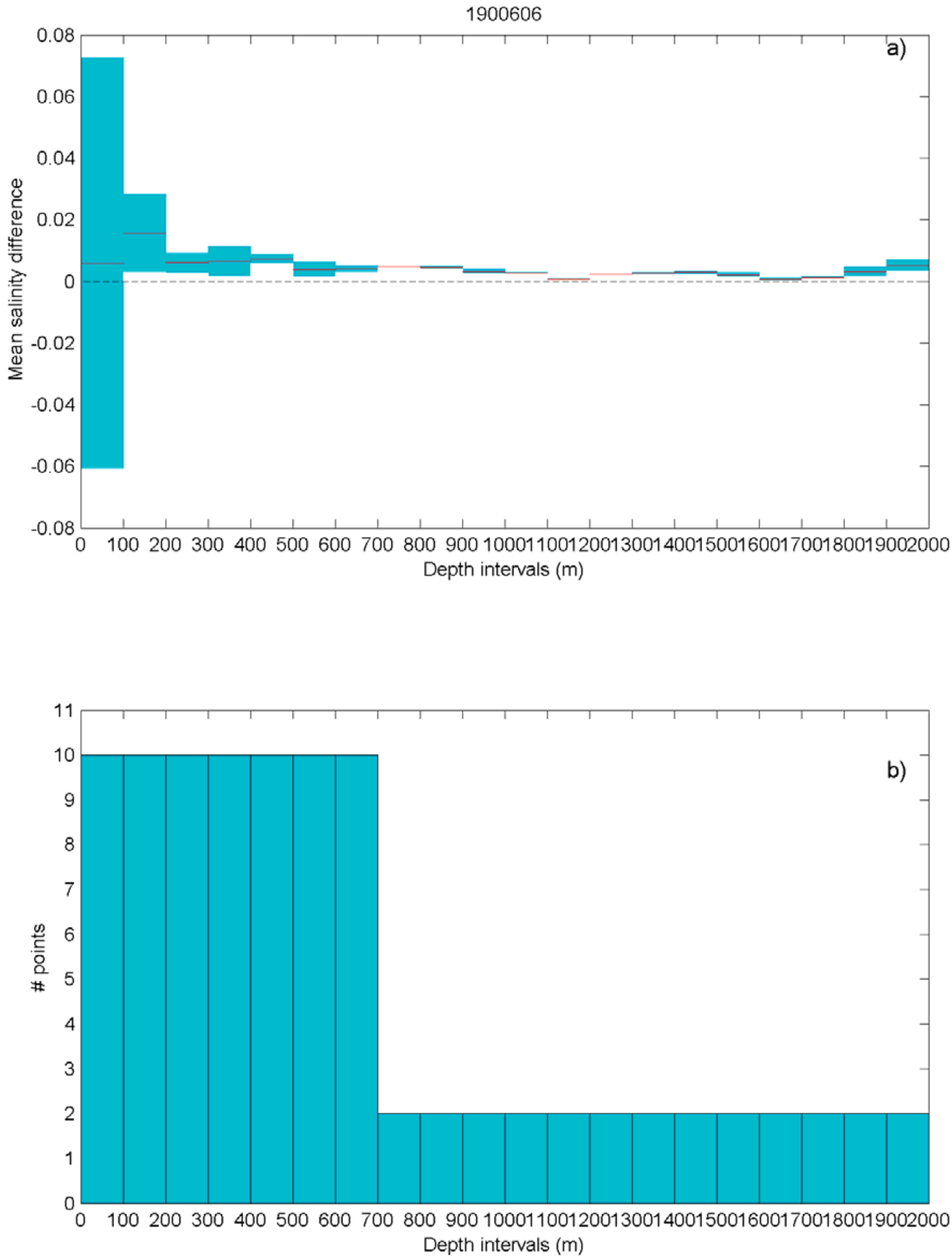


Figure 22. Same as Figure 21 but for salinity.

WMO	1900602		1900603		1900604		1900605		1900606	
Depth (m)	mean	std	mean	std	mean	std	mean	std	mean	std
0-100	-0.0256	0.1245	-0.0337	0.0139	0.0584	0.2637	0.0858	0.0515	0.0235	0.2054
100-200	0.0304	0.0222	0.005	0.0126	-0.1725	0.1724	0.0599	0.0485	0.0306	0.0212
200-300	-0.0028	0.0134			-0.1383	0.1628	0.0525	0.0771	0.0303	0.0267
300-400	0.0038	0.017			-0.0003	0.0165	-0.021	0.0386	0.0143	0.0257
400-500	0.0038	0.0196	0.0935	0.0452	0.0066	0.0148	0.0061	0.0596	0.0198	0.0065
500-600	0.0414	0.0054	0.0932	0.0637	0.0162	0.0066	0.1224	0.0311	0.004	0.01
600-700	0.0183	0.0038	0.0514	0.0843	0.0058	0.006	0.0432	0.017	0.0044	0.0046
700-800	0.0102	0.0059	-0.0326	0	0.0023	0.0017	0.0327	0.0016	0.0078	0.0014
800-900	0.0181	0.0014	-0.0377	0.0233	0.0002	0.0013	0.0075	0.0017	0.007	0.0012
900-1000	0.0099	0.0015	0.0102	0.0005	0.0029	0.0016	0.0006	0.0002	0.0054	0.0018
1000-1100			0.0142	0	0.0001	0.0011			0.0028	0.0006
1100-1200			-0.0144	0	-0.0002	0.0006			-0.0029	0.0011
1200-1300			-0.0103	0	-0.002	0.001			0.0003	0.0001
1300-1400			-0.0067	0	-0.0028	0.0033			0.0018	0.001
1400-1500					0.0089	0.002			0.0011	0.0013
1500-1600					-0.0048	0.0001			-0.0011	0.0015
1600-1700					0.0051	0.0044			-0.0042	0.0017
1700-1800					0.001	0.0002			-0.0045	0.0004
1800-1900					0.0205	0.0036			0.0017	0.0037
1900-2000					0.0145	0.0036			0.0074	0.005

Table 2. Statistics (mean and standard deviation) of the potential temperature difference (ship-PROVOR) versus depth intervals for each float.

WMO	1900602		1900603		1900604		1900605		1900606	
Depth (m)	mean	std	mean	std	mean	std	mean	std	mean	std
0-100	0.012	0.0339	0.0109	0.0001	-0.0003	0.0297	0.0643	0.0134	0.0059	0.0667
100-200	0.0017	0.006	0.0131	0.002	-0.0304	0.0612	0.021	0.0154	0.0155	0.0126
200-300	0.0047	0.0025			0.0149	0.0162	-0.0102	0.0262	0.006	0.0032
300-400	0.0055	0.0031			0.0145	0.0029	0.0049	0.0038	0.0065	0.005
400-500	0.0047	0.0041	0.0311	0.0116	0.0139	0.0029	0.0083	0.0088	0.0073	0.0015
500-600	0.0124	0.0011	0.0198	0.016	0.0163	0.0014	0.0281	0.0053	0.0039	0.0024
600-700	0.0079	0.001	0.0216	0.0153	0.0139	0.0016	0.012	0.0035	0.0041	0.0011
700-800	0.0069	0.0015	0.0046	0	0.0131	0.0003	0.0092	0.0005	0.0048	0
800-900	0.0081	0.0001	0.0034	0.0048	0.0129	0.0001	0.0031	0.0001	0.0045	0.0004
900-1000	0.0054	0.0009	0.0131	0.0003	0.0134	0.0006	0.0016	0.0004	0.0032	0.0007
1000-1100			0.0148	0	0.0129	0.0004			0.0028	0.0001
1100-1200			0.008	0	0.0127	0.0002			0.0009	0.0002
1200-1300			0.0086	0	0.0116	0.0002			0.0024	0
1300-1400			0.0115	0	0.0115	0.001			0.0028	0.0004
1400-1500					0.0156	0.0005			0.0029	0.0006
1500-1600					0.0112	0.0001			0.0022	0.0008
1600-1700					0.0144	0.0012			0.0008	0.0004
1700-1800					0.0134	0.0007			0.0012	0.0004
1800-1900					0.0197	0.0011			0.0033	0.0016
1900-2000					0.0183	0.0009			0.0052	0.0017

Table 3. Same as in Table 2 but for salinity difference.

3.3 Scatter diagrams and linear regressions

Scatter diagrams of the PROVOR temperatures and salinities versus the respective values obtained with the ship-based CTD are shown as Figures 23 to 27 for the pairs considered. Linear regression models were fitted to the data. Since the PROVOR readings are less accurate than the ship CTD measurements, because of the vertical averaging and digitization necessary for the data telemetry, the PROVOR data were regressed onto the ship CTD values. The regression and the 1:1 lines are drawn in the scatter diagrams (Figures 23 to 27). The parameters of the regression models, including the coefficient of determination r^2 (or skill or ratio of explained variance over the total variance) are also posted.

In general, for the temperature, both models (full regression and 1:1 line fit) have very similar coefficients of determination, meaning that there is not significant departure from the 1 to 1 relationship. In terms of salinity, however, there is a slight increase of skill of 1-3% when using the full regression. The offset can be positive or negative and can be as large as 2.

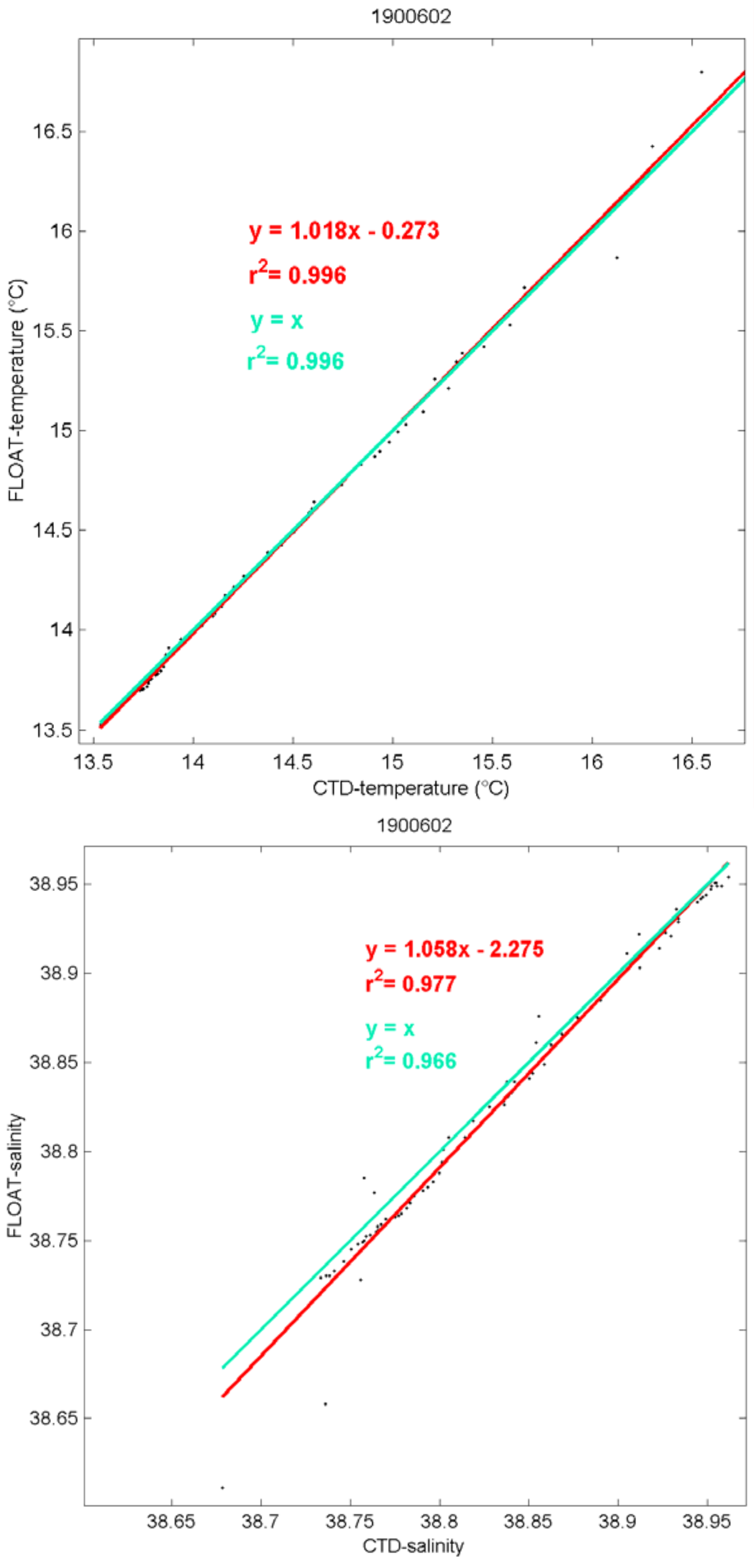


Figure 23. Scatter diagram of the ship CTD potential temperatures (CTD cast 1, top panel) and salinities (bottom panel) versus the PROVOR WMO 1900602 CTD readings with regression line (red) and 1:1 line (cyan). The parameters of the regression model are posted in the figure along with the coefficients of determination.

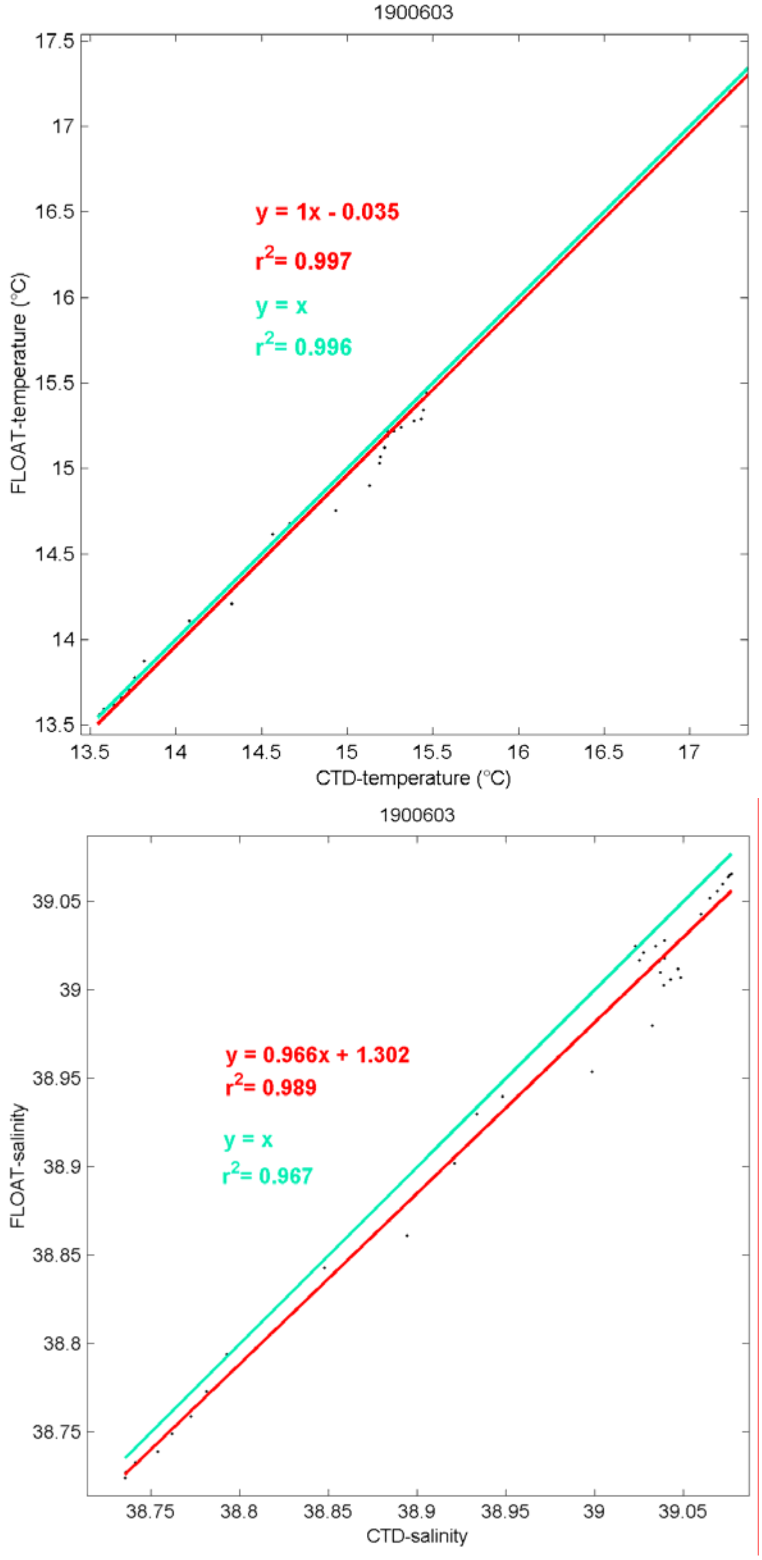


Figure 24. Same as Figure 23 but for ship CTD cast 107 and PROVOR WMO 1900603 profile.

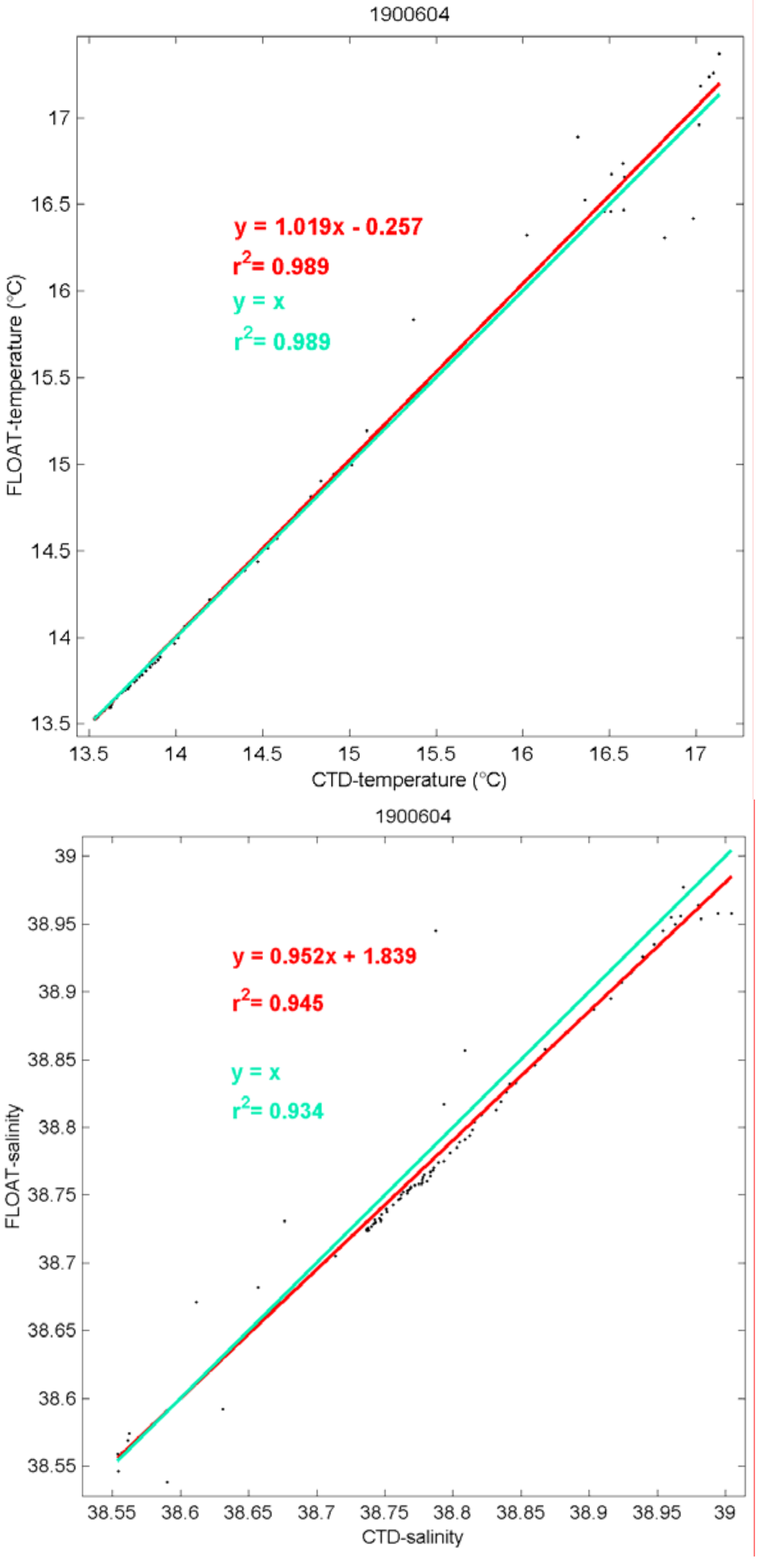


Figure 25. Same as Figure 23 but for ship CTD cast 049 and PROVOR WMO 1900604 profile.

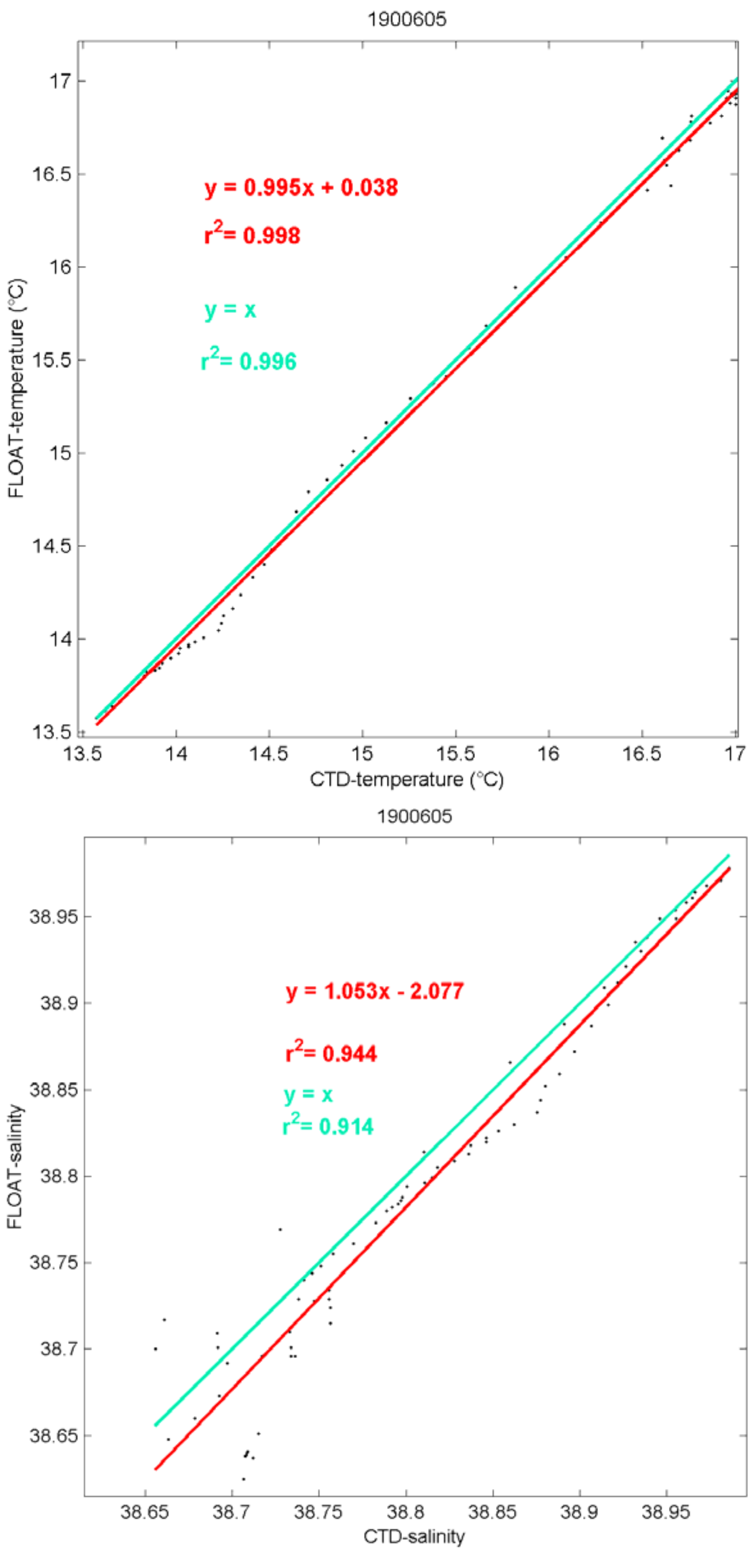


Figure 26. Same as Figure 23 but for ship CTD cast 002 and PROVOR WMO 1900605 profile.

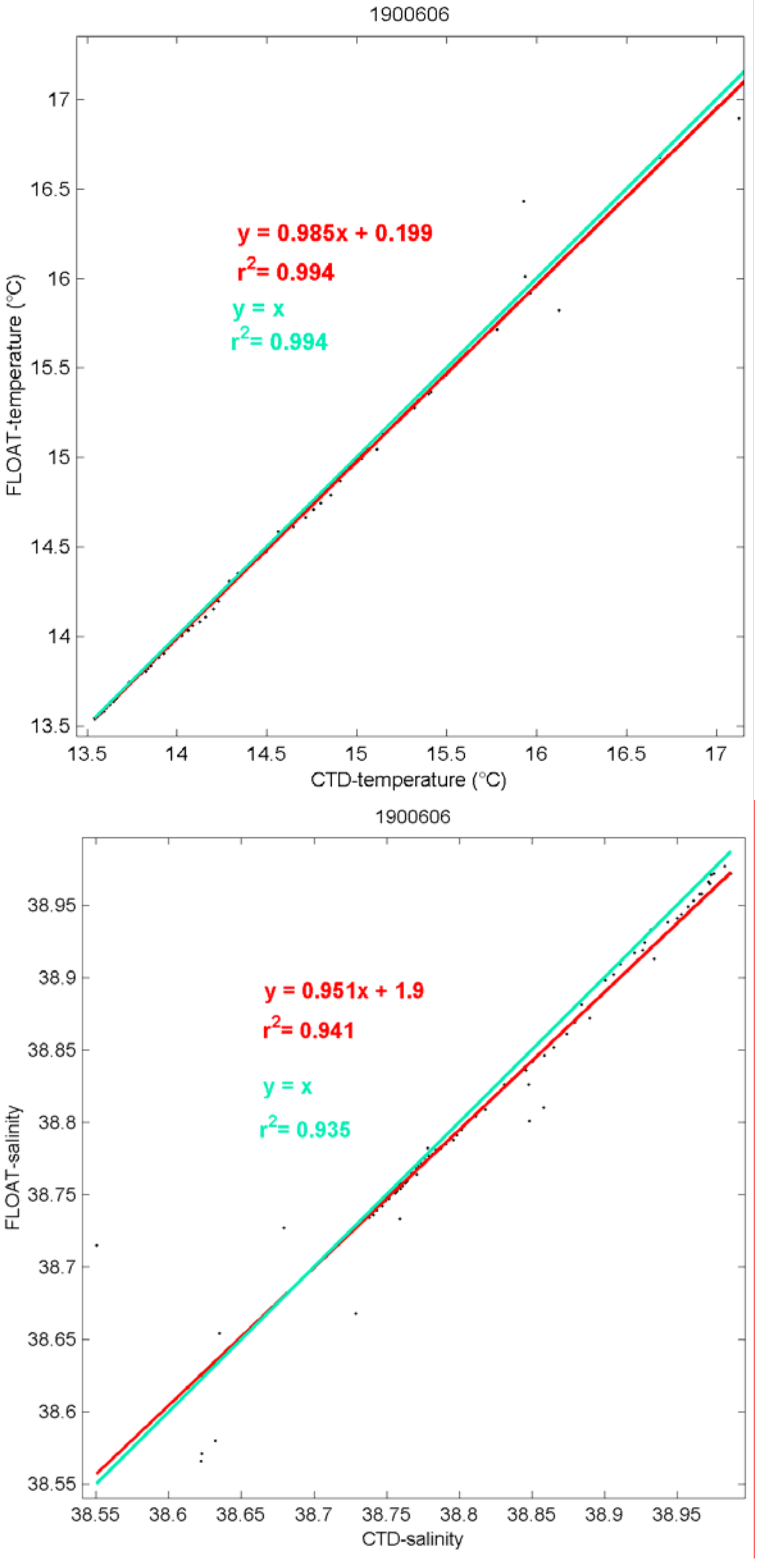


Figure 27. Same as Figure 23 but for ship CTD cast 097 and PROVOR WMO 1900606 profile.

4. Conclusions

The differences in temperature and salinity between Argo floats and ship-based CTD casts quasi-collocated and quasi-simultaneous were assessed in the Eastern Mediterranean. The results show that below 500-900 m, where the natural variability of the thermohaline properties is reduced, the temperature difference is typically less than 0.01 ºC (especially for PROVORs 1900602, 1900604 and 1900606 which were separated from the ship CTD casts by less than 5 km and less then 35 hours). In salinity, differences at depth are usually less than 0.01, except for float 1900604 which has a salinity difference approaching 0.02 near 2000 m

Note that the measured differences are always larger than the accuracy and resolution of the individual measurements. However, since the estimated differences of 0.01 and 0.01-0.02 are of the same order of magnitude as the natural variability of temperature and salinity, even at depth, we cannot conclude that there is any significant offset between the Argo float and ship-based observations. The possible calibration shift of the ship CTD conductivity sensor (corresponding to 0.001 in salinity) is not crucial for this analysis.

The best agreement is for the pair (PROVOR 1900606 and cast 97) separated only by 3 km and 34 hours. In this case the temperature difference is only a few thousandths and the salinity difference is bounded by 0.005.

5. References

Martec (2005) PROVOR CTS3 – User's manual, DOC05053, Martec Serpe-Iesm, Guidel, France, pp 60.

Taupier-Letage, I. (2006) Report of the EGYPT-1 campaign (Cruise FS Poseidon P335) Messina (Italy) 8 April 2006 – Heraklion (Greece) 26 April 2006. (http://www.ifremer.fr/lobtln/EGYPT/condensed_EGYPT1_P335-report.pdf)

6. Appendices

Appendix 1 : Seabird conductivity calibration reports

Temperature on 13 June 2006

SBE SEA-BIRD ELECTRONICS, INC.
1808 - 136th Place Northeast, Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Temperature Calibration Report

Customer:	CNRS		
Job Number:	43240	Date of Report:	6/13/2006
Model Number	SBE 03-02/F	Serial Number:	030970

Temperature sensors are normally calibrated 'as received', without adjustments, allowing a determination sensor drift. If the calibration identifies a problem, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing coefficients to convert sensor frequency to temperature. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients using the program SEACON. The coefficient 'offset' allows a small correction for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair apply only to subsequent data.

'AS RECEIVED CALIBRATION'

Date: 6/13/2006

☑ Performed ☐ Not Performed

Drift since last cal: +.00027 Degrees Celsius/year

Comments:

'CALIBRATION AFTER REPAIR'

Date:

☐ Performed ☑ Not Performed

Drift since Last cal: Degrees Celsius/year

Comments:

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0970
CALIBRATION DATE: 13-Jun-06

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPRATURE SCALE

ITS-90 COEFFICIENTS
g = 4.90149185e-003
h = 6.87597077e-004
i = 2.96147179e-005
j = 2.47448479e-006
f0 = 1000.0

ITS-68 COEFFICIENTS
a = 3.68121395e-003
b = 6.01810978e-004
c = 1.54908278e-005
d = 2.47601943e-006
f0 = 6728.080

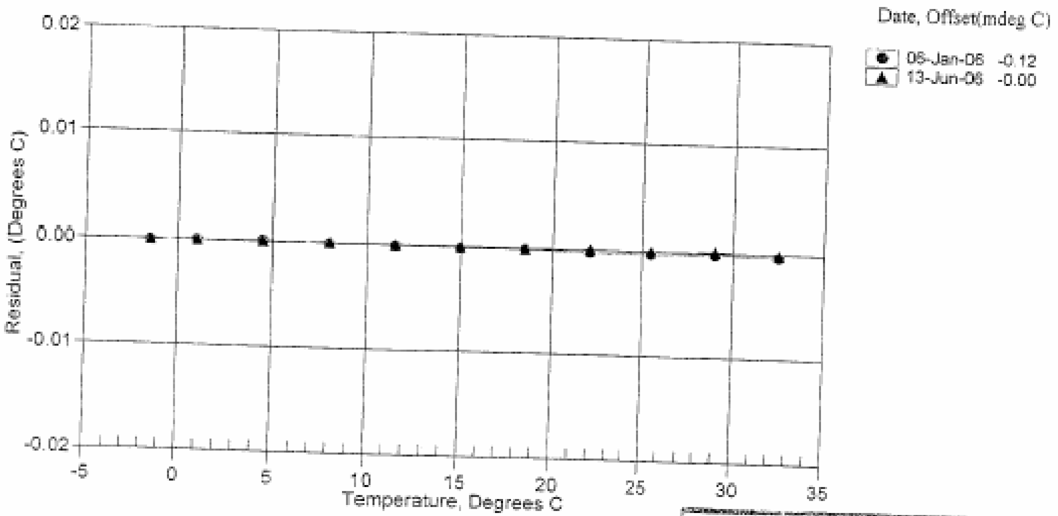
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5001	6728.080	-1.5001	-0.00002
0.9999	7114.707	0.9999	0.00001
4.4999	7682.546	4.4999	0.00002
7.9999	8282.149	7.9999	0.00003
11.4999	8914.329	11.4999	-0.00001
14.9999	9579.899	14.9999	-0.00002
18.4999	10279.616	18.4998	-0.00007
21.9999	11014.254	21.9999	0.00002
25.5000	11784.492	25.5000	-0.00001
28.9999	12591.003	29.0000	0.00013
32.4999	13434.377	32.4998	-0.00008

Temperature ITS-90 = $1/\{g + h[ln(f_0/f)] + i[ln^2(f_0/f)] + j[ln^3(f_0/f)]\} - 273.15$ (°C)

Temperature ITS-68 = $1/\{a + b[ln(f_0/f)] + c[ln^2(f_0/f)] + d[ln^3(f_0/f)]\} - 273.15$ (°C)

Following the recommendation of JPOTS: T_{68} is assumed to be $1.00024 * T_{90}$ (-2 to 35 °C)

Residual = instrument temperature - bath temperature



POST CRUISE CALIBRATION

Conductivity on 13 June 2006

SBE SEA-BIRD ELECTRONICS, INC.
1808 - 136th Place Northeast, Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Conductivity Calibration Report

Customer:	CNRS		
Job Number:	43240	Date of Report:	6/13/2006
Model Number	SBE 04-02/0	Serial Number:	040606

Conductivity sensors are normally calibrated 'as received', without cleaning or adjustments, allowing a determination of sensor drift. If the calibration identifies a problem or indicates cell cleaning is necessary, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing the coefficients used to convert sensor frequency to conductivity. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients using the program SEACON. The coefficient 'slope' allows small corrections for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair or cleaning apply only to subsequent data.

'AS RECEIVED CALIBRATION' ✓ Performed ☐ Not Performed

Date: 6/13/2006 Drift since last cal: -.00100 PSU/month*

Comments:

'CALIBRATION AFTER CLEANING & REPLATINIZING' ☐ Performed ✓ Not Performed

Date: Drift since Last cal: PSU/month*

Comments:

**Measured at 3.0 S/m*

Cell cleaning and electrode replatinizing tend to 'reset' the conductivity sensor to its original condition. Lack of drift in post-cleaning-calibration indicates geometric stability of the cell and electrical stability of the sensor circuit.

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0606
CALIBRATION DATE: 13-Jun-06

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS
g = -4.12465126e+000
h = 4.41435010e-001
i = -2.80930490e-005
j = 2.37344711e-005
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS
a = 1.66870875e-005
b = 4.41422380e-001
c = -4.12498079e+000
d = -8.89488488e-005
m = 4.1
CPcor = -9.5700e-008 (nominal)

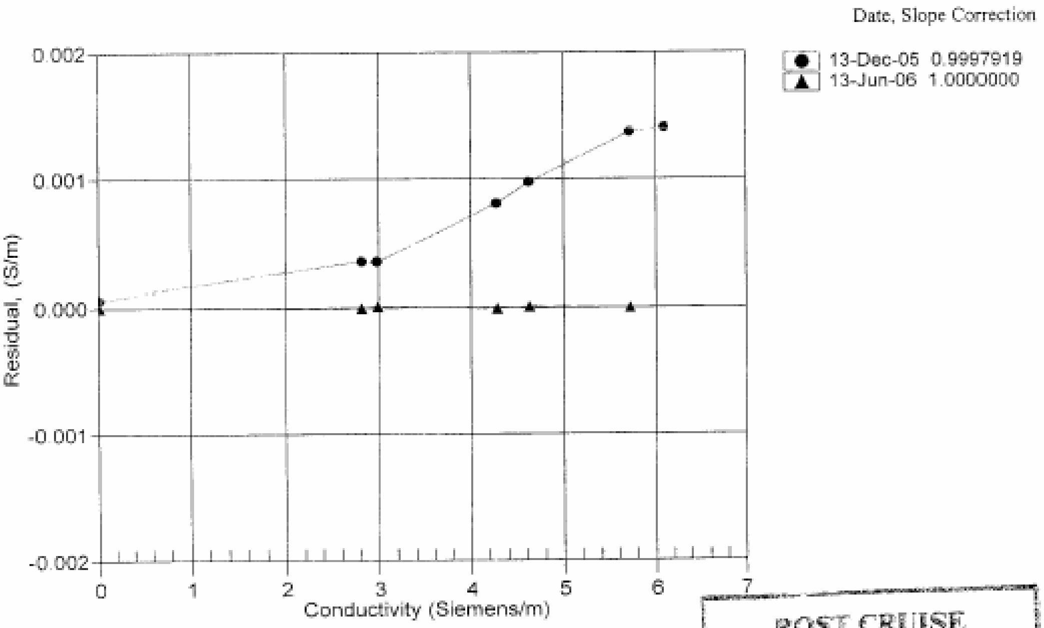
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	3.05628	0.00000	0.00000
-1.0001	34.9334	2.81312	8.53372	2.81311	-0.00001
1.0410	34.9337	2.98860	8.76197	2.98861	0.00001
14.9999	34.9348	4.28460	10.28958	4.28459	-0.00001
18.4999	34.9348	4.63238	10.66169	4.63239	0.00001
28.9999	34.9306	5.71892	11.74684	5.71891	-0.00000

Conductivity = $(g + hf^2 + if^3 + jf^4)/10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10 (1 + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



POST CRUISE
CALIBRATION

Conductivity on 15 September 2006

SBE SEA-BIRD ELECTRONICS, INC.
1808 - 136th Place Northeast, Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Conductivity Calibration Report

Customer:	CNRS		
Job Number:	44217	Date of Report:	9/15/2006
Model Number	SBE 04-02/0	Serial Number:	040606

Conductivity sensors are normally calibrated 'as received', without cleaning or adjustments, allowing a determination of sensor drift. If the calibration identifies a problem or indicates cell cleaning is necessary, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing the coefficients used to convert sensor frequency to conductivity. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients using the program SEACON. The coefficient 'slope' allows small corrections for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair or cleaning apply only to subsequent data.

'AS RECEIVED CALIBRATION' ✓ Performed ☐ Not Performed

Date: 9/15/2006 Drift since last cal: 0.0000 PSU/month*

Comments:

'CALIBRATION AFTER CLEANING & REPLATINIZING' ☐ Performed ✓ Not Performed

Date: Drift since Last cal: PSU/month*

Comments:

**Measured at 3.0 S/m*

Cell cleaning and electrode replatinizing tend to 'reset' the conductivity sensor to its original condition. Lack of drift in post-cleaning-calibration indicates geometric stability of the cell and electrical stability of the sensor circuit.

cond 2 Eqe 4 (pré. calib)
Aux CD 9P 253

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0606
CALIBRATION DATE: 15-Sep-06

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS
g = -4.12625292e+000
h = 4.41793057e-001
i = -1.03798241e-004
j = [illegible].77927034e-005
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS
a = 1.28053144e-005
b = 4.41489444e-001
c = -4.12540014e+000
d = -8.59790092e-005
m = 4.2
CPcor = -9.5700e-008 (nominal)

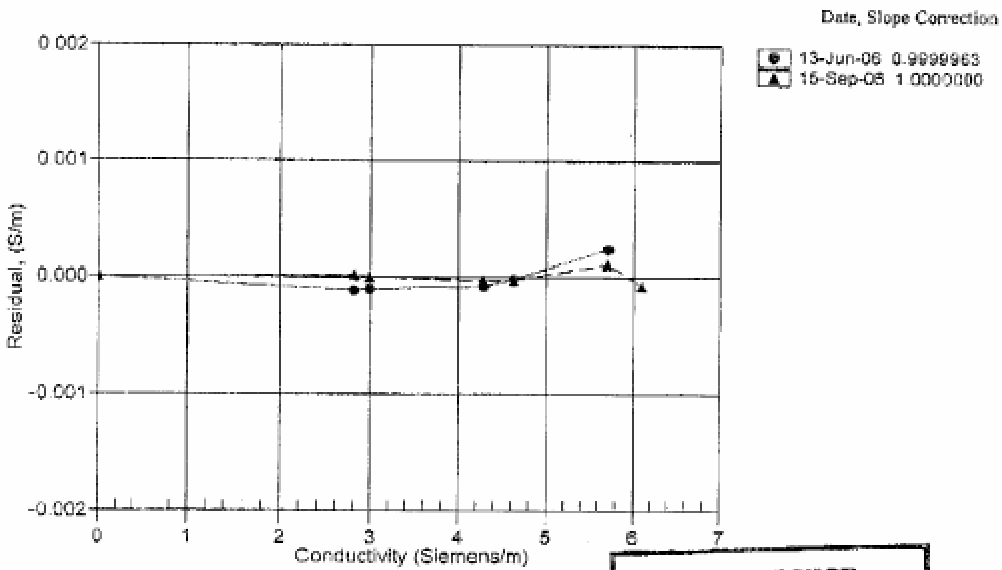
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	3.05630	0.00000	0.00000
-1.0000	34.9040	2.81098	8.53108	2.81100	0.00002
1.0000	34.9044	2.98278	8.75461	2.98277	-0.00000
15.0000	34.9042	4.28125	10.28599	4.28123	-0.00003
18.5000	34.9040	4.62874	10.65786	4.62872	-0.00002
29.0000	34.9015	5.71470	11.74270	5.71481	0.00011
32.5000	34.8943	6.08805	12.09240	6.08798	-0.00007

Conductivity = $(g + hf^2 + if^3 + jf^4)/10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10 (1 + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



POST CRUISE CALIBRATION

Appendix 2 : Configuration of SeaSoft software suite for the EGYPT-1 ship-based CTD casts

```
* Sea-Bird SBE 9 Data File:
* FileName = D:\Sea-bird\Experiments\DATAEGYPT\egypt049.DAT
* Software Version Seasave Win32 V 5.37d
* Temperature SN = 970
* Conductivity SN = 606
* Number of Bytes Per Scan = 18
* Number of Voltage Words = 2
* Number of Scans Averaged by the Deck Unit = 1
* System UpLoad Time = Apr 18 2006 10:31:54
** Ship:      POSEIDON
** Cruise:    EGYPT
** Station:    049
** Latitude:   32°42.301
** Longitude:  24°58.051
# nquan = 5
# nvalues = 2437
# units = specified
# name 0 = prDM: Pressure, Digiquartz [db]
# name 1 = t090C: Temperature [ITS-90, deg C]
# name 2 = flC: Fluorescence, Chelsea Aqua 3 Chl Con [ug/l]
# name 3 = sal00: Salinity [PSU]
# name 4 = sbeox0ML/L: Oxygen, SBE 43 [ml/l], WS = 2
# span 0 =      1.000,   2437.000
# span 1 =    13.6989,    17.3972
# span 2 =    -0.0085,     0.1075
# span 3 =    38.5510,    39.0068
# span 4 =    3.78076,    4.99020
# interval = decibars: 1
# start_time = Apr 18 2006 10:31:54
# bad_flag = -9.990e-29
# sensor 0 = Frequency  0  temperature, 970, 06/01/2006
# sensor 1 = Frequency  1  conductivity, 606, 13/12/2005, cpcor = -9.5700e-08
# sensor 2 = Frequency  2  pressure, 63488, 28/11/95
# sensor 3 = Extrnl Volt  0  Oxygen, SBE, primary, 0230, 04/06/05
# sensor 4 = Extrnl Volt  2  fluorometer, chelsea, 088081, 10/12/04
# datcnv_date = Apr 19 2006 03:56:51, 5.33
# datcnv_in = D:\Mixa\CAMPAN\EGYPT1\CTDe1\RAW\egypt049.dat
D:\Mixa\CAMPAN\EGYPT1\CTDe1\RAW\egypt049.CON
# datcnv_skipover = 0
# wildedit_date = Apr 19 2006 03:59:16, 5.33
# wildedit_in = D:\Mixa\CAMPAN\EGYPT1\CTDe1\PROCESS\egypt049.cnv
# wildedit_pass1_nstd = 2.0
# wildedit_pass2_nstd = 20.0
# wildedit_pass2_mindelta = 0.000e+000
```

```
# wildedit_npoint = 100
# wildedit_vars = prDM t090C c0S/m sbeox0V sbeox0Mm/Kg flC
# wildedit_excl_bad_scans = yes
# celltm_date = Apr 19 2006 04:00:00, 5.33
# celltm_in = D:\Mixa\CAMPAN\EGYPT1\CTDe1\PROCESS\egypt049.cnv
# celltm_alpha = 0.0300, 0.0000
# celltm_tau = 7.0000, 0.0000
# celltm_temp_sensor_use_for_cond = primary,
# filter_date = Apr 19 2006 04:01:05, 5.33
# filter_in = D:\Mixa\CAMPAN\EGYPT1\CTDe1\PROCESS\egypt049.cnv
# filter_low_pass_tc_A = 0.030
# filter_low_pass_tc_B = 0.150
# filter_low_pass_A_vars =
# filter_low_pass_B_vars = prDM
# loopedit_date = Apr 19 2006 04:02:10, 5.33
# loopedit_in = D:\Mixa\CAMPAN\EGYPT1\CTDe1\PROCESS\egypt049.cnv
# loopedit_minVelocity = 0.250
# loopedit_excl_bad_scans = yes
# alignctd_date = Apr 19 2006 04:03:18, 5.33
# alignctd_in = D:\Mixa\CAMPAN\EGYPT1\CTDe1\PROCESS\egypt049.cnv
# alignctd_adv = sbeox0V 5.000, sbeox0Mm/Kg 5.000, flC 3.000

# Derive_date = Apr 19 2006 04:04:19, 5.33
# Derive_in = D:\Mixa\CAMPAN\EGYPT1\CTDe1\PROCESS\egypt049.cnv
D:\Mixa\CAMPAN\EGYPT1\CTDe1\PROCESS\egypt049.CON
# derive_time_window_docdt = seconds: 2
# binavg_date = Apr 19 2006 04:05:48, 5.33
# binavg_in = D:\Mixa\CAMPAN\EGYPT1\CTDe1\PROCESS\egypt049.cnv
# binavg_bintype = decibars
# binavg_binsize = 1
# binavg_excl_bad_scans = yes
# binavg_skipover = 0
# binavg_surface_bin = yes, min = 0.000, max = 0.500, value = 0.000
# wfilter_date = Apr 19 2006 04:06:46, 5.33
# wfilter_in = D:\Mixa\CAMPAN\EGYPT1\CTDe1\PROCESS\egypt049.cnv
# wfilter_excl_bad_scans = yes
# wfilter_action prDM = median, 5
# wfilter_action t090C = median, 5
# wfilter_action c0S/m = median, 5
# wfilter_action sbeox0V = median, 5
# wfilter_action sbeox0Mm/Kg = median, 5
# wfilter_action flC = median, 5
# wfilter_action sal00 = median, 5
# wfilter_action sbeox0ML/L = median, 5
# file_type = ascii
*END*
```